CAL RIPKEN, SR. Foundation

TRANSFORM COMMUNITIES
CHANGE KIDS' LIVES

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Ripken Foundation STEM Center

Middle School Curriculum Guidebook

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INTRODUCTION

INTRODUCTION

ABOUT THE CAL RIPKEN, SR. FOUNDATION

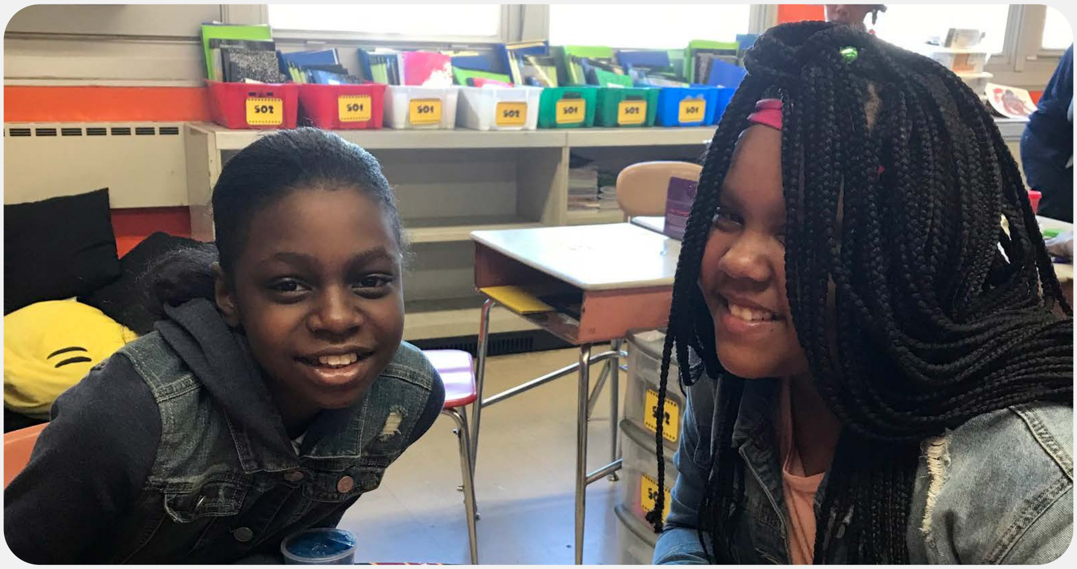
During his 37-year career with the Baltimore Orioles organization, Cal Ripken, Sr. taught the basics of the game and life to players big and small. After he passed away, his sons Cal and Bill recognized that not every child is lucky enough to have such a great teacher/mentor and role model. In this spirit,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

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 5E

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

Explore

Once kids have completed their initial activity, there is still a need to explore ideas. In the Exploration stage, activities are designed so kids 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, kids question events, monitor patterns, classify and test variables, and create causal relationships. Teachers/Mentors should facilitate learning during the Explore stage, allowing kids to investigate the problem and provide support as a guide as they record and analyze observations or data, creating models or initial explanations.

Explain

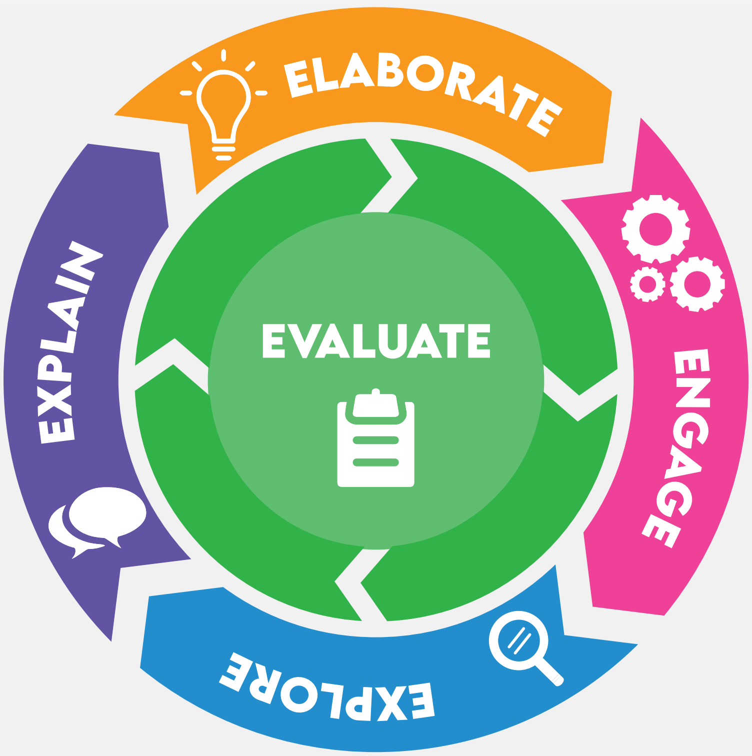
The Explanation stage consists of two parts: the teacher/mentor asking kids to share their initial models and/or explanations from the previous stages and the teacher/mentor providing resources and information to support learning, while introducing scientific or technological concepts. Once kids receive 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 kids may still have misunderstandings or they may only understand a concept in terms of the investigative experience. The Elaboration stage gives kids 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/mentors to give feedback on the quality of their works, especially, their explanations. This can occur throughout the learning process or more formally, the teacher/mentor can administer a summative evaluation at the end of the learning sequence. The Evaluation stage encourages kids to assess their knowledge and abilities while allowing teachers/mentors to evaluate 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 educational STEM Center products and STEM Kits.

RIPKEN FOUNDATION MIDDLE SCHOOL STEM CURRICULUM

"This curriculum, which is included in each 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. Teachers/mentors can sign up for free at *www.ripkenfoundation.org/resource-portal*

PRODUCT GUIDE

PRODUCT GUIDE

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

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 at 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:
The curriculum provided for the Center is based on the Next Generation Science Standards

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 Flavors Stackable Chairs, seven Elemental Clover Tables that seat up to four kids 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**
- **Sphero BOLT Power Pack**
- **Makey Makey**
- **Snap Circuits SC-750R**
- **STEM Pathways**
- **Tello Drone**
- **3D Printer**

LITTLEBITS

OVERVIEW

The littleBits Pack is the ultimate STEAM learning toolkit, containing 240 Bits, 10 newly designed durable storage containers, printed teacher/mentor support materials and 40+ standards-aligned lessons to engage kids. Integrate programming with the FUSE app to level up and create digital circuits.

PRODUCT SPECIFICS

littleBits Pack:

- **1 STEAM+ Class Pack**
- **10 STEAM+ Coding Kit Expansion Packs**

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 Kits 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

Use the camera feature on your device to scan the codes below. They will provide you with direct access or a link to the content.

- *Get to Know Your Bits*
- *Bit Basics*

The littleBits Pro Library and littleBits STEAM+ Classpack can both be used for all littleBits lessons.

SPHERO BOLT POWER PACK

OVERVIEW

The Sphero BOLT Power Pack lets you charge, store, and carry 15 Sphero BOLT robots. Built with an integrated cooling system, your robots can charge safely all from one place.

The Sphero BOLT Power Pack is the top-of-the-line kit for teachers/mentors using the Sphero Edu program in a classroom, robotics club, or in any maker environment you can dream up. Plus, it's loaded with Turbo Covers, maze tape, and protractors, so the activities can get started anytime, anywhere.

PRODUCT SPECIFICS

Sphero BOLT Power Pack includes:

- **15 Sphero BOLTs**
- **Storage Case with an integrated cooling system**

TEACHER AND MENTOR NOTES

The Sphero Edu app contains 100+ guided STEAM and Computer Science lessons, activites, and programs, consisting of varying skill level and content areas. We've curated a selection of seven activities that will help guide you as you get started.

ONLINE RESOURCES

Use the camera feature on your device to scan the codes below. They will provide you with direct access or a link to the content.

- *Sphero Edu Browser*
- *Sphero Educator Resource Guide*
- *Sphero Edu App*

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 SC-750R

OVERVIEW

Snap Circuits SC-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 SC-750R includes:

- **12 Snap Circuits SC-750R Kits 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 SC-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 SC-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

- *https://shop.elenco.com/consumers/sc-750r-snap-circuits-training-program.html*

STEM PATHWAYS LAB

OVERVIEW

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

PRODUCT SPECIFICS

STEM Pathways Kit includes:

- **6 STEM Pathways Labs**
- **6 Spark:bit Robotic Controllers**

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*

TELLO DRONE

OVERVIEW

Tello is a drone that helps kids learn the basics of coding through a mobile coding app. Kids can command Tello to perform corresponding movements and further develop their programming skills by playing games and completing levels using a smart mobile device.

PRODUCT SPECIFICS

Includes:

- **15 Tello Drones**
- **4 pairs of propellers**
- **1 propeller guard set**
- **3 batteries**
- **1 USB charging cable**
- **1 battery charging hub**

TEACHER AND MENTOR NOTES

The Tello Drone is easy enough for middle school aged youth to use indoors our outdoors.

The EDU app supports Scratch, a kid-friendly programming language. With a mobile device, kids can drag coding blocks that command Tello to perform exciting movements. Games with challenging levels teach more programming skills in a fun way.

The Tello has a flight controller powered by DJI that lets you perform awesome tricks for indoors and outdoors. Use it like an FPV drone, grab your remote control, and start a racing game. Flying has never been so fun and easy.

ONLINE RESOURCES

- *https://www.ryzerobotics.com/tello*

The Federal Aviation Administration requires registration of many drones flown in the US, for hobby or commercial purposes. To learn more about drone registration requirements, visit the Federal Aviation Administration's drone page https://www.faa.gov/uas/

3D PRINTER

OVERVIEW

A 3D printer is a printer capable of bringing digital, 3-dimensional models to life! Kids learn important lessons about trial and error, problem-solving, patience, and time management for a wide range of projects.

PRODUCT SPECIFICS

3D Printer includes:

- **12 rolls of filament**
- **Spare Parts Pack**
- **Quick Start Guide**
- **Tool Kit**

TEACHER AND MENTOR NOTES

Be sure to prepare files for printing using slicing software such as Cura or Matter control. The slicing process is an essential part of the printing process to establish the setting for the printer. When you are ready to print, download an object fill compatible with your 3D printer.

Make sure to warm up the printer prior to starting the printing process. Be sure the printer is calibrated and the filament is properly fed to the print nozzle.

ONLINE RESOURCES

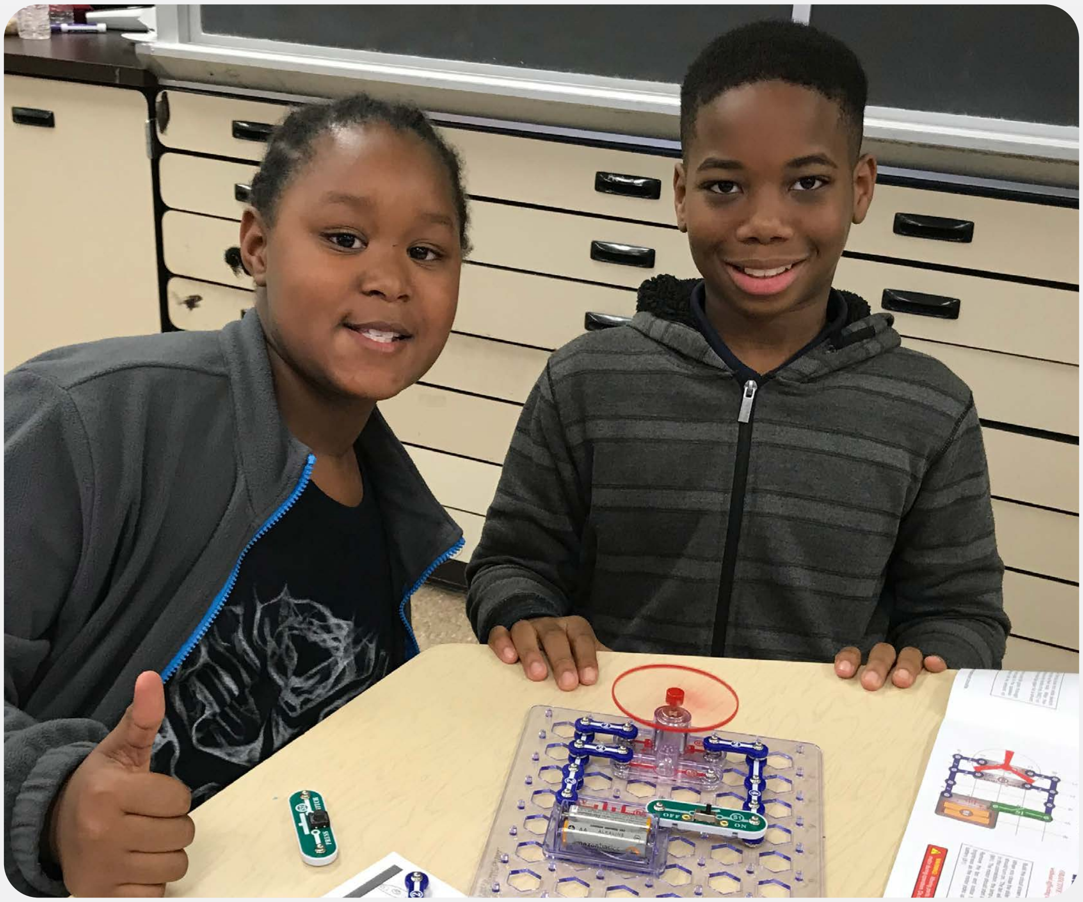
- *https://www.tinkercad.com/*
- *https://www.tinkercad.com/lessonplans*

LESSONS

PHYSICAL SCIENCES

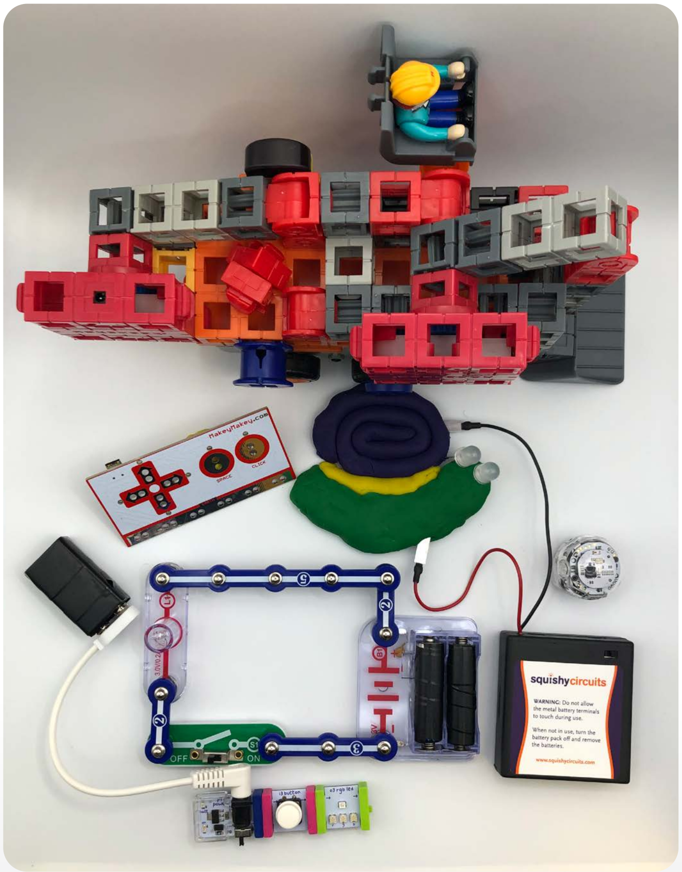
LIFE SCIENCES

EARTH & SPACE SCIENCES



LESSONS

We put together several lessons that utilize the Ripken Foundation STEM Kit. The lessons will rely heavily on the equipment provided, but may call for some additional resources. These lessons are designed for intermediate elementary and middle school age-range youth.



All of our lessons were developed to align with the Next Generation Science Standards, a national set of educational standards for STEM fields. These standards are used with in-school plans of study creating a cohesive learning experience for kids. The Next Generation Science Standards were developed to establish skills and concepts crucial to STEM learning. By basing our curriculum on these standards, we ensure that our activities and lessons align with national standards that are dedicated to education and youth development. For more information, visit *https://www.nextgenscience.org/*

OVERALL TIME *45- to 60-minute lesson*

OBJECTIVE

Kids will use littleBits to design a device that performs multiple energy transformations.

OVERVIEW

Kids 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**
- **Regular flashlight**
- **Crank Powered Flashlight (or other mechanically powered flashlight)**
- **Paper**
- **Pencil/pen**

Next Generation Science Standards

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 littleBits kits are organized and contain the parts needed to construct the Ferris wheel. To save time during the lesson, teachers/mentors 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. Kids will compare and contrast the two flashlights in terms of energy and energy transformations.
3. As a group, discuss the energy transformations in each flashlight.

Explore *(10 to 15 minutes)*

1. Challenge kids 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 groups.

Explain *(10 minutes)*

1. Introduce kids 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 kids to use littleBits to construct a device that converts the chemical energy in a battery to as many other forms of energy as possible.
   - Kids 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 kids draw a diagram of their device and label where the different energy transferred occurred in the device.

Next Generation Science Standards

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-minute lesson*

OBJECTIVE

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

OVERVIEW

Kids will learn about gravitational potential energy and will use littleBits to construct a device that changes the gravitational potential energy of another object. Kids 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**
- **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 kids have not used littleBits in the past, plan to add time to this lesson to introduce kids 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 kids for a prediction of what will happen when the slinky is released.
2. Kids 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 kids what type(s) of energy is (are) involved.

Explore *(15 to 20 minutes)*

1. Challenge kids 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.

Explain *(5 to 10 minutes)*

1. Introduce or remind kids 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 room. For example, calculate the gravitational potential energy of a textbook sitting on a table (with the change in height measured from the floor).

Elaborate *(15 to 20 minutes)*

1. Kids will use the device that they constructed during the Exploration phase to lift a small mass at least 20 centimeters off the floor or the surface of their desks/tables.
2. Kids 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.
    - Kids can use either 9.8 m/s2 or 9.81 m/s2 for gravitational acceleration in free fall.
3. Instruct kids to repeat the previous two steps using a different mass.
4. Ask kids *what happens to the gravitational potential energy of the mass if it is dropped*?

Evaluate *(10 minutes)*

1. Kids will answer the 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-minute lesson (may need to divide over lessons)*

OBJECTIVE

Kids 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.

Next Generation Science Standards

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.

OVERVIEW

Kids will construct an electronic car using the littleBits and 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. Kids will run various trials where the speed or mass of the car varies. Kids 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 (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 kids have not used littleBits in the past, plan to add time to this lesson to introduce kids 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 kids. An accommodation for kids with limited experience with graphing would be to provide graphs with pre-labeled axes.

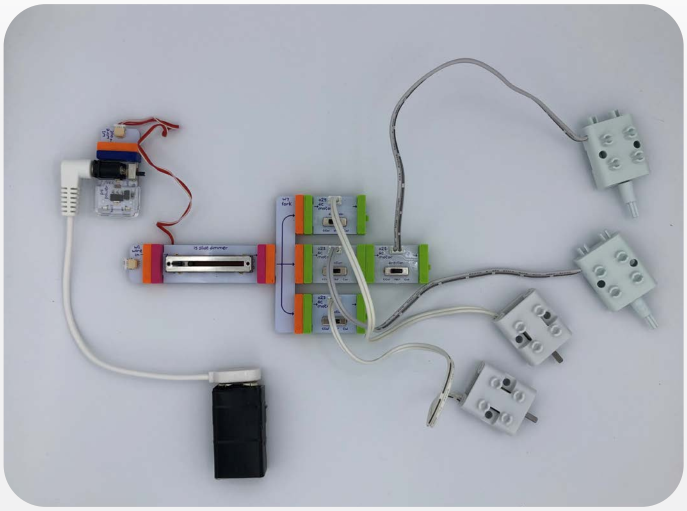
LESSON SEQUENCE

Engage *(5 minutes)*

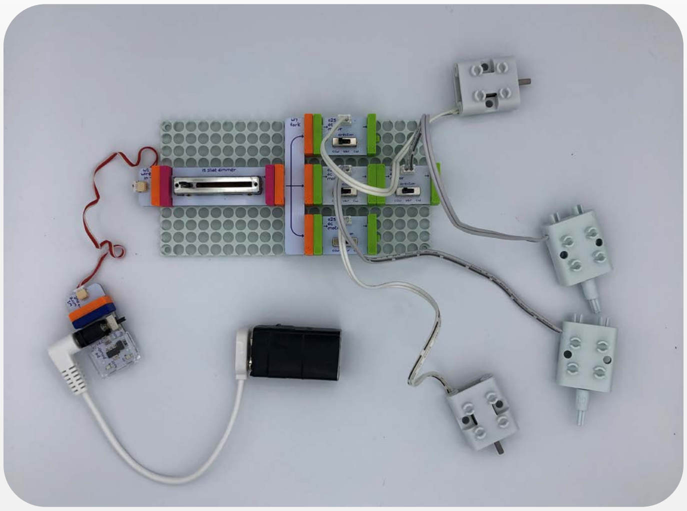
1. Roll a tennis ball and a basketball across the floor at the same speed.
2. Kids will discuss the following question with a partner:
    - *Which ball had more energy while it was rolling across the floor? Explain your reasoning.*
3. Discuss answers as a group.

Explore *(15 to 20 minutes)*

1. Kids 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 1a).
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 1b).

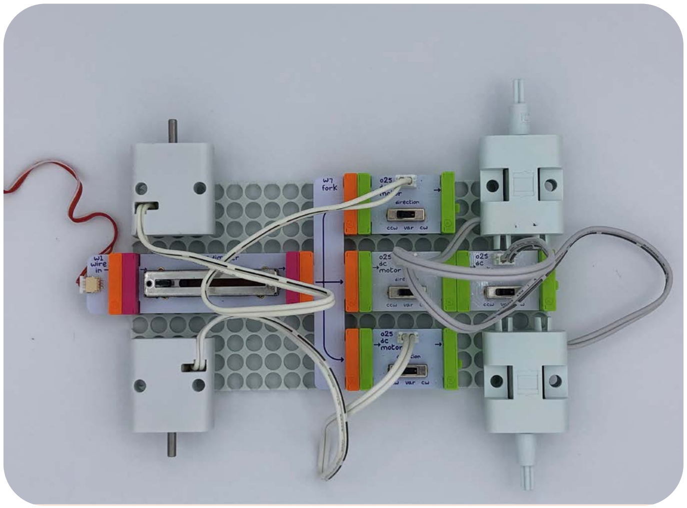


Picture 1a

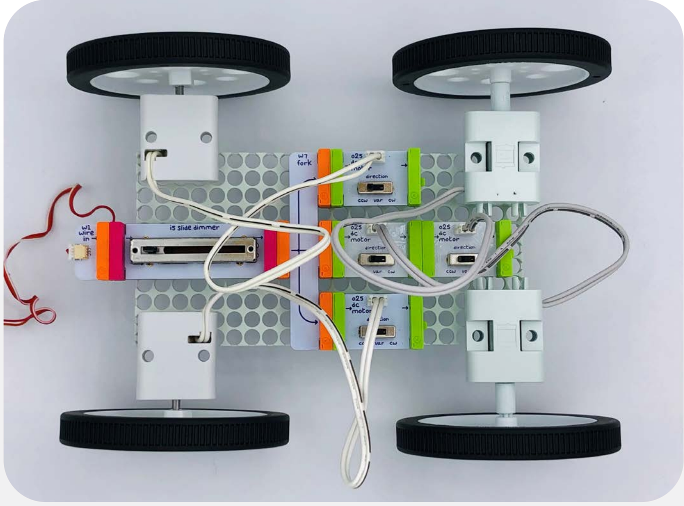


Picture 1b

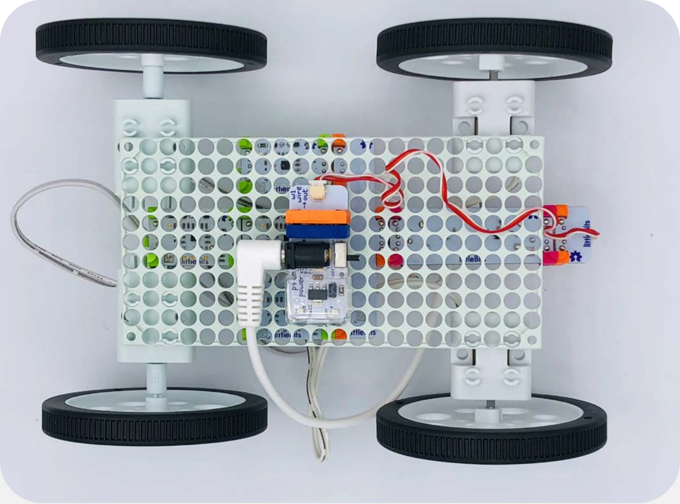
4. Attach one motor in each of the four corners of the board (Picture 1c).
5. Add a wheel to each motor (Picture 1d).
6. Attach the power bit to the underside of the board (Picture 1e).
7. Tape the battery in place on the topside of the car so that it doesn't block any of the controls (Picture 1f).
8. Adjust the direction of each motor to either "ccw" or "cw" so that all the wheels turn forward when the motors are on.
9. Kids will identify what energy transformations are occurring in the model car.



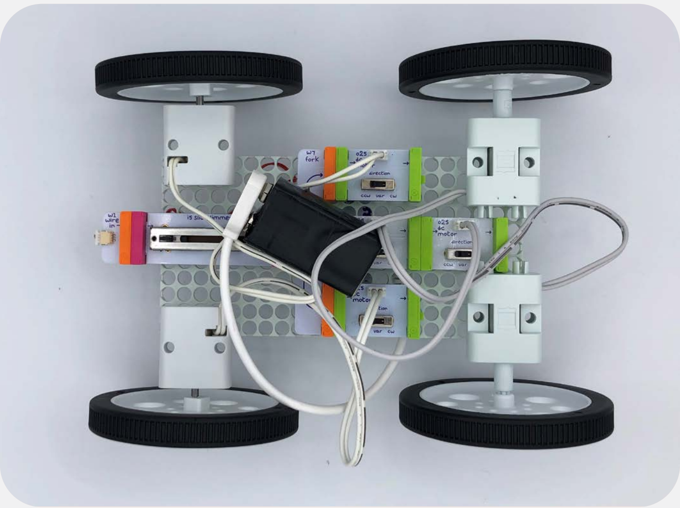
Picture 1c



Picture 1d



Picture 1e



Picture 1f

Explain *(10 to 15 minutes)*

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

Part 2 - Changing mass

1. Kids 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. Kids will use the same travel distance that was already measured on the floor or lab table.
3. Kids will place a small mass on the model car (ex: 50 grams) and measure the mass of the model car. Remind kids that the mass should be measured in kilograms.
4. Kids will set the adjustable slider on the car to full power.
5. Kids will release the car and use the stopwatch to measure how long it takes to travel the measured distance.
6. Kids will use the distance and travel time to calculate the velocity of the model car.
7. Kids will use the mass and velocity of the model car to calculate the kinetic energy of the model car.
8. Kids 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. Kids 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. Kids will explain how changing the mass and velocity of the car affected its kinetic energy.
3. Kids will compare and contrast the graphs, noting any differences in the shapes of the graphs.
4. Discuss results as a group.

WORK AND POWER

Next Generation Science Standards

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.

OVERALL TIME *50- to 65-minute lesson*

OBJECTIVE

Kids will calculate the approximate power of a motor from the littleBits.

OVERVIEW

Kids will use a littleBits motor to construct a simple crane and will use the motor to lift various masses. Kids 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 (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 kids have not used littleBits in the past, plan to add time to this lesson to introduce kids 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 kid a stack of books. Ask them to lift the stack slowly and place it on a table. Measure the time to lift the books.
2. Ask another kid to do the same thing but to do it as fast as possible. Measure the time to lift the books.
3. *Ask kids whether they did the same amount of work. If not, what was different?*

4. Guide kids to the conclusion that they did do the same amount of work, but they did the work at different rates.

Explore *(5 to 10 minutes)*

1. Give kids 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 kids 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. Kids will construct the following table in their notebook:

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

2. Kids 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: Kids 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 kids to give an example in which little work is done, but much power is required and vice versa.

CONSTELLATIONS

OVERALL TIME *60- to 75-minute lesson*

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.

Next Generation Science Standards

MS-ESS1-3

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

OBJECTIVE

Kids will use littleBit to construct a three-dimensional scale model of a fictitious constellation.

OVERVIEW

Kids 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 kids understand the scale relationships of large distances.

LEVEL OF DIFFICULTY

Intermediate

MATERIALS

- **littleBits (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 kids, it might be necessary to order additional LED bits. If kids have not used littleBits in the past, plan to add time to this lesson to introduce kids 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 kids. 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. Kids 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)*

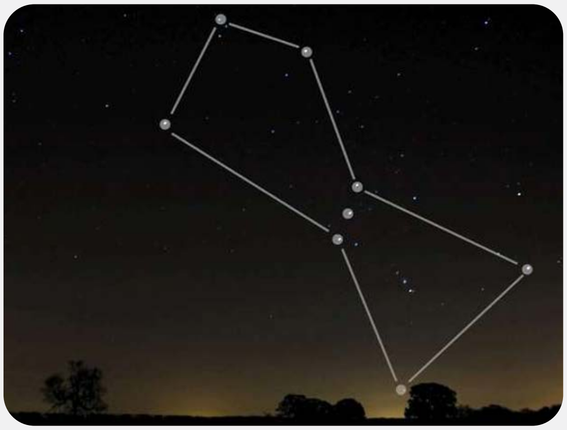
1. As a group, construct a human scale model of a fictitious constellation.
2. Tape or designate a line on the floor that will represent Earth's surface.
3. Use small pieces of tape or other markers to mark distances in one-meter increments from Earth's surface (1 meter, 2 meters, 3 meters, etc.).
4. 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 space available in the room, work as a group to decide on an appropriate scale for the mode (Example: 20 light-years = 1 meter).
6. Work as a group to complete the table to find the scaled distances for each star.
7. Select five kids, one to represent each star, and give each kid a flashlight.
8. Each kid will stand the scaled distance away from Earth's surface and hold their flashlight so that it points towards the front of the room. Kids can hold their flashlights at different heights to create the shape of the fictitious model constellation.

Explain (*5 minutes)*

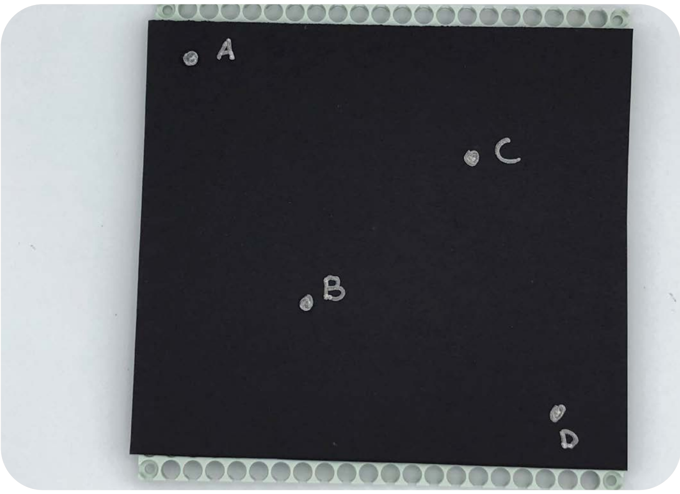
1. Explain that a constellation is a group of stars forming a recognizable pattern that is traditionally named after its apparent form or identified with a mythological figure.
   - Modern astronomers divide the sky into 88 constellations with defined boundaries.
   - Though constellations look flat 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.



Picture1g

Elaborate (*30 to 20 minutes)*

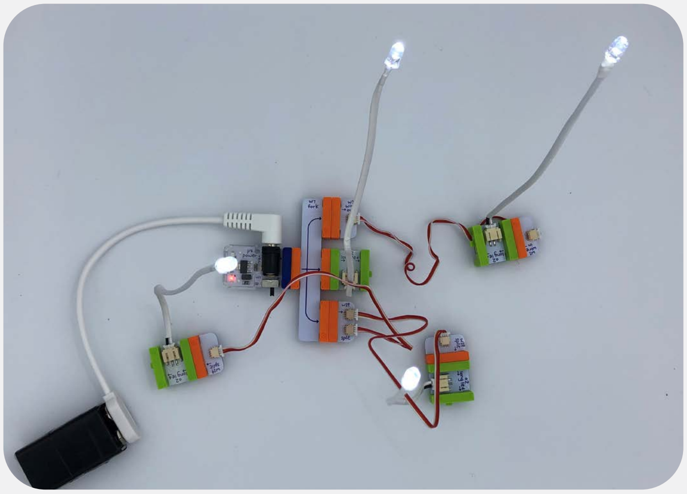
1. Kids will work with a group to use littleBits to create a scale model of a fictitious constellation.
2. Cut a piece of blank printer paper so that it fits on a littleBits base grid.
3. On the paper, mark locations in the light sky for Star A, B, C, and D.
4. Tape paper to a littleBits base grid, which will represent Earth's surface. (Picture 1h)
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 1h

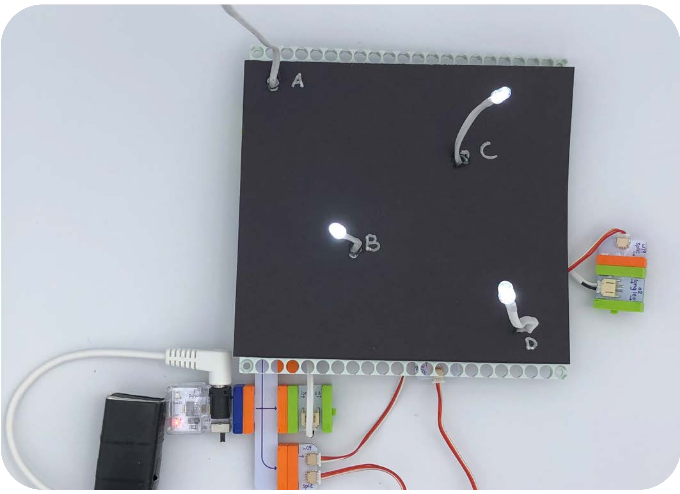
Star	Distance from Earth	Scale Distance from Earth
A	112 light-years	
B	67 light-years	
C	35 light-years	
D	123 light-years	

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 1i)
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.

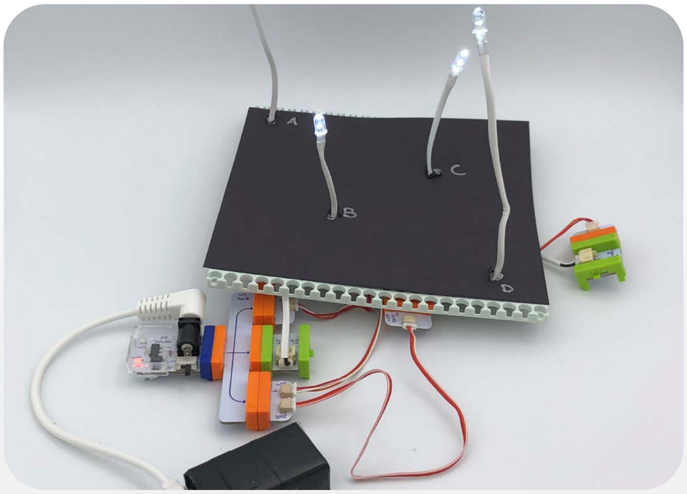


Picture 1i

9. Create a small hole in the paper by each star and push each long LED up through one of the holes. (Picture 1j)
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 1k)



Picture 1j



Picture 1k

Evaluate (*5 minutes)*

1. Kids 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.

OVERALL TIME *120- to 135-minute lesson (can split into multiple lessons)*

OBJECTIVE

Kids will identify how Sphero BOLTs can power a land-based vehicle constructed from craft supplies. The kids can iterate on and adjust their program to match the land-based vehicle they created. TKids can collaborate on making their land-based vehicle more effective.

LEVEL OF DIFFICULTY

Beginner

MATERIALS

- **Sphero BOLT**
- **Pencil/pens**
- **Plastic cups**
- **Popsicle sticks**
- **Straws**
- **Tap**
- **Construction paper**
- **Tag board paper**
- **CD's or objects that are round**
- **Different size paper clips**
- **Have a copy of our Ripken Foundation 5E Model of Instruction**

PREPARATION

Ensure the BOLT is charged and the kids have access to Chromebooks or Tablets to program the BOLT. The craft supplies should be easily accessible to the kids, so they can build their land-based vehicle.

LESSON SEQUENCE

Engage *(10 to 15 minutes)*

1. A wheelbarrow is a very efficient way to transport materials form point A to point B by using only one wheel and a bucket to carry that material. The BOLT can be used similarly as a wheel, but because it is spherical, there is no spot for an axle to brace a bucket on top of it. This presents a problem for being able to transport, carry, push, and build with a BOLT.
2. *What could you do to use the BOLT as a motor/wheel for a chariot or other land-based vehicle to use to carry materials between different points?*

Explore *(10 minutes)*

1. Assign kids to groups or partners.
2. Each pair or group will conduct online research to identify different modes of transportation that require wheels.
3. Kids organize research and summarize findings.

Explain (10 to 15 minutes)

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

Elaborate *(30 to 40 minutes)*

Use your research to elaborate, noting their design and function. Find photos and videos, noting their design and function.

- *What materials were they made of?*
- *How many wheels did they have and how big were the wheels?*
- *How many horses/other animals were used to pull them?*

If your team were to use a BOLT like a horse is used to pull a chariot, how would you engineer your Chariot? Sketch out some ideas.

Evaluate *(15 minutes)*
How might the BOLT be used to pull a chariot? The video below is a good place to start.

▶ *https://youtu.be/IqYEcTHzA2Y*

Examine the chariot construction and decide on what materials will be used to build a chariot. Brainstorm a couple designs by experimenting with materials.

- *Will you use a wheel?*
  - *What kind and size?*
  - *What will you use for an axle?*
- *Which chariot design might work best? and why?*

Select your favorite idea and share among your team.

Elaborate (30 minutes)

1. Have the kids start building their chariot prototype.
   - Look to see what is touching or dragging on the ground.
   - *Is the chariot too heavy for the BOLT to pull?*
   - Check for anything else that may keep the Sphero BOLT from pulling the chariot.

2. Now it is time to program the BOLT and chariot to move around the room.
    - Program the BOLT to navigate around a couple of obstacles in the room.
    - Use roll blocks and delay blocks to achieve precision turns and navigate to specific distances.
    - Now that you have tried programing the BOLT around the classroom with the chariot, try the exact same program but this time without the chariot attached to the BOLT. Observe and record your findings.

Evaluate (15 minutes)

- *What do you notice about how the program runs with or without the chariot?*
- *How does the mass or weight of the chariot change the program?*
- *What worked well with your program? What worked well with the chariot?*
- *What would you want to change with the program?*

OVERALL TIME *70- to 80-minute lesson*

OBJECTIVE

Kids will learn about the Sphero BOLT's onboard sensors and explore how to manipulate them to control the BOLT's behavior and report data.

LEVEL OF DIFFICULTY

Beginner

MATERIALS

- **Sphero BOLT**
- **Chromebook or Tablet**

PREPARATION

Ensure the BOLT is charged and the kids have access to Chromebooks or Tablets to program the BOLT.

LESSON SEQUENCE

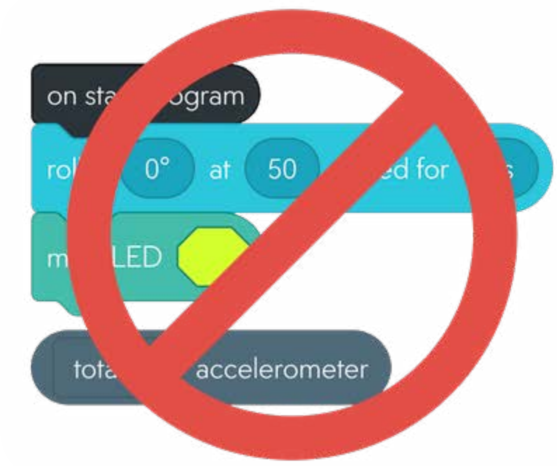
Engage *(10 minutes)*

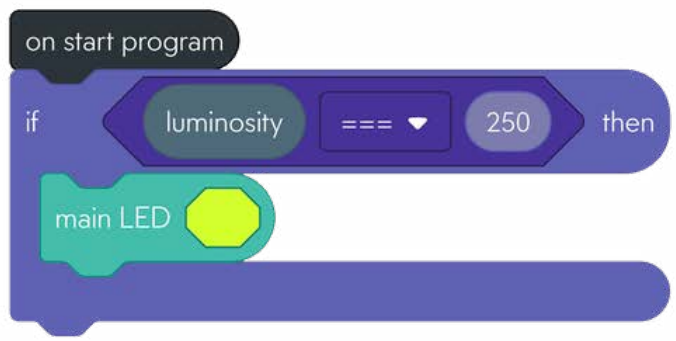
Let's look at the possible **Sensor Blocks** that you can program with your BOLT:

- Accelerometer
- Pitch
- Gyroscope
- Velocity
- Location
- Distance
- Speed
- Heading
- Time Elapsed
- Compass Direction
- Luminosity

You will notice that the **sensor** blocks are mostly pill shaped, which means they do not stack like other coding blocks. Instead, sensor blocks fit inside of other coding blocks. This is because a **sensor** block will return a numerical value. So, anywhere that circular/pill-shaped block fits is a numerical value in the program.

Explore each category and look for blocks that can include a **sensor** block. All you need to do is match the shape!

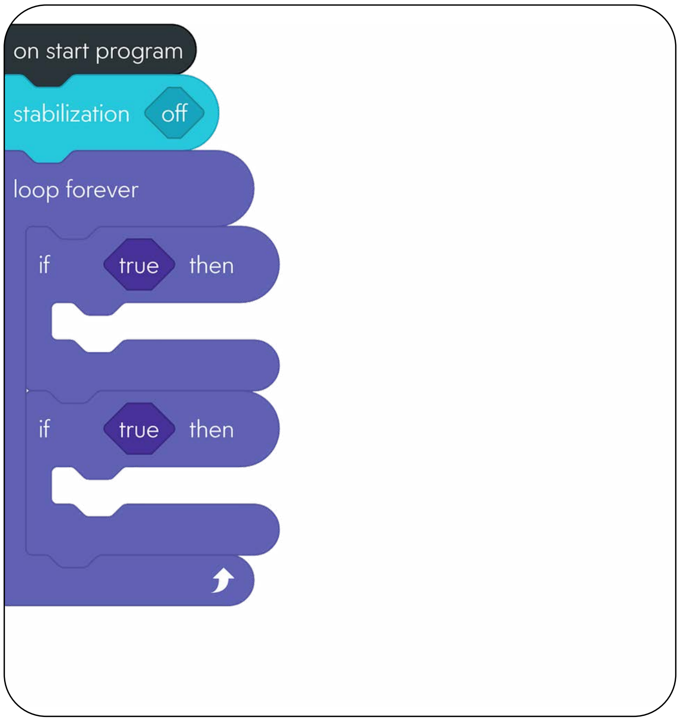


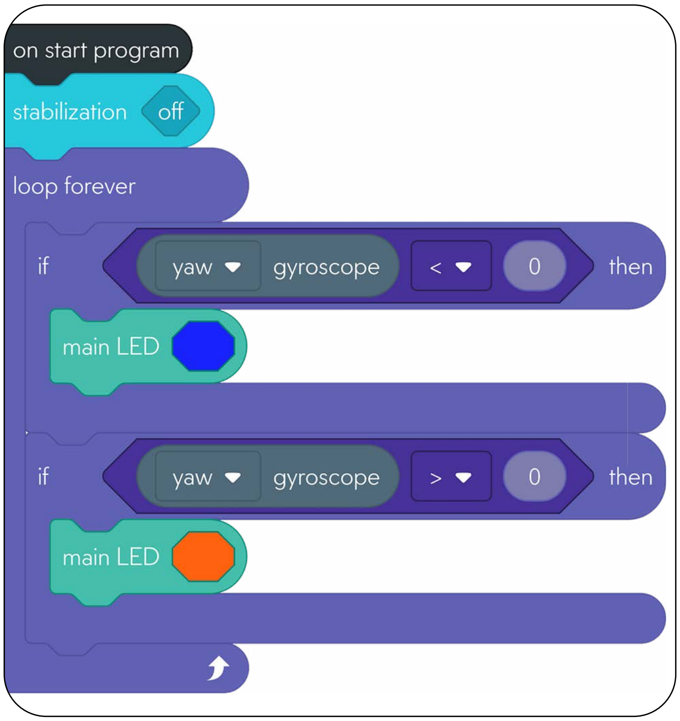


Explore *(30 minutes)*

Activating Sensors

1. Sensor blocks are often used in **conditional** and **comparator** blocks. The **sensor blocks** are used in a **comparator block** to compare the value of the sensor and another numerical value. The second numerical value is the threshold or conditions that gives the program a flow.
    - Let's build a simple program to see how this works. Use the pictures below to guide you. Just by looking at the pictures, *do you know what this program will do*? When you are done, share the results with another peer.
        - *What does this program do?*
        - *Can you explain to a partner what each command is doing and why?*
        - Build the program as outlined in the images.
        - Run the program.
        - Explain to your partner when the **main LED** will change color based on sensors.
2. Now that you have the structure/logic of a program that uses the sensors, the same structure can be used by just switching out the sensor block with a different sensor.
    - Find another one of the sensor blocks and substitute the **yaw gyroscope** with the new **sensor block**.
    - Adjust the numerical value that the comparator block is comparing the sensor block against.
        - If you do not know how a sensor is being used, long press or right click on the sensor block and it will provide you with a brief detailed description of how that sensor block is being measured.





Explain *(20 minutes)*

Debugging

- There are several ways that you can use the different sensors, but it's always important to be able to know what the sensors are reading.
- If you want to view the sensor data of a BOLT robot, you can run a program to view the following data points in the live sensor data (only available on the iOS and Android version of The Sphero Edu app)
  - Location
  - Orientation
  - Gyroscope
  - Accelerometer
  - Velocity
  - Distance

Elaborate *(20 minutes)*

Some of the sensors, like the Ambient Light sensor, don't have a live sensor view available. You can take advantage of the concept of "building strings" in the Sphero Edu App to report that data back to the user through a **speak block** or a **scrolling text block**.

- Let's start by understanding the lux value of the ambient light of where you are. To do this, we'll need to build a **string**.

- Start with a loop forever block. You want the program to continually check the lux value.
- Add a delay block and set the duration of 0.1 second. This allows the light sensor to gather the most accurate reading.
- Add a **speak block** and embed a **build string** operator.
    - Select the edit pencil on the operator block. Delete the first string.
    - Add a number and string.
- Place the luminosity sensor block in the number box and type “lux” in the string box.

Evaluate *(15 minutes)*

- Now, run the program. You should hear your programming device speak out the lux value that the ambient light sensor is recording every second or so.
- Try using a flashlight or putting your robot in a backpack or dark space to see how the values change based on how the BOLT is sensing the light intensity.

OBJECTIVE

Kids will be able to use appropriate software to design a program capable of navigating a given path.

Next Generation Science Standards

K-PS2-2
Analyze data to determine if a design solution works as intended to change the speed or direction of an object with a push or a pull.

3-5-ETS1-1
Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

MS-ETS1-2
Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

MATERIALS

- **Sphero BOLTs in sufficient numbers**
- **Bluetooth enabled tablets/smart phones with the Sphero EDU app installed**
- **Sufficient space for each group to drive their robot unimpeded**
- **Measuring tapes**
- **Graph paper**

INSTRUCTIONAL ACTIVITIES

Warm Up

Ask kids to describe how to get to common areas in the school building (cafeteria, library, etc.). Ask them to explain how they learned the directions. Transition to the idea that programmers also need to give robots directions to make them work. *(5 min)*

Teacher/Mentor introduces Sphero BOLT and Sphero EDU app, reviewing basic functionality and class expectations. Teacher/Mentor should begin by demonstrating the Drive function in the app. Give kids time to practice orienting and driving the BOLT. Teacher/Mentor circulates, aiding kids as needed. *(15-20 min)*

Bring kids back together and debrief. What was the easiest part of driving the BOLT? What was the hardest? What is one tip they would give to someone driving a BOLT for the first time? Consider recording thoughts/tips on the board or chart paper for future reference. *(5-10 min)*

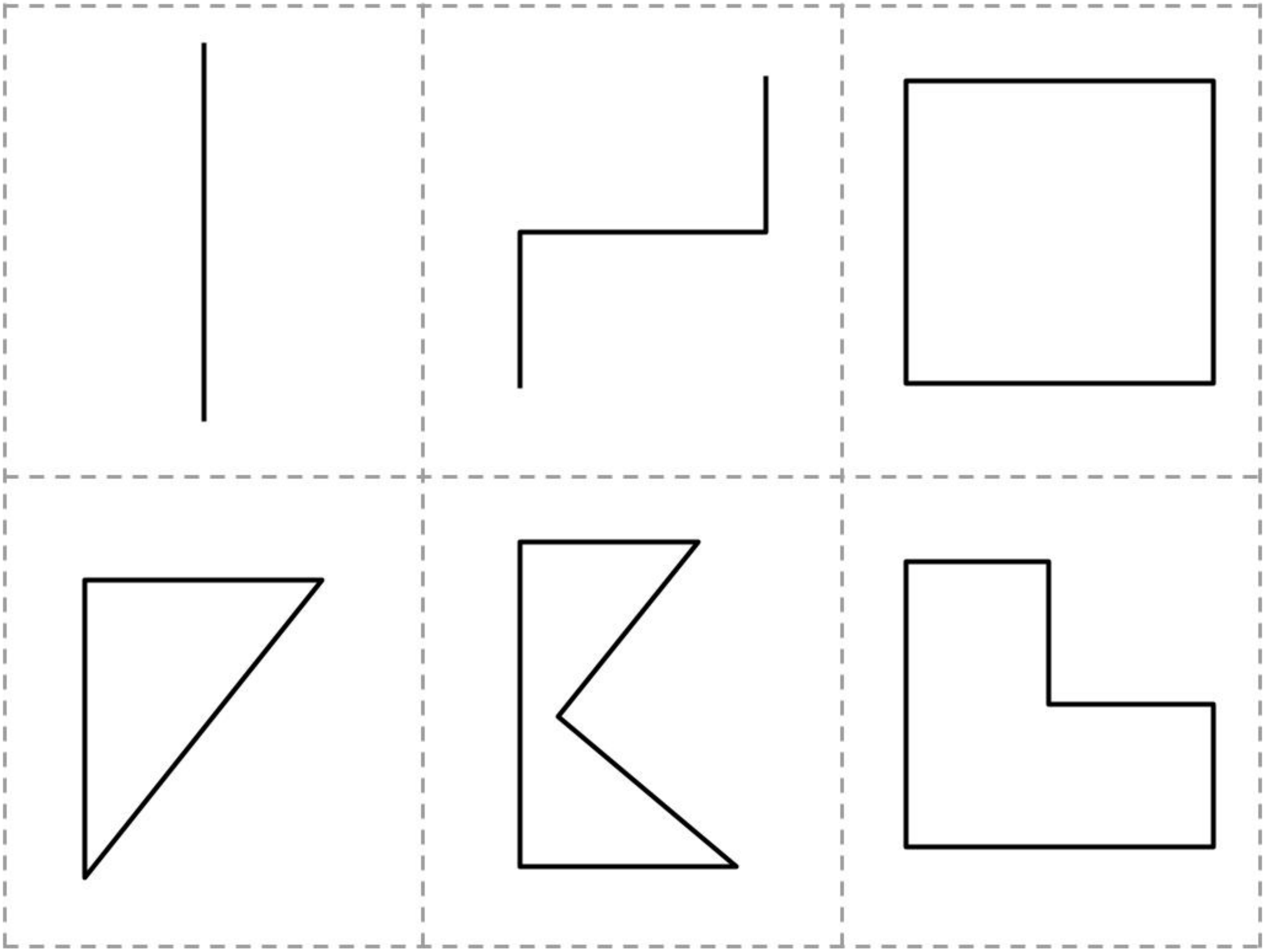
Teacher/Mentor will now intro/demo creating a program in the app. As appropriate to skill level/age, review both the Draw and/or Block coding styles. (*10-15 min*)

Divide the kids into pairs or groups of three (depending on available materials and teacher/mentor discretion). Give kids an increasingly difficult series of shapes (see attached suggestions or create your own). Working together, they should create programs to meet each challenge. Consider having kids draft their programs on paper first. Measuring tapes and graph paper may be useful tools in this process. Each teacher/mentor should define the programming language being used (Draw for lower-level learners/shapes, Blocks for higher levels). Teacher/Mentor circulates, providing assistance, making suggestions, verifying successful programs, etc. *(30 min+)*

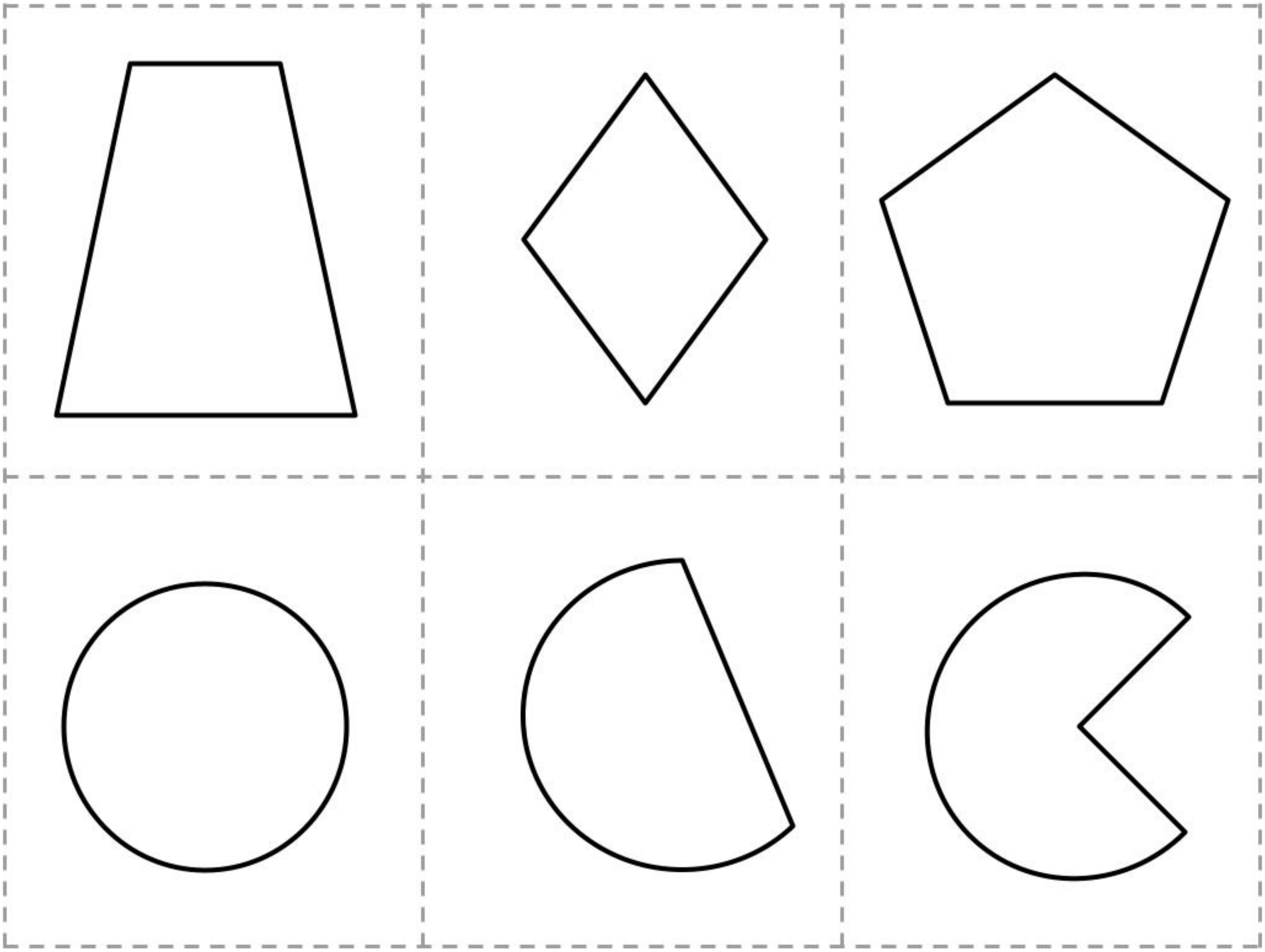
Reflection

What was most challenging about programming your robot? How was giving a robot directions different from giving a human directions? What other kind of shape would you like to try programming? (This can be completed as whole group discussion, small group discussion, written reflection, or some combination of the above. (*10 min)*

SUGGESTED SHAPE CARDS



SUGGESTED SHAPE CARDS



OBJECTIVE

Kids will be able to use appropriate software to design a program capable of navigating a given path.

Next Generation Science Standards

3-5-ETS1-1
Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

MATERIALS

- **Sphero BOLTs in sufficient numbers**
- **Bluetooth enabled tablets/smart phones with the Sphero EDU app installed**
- **Sufficient space for each group to design and test a maze**
- **Masking tape or similar**
- **Plastic cups/bins/etc. to serve as course obstacles (teacher/mentor discretion)**
- **Measuring tapes**
- **Graph paper**

INSTRUCTIONAL ACTIVITIES

Warm Up

Ask kids to describe how to get to common areas in the school building (cafeteria, library, etc.). Ask them to explain how they learned the directions. Transition to the idea that programmers also need to give robots directions to make them work. *(5 min)*

Teacher/Mentor introduces Sphero BOLT and Sphero EDU app, reviewing basic functionality and class expectations. Teacher/Mentor should specifically demo the Draw program type. *(5-10 min)*

Divide kids into pairs or groups of three (depending on available materials). Kids should be given time to experiment with creating simple draw programs (straight lines, squares, etc.). Once they appear comfortable, ask each group to determine how far the BOLT will travel per grid square on the Draw program screen. (approx. 10 inches) Teacher/Mentor circulates, aiding kids as needed. *(5-10 min)*

Setting the robots and tablets aside for now, kids should work in their groups to design a maze/course for their robot on graph paper. The course should require the robot to travel a total of at least 50 inches (distance can be modified to best suit space restrictions and/or the skill level). Once the course has been approved by the teacher/mentor, kids should use masking tape (or similar) to mark out the course on the floor and begin testing their plan with the BOLT. *(20-30 min)* Teacher/Mentor circulates, giving suggestions as appropriate.

Optional Challenge/Extension

Groups rotate to each course and attempt to create a program which enables their robot to navigate accordingly. Consider restricting the time at each course to increase difficulty/intensity (total time will depend on the number of groups and teacher/mentor discretion).

Reflection

What was the most challenging part of programming your robot? How was giving a robot directions different from giving a human directions? (This can be completed as whole group discussion, small group discussion, written reflection, or some combination of the above.) *(10 min)*

OBJECTIVE

Kids will be able to successfully use block coding to develop, test, and execute a program to navigate a given racecourse.

Next Generation Science Standards

MS-ETS1-4

Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process to achieve an optimal design.

MATERIALS

- **Sphero BOLTs in sufficient numbers**
- **Bluetooth enabled tablets/smart phones with the Sphero EDU app installed**
- **Sufficient space to define at least one racecourse and for small groups to test and practice their programs**
- **Masking tape or similar**
- **Plastic cups/bins/etc. to serve as course obstacles (teacher/mentor discretion)**
- **Measuring tapes**

PREP WORK

- Design a racecourse for kids to traverse using the robots. Shapes can be tailored to meet needs/skill level and time constraints. Consider figure eights, zigzags, or other shapes involving curves and turns.
- Using masking tape, painters' tape, or gaffer's tape, courses can be created on the ground, and objects such as plastic cups or bins can be used as navigation obstacles.
- Consider purchasing/designing certificates or other prizes as incentives.

INSTRUCTIONAL ACTIVITIES

Warm Up

What's the shortest distance between two points? (Expect the kids to say "A straight line") What happens when the path you have to take is not straight? Then, what's fastest? Have kids discuss in small groups, followed by a whole group review. *(5 min)*

Teacher/Mentor introduces Sphero BOLT and Sphero EDU app, reviewing basic functionality and class expectations. Teacher/Mentor should specifically demo the Blocks program type. Transition to the idea that kids will use this robot/technology to create a program which will race the designed course in the fastest time possible. *(10 min)*

The teacher/mentor divides kids into groups (2-3 per) and distributes one Sphero BOLT & tablet per group. Kids should be given a few minutes to experiment with the coding blocks and making the Sphero move. Teacher/Mentor circulates, answering questions as needed. *(10 min)*

Kids work in their groups to use the "Movements" section of block coding to design a program which will complete the racecourse in the most efficient time possible. Tape measures will be useful in this phase to help calculate appropriate distances. Allow teams to take turns testing their programs on the course.

Teacher/Mentor circulates, answering questions and making suggestions as needed. *(30 - 60 minutes, depending on the complexity of the course and skill level.)*

Teams should execute their final programs one at a time on the course, with the teacher/mentor keeping track of times on a board or chart paper. *(10-20 minutes, depending on the size of the class.)*

Reflection

What was the most successful part of your program? What adjustments during the trial phase made the biggest difference? What do you wish you could have done better? If you had another chance at it, what is the first thing you would try differently? (This can be completed as whole group discussion, small group discussion, written reflection, or some combination of the above.) *(10 min)*

To view Sphero intermediate lessons, please access the Ripken portal with the QR code below.

IONIC VS. COVALENT BONDS

OVERALL TIME *80- to 100-minute lesson (can split into multiple lessons)*

Next Generation Science Standards

MS-PS1-1

Develop models to describe the atomic composition of simple molecules and extended structures.

OBJECTIVE

Kids will use Makey Makey 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. Kids 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 kids/ 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 kid, 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 kids can obtain supplies. Print out copies of the ionic and covalent bonding worksheets.

LESSON SEQUENCE

Engage *(15 to 20 minutes)*

1. Kids will be using red and white poker chips to simulate the valence electrons of elements. As they complete the simulation, kids 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. *(Kids 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 group. 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: Kids should have been introduced to valence electrons and energy shells prior to attempting this lesson.*
3. If additional examples are needed, kids 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: Kids 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)*

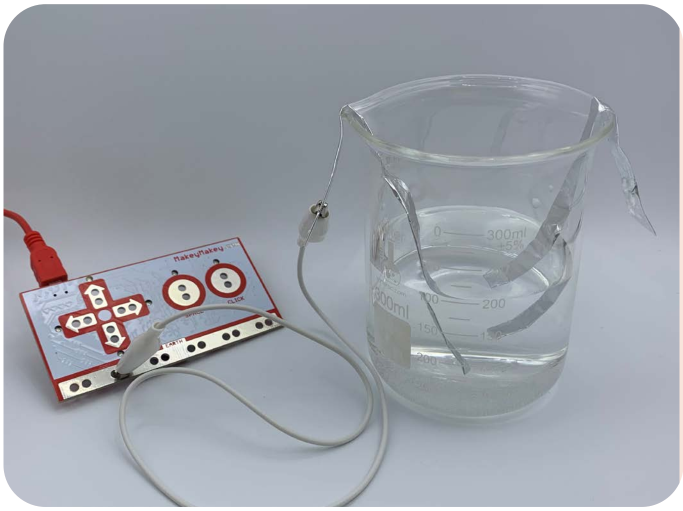
1. Kids will construct a Makey Makey test station to determine if various materials substances or solutions conduct electricity by following the steps below.
2. Kids will construct the following table in their lab notebook.
3. Put the first substance or solution in a small beaker.

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 3a)
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.
8. Connect the other end of the alligator clip to one roll of aluminum foil. (Picture 3b)
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.

Picture 3a

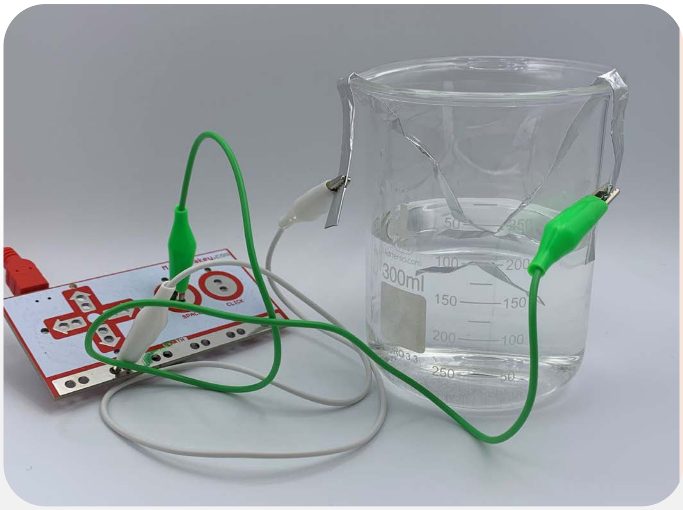
11. Connect the other end of the alligator clip to the other roll of aluminum foil. (Picture 3c)
12. Disconnect the alligator clip from the "Space" button and use that end of the alligator clip to touch either the "Space" button or the up, down, left or right arrow. If the material conducts electricity, 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 3b

Explain *(15 minutes)*

1. Discuss the results of the Exploration activity with kids 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-).



Picture 3c

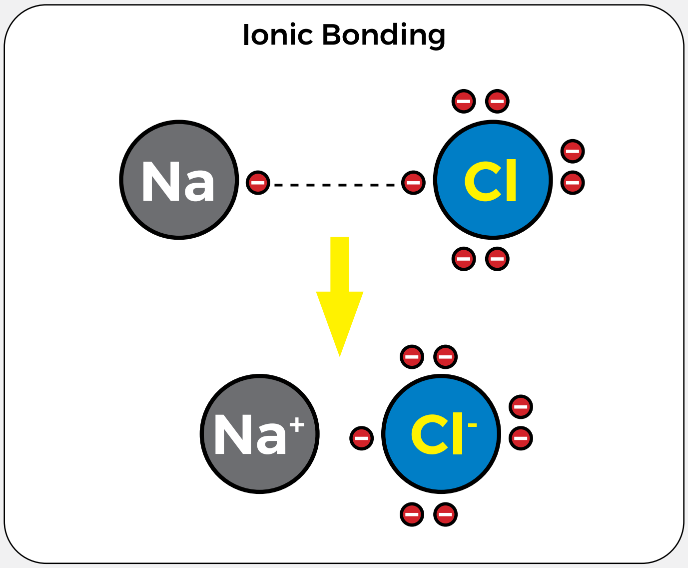


Diagram 3d

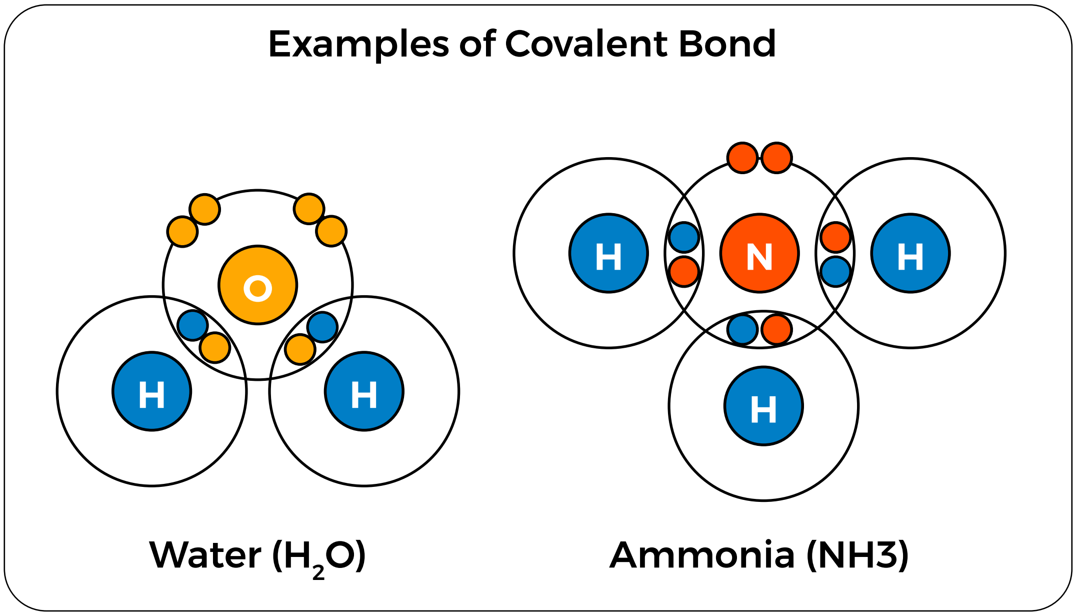


Diagram 3e

- 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 a stable energy state by filling their outer energy shell with 8 valence electrons. Hydrogen will share valence electrons to 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)*

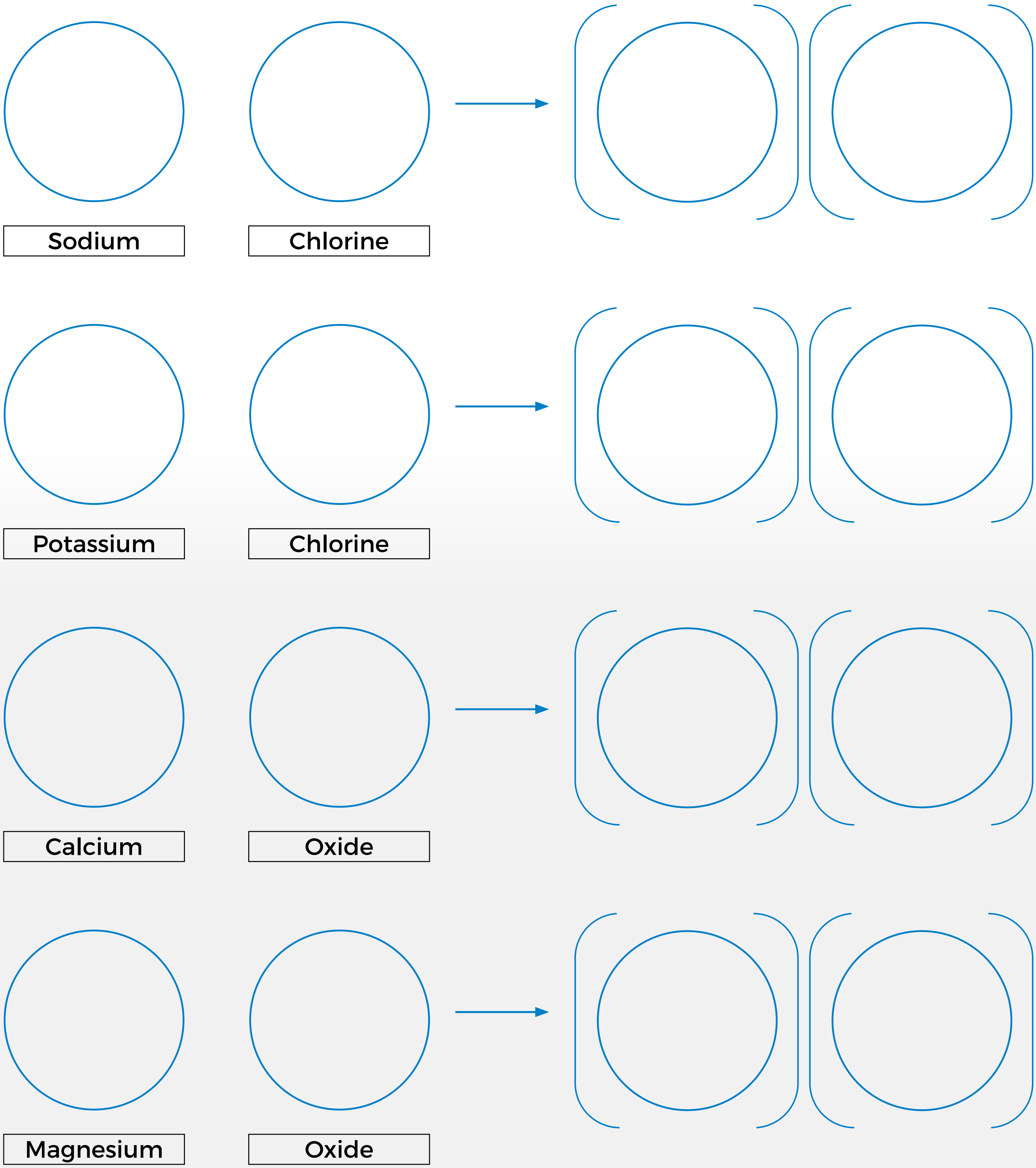
1. Kids will complete two worksheets in which they draw diagrams to show how valence electrons are exchanged in ionic bonds and shared in covalent bonds.
   - Ionic bonds worksheet
   - Covalent bonds worksheet

Evaluate *(5 minutes)*

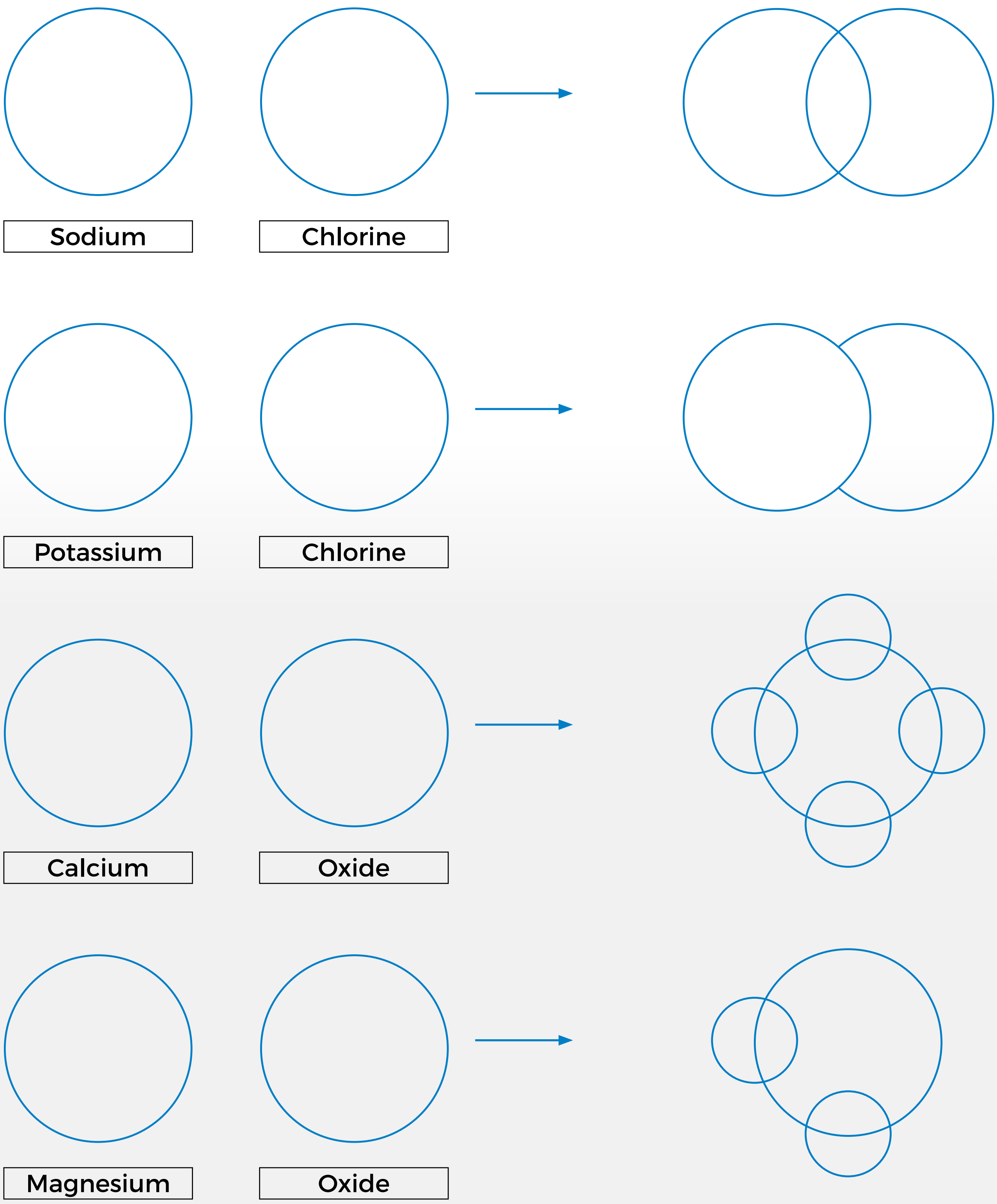
1. Kids will add a column to their table from the Exploration activity and identify whether each substance is formed by ionic or covalent bonds.

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		

DOT AND CROSS DIAGRAMS FOR IONIC COMPOUNDS



COVALENT COMPOUNDS
VENN DIAGRAM



OVERALL TIME *50- to 70-minute lesson*

OBJECTIVE

Kids 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. Kids will use Makey Makey to construct a testing station to determine whether various materials conduct electricity.

Next Generation Science Standards

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.

LEVEL OF DIFFICULTY

Beginner

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

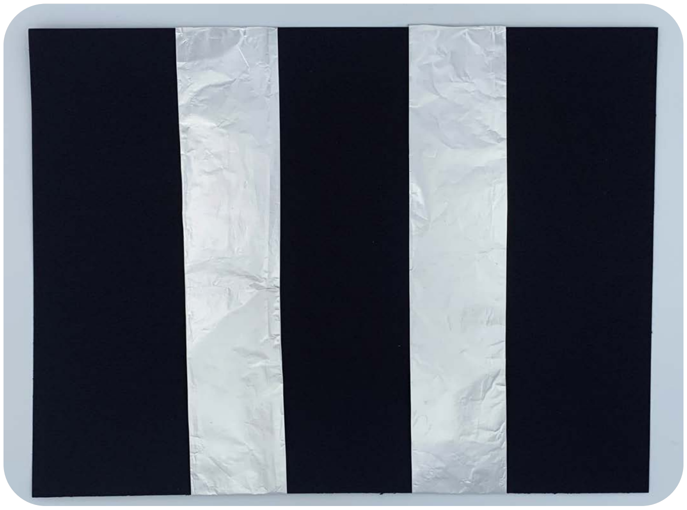
Engage *(10 minutes)*

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

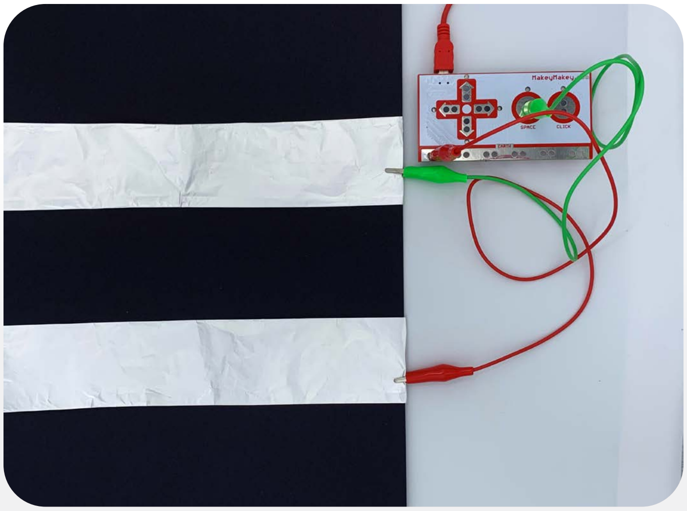
6. Show kids that the light bulb does not illuminate.
7. Ask kids to explain their observations.

Explore *(20 to 30 minutes)*

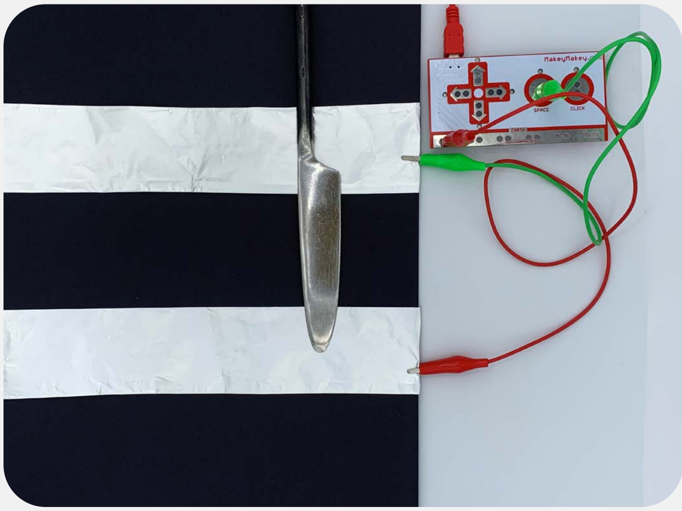
1. Kids will construct a Makey Makey test station to determine if various materials conduct electricity by following the steps below.
2. Cut two strips of aluminum foil approximately one inch wide and one foot long.
3. Tape the two strips of aluminum foil on a one-foot square piece of square, approximately one inch apart. (Picture 3f)
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 3g)
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 3g)
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 3h)
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. Kids will complete a table showing with materials are conductors and which materials are insulators.



Picture 3f



Picture 3g



Picture 3h

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.

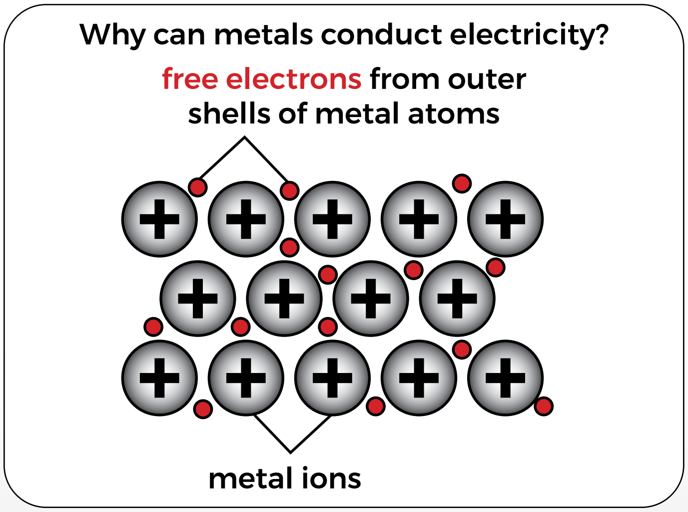


Diagram 3i

Elaborate (10 minutes)

1. Kids 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. Kids 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 kids construct their proposed testing stations.

Evaluate (5 to 10 minutes)

1. Kids 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.”

OVERALL TIME *95- to 115-minute lesson (can split into multiple lessons)*

OBJECTIVE

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

OVERVIEW

Kids will use Snap Circuits SC-750R 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

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 SC-750R 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 SC-750R 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 kids to write their own experimental design.

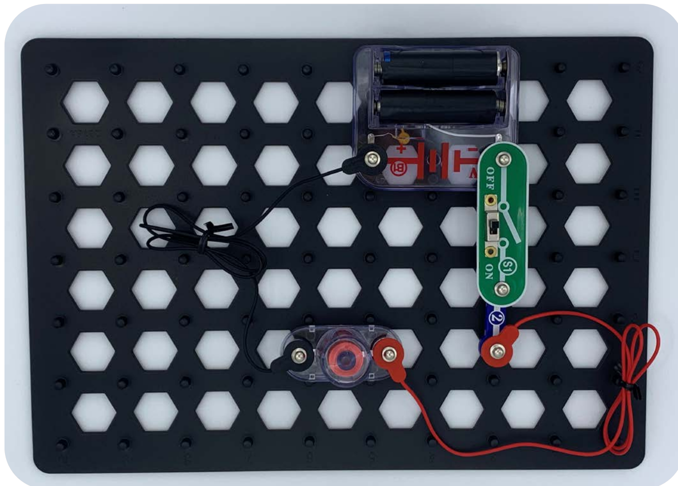
LESSON SEQUENCE

Engage *(10 to 15 minutes)*

1. Kids will construct a circuit with two battery holders, one light bulb, and a switch.
2. Kids 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. Kids will use Snap Circuits SC-750R 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 4a)
3. Kids will turn on the circuit and move the electromagnet attachment over paperclips.
4. Discuss observations.



Picture 4a

Explain *(5 minutes)*

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

Elaborate *(60 to 70 minutes)*

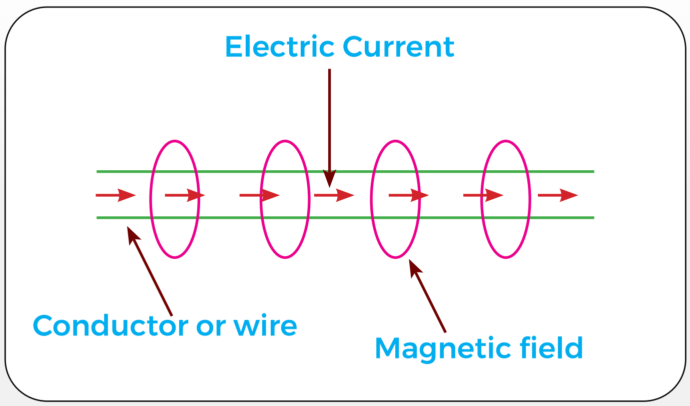


Diagram 4b

1. Kids 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, kids should coil wire around a ferromagnetic core and use two ends of the wire to complete the circuit).
3. Once kids 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, kids 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. Kids 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/mentors 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. Kids will write a conclusion summarizing the results of their experiment and answering their experimental question.

OVERALL TIME *55- to 70-minute lesson*

OBJECTIVE

Kids will use Snap Circuits SC-750R to determine the mathematical relationship between voltage, current and resistance.

Next Generation Science Standards

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

OVERVIEW

Kids will use Snap Circuits to construct simple circuits that contain various resistors. Kids 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 SC-750R 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)

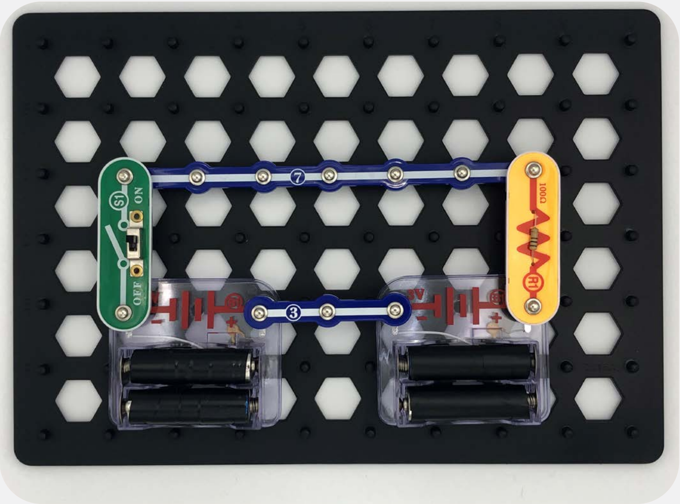
1. Open PHET Circuit Construction Kit on a computer and use a projector to show on the front board (*https://phet.colorado.edu/sims/html/circuit-construction-kit-dc/latest/circuit-construction-kit-dc_en.html*).
2. Show kids a simple circuit with one light bulb.
3. Now, add a second light bulb into the circuit.
4. Kids 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. Kids will use Snap Circuits to investigate the relationship between voltage, current, and resistance.
2. Teacher/Mentor will demonstrate how to use a multimeter to measure voltage, current, and resistance. Introduce kids to the correct units for each measurement. The following video explains how to use a multimeter: ▶ *https://www.youtube.com/watch?v=TdUK6RPdIrA*.
3. Kids will construct the following table in their notebook:

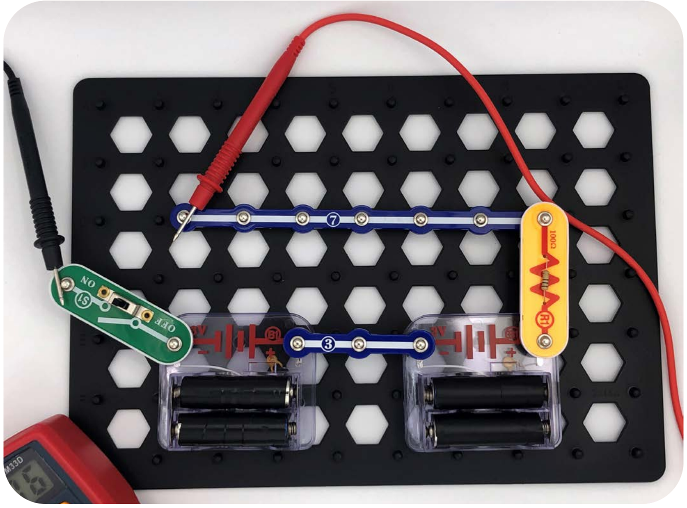
Number of Battery Packs	Resistance (Ω)	Voltage (V)	Current (A)
1	100		
1	1,000 (1K)		
1	10,000 (10K)		
2	100		
2	1,000 (1K)		
2	10,000 (10K)		



Picture 4c

4. Kids will construct a circuit using the specified number of battery holders, the specified resistor, and a switch. (Picture 4c)
5. For each combination of circuit design, kids will use the multimeter to measure the voltage and current and record this data in their table.
6. When kids 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 kids measure current, they will need to disconnect the Snap Circuit so that they can connect the multimeter in the series. (Picture 4d) Also, it is important to ensure that kids 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. Kids 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, kids 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 4d

Explain *(5 minutes)*

1. Discuss the results of the experiment with kids.
2. Ask kids 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 kids 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 kids 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 group.
4. Provide guidance as needed to lead to the correct formula for Ohm's Law (V = iR).
5. Instruct kids 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 kids to identify sources of error that might have led to these results.

Evaluate *(5 minutes)*

1. Kids 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-minute lesson*

Next Generation Science Standards

MS-PS2-3

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

OBJECTIVE

Kids will use Snap Circuits SC-750R to investigate the difference between parallel and series circuits.

OVERVIEW

Kids will use Snap Circuits to construct series and parallel circuits. Kids 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 SC-750R 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 paper copies.

LESSON SEQUENCE

Engage *(5 minutes)*

1. Show a picture of the following circuits:

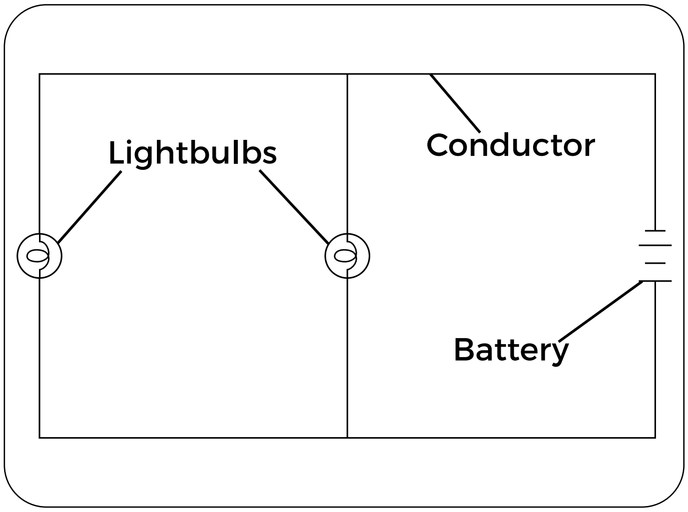


Diagram 4e

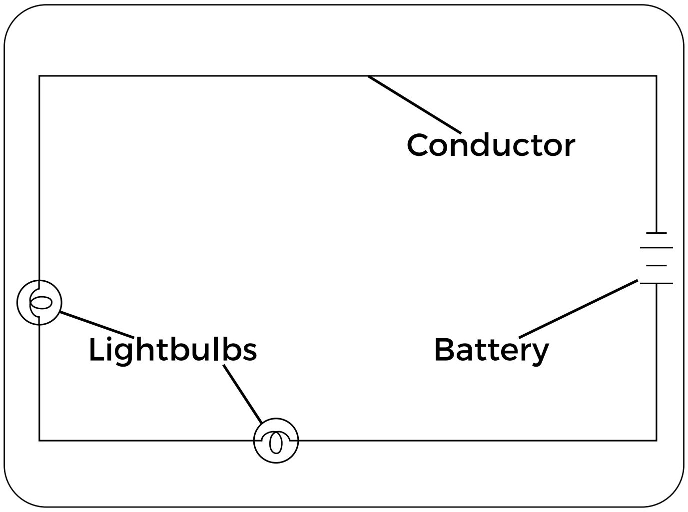
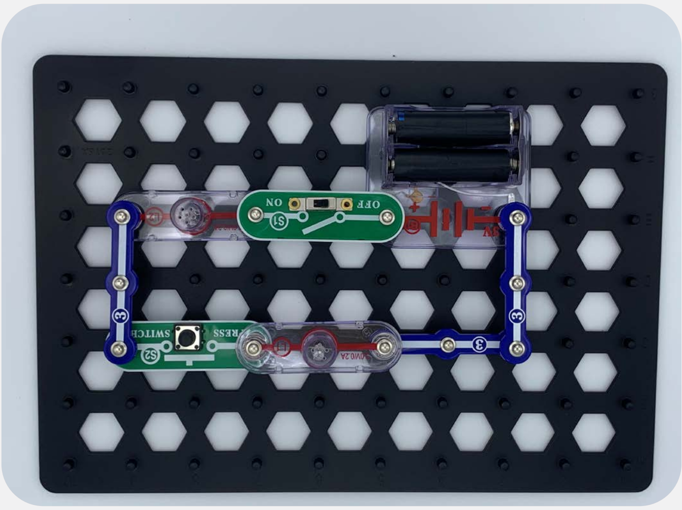


Diagram 4f

2. Kids 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 kids 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?*

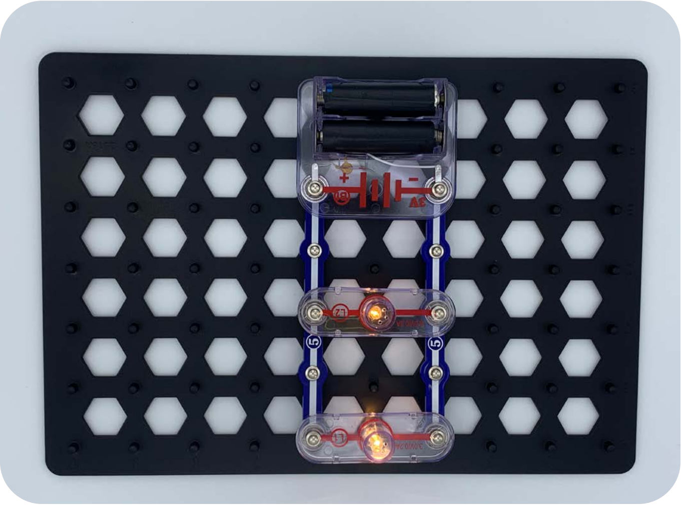
Explore *(30 to 40 minutes)*

1. Kids 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 4g)
2. Kids 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?*

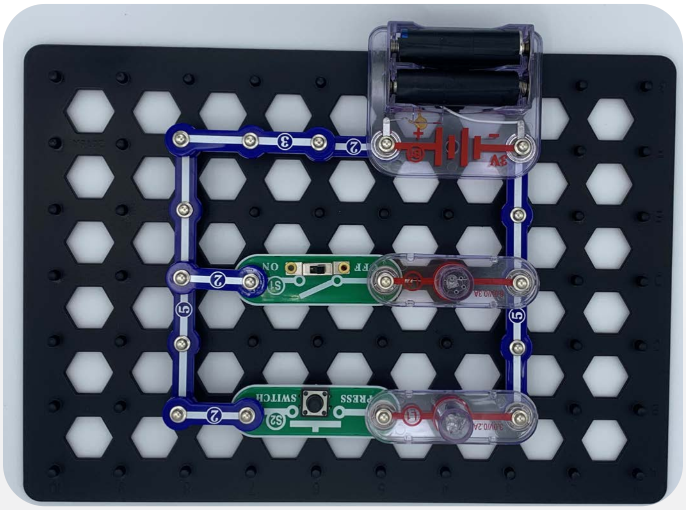


Picture 4g

3. Use what you already know about electric current to explain these observations.
4. Kids will construct a parallel circuit with one battery holder and two light bulbs. (Picture 4h)
5. Kids 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. Kids will modify the parallel circuit to add a switch in front of each lightbulb. (Picture 4i)
7. Kids 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 4h



Picture 4i

Explain *(5 minutes)*

1. Discuss the results of the activity with kids.
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 kids 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. Kids will identify whether the following diagrams show series or parallel circuits.

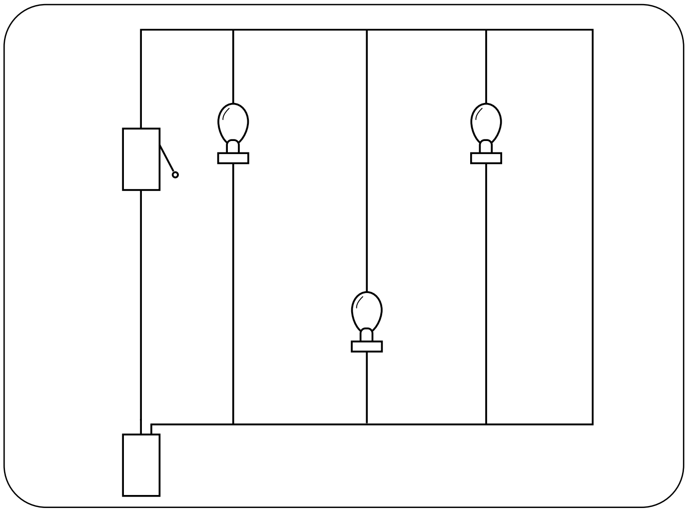


Diagram 4j

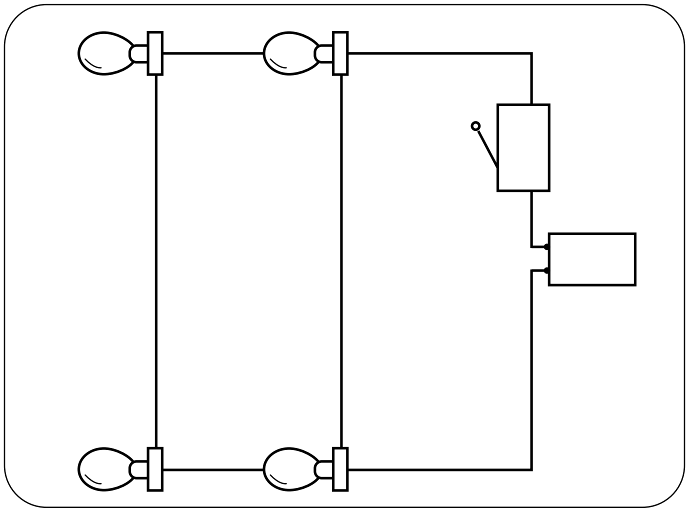


Diagram 4k

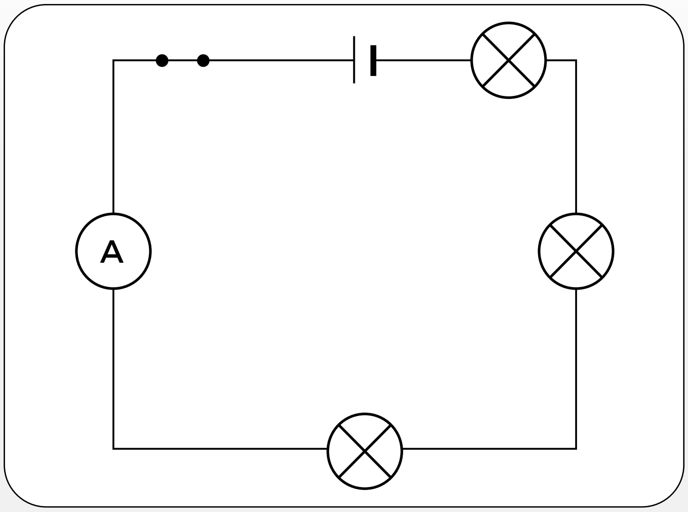


Diagram 4l

Evaluate *(5 minutes)*

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

SERIES AND PARALLEL CIRCUITS
(PART 2)

OVERALL TIME *55- to 70-minute lesson*

OBJECTIVE

Kids will use Snap Circuits SC-750R to investigate how voltage and current differ in series and parallel circuits.

Next Generation Science Standards

MS-PS2-3

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

OVERVIEW

Kids will use Snap Circuits to construct series and parallel circuits. Kids 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 SC-750R 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)*

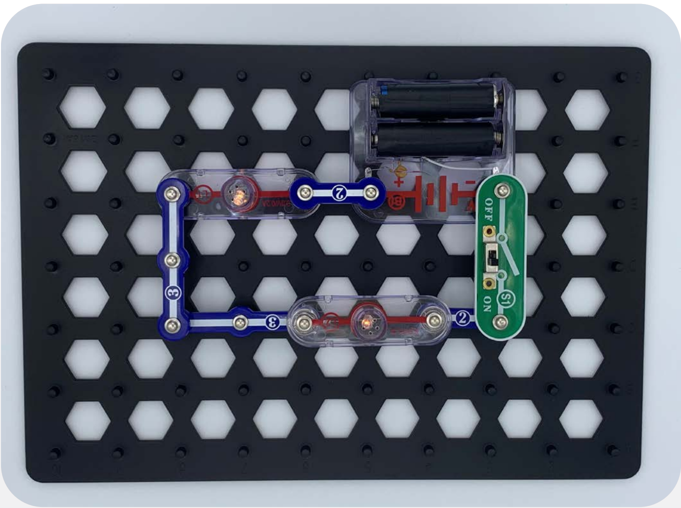
1. Ask kids the following question:
   - There are two circuits with equivalent power sources. One circuit is a series circuit with two light bulbs. The other circuit is a parallel circuit with the same two light bulbs. *In which circuit will the light bulbs produce more light?*
2. Use a think-pair-share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

Explore *(30 to 40 minutes)*

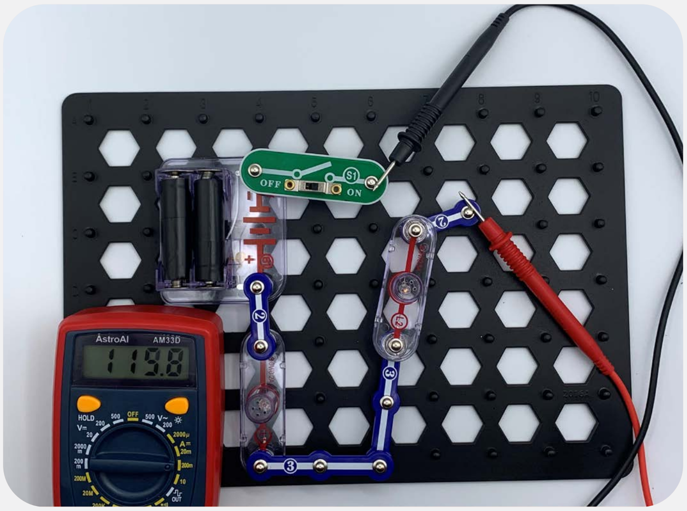
1. Kids will use Snap Circuits to explore the answer to this question.

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

2. Kids will construct the following table in their lab notebook:
3. Kids will use Snap Circuits to construct a series circuit with one battery holder, two light bulbs, and one switch. (Picture 4m)
4. Kids 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 kids 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. Kids will use a multimeter to record the voltage across the battery holder and across each light bulb. (Picture 4n)
6. Kids 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 4n)
    - It is important to ensure that kids 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



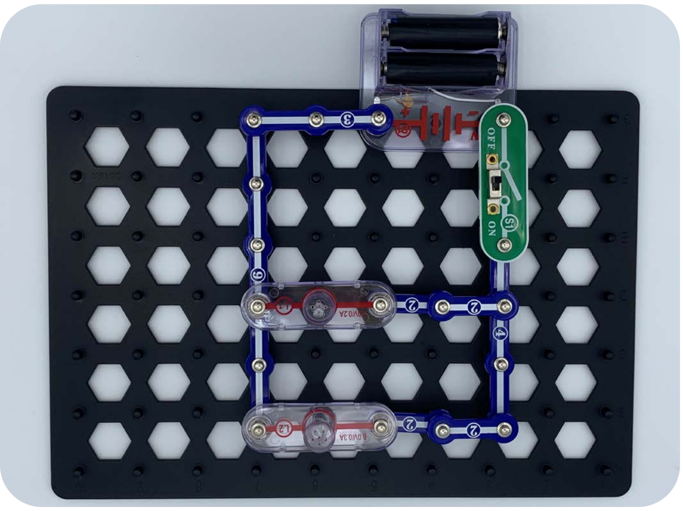
Picture 4m



Picture 4n

milliamps is equal to 0.06 amps, a reading of 6 milliamps is equal to 0.06 amps, etc.

7. Kids will use Snap Circuits to construct a parallel circuit with one battery holder, two light bulbs, and one switch. (Picture 4o)
8. Kids will repeat observations of light bulb brightness and measurements of voltage and current in the parallel circuit.



Picture 4o

Explain *(5 to 10 minutes)*

1. Discuss the results of the activity.
2. Guide kids 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 kids 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 kids 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 kids to discuss the scenario with their group and then share their responses.

Evaluate *(5 minutes)*

1. Kids 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-minute lesson*

OBJECTIVE

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

Next Generation Science Standards

MS-PS2-3

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

OVERVIEW

Kids will use Snap Circuits SC-750R to construct series and parallel circuits that meet specified criteria regarding how switches should control light bulbs in different ways.

LEVEL OF DIFFICULTY

Intermediate

MATERIALS

- **Snap Circuits SC-750R 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. Kids 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 responses.

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 4p and 4q). 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.

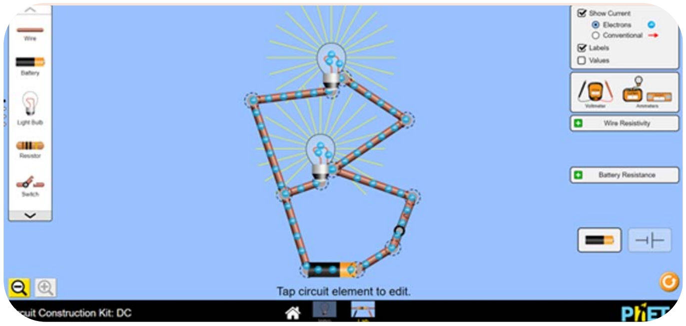


Diagram 4p

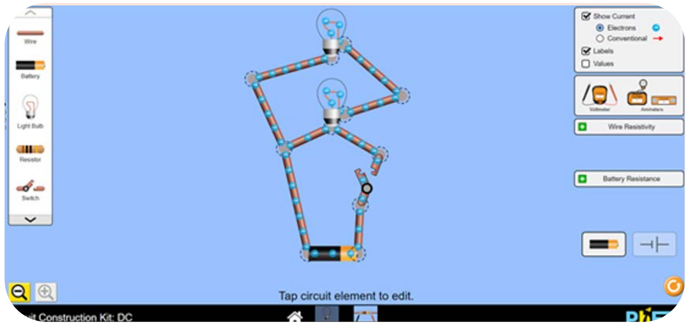


Diagram 4q

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

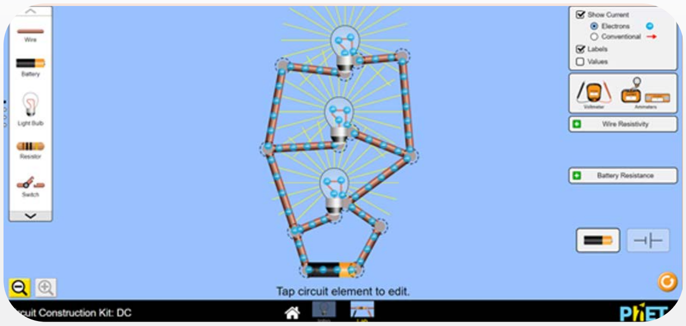


Diagram 4r

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 room, demonstrate how the switches in the room control different banks of lights.

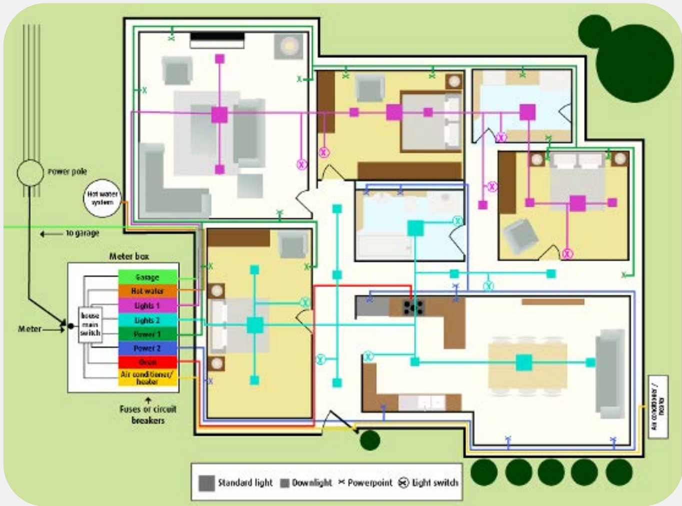


Diagram 4s

Elaborate *(30 to 40 minutes)*

1. Kids 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. Kids 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.

OVERALL TIME *55- to 70-minute lesson*

OBJECTIVE

Kids will use the Snap Circuits SC-750R Kit to investigate how voltage affects the strength of electric current in a circuit.

Next Generation Science Standards

MS-PS2-3

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

OVERVIEW

Kids 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 SC-750R 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 kids discuss the following question:
   - *What is needed to make an electrical circuit?*
2. Kids can write their answers on handheld whiteboards or discuss with a partner using a think-pair-share strategy.
3. Discuss answers as a group 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)*

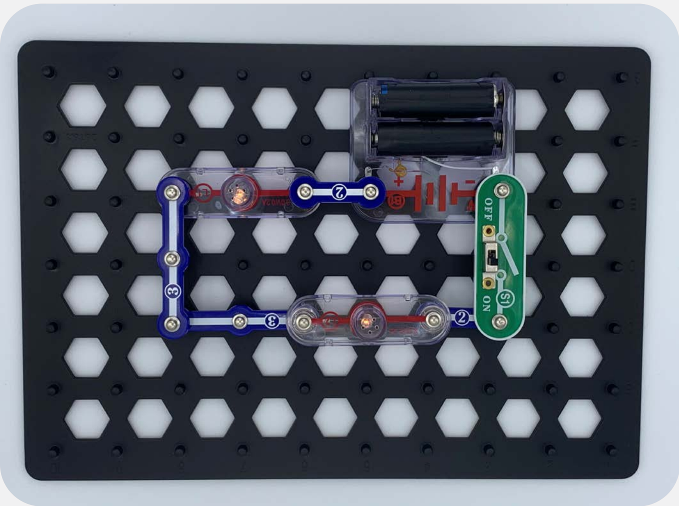
1. Kids will complete a lab in which they investigate the relationship between the number of batteries in a circuit and the brightness of a light bulb or the speed of an electric motor.
2. Kids should record the following lab question in their notebook: *How does increasing the number of batteries in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

Experimental Procedure

1. Draw the following table in your notebook:

Number of Batteries	Brightness of Light Bulb	Speed of Motor

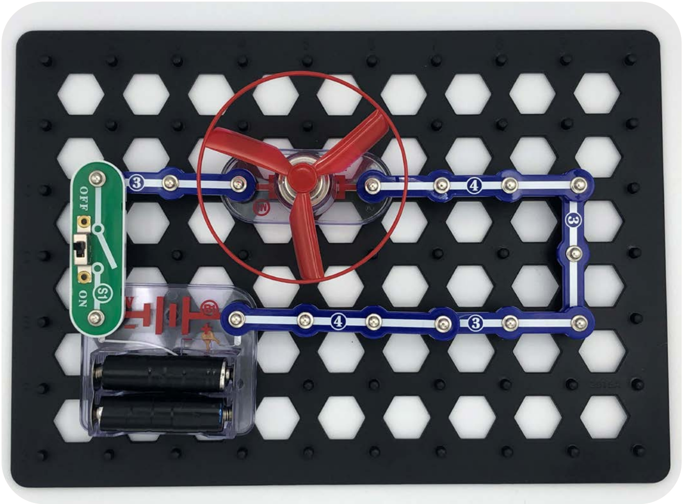
2. Using Snap Circuits, make a circuit by using wires to connect one battery holder, a switch, and a light bulb. (Picture 4t)
3. Turn on the switch and record the brightness of the light bulb on a scale of one to 10.
4. Turn off the switch and replace the light bulb with the motor and fan blade. (Picture 4u)
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 4v)
7. Turn on the switch and record the brightness of the light bulb on a scale of one to 10.
8. Turn off the switch and replace the light bulb with the motor and fan blade. (Picture 4w)
9. Turn on the switch and record the speed of the motor on a scale of one to 10.



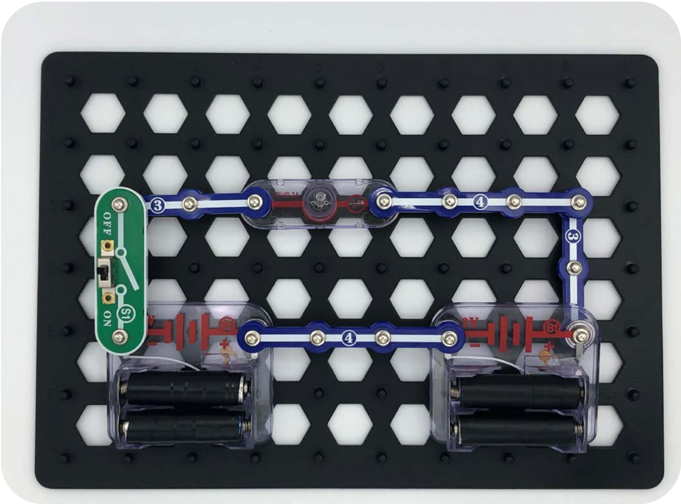
Picture 4t

Explain *(5 to 10 minutes)*

1. Discuss the results of the experiment.
2. Ask kids to identify possible Explanations for their results.

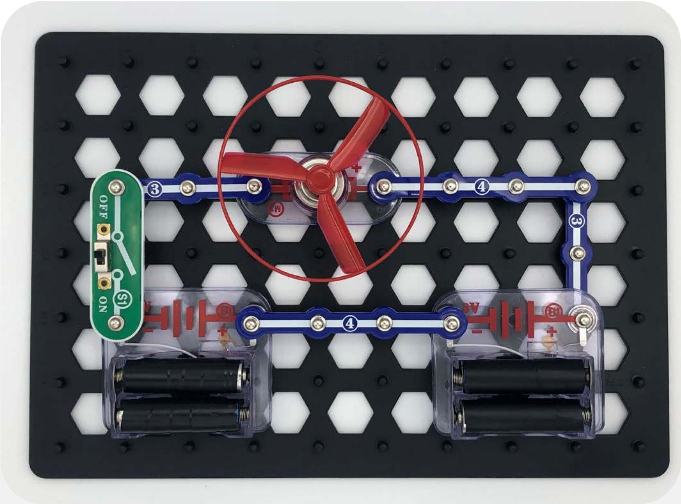


Picture 4u



Picture 4v

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.



Picture 4w

Elaborate *(10 minutes)*

1. Kids 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)?*

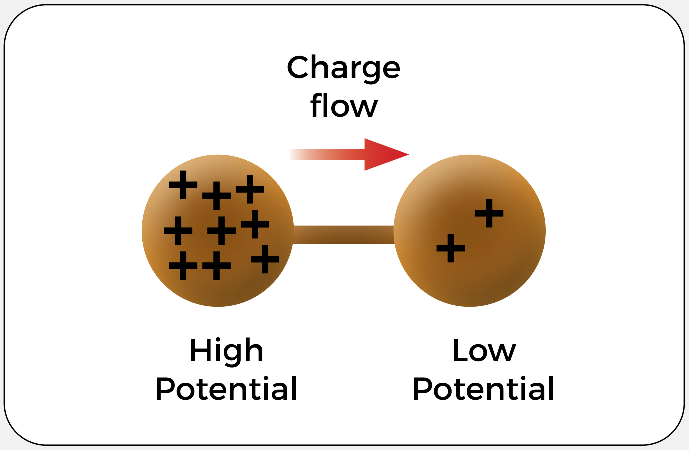


Diagram 4x

- *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?*

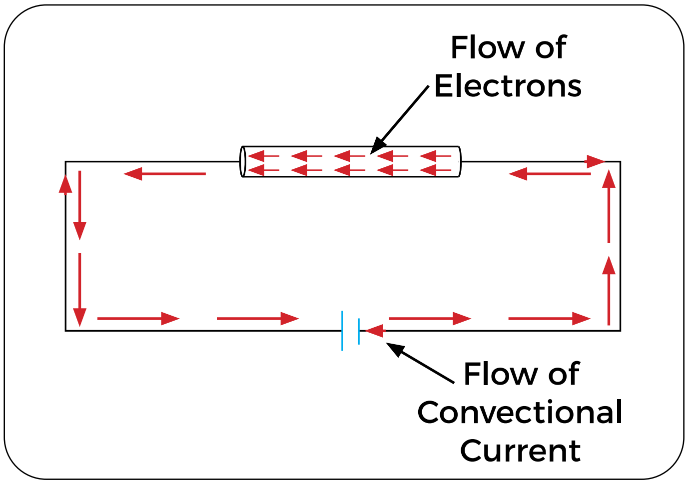


Diagram 4y

Evaluate *(5 minutes)*

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

OVERALL TIME *55- to 70-minute lesson*

OBJECTIVE

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

Next Generation Science Standards

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.

OVERVIEW

Kids will use Snap Circuits to construct simple circuits that contain various resistors. Kids 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 SC-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**
- **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. Kids 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 responses.

Explore *(30 to 40 minutes)*

1. Kids 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. Kids will construct a circuit with the solar panel, flexible and rigid connecting wires, resistors, and meter. (Picture 4z)
3. Kids 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. (Picture 4aa) 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/Mentor 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 4z

Picture 4aa

Explain *(5 to 10 minutes)*

1. Discuss the results of the activity.
2. Introduce kids 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.

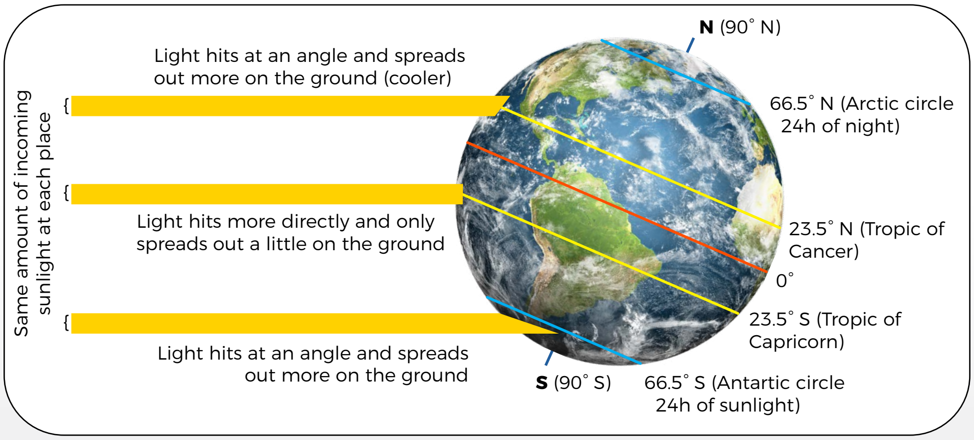


Diagram 4bb

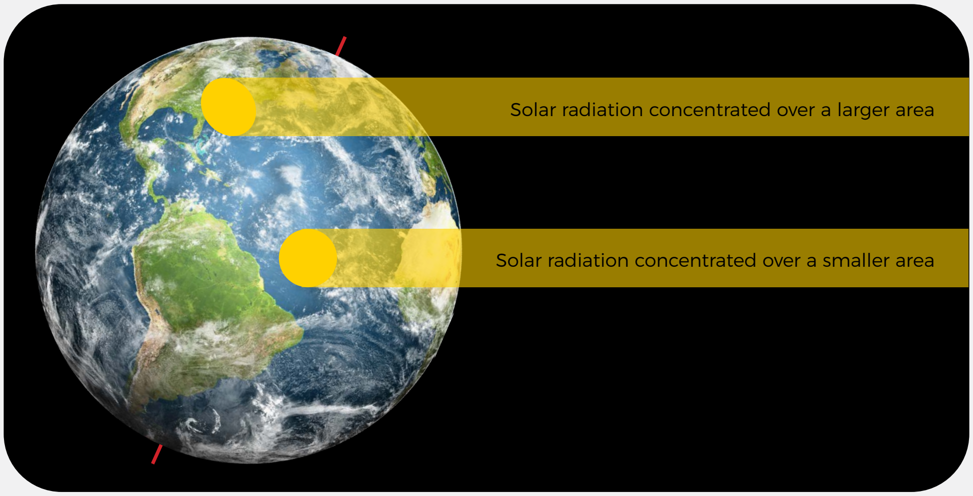


Diagram 4cc

Elaborate *(5 to 10 minutes)*

1. Kids 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. Kids 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-minute lesson*

Next Generation Science Standards

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

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

OVERVIEW

Kids will use the solar panel included in the Snap Circuits SC-750R 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 kids 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 SC-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. Practice using the online interactive that will be used in the Elaboration activity.

LESSON SEQUENCE:

Engage *(5 minutes)*

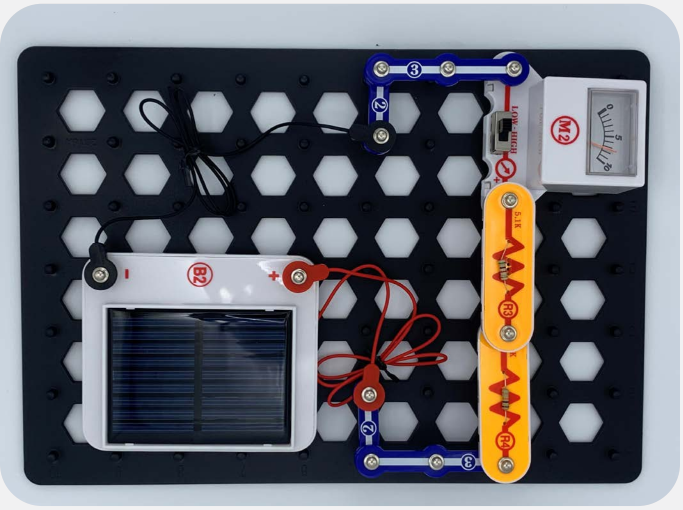
1. Ask kids to brainstorm words related to different seasons. Have kids share their ideas and record the words on the front board.
2. Ask kids to discuss the following question with a partner: *What are seasons and what makes them different?*
3. Discuss responses as a group.

Explore *(30 to 40 minutes)*

1. Kids 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. Kids will use Snap Circuits to construct a circuit with the solar panel, flexible and rigid connecting wires, resistors, and meter. (Picture 4dd)
3. Kids 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 4ee)
4. Use the protractor to measure the approximate angle between the solar panel at a horizontal surface. Record the angle in the table.
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.



Picture 4dd

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.
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.

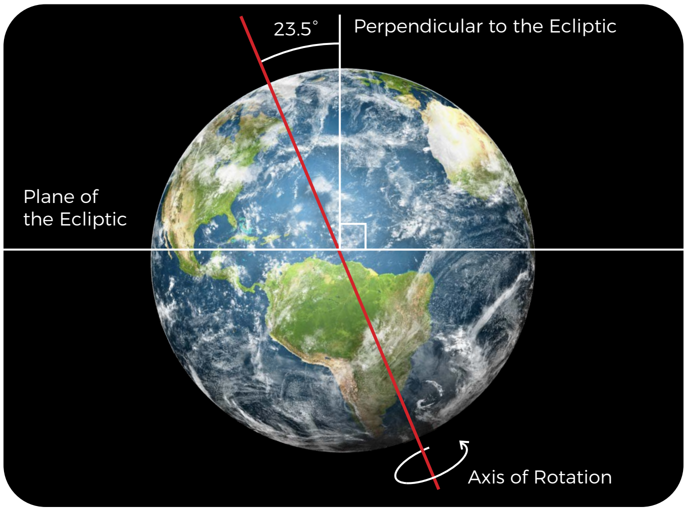


Diagram 4ee

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.
2. Introduce kids 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.

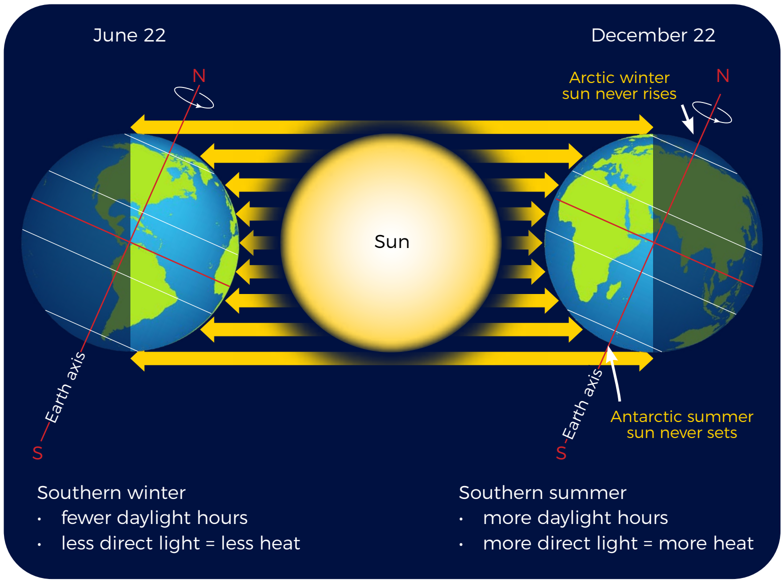


Diagram 4ff

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 kids 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 kids 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 kids to observe how the sunlight angle and average daily temperature change during different times of the year.

Evaluate (5 minutes)

1. Kids 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.

OVERALL TIME *60-minute lesson*

Next Generation Science Standards

1B-CS-01

Describe how internal and external parts of computing devices function to form a system.

OBJECTIVE

- Identify the features on the Spark:bit robotics controller.
- Identify and observe input sensors and output modules that can interface with the Spark:bit.
- Assemble and test a mechanical system using the Spark:bit.

OVERVIEW

In this lesson, kids will learn how the Spark:bit works and how it can be used to control a simple mechanism. Kids will upload an example program to the Spark:bit and test and observe the connected inputs and outputs.

PREPARATION

Prepare enough lesson materials for each team.
Review the Spark:bit Basics section to familiarize yourself with the Spark:bit, sensors, and output modules that will be used in the Robotics and Coding 101 Curriculum.
Get hands on! We highly recommend teachers/mentors complete the lesson prior to instruction. For this lesson, kids will be required to use MakeCode to upload an example program to the Spark:bit. Instructions for how to upload the program can be found in the MakeCode tutorial for this lesson.

CONVERGENT LEARNING ACTIVITY

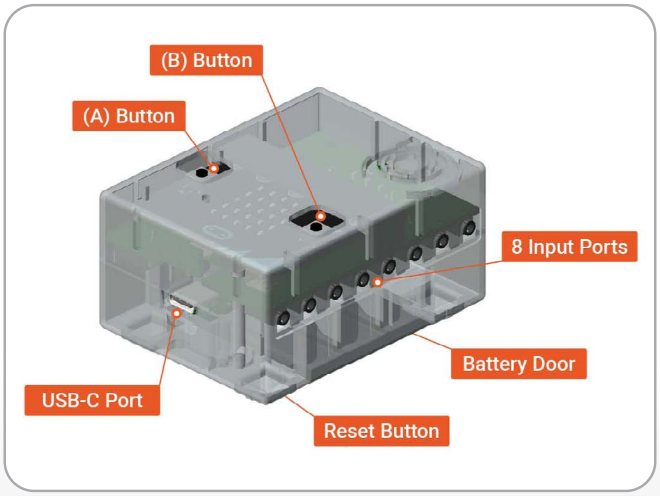
1. Introduce kids to the Spark:bit robotics controller. Instruct kids to locate and observe all of the features on the Spark:bit.
2. Work with kids as they locate and observe all of the sensors, output modules and cables that interface with the Spark:bit.
3. Work with teams as they assemble a simple mechanism.
4. Work with teams as they test the mechanism using the Spark:bit. *Note: For this section, kids will be uploading an example program to the Spark:bit using the MakeCode online programming environment. You may need to help kids locate the online tutorial that will guide them through how to upload the program.*

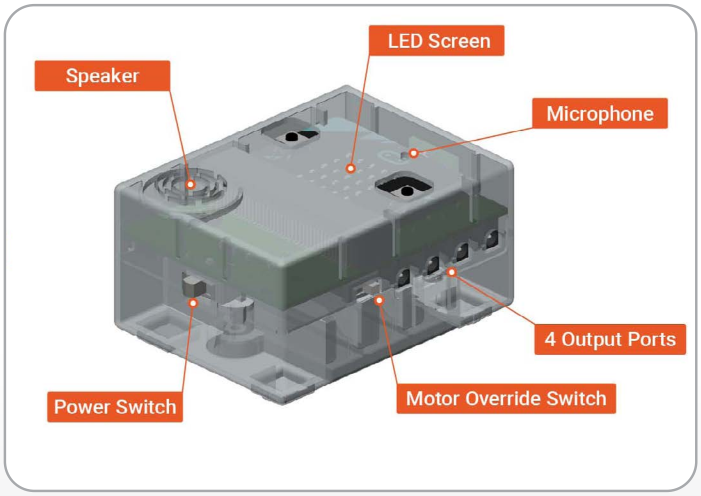
CONVERGENT LEARNING ACTIVITY:

1. The Spark:bit

The Spark:bit is a robotics controller that can be programmed to read information from sensors connected to input ports, process that information into relevant commands, and send those commands to modules connected to the output ports.

Instructions: Locate the Spark:bit robotics controller and observe all of the features on it.



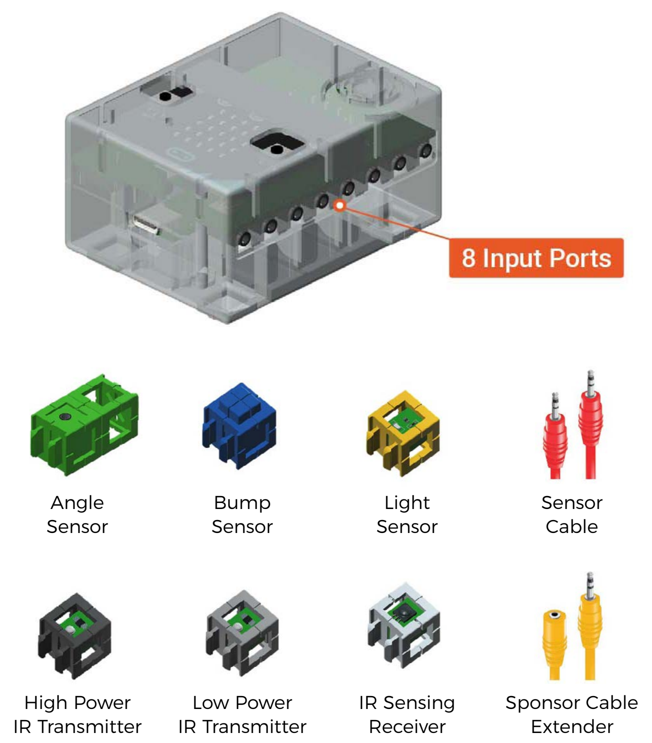


2. Inputs and Outputs

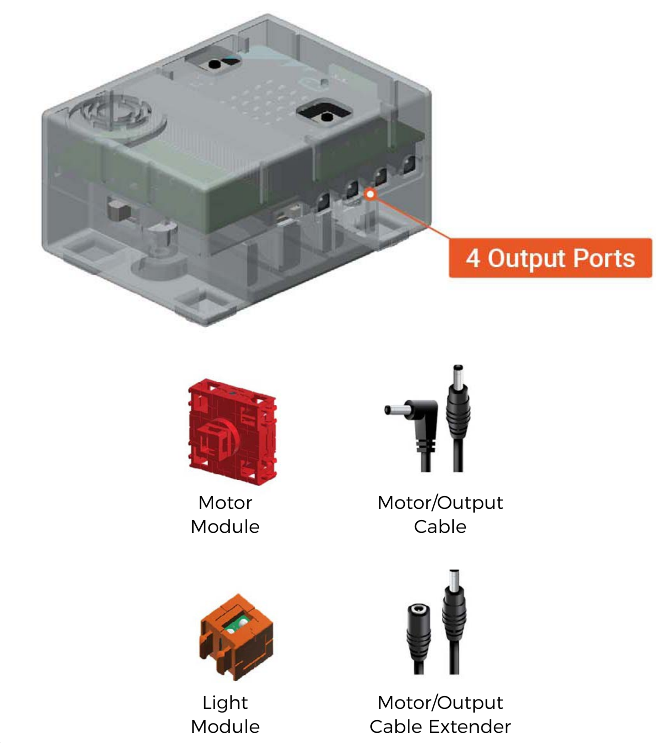
The Spark:bit includes 8 input ports and 4 output ports. A variety of sensors can be connected to the input ports, while Motor Modules and Light Modules can be connected to the output ports.

Instructions: Locate and observe all of the sensors, output modules, and cables shown below.

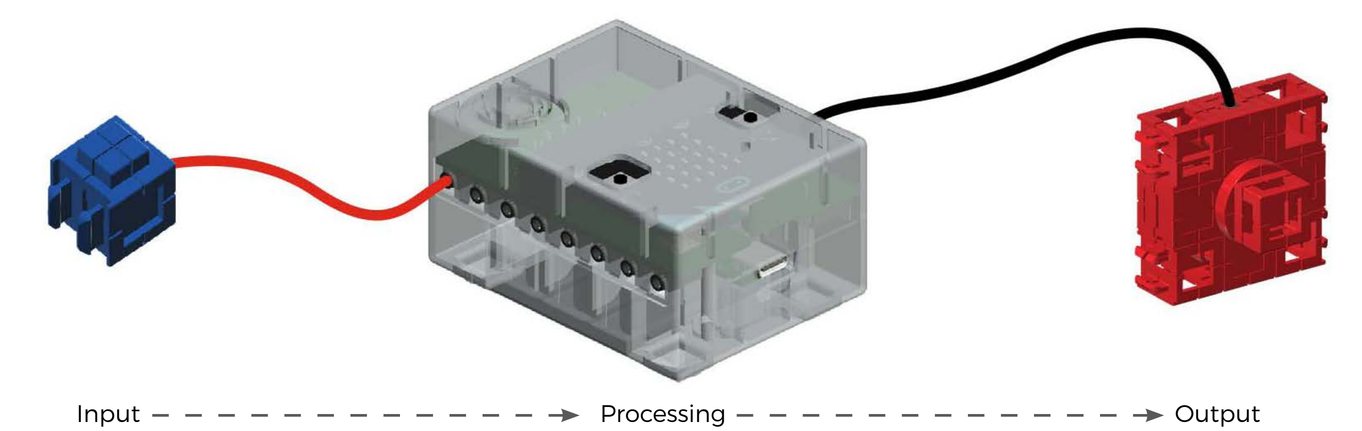
Input Sensors & Cables



Output Modules & Cables



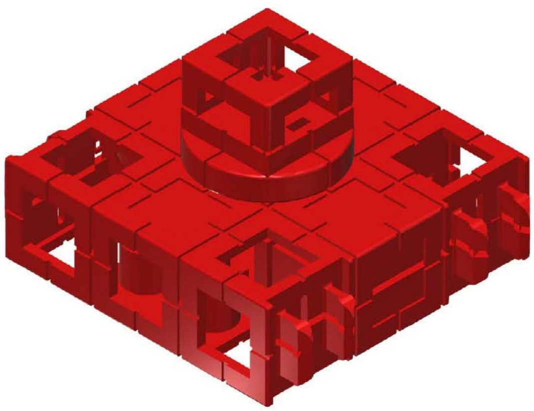
The Spark:bit can be programmed to detect information from connected sensors, process that information into relevant commands, and then send those commands to connected output modules.



INSTRUCTIONS

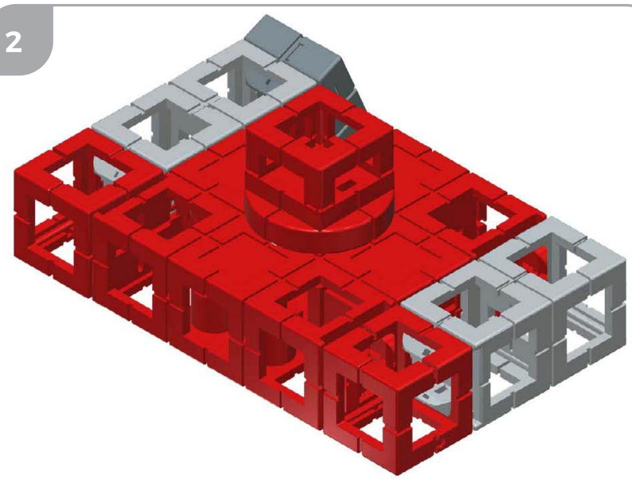
Follow the step-by-step instructions to assemble the mechanism.

1



1x
Motor Module

2

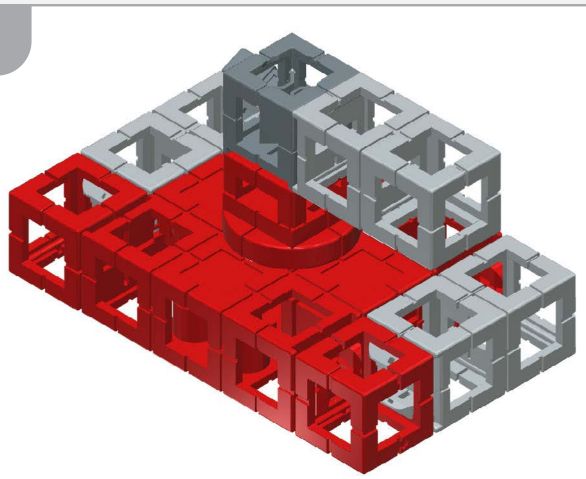


2x
Block

2x
Riser

1x
30° Block

3

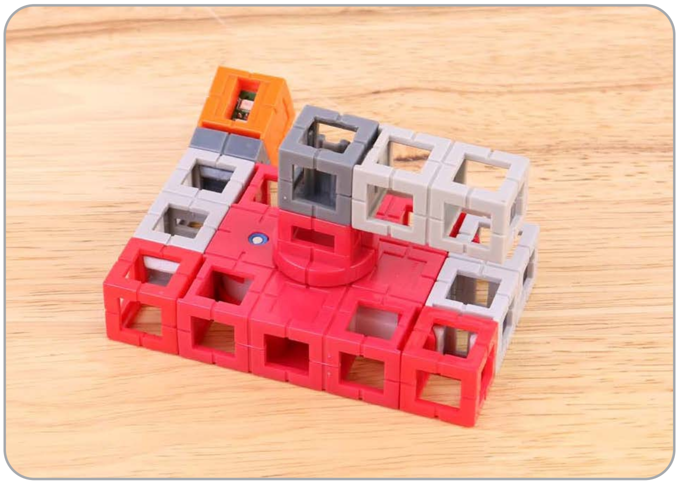


1x
Single Snap Block

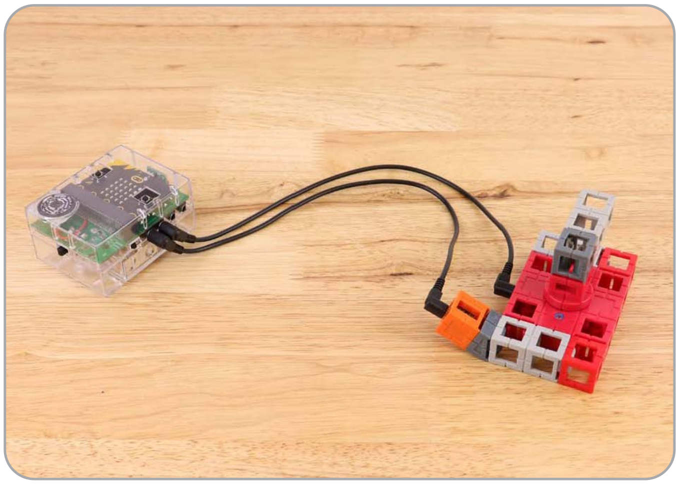
1x
Riser

INSTRUCTIONS

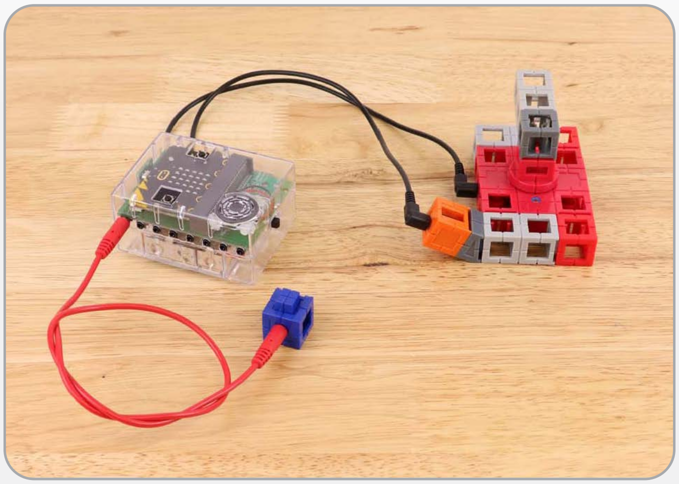
Follow the step-by-step instructions to connect a Light Module and the Spark:bit to the mechanism.



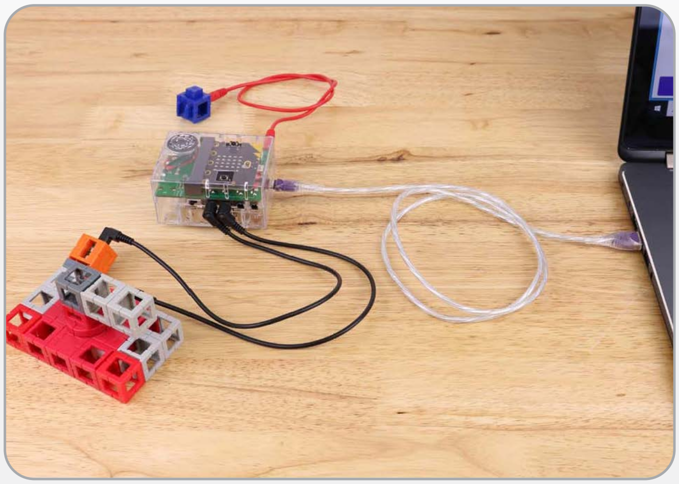
Step 1: Attach a Light Module to the Mechanism as shown.



Step 2: Using two Motor/Output Cables, connect the Light Module to output port 1 on the Spark:bit, and the Motor Module to output port 2 on the Spark:bit.



Step 3: Using a Sensor Cable, connect a Bump Sensor to input port 1 on the Spark:bit. *Note: To ensure a good connection, make sure the cable connectors are pressed firmly into the ports of the sensor and the Spark:bit.*



Step 4: Using a USB Cable, connect the Spark:bit to a computer.

3. Uploading an Example Program to the Spark:bit

Follow the instructions to download an example program to the Spark:bit.

Instructions:

Step 1: Visit *www.kidsparkeducation.org/robotics*

Step 2: Select Unit - Robotics & Coding 101

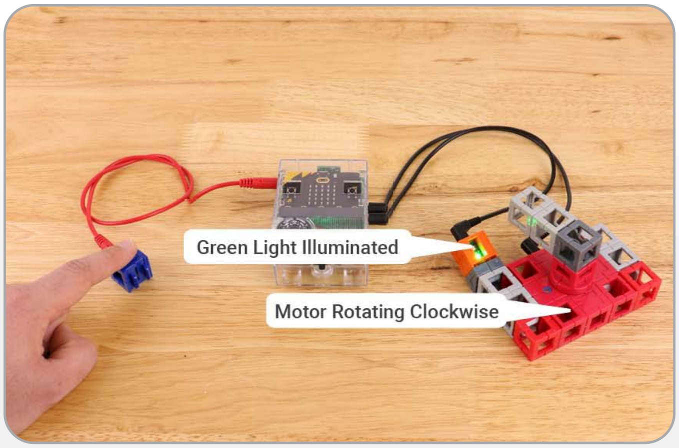
Step 3: Locate Lesson - The Spark:bit

Step 4: Launch Tutorial 1 - The Spark:bit

Step 5: Follow the steps in the MakeCode tutorial to download an example program to the Spark:bit.

Note: MakeCode is a browser-based programming environment where users can create custom programs that can be uploaded to the Spark:bit. Users will learn much more about MakeCode and how to create custom programs in the following lessons.

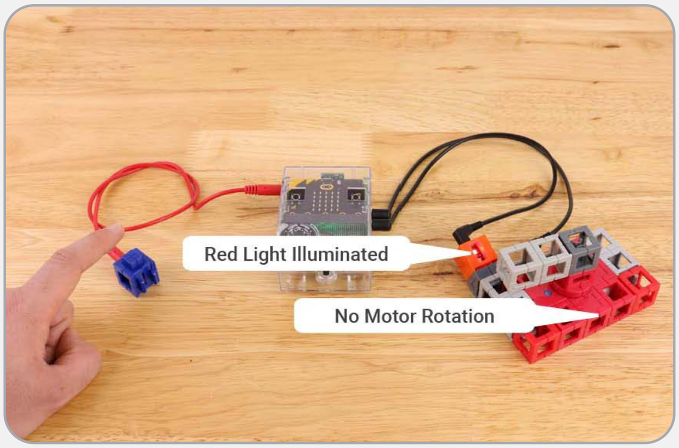
In this example, the Spark:bit and a Bump Sensor are being used to control the mechanism. The program that was uploaded tells the Spark:bit to recognize that a Bump Sensor is connected to input 1, a Light Module is connected to output 1, and a Motor Module is connected to output 2.



Bump Sensor Engaged

You can think of the program that was uploaded to the Spark:bit like a set of instructions that tells the Spark:bit what to do. In this example, the program or instructions for the Spark:bit were:

- If the Bump Sensor (connected to input 1) is pressed, rotate the Motor Module (connected to output 2) clockwise, and illuminate the Light Module (connected to output 1) green.
- If the Bump Sensor (connected to input 1) is **not** pressed, do not rotate the Motor Module (connected to output 2), and illuminate the Light Module (connected to output 1) red.



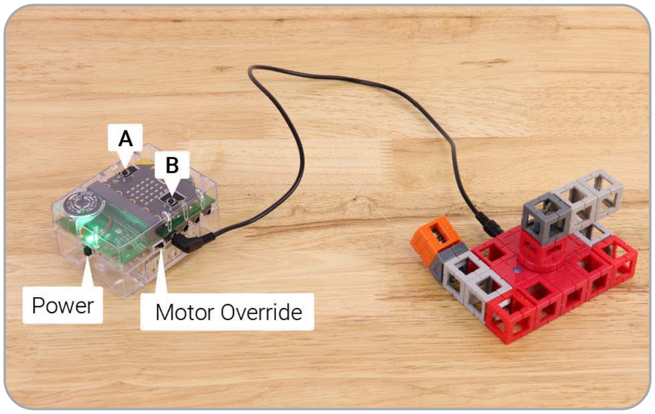
Bump Sensor Disengaged

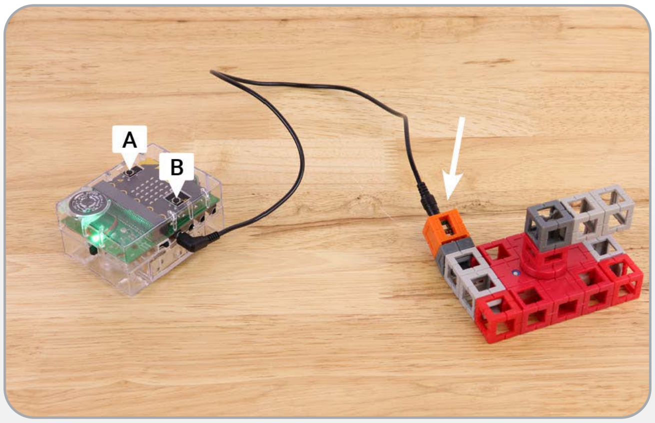
The Spark:bit will continue to execute this program or set of instructions until another program is downloaded to it.

4. Using Motor Override Mode

Follow the instructions to learn how to use Motor Override Mode on the Spark:bit. *Note: This feature can be used to control Motor Modules and Light Modules that are connected to output 1 on the Spark:bit with no programming required. This feature can be extremely useful when prototyping and testing robotics builds.*

Instructions:





Step 1: Disconnect all of the cables and sensors that are connected to the Spark:bit. Then, use a Motor/Output Cable to connect the Motor Module to output 1.

Step 2: Power on the Spark:bit.

Step 3: Activate Motor Override Mode on the Spark:bit using the switch located next to output 1.

Step 4: Press the A/B buttons on the top of the Spark:bit and observe how the Motor Module rotates clockwise and counterclockwise.

Step 5: Disconnect the cable from the Motor Module and connect it to the Light Module.

Step 6: Press the A/B buttons on the top of the Spark:bit and observe how the Light Module illuminates red and green.

5. Lesson Review and Cleanup

In this lesson, we identified the features of the Spark:bit and observed all of the input sensors and output modules that can interface with it. We learned that the Spark:bit can be programmed to detect information from sensors connected to the input ports, process that information into relevant commands, and then send those commands to modules connected to the output ports. We also learned how to use Motor Override Mode on the Spark:bit to control Motor Modules and Light Modules with no programming required. In the following lessons, you will learn how to create custom programs that can be uploaded to the Spark:bit and used to control different types of robotic systems.

Instructions: Disassemble the mechanism and place all engineering materials back in the STEM Lab.

TEAM MEMBERS

1. .... 3. ....

2. .... 4. ....

THE SPARK:BIT

Instructions:

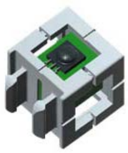
1. Locate the Spark:bit robotics controller and observe all of its features.

INPUTS AND OUTPUTS

Instructions: Write the letter of the corresponding input sensor, output module, or cable in the spaces provided below.

2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________
6. ______________________________
7. ______________________________
8. ______________________________
9. ______________________________
10. ______________________________
11. ______________________________
12. ______________________________
13. ______________________________

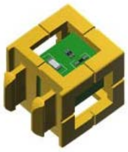

A.


B.


C.


D.


E.


F.


G.


H.


I.


J.


K.


L.

BUILDING AND TESTING A SIMPLE MECHANISM USING THE SPARK:BIT

14. Follow the step-by-step instructions on pages E80 - E82 to assemble and test a mechanism using the Spark:bit.
15. Follow the step-by-step instructions on page E83 to test a mechanism using Motor Override Mode on the Spark:bit.

LESSON REVIEW AND CLEANUP

16. Disassemble the build and correctly pack all of the engineering materials back in the STEM Lab.
17. In the space provided below, write down some ideas for different types of robots that you might like to build throughout future Kid Spark lessons.

VARIOUS ANSWERS

TEAM MEMBERS

1. .... 3. ....

2. .... 4. ....

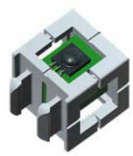
THE SPARK:BIT

INPUTS AND OUTPUTS - ANSWERS

Instructions: Write the letter of the corresponding input sensor, output module, or cable in the spaces provided below.

5. **E.** Motor/Output Cable Extender
6. **H.** High Power IR Transmitter
7. **J.** Motor/Output Cable
8. **D.** Angle Sensor
9. **I.** Bump Sensor
10. **K.** Low Power IR Transmitter
11. **F.** Light Sensor
12. **B.** IR Sensing Receiver
13. **C.** Sensor Cable
14. **A.** Light Module
15. **G.** Motor Module
16. **L.** Sensor Cable Extender

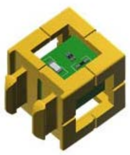

A.


B.


C.


D.


E.


F.


G.


H.


I.


J.


K.


L.

OVERALL TIME *60- to 80-minute lesson*

OBJECTIVE

Kids will use the STEM Pathways to investigate energy transformations.

OVERVIEW

Kids will learn how energy can change forms between gravitational potential energy and kinetic energy by constructing a ROK Blocks Ferris wheel and observing energy transformations.

LEVEL OF DIFFICULTY

Intermediate

Next Generation Science Standards

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.

MATERIALS

- STEM Pathways Mobile STEM Lab
- 7 beams (black)
- 4 small curved beams (red)
- 4 blocks (red)
- 2 single snap blocks (dark gray)
- 2 axle blocks (red)
- A small, dense mass (ex: a rock, a 50-gram mass, etc.)
- Computer with projector
- Ball
- Duct tape
- Printed Elaboration activity instructions
- Printed pictures of Ferris wheel
- Paper
- Pencil/pen

PREPARATION

Ensure that Engineering Pathway STEM Labs are organized and contain the parts needed to construct the Ferris wheel. To save time during the lesson, teachers/mentors 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. Call one volunteer to the front of the room.
2. Have them stand on a chair and hold a ball above their head.
3. Ask the group what type of energy the ball has (gravitational potential energy).
4. Instruct the volunteer to drop the ball.

5. Ask kids what types of energy the ball has as it falls through the air (Answer: gravitational potential energy and kinetic energy).
6. Ask kids what type of energy the ball has just before it hits the floor (Answer: kinetic energy).
7. Ask kids to describe what happens to the ball after it hits the floor and what types of energy transformations they observe.

Explore *(10 to 15 minutes)*

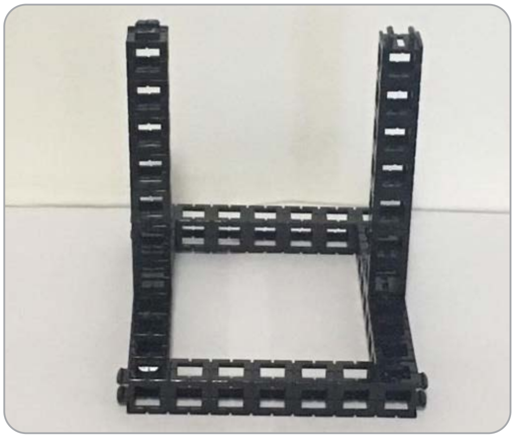
1. Write Project "PHET - Energy Skate Park" on the front board (*https://phet.colorado.edu/en/simulation/energy-skate-park-basics*)
2. Click the play button.
3. Select "Intro."
4. Check "Bar Graph."
5. Place the skater at the top of the ramp and release the skater.
6. Ask kids to discuss the following questions with a partner:
   - *What energy transformations do you observe?*
   - *What happens to the total energy of the system?*
   - *Do you think there is friction between the skater and the ramp in this example?* Explain your reasoning.
7. Discuss answers as a group.
8. Explain that there was not friction between the skater and the ramp, but this in the real world it is not possible to have a frictionless ramp.
9. Select the "Playground" button at the bottom of the screen.
10. Build a ramp similar to the ramp in the "Intro" by moving the three red dots to the screen.
11. Check "Bar Graph" and make sure that friction is not set to "None."
12. Place the skater at the top of the ramp and release the skater.
13. Ask kids what is different about the energy transformations in this example, but point out that the total energy of the system remains the same.

Explain *(5 to 10 minutes)*

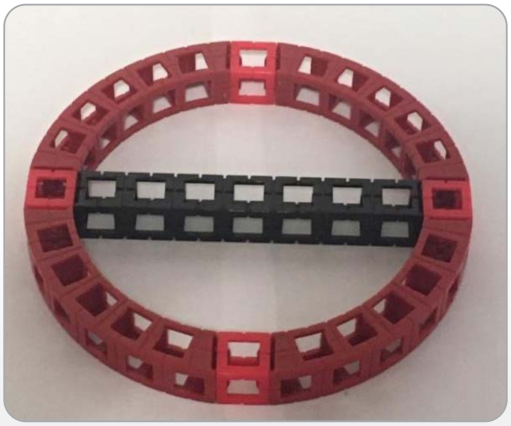
1. Introduce kids to the following types of energy:
   - Mechanical energy - energy of an object due to position and motion.
   - Kinetic energy - energy of an object due to motion.
   - Gravitational potential energy - stored energy in an object due to its position above Earth.
   - Thermal energy - internal energy of a system due to the movement of molecules and transferred as heat.
2. Explain to kids that energy can change forms. For example from gravitational potential energy to kinetic energy. However, remind kids that energy cannot be created or destroyed. Therefore, the total energy in a closed system will remain the same.

Elaborate *(30 to 40 minutes)*

1. Kids will use ROK Blocks to construct a model Ferris wheel.
2. Kids will use six beams to construct a base for the Ferris wheel. See picture 5a.
3. Kids will use one bean, four small curved beams, and four blocks to construct a wheel for the Ferris wheel. See picture 5b.
4. Kids will use two snap blocks and two axle blocks to attach the wheel to the base. See picture 5c.
5. Kids will use duct tape to attach a small, dense mass to the Ferris wheel.
6. Kids will hold the Ferris wheel so the attached mass is at the top of the Ferris wheel and will then release the mass.
7. Kids will observe the motion of the mass and the energy transformations that occur.
8. Kids will answer the following questions.
    - *What energy transformations do you observe?*
    - *Why does the mass not make it all the way back to the top of the Ferris wheel?*



Picture 5a



Picture 5b

Possible Extension

1. Allow kids to calculate the speed of the mass when it first reaches the bottom of the Ferris wheel after being released.
    - They will be assuming that all of the gravitational energy is converted to kinetic energy. This is not fully correct, since some energy is converted to thermal energy by friction within the ROK Block axles, but the assumption will allow kids to approximate the velocity of the mass when it reaches the bottom of the Ferris wheel.
2. Kids will measure the change in height from the top of the Ferris wheel to the bottom of the Ferris wheel. *Note: Kids should not measure to the table surface but to the lowest position of the mass.*
    - If needed, kids should convert their height measurement from centimeters to meters. For example, 20 centimeters is equivalent to 0.2 meters.
3. Kids will measure the mass of the small, dense mass that is attached to the Ferris wheel. The mass must be measured in kilograms or converted to kilograms. For example, 50 grams is equivalent to 0.05 kilograms.

Picture 5c

4. Kids will calculate the change in gravitational potential energy from the top of the Ferris wheel to the bottom of the Ferris wheel using the following equation, where “m” = mass, “g” = gravitational acceleration (9.81 m/s2), and Δh = change in height.

$$\Delta GPE = mg\Delta h$$

   - Since kids may neglect friction and assume that all of the change in gravitational potential energy is converted to kinetic energy, the change in kinetic energy equals the change in gravitational potential energy.

$$\Delta GPE = \Delta KE$$

5. Using the formula KE = ½ mv2, kids can calculate the maximum velocity of the mass by rearranging the formula.

$$V = \sqrt{\frac{2\Delta KE}{m}}$$

Evaluate *(10 minutes)*

1. Have kids draw a diagram of the Ferris wheel model and label where energy transformations occurred, where the mass had the greatest gravitational potential energy, and where the mass had the greatest kinetic energy.

OVERALL TIME *60- to 75-minute lesson*

OBJECTIVE

Kids will use the STEM Pathways to calculate the static friction between various surfaces and ROK Blocks models.

Next Generation Science Standards

MS-PS2-2

Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

OVERVIEW

Kids will learn about different types of friction and will use the Engineering Pathways Mobile STEM Lab to complete an investigation in which they will calculate the static friction between various surfaces and a ROK Blocks model.

LEVEL OF DIFFICULTY

Intermediate

MATERIALS

- STEM Pathways
- 2 beams (black)
- 2 half beams (black)
- 4 wheels
- A stack of 3-5 textbooks
- Skateboard or equivalent object with wheels
- Small pieces of 2” x 4” wood with hook in the end of the wood
- Spring scale
- Electronic scale
- Meter stick or measuring tape
- A variety of solid surfaces (ex: whiteboards, plywood, sandpaper, etc.)
- Protractor
- Calculator with sine function
- Printed Elaboration activity instructionsPrinted pictures of the simple rectangle and simple rectangle with wheels
- Notebook
- Paper
- Pencil/pen

PREPARATION

Ensure that Engineering Pathway STEM Labs are organized and contain enough wheels to construct a model car. Cut or gather small pieces of 2” x 4” wood and screw a small hook into one end of the wood. Print instructions for Elaboration activity with pictures of a simple rectangle and a simple rectangle with wheels. Instruct kids on how to use sine functions on their calculators and ensure that the calculators are set to use angle measurements in degrees.

LESSON SEQUENCE

Engage *(5 minutes)*

1. Call one volunteer to the front of the room.
2. Instruct the volunteer to push a stack of 3 to 5 textbooks across the floor or the surface of a desk.
3. Now, place the stack of 3 to 5 textbooks on a skateboard and ask the kids to push the textbooks across the floor.
4. Ask: "*When was more force required to get the textbooks to move or accelerate? Explain why.*"
5. Discuss as a group and tell kids to justify their answers.

Explore *(10 to 15 minutes)*

1. Give each pair or group a small piece of 2" x 4" wood with a hook in one end of the wood.
2. Kids should place the spring scale on the hook in the wood.
3. Kids will use the spring scale to slowly apply a horizontal force to the piece of wood until it begins to move along the surface of their desk.
4. Kids should note the amount of force applied by the spring scale just before the wood starts to move and the amount of force applied by the spring scale as the wood moves across the desk at a constant velocity.
5. Discuss observations as a group.

Explain *(5 to 10 minutes)*

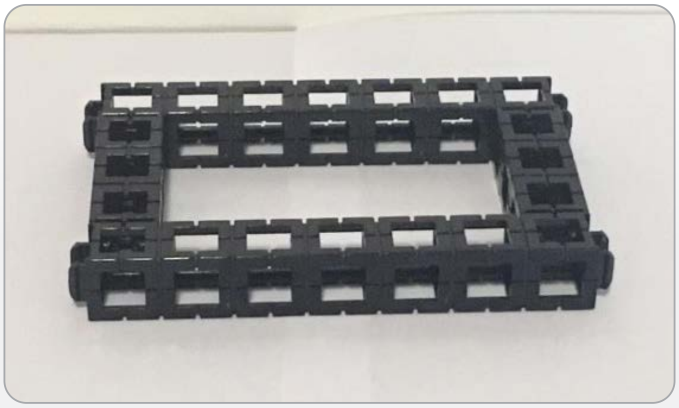
1. Introduce kids to the definition of friction and the different types of friction.
    - **Friction** - A force that resists the motion of one object relative to another.
    - **Static Friction** - Friction between a stationary object and the surface on which it is resting. If static friction is greater than the applied force on an object, the object will not move.
    - **Sliding Friction** - Friction between a sliding object and the surface over which it is sliding. The applied force is greater than the sliding friction, so the object will continue to move as long as the force continues to be applied, but sliding friction does affect the velocity of the object and will bring the object to a stop if the applied force is removed. Sliding friction is less than static friction.
    - **Rolling Friction** - Friction between a rolling object and the surface over which it is rolling. The applied force is greater than the rolling friction, so the object will continue to move as long as the force continues to be applied, but rolling friction does affect the velocity of the object and will bring the object to a stop if the applied force is removed. Rolling friction is less than sliding friction.
    - **Fluid Friction** - Friction provided by a fluid substance, such as liquid or gas. For example, a swimmer experiences fluid friction as they move through the water.

Elaborate *(30- to 40-minute lesson)*

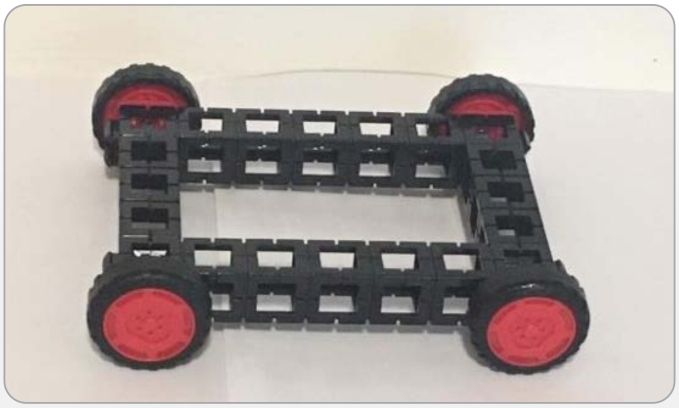
1. Kids will construct the following table in their notebooks:

Kids	Static Friction Between Surface and Simple Rectangle	Static Friction Between Surface and Simple Rectangle with Wheels

2. Kids will use the Engineering Pathways STEM Lab to construct a simple rectangle and a simple rectangle with wheels. See pictures below.



Picture 5d



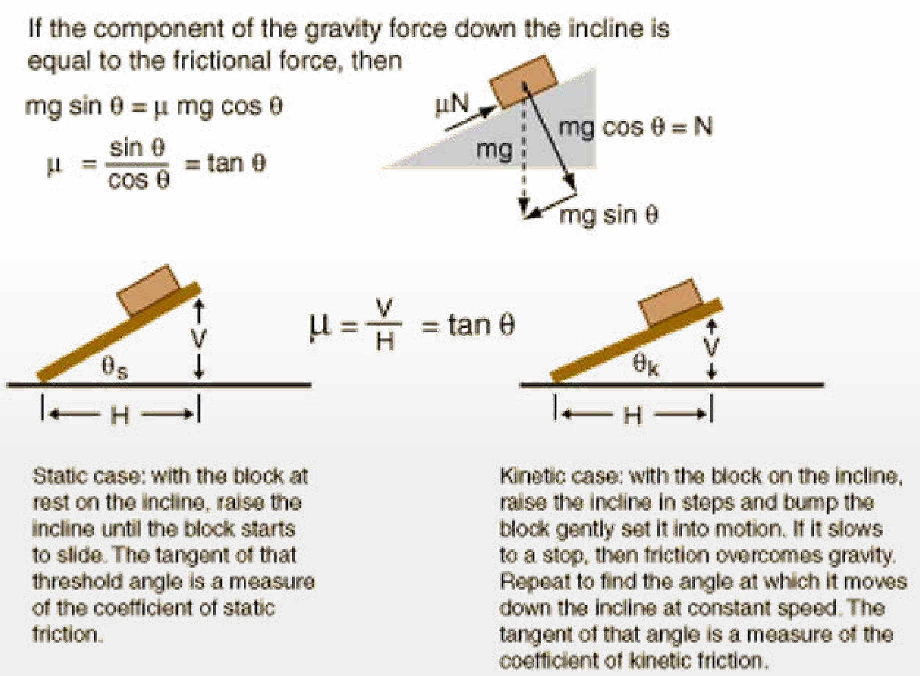
Picture 5e

3. Kids will measure the mass of the simple rectangle and the mass of the simple rectangle with wheels. The mass should be measured in kilograms so kids must convert from grams to kilograms if needed. For example, 150 grams is equivalent to 0.15 kilograms.
4. Kids will place the simple rectangle on one of the surfaces (for example, a whiteboard) that will be tested to determine the amount of static friction.
5. Kids will slowly lift one end of the surface so that it creates a ramp with a slowly increasing incline.
6. Kids will watch the simple rectangle and they will stop increasing the incline of the ramp the moment the rectangle starts moving.
7. Kids will use a protractor to measure the angle between the ramp and the horizontal surface of the desk or floor.

8. Kids will calculate the static friction between the surface and the simple rectangle using the following formula, where “m” is the mass of the rectangle in kilograms, “g” is gravitational acceleration (9.81 m/s2), and θ is the angle between the ramp and the horizontal surface. If kids have not used the sine function before, demonstrate how to use this on a calculator and ensure that the calculators are set to use angle measurements in degrees and not radians.

Static Friction = mg sin(θ)

9. Repeat the above process with the simple rectangle with wheels.
10. Repeat the above process with both models, but use a different surface.



Evaluate (*10 minutes)*

1. Kids will answer to following question:
   - *Which trial had more static friction between the surface and the model?* Explain why you think this occurred.
2. Discuss responses as a group.

Ask kids to share anything they know or think they know about drones.

- *How do they work? How big can they be? What can they be used for?*

Show kids the different parts of the drone and familiarize them with each area and component.

Safety

- ALWAYS safety first.
- Standards and procedures need to be set out with kids before any drone use begins to ensure that drones are used as safely and responsibly as possible.
- Tello drones should be used in a large, open space with minimal airflow, as they are extremely light and can easily be pushed off course by airflow (a gym or large open room would work well).
- Set clear demarcations for kids of where they should be when drones are flying.
- Be sure to revisit safety standards regularly, as over time they may grow over-confident with their drone usage.
- Until teacher/mentor/kids are confident in usage, drones should only be deployed or used one at a time.

Compliance

- Educational/room use counts under "Recreational" rules and requirements.
- Because the Tello drones are < .55 lbs, they do not need to be individually registered.
- Teachers/mentors and kids must pass The Recreational UAS Safety Test (TRUST) and maintain certificate of completion.
    - This can be done together as a group or separately as individuals.
    - The FAA has a list of providers for the free online test: *https://www.faa.gov/uas/recreational_flyers/knowledge_test_updates*
    - All that is required to take the test is an email address and name.

Go Over Center-Specific Safety Rules and Requirements

- Where kids will be located while drones are flying.
- Where drones will be located while flying - “Airspace”.
- Make sure kids know which areas they are allowed to be in when:
    - No kids in “Airspace” while any drones are beginning, completing, or ending missions, no matter how far away they seem.
    - Can have a child or two (rotating) set up as “Air Traffic Controllers” and letting everyone know when it is safe/allowable to move into the “Airspace”.
        - Most relevant for when multiple flight missions are being executed at the same time.
- If desired, start kids off with sequential mission orders, so only one drone is flying at a time as all users get used to the commands and controls.
    - Most pertinent at the very beginning of the course, as well as in smaller spaces or ones with higher likelihood of cross-breeze or extra obstacles.

INTRO TO DRONEBLOCKS & BLOCK-CODING

The amount of time this will take will depend on the level of familiarity kids already possess with Block Coding systems.

Under the direction of the teacher/mentor, kids will need to download the Droneblocks extension on their Chromebooks, or their devices.

Link to iOS, Android, and Chrome download links
https://www.droneblocks.io/app

Note: Kids can begin using the Droneblocks app immediately without needing to create logins/ accounts, but they will need to make accounts before they get to the point of multi-day or more complex coding projects, as they will not be able to save their work otherwise. This would likely be around Lesson 5, but is ultimately up to the teacher/mentor.

Next Generation Science Standards

6-8.AP.15
Seek and incorporate feedback from team members and users to refine a solution that meets user needs.

6-8.AP.17
Systematically test and refine programs using a range of test cases.

CCSS.ELA-Literacy.RST.6-8.9
Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.

MS-ETS1-2
Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

To connect to their drone, kids can access the instructions in the top right corner of the application:

1. Power up Tello.
2. Go to your computer's network settings and look for the Tello network.
3. Connect to the Tello network. No password will be required.
4. Wait a few seconds for the network connection to be established.
5. Click the Connect button below and you should see Tello's battery percentage in the top left of DroneBlocks.

Teacher/Mentor Note: For clarity and efficiency, teacher/mentor should find some method to note the number of each drone on its body as it appears in the Connect/network menu. This will allow kids to double-check and make sure that they are connected to their assigned drone when multiple drones are in use at once.

PRE-FLIGHT CHECKLIST - IMPORTANCE & EXPLANATION

Teacher/Mentor: Go over each step of the Pre-Flight Checklist with kids and discuss its importance to them as well as for other areas and participants of aeronautics.

Steps:

- Inspect your drone visually for any physical defects, and make sure that the propellers are properly secured, and not dented or damaged.
- Make sure that the batteries you will be using are fully charged.
- Check your flight space.
  - Make sure you are within the bounds assigned to you by the teacher/mentor.
  - Make sure any fans - overhead or otherwise - are turned off, and windows and doors are closed so as not to invite a cross-breeze that might blow drones off course.
  - Make sure there is no one else too close to you.
- Review the parameters of your assignment and your code, perhaps with a partner.
- *Do you see any deviations or potential problems?*
  - Mentally map out the path you have coded your drone to take. *Do you see any potential pitfalls? Is it likely to cross paths with a person, other drone, or fixture in the room?*
- Make sure your drone looks properly connected and that you are not accidentally connected to someone else's drone.

TAKEOFF/LAND BLOCKS - CODING THE FIRST TEST FLIGHT

Note: When using the Takeoff block, the drone will rise 4 to 5 feet For the best results, always start the drone from the ground, not a raised surface (such as a desk or table, etc.)

Have kids make a short test flight code, following the program provided or shown.

- If desired, teacher/mentor can provide kids with a range of values that they can use with their "fly up" code.
  - However, it is also totally fine to have all kids start with the same base code.
- For the first test flight, just have kids fly their drone up and hover it in the air. The point of this lesson is familiarizing them with the block codes mechanically and the importance of the pre-flight checklist. More complex flights will come later.
- Use this first flight as an opportunity to make sure every kid understands and is executing the pre-flight checklist, as well as connecting their drones.
  - This will also serve to get a general sense of how well your kids will abide by the safety guidelines.

PRE-LESSON INFORMATION

In this lesson, the teacher/mentor will introduce kids to the basic physics concepts that allow drones to fly and that should be kept in mind as they are operated.

Kids will be introduced to moving their drones forward and backward on command.

MATERIALS

- **Parts of the Drone Reference Sheet (Page E120)**

PHYSICS & HOW DRONES FLY

The movement of drones is a constant balancing act which is why it can be thrown off course so easily. The computer-automated elements of the drone are so important because they are constantly running background calculations to ensure a proper and safe execution of the commands given by the operator.

Terms

Rotor - an assembly of rotating blades that supplies lift or stability for a rotorcraft [Merriam-Webster].

Thrust - a force or push that moves something forward; opposite of drag [NASA].

The rotors on a drone, also known as their propellers, allow it to hover by creating a downward thrust equal to the gravitational pull acting to pull it downward.

Next Generation Science Standards

6-8.AP.15
Seek and incorporate feedback from team members and users to refine a solution that meets user needs.

6-8.AP.17
Systematically test and refine programs using a range of test cases.

CCSS.ELA-Literacy.RST.6-8.9
Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.

MS-ETS1-2
Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

MS-PS2-2
Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

MS-PS2-4
Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.

Drones increase their height when the speed of their rotors is increased to the point that they are producing an upward force greater than the gravitational pull of gravity.

You can use the example of rowboats to help kids understand how drones move:

- Just like when paddling a rowboat, the sides of the craft need to be propelled equally but oppositely to keep it steady.
- A typical drone has four rotors, and as such, to keep it stable, two of them rotate clockwise, while two rotate counterclockwise. Because it has four points of movement, the rotors diagonal to one another will be spinning in the same direction.

FLIGHT ACTIVITY

Drones can be programmed to fly forward or backward using the "Fly Forward/Fly Backward" blocks.

- The default value is 20 inches, but this can be adjusted, just as with the fly up/fly down blocks.

Have kids complete a sample mission sending their Tello equal, pre-determined (small) distances forward and back.

- Mark points within the flight zone (with tape, small objects/boxes, etc.) to use as reference points for the flight objectives.
- Kids will be instructed to build on their previous experience with the Takeoff/Land blocks by building a program that sends their drone up, moves it forward to the objective point set by their teacher/mentor, moves it back to its starting location, and lands it safely.

OPTIONAL ACTIVITY

Tello does not have any GPS capabilities, so its measurements will not always be quite as accurate as if it did, since it relies on its internal sensors to determine distances.

- This could be an opportunity for a round of experimentation and discussion with kids, having them test exactly how accurate their Tello is by sending it to a pre-measured location multiple times, and compiling the average range of discrepancy by comparing their gathered data.

PRE-LESSON INFORMATION

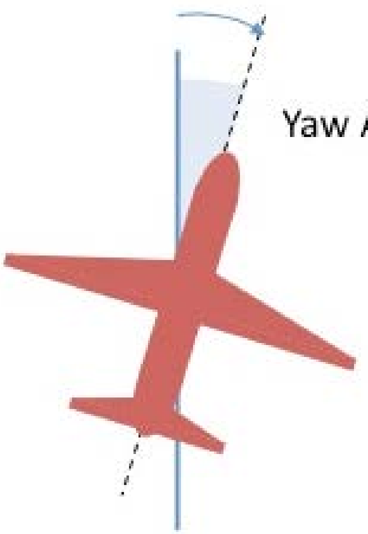
Teacher/Mentor will introduce kids to the concept of yaw, and guide them in a hands-on exploration of the differences in programming their drone to “Fly” right or left compared to “Yaw” right or left.

MATERIALS

- Yaw v. Fly Reference Sheet (Page E121)

INTRODUCING YAW

“Yaw” is a term used for rotation around a vertical axis, used largely in aeronautics/3D movement.



A yaw rotation is a movement around the yaw axis of an aircraft that changes the direction the vehicle is facing, to the left or right of its direction of motion.

Next Generation Science Standards

6-8.AP.15
Seek and incorporate feedback from team members and users to refine a solution that meets user needs.

6-8.AP.17
Systematically test and refine programs using a range of test cases.

CCSS.ELA-Literacy.RST.6-8.9
Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.

MS-ETS1-2
Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

6-8.DA.9
Test and analyze the effects of changing variables while using computational models.

6-8.CS.3
Systematically apply troubleshooting strategies to identify and resolve hardware and software problems in computing systems.

FLIGHT ACTIVITY

Have kids build two sets of box pattern code, yawing 90° in the second but not the first, and observing what occurs/changes in the flight path of their drone between the two.

Have kids share their observations on the differences between the flight paths and the code blocks.

Kids should note that the Yaw blocks have a changeable value for the degree of the turn, while the Fly Right/Left blocks do not.

Have kids code a second flight with a different angle value than 90, and observe the results.

Note: Make sure to use small values of distance, to minimize risk to kids and flight area.

DISCUSSION

Invite kids to discuss and consider situations in which they would want to use one or the other forms of side-to-side movement.

- *What is a situation in which they would not want to use yaw? A situation in which they would?*
- Teacher/Mentor can have a practice sheet for kids with some examples of situations their drone might be in, and ask them to pick Yaw or Fly Right/Left movement, and explain their choices.
- Yaw is an important concept to keep in mind with any aeronautical machine, especially with those such as planes, where it needs to be calculated carefully in relation to all other movements of the craft.

OPTIONAL ACTIVITY

If kids complete flight activities well before the end of class, teacher/mentor can set them a more complex challenge flight with 3 or more objectives, incorporating all movement blocks learned to date.

PRE-LESSON INFORMATION

Teacher/Mentor will introduce the concept of loops and variables to kids, and discuss the role they play in coding. Kids will be given the opportunity to explore the use of loops and variables in their own drone coding.

Next Generation Science Standards

6-8.AP.15
Seek and incorporate feedback from team members and users to refine a solution that meets user needs.

6-8.AP.17
Systematically test and refine programs using a range of test cases.

CCSS.ELA-Literacy.RST.6-8.9
Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.

MS-ETS1-2
Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

6-8.DA.9
Test and analyze the effects of changing variables while using computational models.

6-8.AP.11
Create clearly named variables that store data, and perform operations on their contents.

OPTIONAL

If kids are new to coding concepts and extra practice would be beneficial, the teacher/mentor can begin the class by giving a short presentation on Loops and Variables in general coding, using a site such as *scratch.mit.edu*.

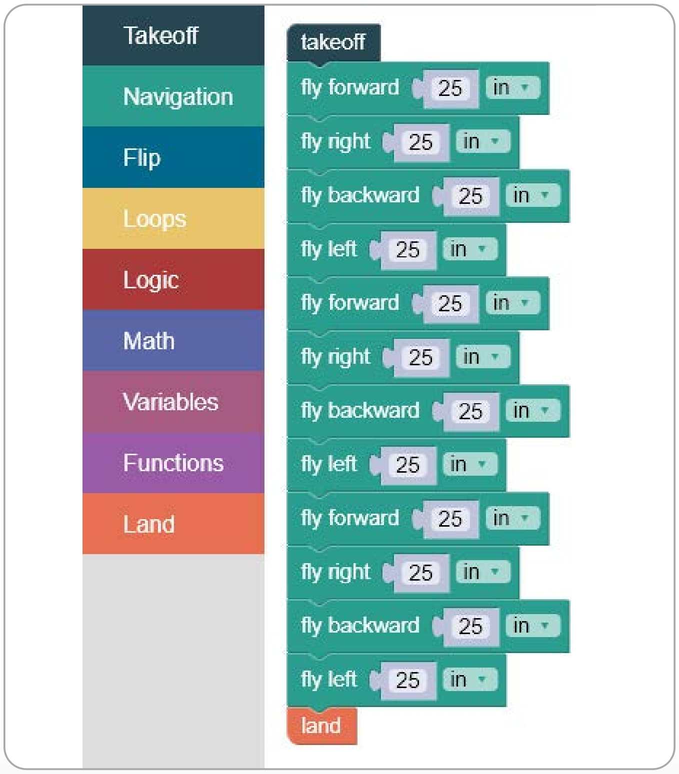
FLIGHT ACTIVITY - LOOPS

Assign kids a repetitive mission with limits on the blocks that they can use.

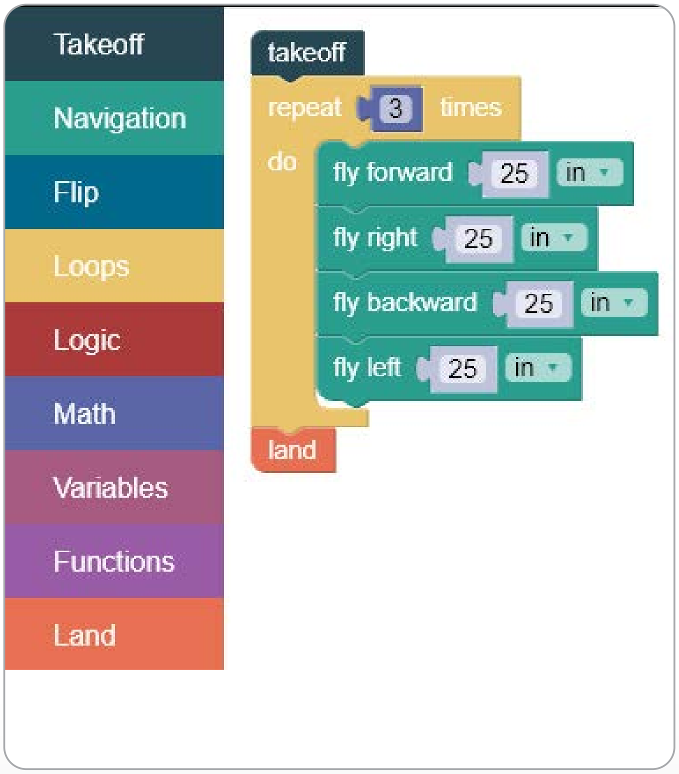
- The exact specifics of the mission can be left up to the teacher/mentor, but one example would be a repeated box flight, e.g.:
  - Fly to point A (25 inches forward), point B (25 inches right), point C (25 inches backward), and point D (25 inches left), three times in a row.
  - The teacher/mentor can choose to make this list of objectives more or less complex, as desired.
- Take note of the number of blocks each kid ends up taking, starting a discussion of how long it took them to code, and how easy or difficult it would be for someone else to come in and read that code to see what it was meant to do.

After this intro, introduce the concept of loops to kids (or refer back to it, if starting with the Scratch code presentation), and instruct them to revise their code by adding loops where applicable.

- Discussion: *How much does this reduce the number of blocks needed for the code? Increase comprehension?*



Example of mission code without using loops



Example of mission code using loops

FLIGHT ACTIVITY - VARIABLES

Assign kids a mission with multiple steps and a changing value for each step, e.g.:

- A box flight that grows bigger with every repetition:
    1. Fly to point A (25 inches forward), point B (25 inches right), point C (25 inches backward), and point D (25 inches left).
    2. Repeat this box flight, but this time adding 10 inches to each value. Repeat again, once again adding 10 inches to each value.
- The teacher/mentor can also come up with their own mission for kids, if desired.

Once again, have kids take note of the number of blocks required to complete the task, and ways that it could be streamlined.

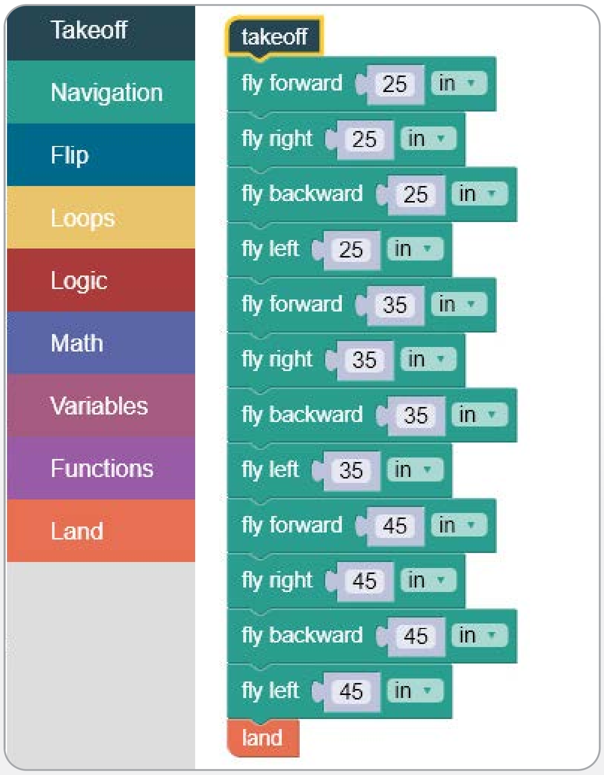
Discuss with kids how such an objective could be accomplished with greater efficiency and comprehension (either introducing variables or referring back to them).

Work with kids to create a revised version of the program that uses variables to reduce the total number of code blocks needed.

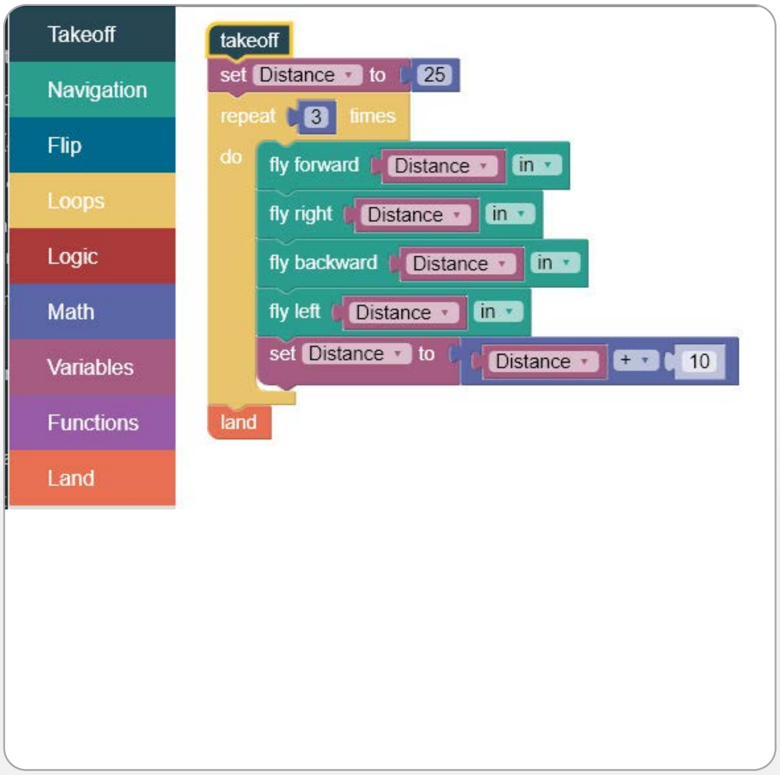
Note: If the added value is the same amount each repetition, kids can combine their understanding of loops and variables, as shown. If the added value is different every time (for example, adding 10 the first repetition, but 15 the second) they will have to use a few more sets of code.

Kids should understand that variables are used when we need a value to be dynamic and changeable during the period of time that the code is being executed.

- Variables can be used to store values, and those values can change with additional formulas and information over the course of the program.
- We can use logic and math to create more and more complex mechanisms to streamline our programming and communicate better to our device.
- Discussion:
    - Ask kids some other applications for variables that they can think of, now that they've experienced one such application.



Example of mission code without using variables



Example of mission code using variables

OPTIONAL ACTIVITY

If there is still time left at the end of the lesson, have the kids build their own program. The teacher/mentor can set a maximum number of blocks/lines using loops and variables, as well as their results/reasoning with each other.

PRE-LESSON INFORMATION

Kids will begin with a hands-on activity that presents a problem they can solve with enough iteration, but not efficiently or consistently. The lesson portion will give them the information they need to be able to solve this problem efficiently and consistently in the future, and their final flight activity will give them an opportunity to put their new knowledge into practice.

MATERIALS REQUIRED

- **Supplementary Angles Reference Sheet (E122)**

INTRO ACTIVITY - MINIMUM DISTANCE

Challenge: Get your drone from Point A to Point B with the minimum distance crossed possible.

- Teacher/Mentor can set the specific challenge; drones should start facing the same direction (forward), and the teacher/mentor should give a Point B that is to the side at an angle from the starting point, so kids will need to trial-and-error the right angle for the job.

CALCULATING INTERIOR AND SUPPLEMENTARY ANGLES OF TRIANGLES

Note: Depending on specific grade level and time of year, this could be a first introduction or a review, and can be expanded or adjusted accordingly.

Next Generation Science Standards

6-8.AP.15
Seek and incorporate feedback from team members and users to refine a solution that meets user needs.

6-8.AP.17
Systematically test and refine programs using a range of test cases.

CCSS.ELA-Literacy.RST.6-8.9
Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.

MS-ETS1-2
Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

CCSS.Math.Content.7.G.B.5
Solve real-life and mathematical problems involving angle measure, area, surface area, and volume.

CCSS.Math.Content.7.G.A.1
Draw, construct, and describe geometrical figures and describe the relationships between them.

This portion of the lesson, building on the intro activity, will serve to familiarize kids with the conception of calculating angles in aviation.

Kids should be instructed or reminded that the sum of interior angles of a triangle will always equal 180 degrees.

Additionally, given the flight path of a drone along a line of a triangle or polygon, the angle that it needs to turn - the supplementary angle - will add up to 180 along with the interior angle, as it works as a half-circle in rotation. [See Supplementary Angles Sheet]

- *Note: The teacher/mentor can go over this initially in the lesson portion, or let kids find out for themselves in coding their drone flights that using the interior angle as the angle command for their drone's turn will not work, and use that as a jumping-off point to introduce them to the concept of the supplementary angle.*

- If there are concerns with the flight area such that there might be additional risk with drones flying in not-quite-correct directions, it might be best to inform kids of the importance of the supplementary angles beforehand.
- Another option is for the teacher/mentor to set each kid or group to coding their flight program, and then clearing the flight area and testing one code at a time themself, encouraging the entire group to observe the results and discuss what might have gone wrong, before leading into the discussion of the supplementary angles.

FLIGHT ACTIVITY

Kids will be given a specific triangle path for their drone.

- This can be assigned to individual kids or small teams, depending on the teacher's/mentor's preference and the number of available drones.
- Triangles should be marked on the floor with tape or paper, or kids can be given a paper copy to base their path on.
- The given triangle information should include the interior angles, as well as the length of the sides.
  - Kids will then be set to programming their drone to trace the path of their triangle as accurately as possible.
  - They will need to code their drone to travel the distance of each side, and turn the correct angles before returning to its starting point.

CONCLUSION

Have kids discuss/showcase their completed triangle paths, and share any observations they have from their experience.

OPTIONAL ACTIVITY

Teacher/Mentor can gradually increase the complexity of the shapes involved, and give kids the opportunity to work out the necessary angles, dividing squares, rectangles, and even more complex shapes into triangles to determine the proper angles.

PRE-LESSON INFORMATION

Teacher/Mentor will introduce or review with kids the concept of square roots and squaring, if necessary, to ensure they have the necessary foundation for Pythagorean Theorem, before introducing/reviewing the Pythagorean Theorem with them. Their flight activity will give them hands-on experience with the way pilots can use the Pythagorean Theorem in navigation.

By the end of this lesson, kids will be able to determine mathematically the distance they need to program their drones from one point to another (without having to measure it themselves) before they start coding.

This will allow kids to maximize the efficiency of their drone's limited battery life, and they will no longer need to guess at distances when coding their drone, so long as they have two related distances.

Next Generation Science Standards

6-8.AP.15
Seek and incorporate feedback from team members and users to refine a solution that meets user needs.

6-8.AP.17
Systematically test and refine programs using a range of test cases.

CCSS.ELA-Literacy.RST.6-8.9
Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.

MS-ETS1-2
Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

CCSS.Math.Content.5.G.A.2
Graph points on the coordinate plane to solve real-world and mathematical problems.

CCSS.Math.Content.6.EE.A.2
Apply and extend previous understandings of arithmetic to algebraic expressions.

CCSS.Math.Content.7.EE.B.4
Solve real-life and mathematical problems using numerical and algebraic expressions and equations.

CCSS.Math.Content.8.G.B.7
Understand and apply the Pythagorean Theorem.

MATERIALS REQUIRED

- **Pythagorean Triangle Worksheet (Page E124)**
- **Pythagorean Theorem Flight Activity Reference Sheet (Page E126)**
- **Compass Rose Sheet (Page E127)**

INTRODUCING/REVISITING SQUARE ROOT/ SQUARING

Squaring in mathematics is the process of multiplying a number by itself.

- Example: Squaring the number 2 would result in the number 4. Squaring the number 4 would result in the number 16.

This is called squaring because it also describes the area of a square: multiplying two (always equal) sides of a square together.

INTRODUCING PYTHAGOREAN THEOREM

The Pythagorean Theorem holds that, for any right-angled triangle, the squares of the legs will be equal to the square of the hypotenuse - the side opposite of the right angle.

- $a^2 + b^2 = c^2$
- GIF visual of Pythagorean Theorem Proof
  - *https://upload.wikimedia.org/wikipedia/commons/9/9e/Pythagoras-proof-anim.svg*

Real world applications:

- Using the Pythagorean theorem allows pilots (and kids) to calculate the distance of flight between two coordinates, as well as to calculate altitude, and even more complex concepts such as groundspeed (the actual flight speed of an aviation vehicle after accounting for wind and other forces acting for and against its planned movement).

FLIGHT ACTIVITY

Using the **Pythagorean Triangle Worksheet**, kids will be instructed to use the triangle they are given to meet the two points, in any orientation. Kids will gain a visual understanding of the application of Pythagorean Theorem to this problem, and that the only way to make the triangle meet the two given points is with the hypotenuse.

In the flight area, teacher/mentor should mark one “0,0” starting point, at the line that typically demarcates the flight area from the area where kids stand. They will then show kids a point on the ground directly ahead of the starting point, pre-marked.

Note: Teacher/Mentor should make sure to set a consistent unit of measurement for kids, whether centimeter or inches.

Kids will be instructed that they will have one flight opportunity to get their drone as close to that mark as possible (teacher/mentor can use their own discretion on including any “reward” for this challenge) without crossing the flight area line themselves (i.e. no measuring), or using any turn commands.

Teacher/Mentor will give kids the pre-measured coordinates of the target mark [e.g., 300 E, 500 N]. They will also orient for kids a compass with the cardinal directions - as shown in the **Pythagorean Theorem Flight Activity** reference - such that the given co-ordinates are in the northeastern direction.

Using the given coordinates, kids will determine the distance they need to code their drone to fly to reach the target mark.

Note: Initially, kids might erroneously use the coordinates given to code the distance for their drone to fly.

- If this is the case, and no kids manage the correct solution, the teacher/mentor can showcase and explain for them the method they should be using to solve the problem, and either work together with the group as a whole to code a drone to make the correct flight, or let the kids individually try one more time.

CONCLUSION

The takeaway should be that math is a tool, the same way that language is a tool. In this case, they will be using math to find information they don't have by using information that they do have, in the same way that they would use a microscope to look at organisms they can't see with their own eyes.

Kids should understand that they can use Pythagorean theorem in more situations than those with pre-existing simple triangles, and that if they are able to conceptualize a right-angled triangle within a given situation, they can use the theorem to calculate the missing value.

PRE-LESSON INFORMATION

The purpose of this lesson is to give kids a base understanding of the trigonometric method of calculating angles given distance measurements and giving them the opportunity to apply that method and understanding to their work with drones.

Note: While most kids at this grade level will not be introduced to trigonometry until high school, giving them an opportunity to engage with trigonometric principles in a hands-on way will serve as a solid foundation for their future experience.

Teacher/Mentor can refer back to the previous work kids have done with right triangles, and posit to them the question - now that they understand how triangles and associated formulas can be used for navigation - what would they do if they had, rather than two distances, or coordinates, rather only one distance and an *angle*.

- This is the problem that will be introduced to them with trigonometric functions as the solution.

Prior to the lesson/activity, teacher/mentor will need to measure out the triangle flight paths that will be used, distances and angles, and mark the points A, B, and C that kids will be using as reference points.

Next Generation Science Standards

6-8.AP.15
Seek and incorporate feedback from team members and users to refine a solution that meets user needs.

6-8.AP.17
Systematically test and refine programs using a range of test cases.

CCSS.ELA-Literacy.RST.6-8.9
Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.

MS-ETS1-2
Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

CCSS.Math.Content.5.OA.A.1

Write and interpret numerical expressions

CCSS.Math.Content.6.EE.A.2
Apply and extend previous understandings of arithmetic to algebraic expressions.

CCSS.Math.Content.7.G.B.5
Define trigonometric ratios and solve problems involving right triangles

CCSS.Math.Content.HSG.SRT.C.8
Define trigonometric ratios and solve problems involving right triangles

MATERIALS REQUIRED

- **Scientific Calculator [or any calculator with sin|cos|tan functionality] Sine Cosine Tangent Introduction Reference Sheet (Page E128)**
- **Using Trigonometry to Find an Unknown Distance Reference Sheet Sine Cosine Tangent Flight Activity Reference Sheet (Page E130)**

INTRODUCING SINE, COSINE, AND TANGENT

Teacher/Mentor will need to make kids aware of the specifics of the designations *opposite* and *adjacent*.

- All sides are given their designations by their relation to the reference angle, typically marked with the Greek letter *theta*: Θ.
- Adjacent refers to the side next to the reference angle, while Opposite refers to the side across from the given reference angle.
- The reference angle cannot be the right angle.

Trigonometry is the division of math that deals specifically with triangles, and as such, kids should already have seen just how applicable it can be to their aviation projects.

Sine, Cosine, and Tangent (abbreviated as *sin*, *cos*, and *tan*) are trigonometric functions that describe the ratios of the sides of any given right triangle.

- The ratios themselves are: SOH-CAH-TOA, as seen on the **Introduction** reference sheet.

Teacher/Mentor should demonstrate for kids how to solve for each side length in a given angle.

- See: **Using Trigonometry to Find an Unknown Distance** reference sheet.

FLIGHT ACTIVITY

Teacher/Mentor will give the kids a reference mark at the starting line separating the kids' area from the flight area. Kids will be shown two additional points (marked in tape or similar fashion) on the floor of the flight area, as shown in the **Flight Activity** reference sheet. These will be the two additional vertices of the triangle, in addition to their marked starting position.

Kids will be given the pre-measured hypotenuse distance of their triangular flight path [**Line CA** in the reference image], as well as one of the non-right angles. This will leave two distances and one angle that they will need to determine, mathematically.

Kids will be instructed that their objective is to determine the distance that they need to direct their drone forward to Point B, sideways to Point C, and the angle that they need to command it to yaw to bring it back from Point C to their starting position at Point A.

- To encourage kids to do their math properly before programming, and discourage them from relying on random chance, as in the previous lesson, kids will be given one flight opportunity to complete this challenge (unless some mechanical or connection error impedes their flight).

Note: Kids will need to use sin and cos to determine the two missing distances, and refer back to their lesson on supplementary angles (and their knowledge that all interior angles of a triangle will add up to 180 degrees) to determine both the missing angle, and the angle they need to command their drone to yaw to follow Line CA to the starting Point A.

The teacher/mentor can make their own determination as to whether to give all kids the same triangle flight path, or assign different flight paths and reference points to different groups. If the latter, they will need to prepare and measure multiple points/flight paths.

CONCLUSION AND REAL WORLD APPLICATION

Ultimately, once kids are able to calculate Sin/Cos/Tan, they will be able to code their drone to fly in multiple polygonal formations, starting and ending at the same point.

- These theorems and formulas can be utilized if ever flying a drone remotely, to use given coordinates to determine required navigation commands.

PRE-LESSON INFORMATION

This lesson, along with Lesson 10 - the final in this section of curriculum - will act as a final project of sorts, giving kids the opportunity to work on longer, more complex programs, and give them a glimpse of some additional applications for drones.

MATERIALS REQUIRED

- **Metronome, or metronome app**
- **Scratch paper and pencils**
- **Headphones**
- **Stopwatch, or stopwatch app**

LESSON - AERIAL CHOREOGRAPHY

Show kids video(s) of Aerial Choreography for Drones.

- The specific video(s) and number is up to the individual teacher/mentor.
- Some examples include:
  - Traditional Shamisen at Mt. Fuji
    ▶ *https://vimeo.com/163266757*
  - DemoReel from 1st International Drone Show Choreography Competition
    ▶ *https://www.youtube.com/watch?v=ihFutJCFceU*

Next Generation Science Standards

6-8.AP.15
Seek and incorporate feedback from team members and users to refine a solution that meets user needs.

6-8.AP.17
Systematically test and refine programs using a range of test cases.

CCSS.ELA-Literacy.RST.6-8.9
Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.

MS-ETS1-2
Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

6-8.AP.9
Test and analyze the effects of changing variables while using computational models.

6-8.AP.14
Create procedures with parameters to organize code and make it easier to reuse.

Discussion

- Ask kids what changes, if any, they would make to the choreography shown.
- *What features do they think the drones used had to have to make the final product shown possible?*
- *What features would they hope drones would have in the future to make these sorts of visual displays even better?*

Teacher/Mentor can introduce kids to the concept of BPM (beats per minute) as a measurement of rhythm, to help in their planning.

- Teacher/Mentor can utilize the metronome or metronome app and a musical sample of their choice to demonstrate this concept.

FLIGHT ACTIVITY

Divide kids up into small groups for this activity

- *Note: The group sizes will be determined by the teacher/mentor and the number of drones available to the kids. Each group should have two drones.*

Kids will be instructed to work together to decide on a song clip that they want to use to create their own aerial choreography.

- Teacher/Mentor, if desired, can provide a curated set of songs to choose from for kids.
- Songs should be approximately 45 to 60 seconds long.
    - If kids move through the activity very quickly, teacher/mentor can lengthen this time frame as needed.
- Kids should be given 10 minutes to decide on a song choice, especially if they are working in larger groups.

Kids will then be instructed to begin planning their choreography. They should be given scratch paper to note down the different motions they want their drones to take, in accordance with the music.

- *Note: It would be good to have headphones available for each group/kid, as they will need to listen to the song multiple times as they work out the different steps of their choreography, and work to synchronize it to the music.*
- Kids can also be encouraged to do some independent research on both paired figure skating choreography, and additional drone choreographies, to use as inspiration for their design.
- Kids should be encouraged to use the Set Speed block as needed, as well as the Flip blocks and any others to make their aerial choreography more visually engaging.
- The two drones should be coded to move in complementary patterns, similar to paired figure skaters, rather than using the same code for each (which could cause them to crash into one another).
- Kids will need to plan the two starting points for their drones, as well as where they plan for them to end.

Teacher/Mentor should also give kids the opportunity to time the responses of their drones to certain commands. This can be undertaken concurrently with the choreography planning, with the taking turns, or before or after, as preferred.

- This will give kids important data for the programming of their choreography, and allow them to be more precise in matching it to their music choice.
- Kids should measure and record the amount of time it takes their drone to complete the majority of the basic commands that they will be using.
    - This will work best with one kid controlling the stopwatch/measurement and one kid in charge of the control of the drone/recording the data.

Kids will have through the end of the lesson to work on their choreography, and may be reminded that they will have the first half of the next lesson to work on it as well.

FLIGHT ACTIVITY

Kids will be instructed to break back into the groups they were in last week, and continue working on their aerial choreography.

Kids should be given an opportunity at the beginning of the lesson to test the code that they have written so far, and determine what changes, if any, they will need to make.

- This will also allow them to make additional observations that they can take into account as they finish coding their choreographed flights.

Kids within a group will also need to practice synchronizing and signaling their music starting and their drone code beginning.

Kids should be given approximately 30 minutes to finish their choreographies and prepare for their presentations.

Teacher/Mentor can make themselves available to help troubleshoot with groups that may be struggling, and suggest additions to groups that may "finish" too quickly.

PRESENTATION

Groups will be allowed to go up to the designated flight area one at a time to present their aerial choreographies.

Next Generation Science Standards

6-8.AP.15
Seek and incorporate feedback from team members and users to refine a solution that meets user needs.

6-8.AP.17
Systematically test and refine programs using a range of test cases.

CCSS.ELA-Literacy.RST.6-8.9
Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.

MS-ETS1-2
Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

6-8.AP.9
Test and analyze the effects of changing variables while using computational models.

6-8.AP.14
Create procedures with parameters to organize code and make it easier to reuse.

6-8.IC.20
Compare tradeoffs associated with computing technologies that affect people's everyday activities and career options.

Kids should briefly introduce their music choice, why they chose it (if desired) and any design inspirations they would like to share for their choreography.

Teacher/Mentor can play their chosen audios for them.

- If desired, teacher/mentor can allow/request that other kid groups give positive feedback on each choreography.

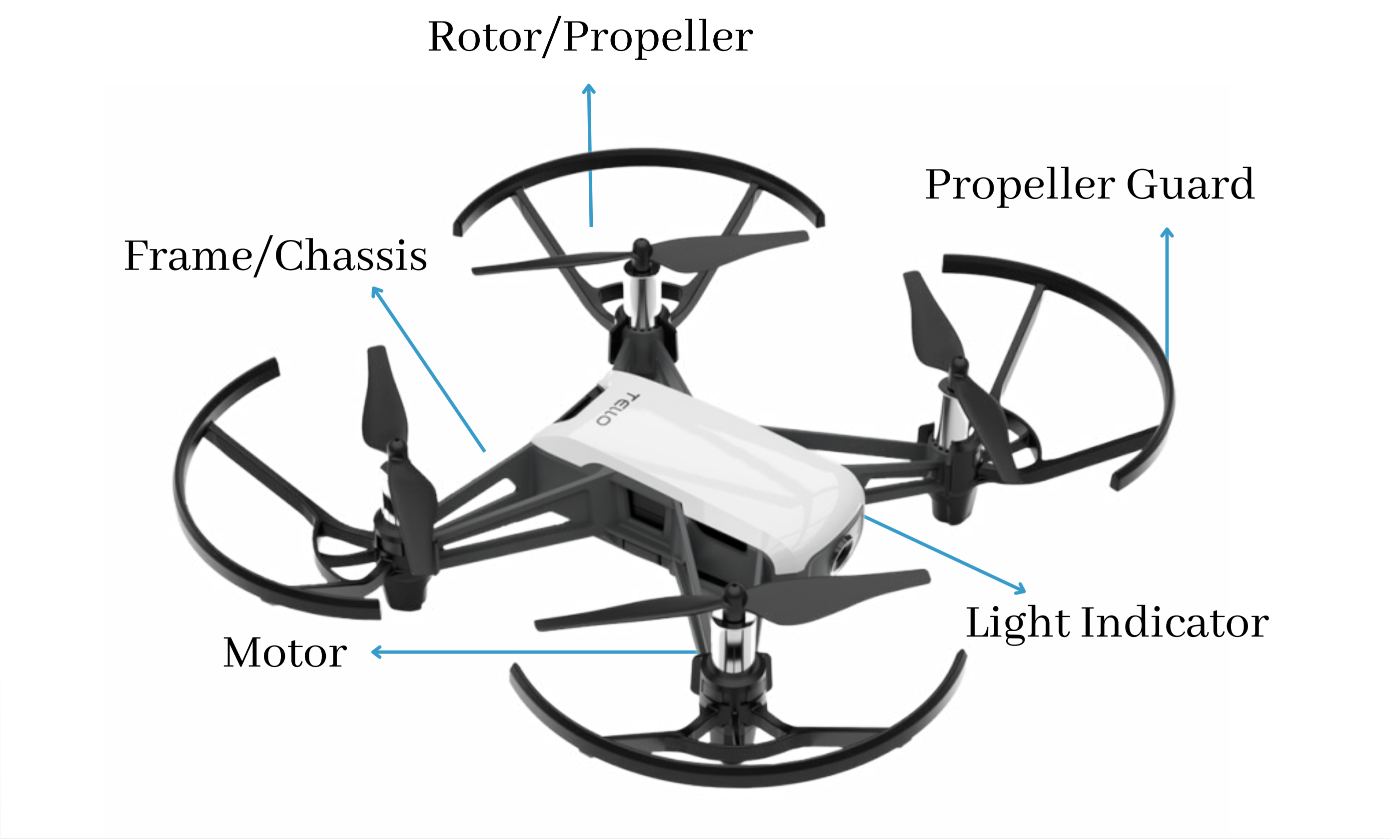
CONCLUSION

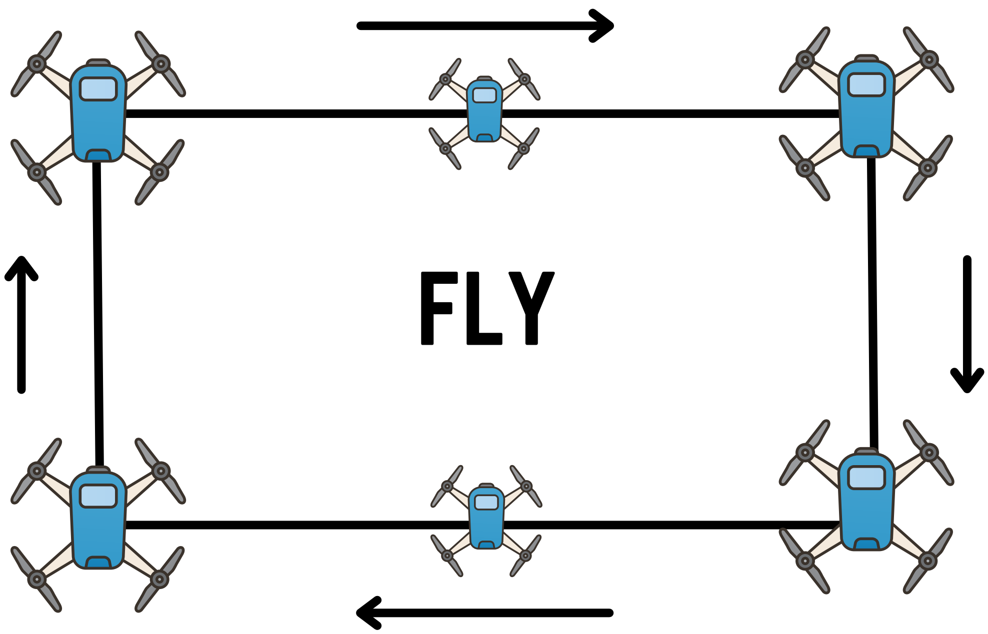
Once every group has shared their choreography, collect all the drones, and return to the general class area.

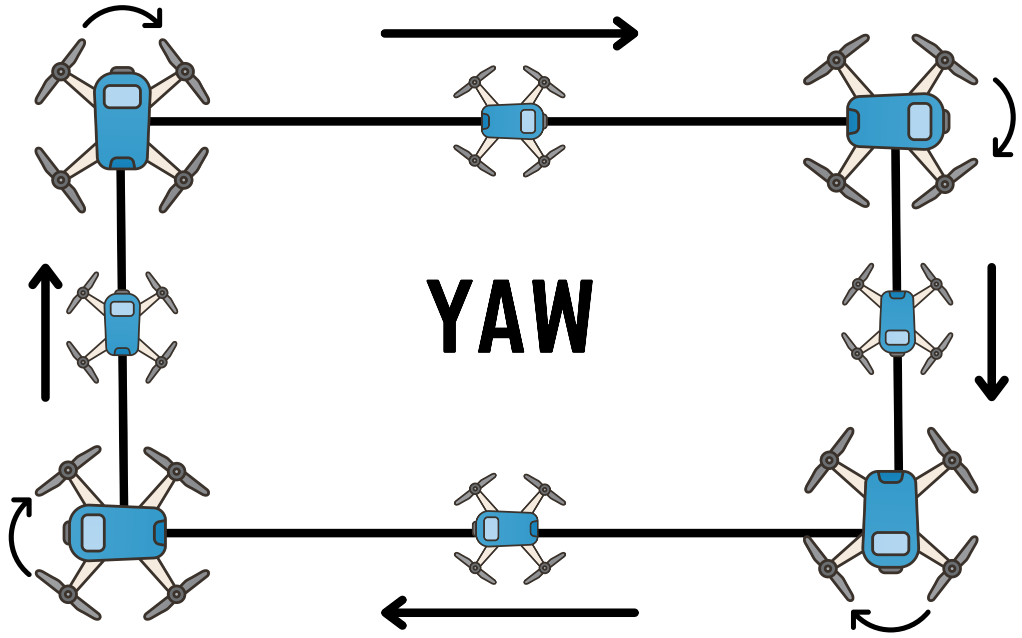
Lead kids in a discussion of the various real-life applications for drones that they have experienced thus far over the course of the programming.

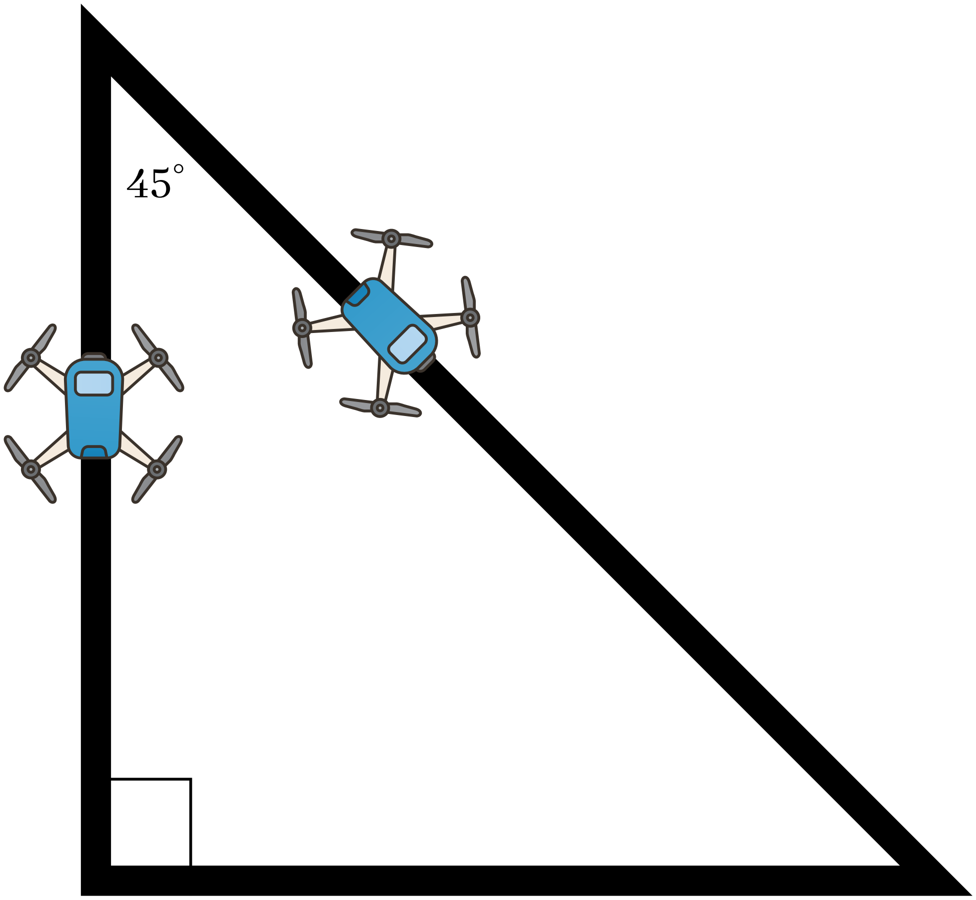
- *What are some other uses for drones that they might know of?*
- *What are some positives and negatives associated with each of those uses?*
- *How do they foresee drones being utilized in the future?*

Give kids an opportunity to share any thoughts they have on their experience with the drones over the duration of the course, and anything they would like to focus on more in any future experiences.


Rotor/Propeller
Propeller Guard
Frame/Chassis
TELLO
Light Indicator
Motor


FLY


YAW

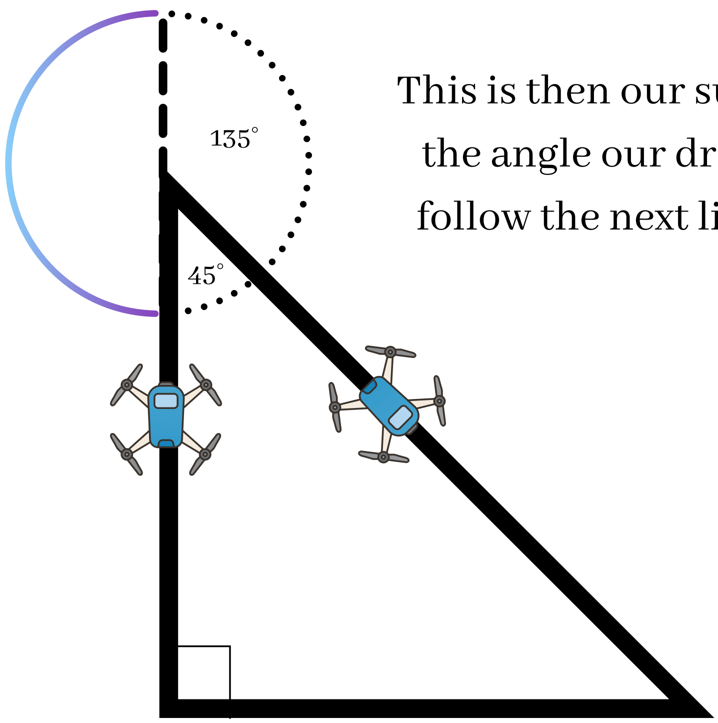


Program the drone to follow the path of the triangle, using the given angle.

Because of the drone's flight path relative to the angle of the path it needs to take, we conceptualize its turn as part of half-circle.

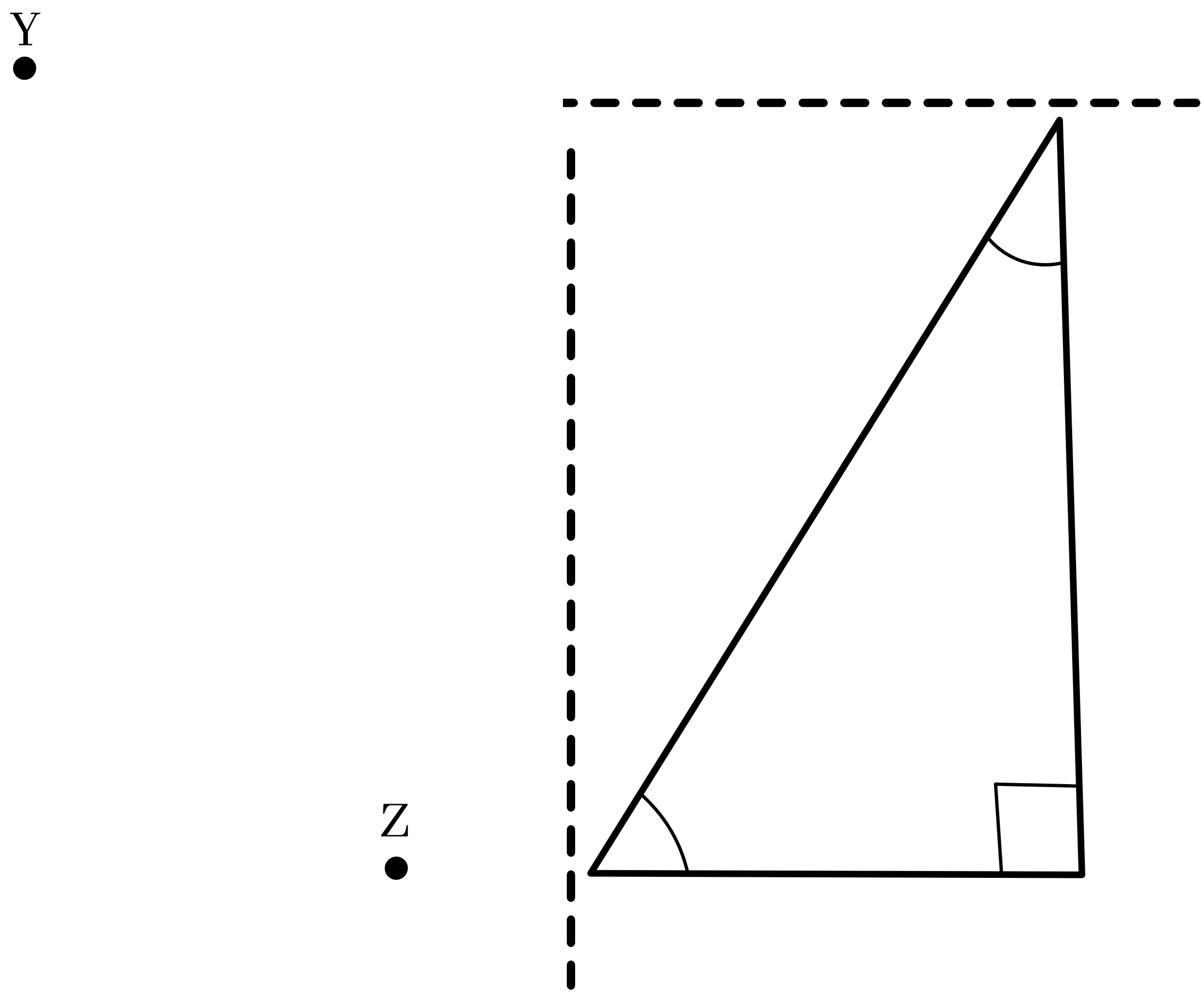
45° is the angle that it needs to end up aligned to, not the angle it needs to turn.

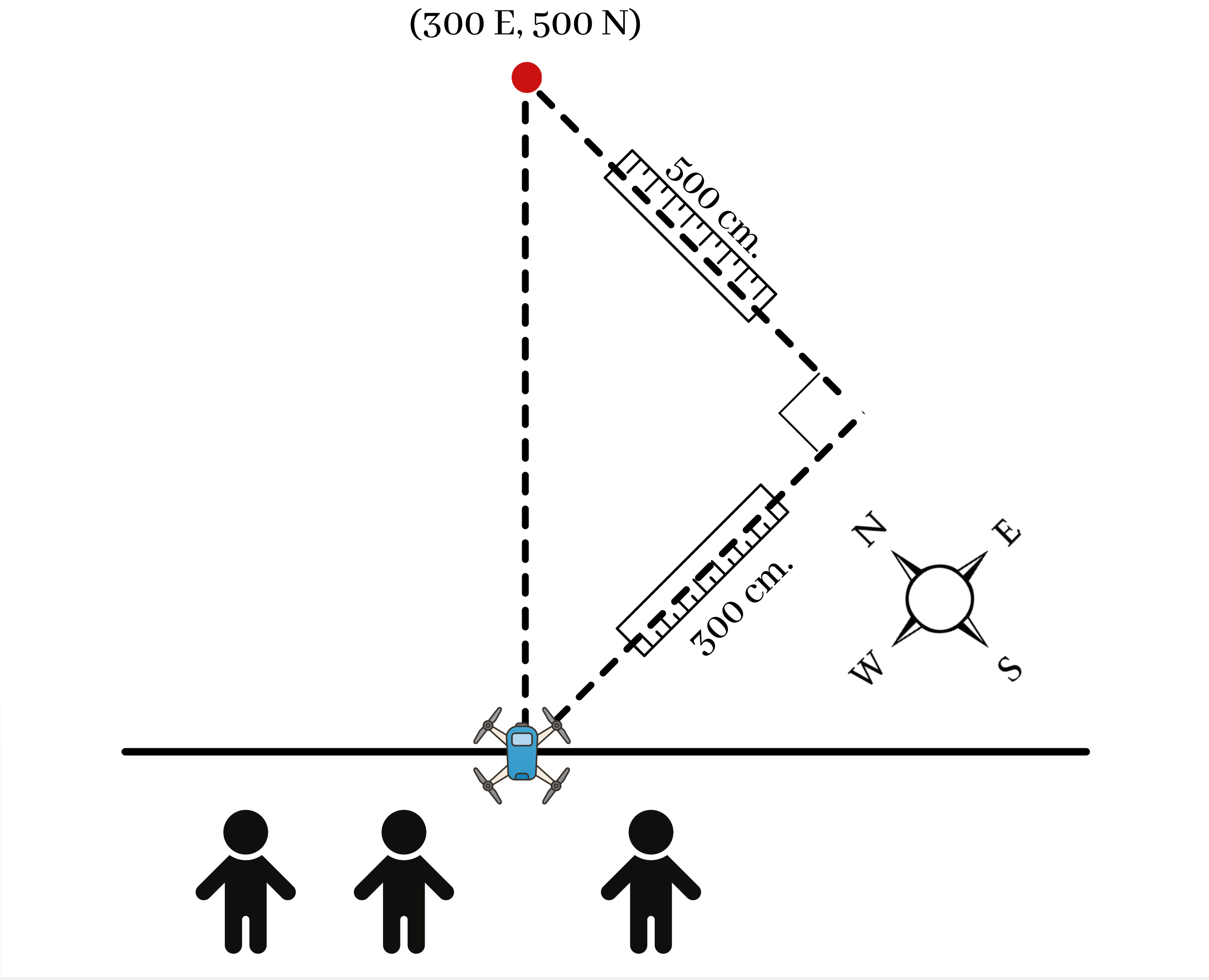
The difference between 180° (the angle of a half-circle) and 45° (the interior angle of our triangle) is equal to 135°.

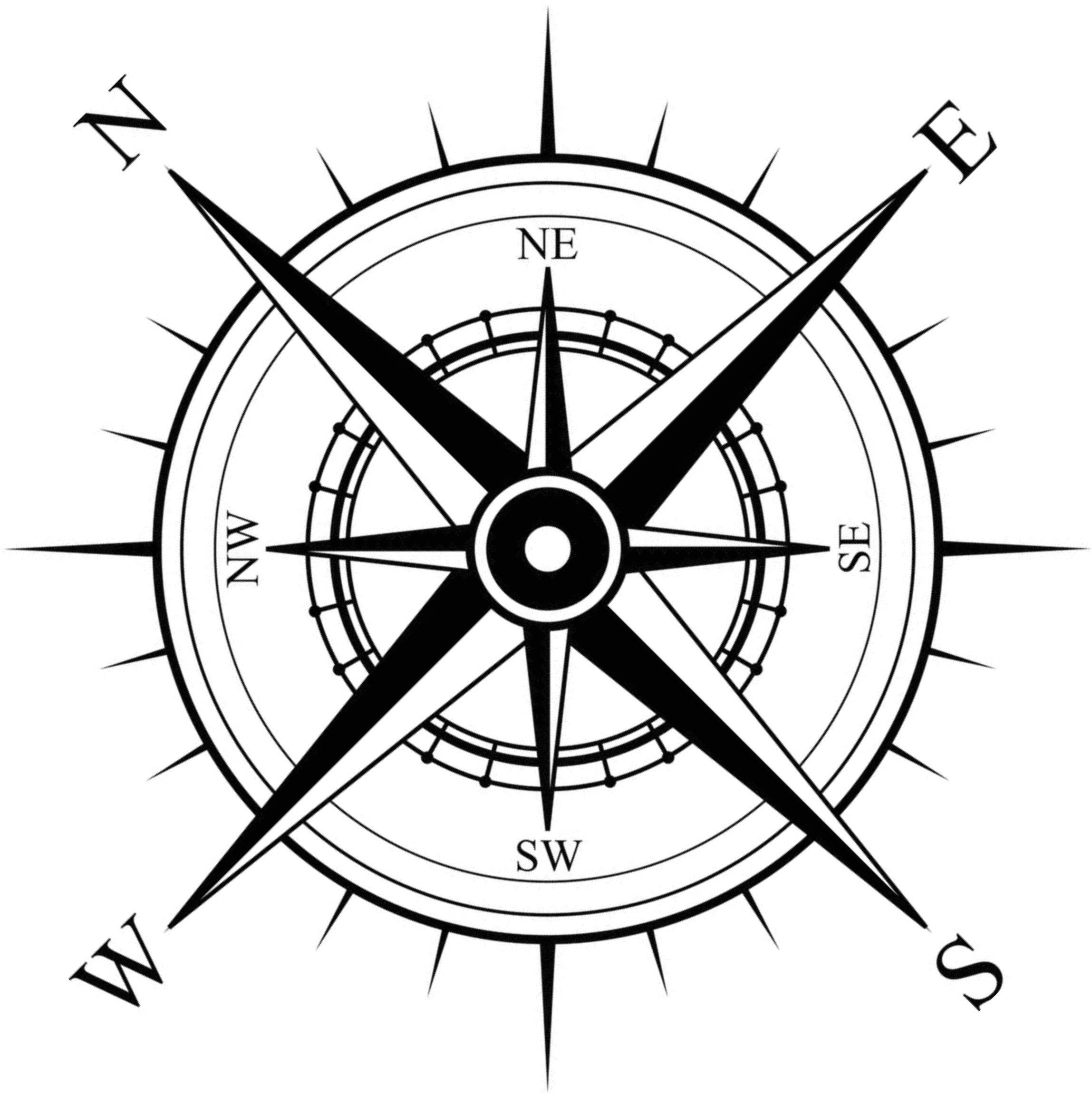


This is then our supplementary angle - the angle our drone needs to turn to follow the next line in its flight path.

1. Cut out the triangle below.
2. Connect the two points Y and Z using any two vertices on the triangle.
3. Which points worked to connect the distance?



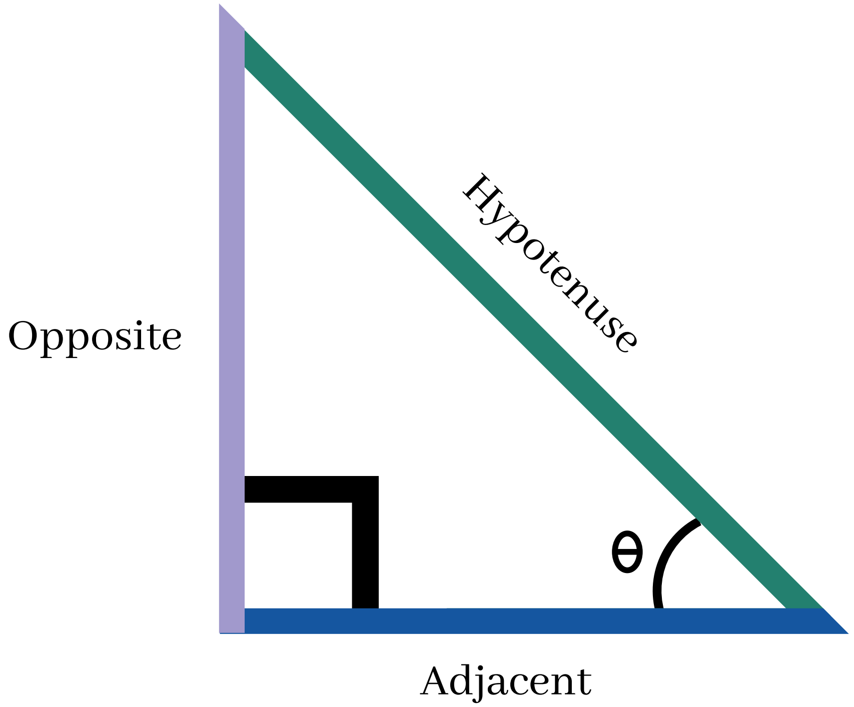

(300 E, 500 N)
500 cm.
300 cm.
N
E
W
S


N
E
NE
NW
SE
SW
W
S

Hypotenuse - Longest Side | Opposite the Right Angle

Adjacent - Side Next To the Non-Right Angle

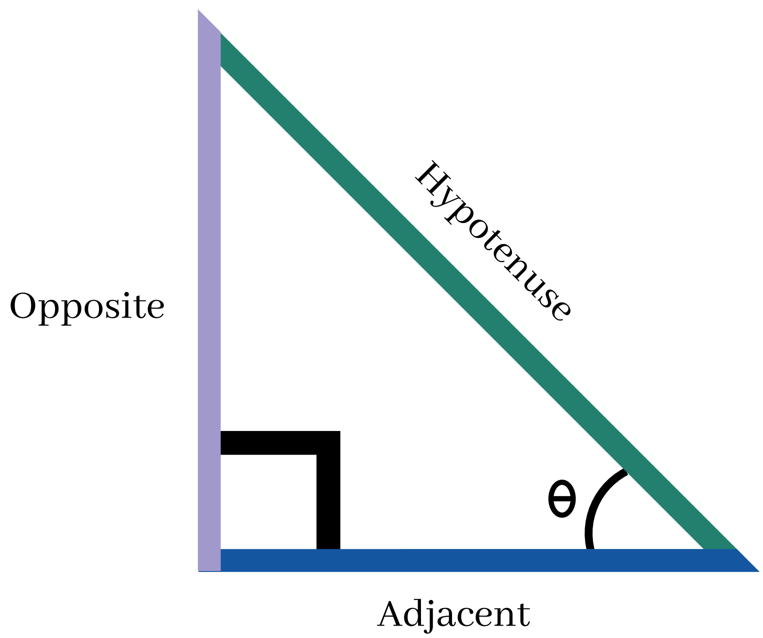
Opposite - Side Opposite To the Non-Right Angle



$$\text{SIN } \theta = \frac{\text{OPPOSITE}}{\text{HYPOTENUSE}}$$

$$\text{COS } \theta = \frac{\text{ADJACENT}}{\text{HYPOTENUSE}}$$

$$\text{TAN } \theta = \frac{\text{OPPOSITE}}{\text{ADJACENT}}$$



USING TRIGONOMETRY TO FIND AN UNKNOWN DISTANCE

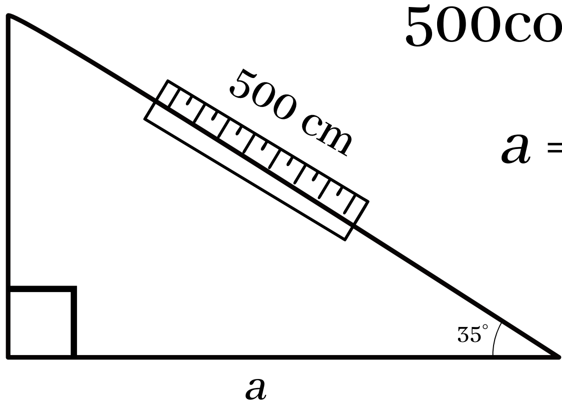
Let's find the length of the side ADJACENT to our reference angle.

We'll call this angle *a.*

We need to use the ratio that includes both Adjacent (the value we need) and Hypotenuse (the value we have).

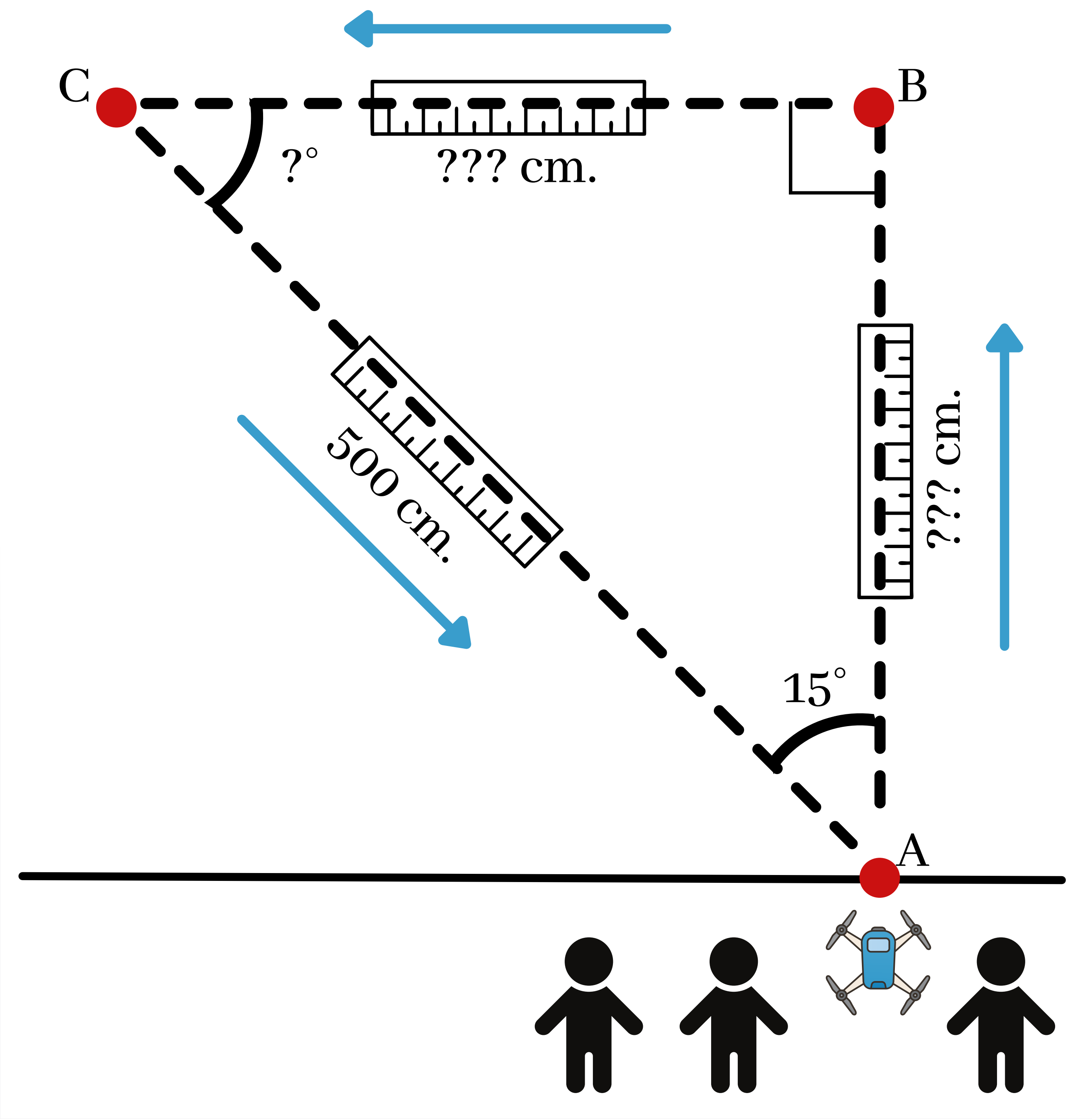
$$\text{Cos } \theta = \frac{\text{Adjacent}}{\text{Hypotenuse}} \longrightarrow \text{Cos } 35^\circ = \frac{A}{500} \longrightarrow 500 * \text{Cos } 35^\circ = A$$

Now that you have your equation properly formulated, it is time to plug it into your calculator!



$$500\cos(35) = 409.6$$

$$a = 409.6 \text{ cm}$$


C
B
A
?°
??? cm.
500 cm.
??? cm.
15°

1. The red points A, B, and C should be marked visibly in the Flight Area.
2. Teacher/Mentor will give the length of the hypotenuse and the degree of one of the non-right angles.
3. Kids will use the Sine, Cosine, and Tangent ratios to determine the two missing distances.
4. They will also use their understanding of triangles and supplementary angles to determine the degree of the missing angle.
5. Once they have determined all missing values, they will code their drone to fly from point A to point B to point C, then back to A, their starting position.
6. Kids will have one flight opportunity (barring mechanical or connection issues) and may not cross into the Flight Area to measure and distances.

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://support.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

- *https://www.adventuresinmath.org/*

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 teachers/mentors 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/*

NASA for Kids: Intro to Engineering

- *https://education.nationalgeographic.org/resource/nasa-kids-intro-engineering*

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*

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/mentors and kids 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

ACKNOWLEDGEMENT

We would like to thank the following sponsor for their generous support of the Ripken Foundation's Middle School STEM Curriculum Guidebook & Activities:

BATTELLE

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We would like to thank the following sponsor for their generous support of the Ripken Foundation's Middle School STEM Curriculum Guidebook & Activities:

PAT & ROBIN TRACY

Pat Tracy - STEM Class of '72

"Theory and Practice"

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WHITING-TURNER

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