spectrUM DISCOVERY AREA

Making & Tinkering COOKBOOK

VERSION 1.0

UNIVERSITY OF MONTANA BROADER IMPACTS GROUP

Martin Family FOUNDATION

UNIVERSITY OF MONTANA spectrUM

UNIVERSITY OF MONTANA

spectrUM DISCOVERY AREA's Making & Tinkering INITIATIVE

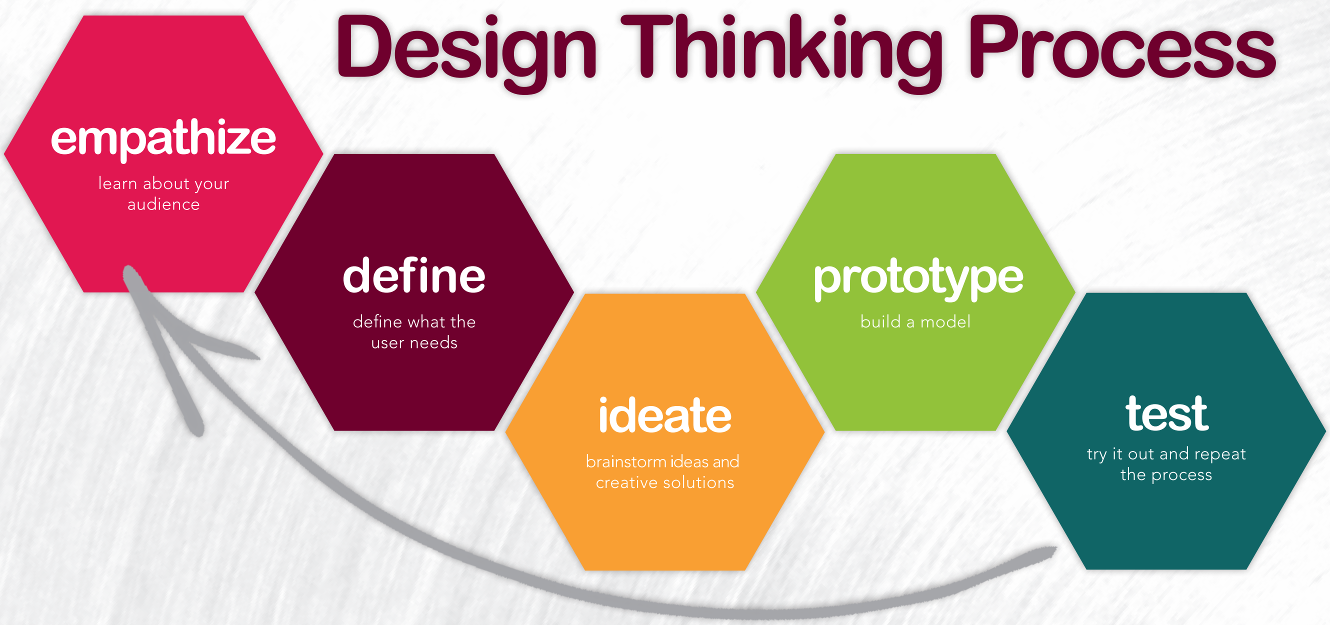
Powered by THE **Martin Family** FOUNDATION

With the goal of inspiring K-12 students about the array of educational and career pathways that await them, the University of Montana Broader Impacts Group – including spectrUM Discovery Area – has teamed up with the Martin Family Foundation, K-12 schools in Hamilton and Corvallis, and a cross-sector Bitterroot advisory group to co-design hands-on educational experiences that align with the local community's real work force strengths and opportunities. These co-created experiences engage children with making and tinkering while connecting them with role models from an array of educational and career pathways.

Our co-creative model is always ripe for new opportunities; for example, we recently added a SciGirls Code club at the Hamilton Middle School library. The club engages middle school girls in designing and coding apps, creating their own robots, and building wearable technology, with a focus on using the engineering design process.

Making and tinkering offer high-risk but low-stakes opportunities for children to experiment, be creative, fail without consequence, and then try a new approach, building their critical thinking and problem solving skills while promoting resilience. In the 2016-2017 school year, a cohort of ten fifth-grade teachers and school librarians joined spectrUM and guest experts from the Science Museum of Minnesota, UM's Phyllis J. Washington College of Education and Human Sciences, and the Bitterroot College FabLab for a two-day Making and Tinkering Institute designed to equip teachers to facilitate making in their schools. Throughout the academic year, spectrUM's resident maker Nick Wethington co-facilitated making activities alongside teachers. The following activities are the result of this collaboration.

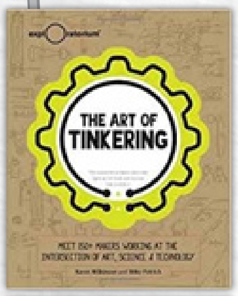
This is a capacity-building project that is designed to build momentum each year, expanding the number of teachers and students served to eventually reach all of Daly Elementary and Corvallis Middle Schools through in-school programming and annual porfessional development workshops for teachers. Additionally, both schools will work with national leaders in the maker movement to design and build an in-school makerspace that is ripe for further funding and implementation.

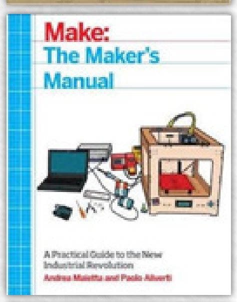


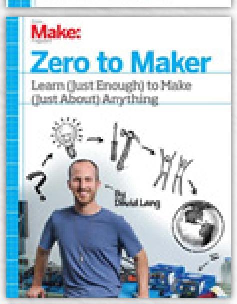
Making & Tinkering STRATEGIES

A simple definition of making is learning through the process of design, iteration, and failure. But it's much more than that, hitting some fundamental aspects of what it is to be human and shape the world around us by exploring the nature of various materials.

Allowing students to struggle and succeed is the most important thing to take away from these activities. The loose "step-by-step" nature of these instructions is meant to be a helpful guide for those who are new to these activities. In the facilitating activities during the year, an example of the item to be created or end goal of a process was presented, then the students were challenged to reverse-engineer the item using their own thoughts about what the process should be. While some basic instructions and safety guidelines are necessary to introduce at the beginning of each activity, an open-ended process of playing, thinking and tinkering with the design to approximate the end goal is what is most important. To that end, here are a few strategies to get in the mindset of facilitating making and tinkering activities.







- Resist the urge to step in and help the students all of the time. A good rule of thumb is to help when they ask or get overly frustrated, but generally leave the process of design up to them. One teacher from the first year's evaluation said it best: "It's important not to steal their struggle."
- When help is required, ask the student what they are trying to achieve at this step of their design. Then ask how they think they might use the tools and information available to them to meet that goal. Give input on their ideas, never saying "that won't work," but rather, "how do you think that will help you get to the next step?" or "what problems do you see with that idea that you might have to solve?"
- Ask questions rather than giving answers when possible. Instead of saying, "Don't put glue on the inside of the rocket straw because it will make your rocket not launch very well," ask, "Do you think you want any glue on the inside of the straw? Why not?"
- Failure and iteration are important. It's only when a student has really struggled through the process that they can be empowered to take ownership over what they create. To that end, a prototype that ends up being a large ball of oozing hot glue that will get thrown in the trash is okay - it will identify one way not to go about creating the desired object or process.
- Even though it may take a few prototypes to get to a good final design, quality over quantity is important to stress. Many kids want to crank out three or four prototypes, but it's hard to make high quality, functional designs in a short class time. Stress at the beginning that a working design that you can be proud of is worth more than three that don't work very well. Have them focus on trying to make one good one, refine it, then think about what they would make given the time and opportunity to make another.
- While competition has its place, a big part of the maker ethos is to do things out of a desire to craft something that represents your ideas, perspective on the world, ingenuity, etc., and not necessarily for an award or to see which is the "best." With that in mind, it's great to offer multiple metrics for success. As an example, for Bouncy Rockets the students are encouraged to make a rocket that flies very high, but also tumbles the most, or flies the straightest, or has the most fins, or fewest fins, or is the smallest, or is the tallest, or flies the craziest, or has the most pink…you get the idea. A successful design is one that the creator can be proud of in its own right.
- Try to encourage decoration and personalization by setting out supplies like markers or different colored paper.
- Lastly, there's no "right way" or "wrong way" to create any of the items or do any of the activities in this booklet. All require students to take a design of their own making - that leap is more important than anything else. To that end, ideas directly generated by the kids have been incorporated into many of the activities, and they are much better for it.

For more resources on the making ethos and strategies for implementing activities or encouraging this mindset, see the following resources:

Making Makers by AnnMarie Thomas • **Zero to Maker** by David Lang • **Make Magazine**
The Maker's Manual by Andrea Maietta and Paolo Aliverti • **The Art of Tinkering** by Karen Wilkinson and Mike Petrich

ACTIVITY 1: **Bouncy Rockets**

Make a rocket that launches high into the air!

Conservation of energy has never been so fun! Each student makes a launcher and multiple rocket designs out of household items. This activity favors iteration of design, is quick to build, and easy to take home to the family dinner table.

These rockets fly pretty high depending on your design, up to 12 or 15 feet if dropped from just a standing position. Dropped off of a chair, staircase, or something further off the ground, they will travel even higher!

SUPPLIES

- **Bouncy ball**
- **Straws** (not jumbo)
- **Hot glue** & **glue guns** (recommended) or **tape** and **glue dots** for younger students
- **Scissors**
- **5/16" x 18 tpi hex nuts** (available at local hardware store or from McMaster-Carr, mcmaster.com, unit #90490A030)
- **3/16" dowel** (available at local hardware store or JoAnn Fabrics), cut to about 6" long
- **Drill bit** and **drill** (use a 3/16" - 1/4" drill bit)
- **Paper**, **craft foam**, **cardboard**, etc. for fin materials
- **Safety glasses** to use when launching rocket

Time Needed: 1 class period
Grade Recommendation: 1st-7th

Preparation

To build your bouncy rocket, you must drill a hole into the bouncy ball. Teachers should do this step in advance.

- Find a spot on the bouncy ball that is far away from any seam. Do not drill into the seam, as this may split the ball.
- Using your drill and drill bit, drill a hole about halfway into the bouncy ball.

Engage

Ask them to share what they know about rockets. How do they fly? What are the parts of a rocket? How do the parts of the rocket affect it's flight?

POINTER: Do not allow hot glue to get into the straw. This will make it difficult to launch!

UNIVERSITY OF MONTANA spectrUM

Explore

BUILD THE LAUNCHER

To build the launcher, stick the dowel into the hole of the bouncy ball. Use hot glue if you would like. Don't push it too far, though, or it will split the ball.

BUILD THE STRAW ROCKET

Your students can build the straw rocket any way they would like. As with most making and tinkering, students' imagination and individual design ideas should guide them. Here are a few tips:

- Cut a straw to the length you would like. It's helpful to have it just a bit shorter than the launcher stick for better launches.
- Fins make the rocket more stable. What shape would you like to make them?
- Adding weights may make the rocket fly with more stability.

Launch Your Rocket

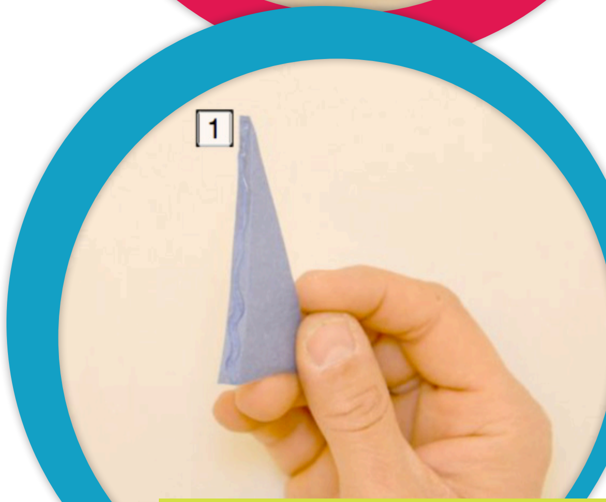
Once you have crafted your launcher and a rocket, it is time to launch. Put on your safety glasses!

- Slide your rocket over the stick in the bouncy ball.
- Drop the launcher with the bouncy ball facing the ground.
- Try dropping it from different heights.

Explain and Expand

Have students share their bouncy rockets with the class. Here are a few questions to ask:

- What can you do to make the rocket tumble more? Less?
- What will happen if you make a really long rocket? A really short rocket?
- What other items might you add to the rocket to make it more stable?
- How could you make the rocket more aerodynamic?
- What challenges did you face while making your rocket?



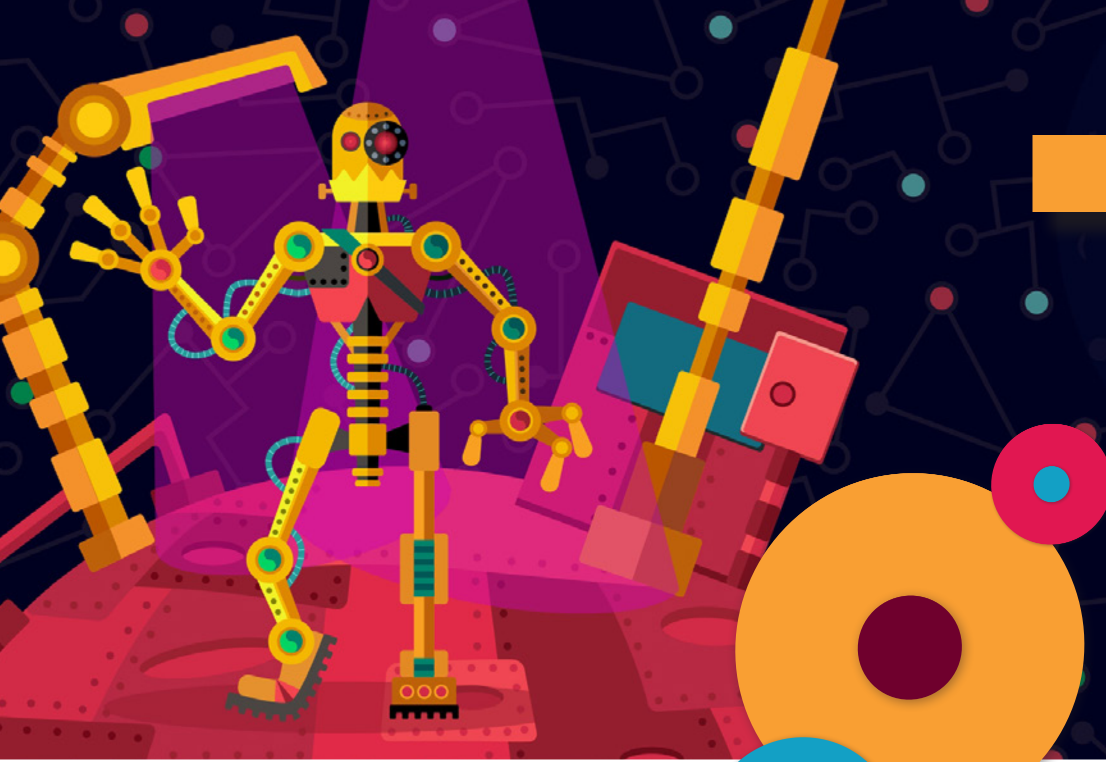
1 It's easier to glue onto the paper or craft foam than stick it to the straw

Evaluate

Here are a few questions to ask during reflection:

- Where should you add weight to make the rocket more stable?
- Where will adding the weight make it tumble the most, or land on its bottom every time?
- How does the number of fins affect the flight of the rocket?
- What functions would your rockets perform?

Full online instructions for this activity can be found at: **www.instructables.com/id/Bouncy-Rockets**



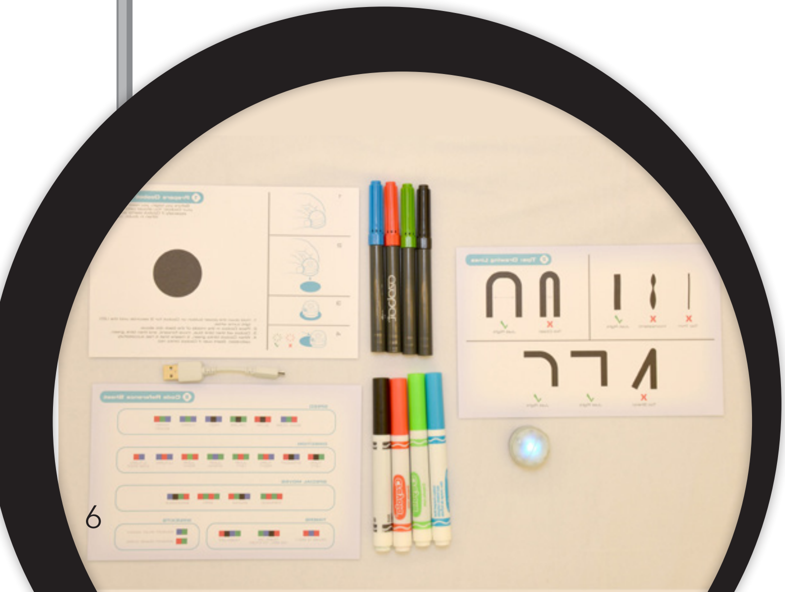
ACTIVITY 2:

Program a real robot using only markers and your imagination.

SUPPLIES

- **Ozobots -** Starter packs and classroom kits can be found at http://ozobot.com.

  THESE ITEMS COME WITH THE OZOBOT:
  - **Markers:** To program the Ozobot, you will need black, red, green and blue. The Ozobot will follow a line of any color.
  - **Micro-USB Charger:** This comes with the Ozobot and charges on any standard USB port.
  - **Code Sheet**
  - **Calibration/Tips Sheet**
- **Additional Markers:** If you would like more markers, broad line Crayola markers work well.
- **White Paper:** Larger paper gives you more room to code and draw.



Time Needed: 1 class period
Grade Recommendation: K-12

Engage

To introduce Ozobots to students, ask them to describe a robot, or share what they think a robot is. How might someone program a robot? What uses do robots have? How do robots interpret instructions? What functions do robots serve in the modern world?

PLAY A GAME

Programming a robot correctly is very important. While humans are able to decipher instructions easily, robots are not good at this. They need very clear, precise instruction. To show this, play a game where you pretend to be a robot.

- Stand furthest from the exit of the room, and place obstacles in the way.
- Ask your students to guide you to the exit using only the instructions forward, backward, left, right, and stop.
- Have one participant at a time give you a command, and follow their command as literally as possible - ham it up!
- You can introduce the unit of steps to the commands (take two steps forward, for example).
- Have participants go around the room giving instructions until you are successfully at the exit.

OZOBOTS IN THE CLASSROOM

An Ozobot is a line-following robot. Students can draw a course for the robots to follow and encode tricks or deviations from the design within the lines. Ozobots are a great tool to teach kids about programming, communication, robotics, and providing detailed and concise instructions to others. Ozobots are accessible, have many entry points, and reward the student no matter their skill level.

Explore

TEST YOUR OZOBOT

- Draw a line, about 6mm thick, on a white sheet of paper.
- Turn on the Ozobot (the power button is near its left "ear").
- Place the Ozobot on the line, and it will follow it to the end.
- Draw a few lines to get familiar with what thickness of line is best for the Ozobot.
- Use different colors for the line - how does the Ozobot respond to the different colors?

PROGRAM THE OZOBOTS

To code the robots, simply generate a sequence of colors within the line that the Ozobot is following.
The codes are indicated on the Code Sheet that accompanies the Ozobot kit, and can also be found in the appendix.

Have students start with the "Speed" and "Cool Moves" codes. Students will draw lines and incorporate the color code into the line. Test the Ozobot to see how it works! What can they make their Ozobot do?

Explain and Expand

Have students share their Ozobots with the class. Here are a few questions to ask:

- How do you think these robots work?
- What uses might they be put to?
- Do any of you have a robot at home (Roomba, etc.) that you use regularly?
- If you could build and design any kind of robot, what would it be?
- What challenges did you have while working with your Ozobots?

POINTER: Ozobots are very particular about how the codes are drawn. Students may require coaching on how to correctly replicate the width and length of the color codes. It may be challenging for kids to accomplish right away. Remind them that with practice, they can achieve it.

Evaluate

Here are a few questions to ask during reflection:

- What uses might these robots be put to?
- What benefits do robots provide to society?
- How do you think robots will be different in the future from what we see today?

Full online instructions for this activity can be found at:
www.instructables.com/id/Ozobots-in-the-Classroom

ACTIVITY 3:
ZIPLINE RACERS

Make a propeller-powered machine that zooms down a string!

Time Needed: 2 class periods
Grade Recommendation: 5th-8th

SUPPLIES

- **Regular size popsicle sticks**
- **Rubber bands** #117B (7" long)
- **Hot glue** and **glue guns**
- **Large paperclips.** Vinyl-coated paperclips create the least friction.
- **5" or 6" hook-nosed propellers** (available at most hobby stores, or at Kelvin Educational, kelvin.com).
- **Fishing line or kite string**
- **Paper** or **craft foam**
- **Masking Tape**

PER SMALL GROUP:

- **Timers**
- **Measuring tape**
- **Paper and pencil**
- **Calculators**

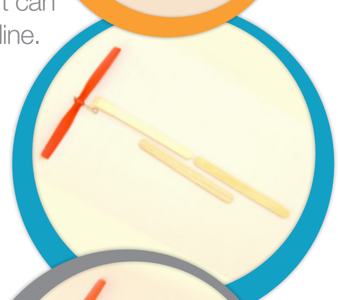
Engage

Ask students what they know about ziplines. Can they describe what a recreational zipline is? What is powering the person in a zipline? Can students define propulsion?

Gravity powers recreational ziplines. We will use propellers that are spun by rubber bands for our propulsion. How does a propeller work? It spins-pulling the object through the air-or forces air over a wing that provides lift. It's helpful to equate the motion of the propeller to how your arms pull your body through the water when you are swimming.

Explore

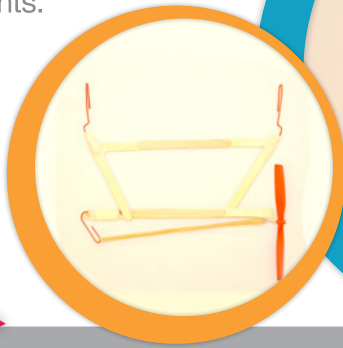
BUILD THE BASE

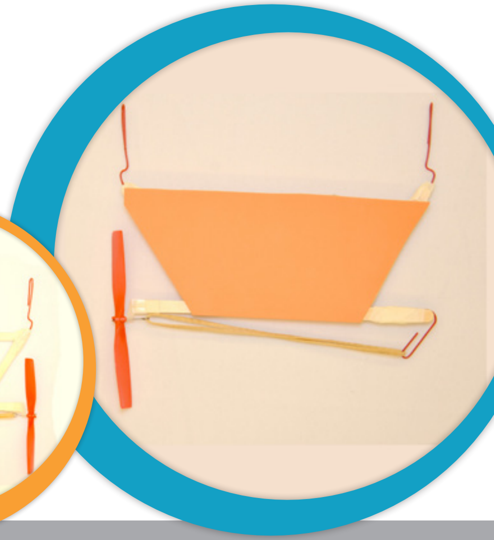


- Start by gluing two popsicle sticks together. Thickly wrap masking tape to one end, where the propeller will fit over.
- Mount the propeller over the masking tape. It can be glued if students are only making one zipline.
- Glue a third stick halfway onto the back of the two sticks, opposite where the propeller is mounted.
- Glue a fourth stick onto the other side of the last stick. This will make your zipline base about 8".
- Bend a paperclip into an "L" shape, and hot glue it on the very end of the craft stick opposite the propeller (use a lot of glue). Once the glue is hardened, wrap with masking tape for extra strength.
- Hook a rubber band into the hook of the propeller, then onto the protruding part of the paper clip. Make sure the hook of the propeller and the paperclip hook are on the same side of the base.

POINTER: Wrap the joints where the paperclips are glued for extra strength, and do this for any other high-stress joints if the zipline seems flimsy.

Propeller-powered ziplines are a great entry point into flight and propulsion using simple and cheap materials. Students will explore the concepts of physics of flight and propulsion, kinetic and potential energy storage, and the challenges of engineering structurally robust components. Students can also determine the speed of their racer by timing its flight and measuring the distance.





BUILD THE TOP

Now that the base is complete, your students can build the top any way they would like. As with most making and tinkering, students' imagination and individual design ideas should guide them. Here are a few tips:

- Build the top high enough so that the propeller doesn't catch the zipline (at least 3-4" tall)
- There must be at least two attachment points for your paperclips to hang the device from the zipline.
- Triangles are stronger than squares.

POINTER: It's important that there is at least a couple of inches between the top of the propeller and the string or the blade of the propeller will become wrapped in the string when launching! Also, keep fingers out of the blade after releasing the zipline.

TEST AND IMPROVE

Give your zipline a test. Lash a piece of string (around 20-30 feet) between two solid structures at least three feet above the ground. Keep the string taught, like a guitar string.

- Wind the propeller in place by turning the blade clockwise as you are facing the front of the zipline.
- Ensure that the zipline is clear all the way down and hang your racer on the line by the hooks.
- Stand aside and release your device. Keep clear of the propeller. Wow!
- Try adding paper or foam to the middle of your zipline racer. How does it change the flight? Decorate your creation.

MEASURE THE DISTANCE, FLIGHT TIME, AND SPEED

Break into small groups and give your students a challenge: Find a ways to measure and calculate the speed of the zipline racer. Give each group measuring tape, timer, paper and pencil, and a calculator. Here are some things to consider:

- How does the number of times you wind the propeller affect the speed?
- You will need to know the distance the racer travelled.
- Speed = time/distance. Measurements units are important (feet per second, for example).
- Try converting your speed into miles per hour! Wow, that is fast!
- Use the Zipline Speed Calculator worksheet in the appendix to record and calculate this data.

Explain and Expand

Have students share their zipline racer with the class. Here are a few questions to ask:

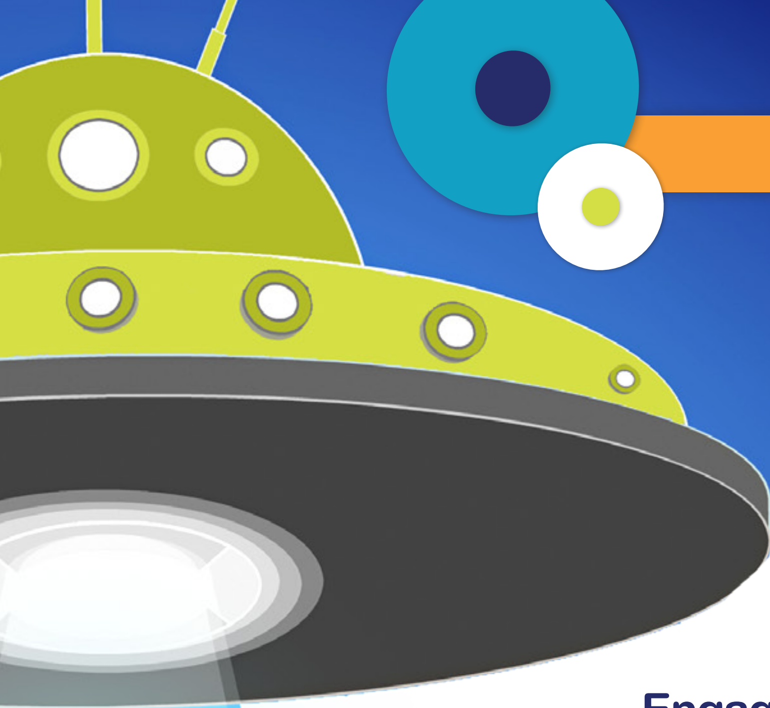
- How does changing the weight, amount of rubber band windings, etc. change the speed of the racer?
- What does adding paper to the racer do to its aerodynamics?
- How can you build a faster zipline racer? A slower one that carries weight?
- How would you modify your design to achieve a different metric (faster, smaller, etc.)?
- What problems did you encounter when making the zipline? How did you overcome those challenges?
- What different materials might you use to make your zipline behave differently?

Evaluate

Here are a few questions to ask during reflection:

- How do different racers fly? How does the design of these racers induce these different outcomes?
- What did you learn while creating the zipline racers?
- What are the uses of ziplines? How could your creation be used in real life?
- How could you create a slow, safe zipline device?
- How would you create the fastest zipline racer?

Full online instructions for this activity can be found at:
www.instructables.com/id/Zipline-Racers-Detailed-Instructable-Remix

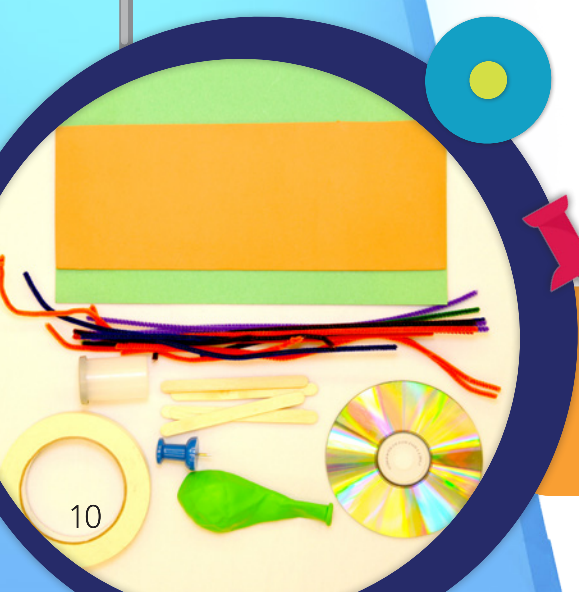


ACTIVITY 4: HOVERCRAFTS

Time Needed: 1 class period
Grade Recommendation: 3rd-8th

SUPPLIES

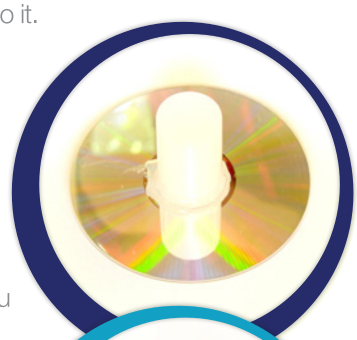
- **CD -** any old used CD or DVD will work. You can also pick up packs of blank CDs at most electronics superstores
- **Film canister or 1/2" PVC pipe -** film canisters can be found at most photo developing stores for free
- **Large balloon (9" or even 12")**
- **Hot glue gun** and **hot glue**
- **Large tack** or **small nail**
- **Pipe cleaners**
- **Craft sticks**
- **Paper, scissors** and **markers**
- **Tape -** masking tape is best
- Optional: Balloon pump with vinyl tube or flexible 3D printed adapter attached



Engage

Try sliding just the plain CD across a smooth surface such as linoleum floor or desk. It kind of slides, but there is a bit of resistance. What is that resistance? We call it friction. What goofy things would happen in our world if there was no friction?

We are going to make a device called a hovercraft that reduces the friction between the CD and surface by pushing air into it. The hovercraft rides on a cushion of air that is really thin and can travel much further and faster when we reduce this friction.



Explore

BUILD THE BASE

First, you'll need to build the base of your hovercraft. Take the lid off the film canister - you can save it for other projects or dispose of it. Put a little glue on the open end of the film canister and stick it to the CD, trying to center it over the center hole in the CD.

At this point, there isn't a good seal at the bottom of the film canister, so some air could escape out the sides. Add a good bead of hot glue around the rim of the film canister to completely seal it up. Allow the glue to cool completely before going on to the next step.

MAKE VENTS FOR THE AIR

For the hovercraft to work well, air will need to flow below the CD. Poke some holes in the film canister with the tack, being careful not to poke your fingers. It's easier to add more holes than take them away, so try a few and add more if you want.

POINTER: Don't get hot glue on the bottom of the CD, or else it will hang up when you're launching! If you are already mostly done, simply glue another CD to the bottom. How will the added weight of the CD change the flight of the hovercraft?

Design a hovercraft that floats along smooth surfaces.

Students explore the principles of friction and air pressure by creating a simple hovercraft using household items. This is certainly an activity that students can take home to share with their friends and family. Additional engineering challenges, such as making a hovercraft that carries a load or keeps the balloon upright, add to the complexity of this activity.

ATTACH BALLOON AND TEST

Get a balloon and stretch it over the top of the film canister. This can be difficult for younger groups or those who don't have a lot of hand strength, so they may need help. You can blow up the balloon through the bottom hole of the CD by either blowing through it with your mouth or attaching the balloon pump. Try out this first iteration of the hovercraft. Are there any leaks? How well does it float and move?

IMPROVE AND ITERATE

Now it's time to build a better hovercraft! Think of a way you can improve the design and support the balloon from flopping around. A simple solution is a band of construction paper, but experiment with popsicle sticks, pipe cleaners, beads, or other materials.

Explain and Expand

Have students share their hovercraft with the class.
Here are a few questions to ask:

- How does changing the weight of the hovercraft change its float?
- What problems did you encounter when making the hovercraft? How did you overcome those challenges?
- What different materials might you use to make your hovercraft behave differently?
- How does the number of holes in the film canister change things? Does the hovercraft float longer with more holes, or travel further, or is it the opposite?

Evaluate

Here are some questions to ask during reflection:

- How would you modify your design to achieve a different metric (faster, smaller, etc.)?
- How are hovercrafts used in industry, the military, or for recreation? How are those hovercrafts different from the ones we made?
- Can you think of other materials than the CD to make a hovercraft out of? What about propulsion sources other than a balloon?
- What would happen if we used a bigger disc? Would the balloon we used be able to lift it?
- What other things can you think of that use air flowing between them to reduce friction (air hockey tables, manufacturing, heavy load lifting, etc)?

Full online instructions for this activity can be found at:
www.instructables.com/id/CD-and-Balloon-Hovercrafts-Engineering-Challenge

ACTIVITY 5:
LIGHT PLAY

Tell a story using light & shadows!

Time Needed: 1 class period
Grade Recommendation: K-12

Engage

There is a lot of science to be learned in this activity! Asking the kids where light comes from and what light is, and talking about the electromagnetic spectrum is a great way to introduce this activity. Outside, the light comes from the sun - shadows are cast by something blocking the sun. Depending on the angle of the sun in relation to the object, the shadow will be longer or shorter. Indoors, lights are used to create shadows. If you have multiple light sources in this activity - what happens when the two lights are far apart? Close together?

Terms to introduce are transparency (most light travels through the material), translucency (some of the light travels through the material), and opacity (little or no light travels through). Objects can be opaque to certain wavelengths of light, but transparent to others - radio waves will travel through our bodies, but visible light will not. Reflection (how light bounces off something) and refraction (how light bends when traveling through something) are also good concepts to explore here.

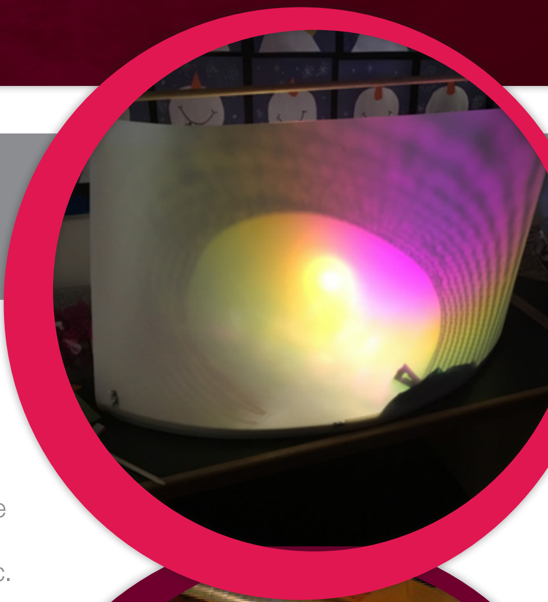
SUPPLIES

This activity does take some preparation in terms of making or assembling the studios, but once those are finished almost anything can work as a prop.

- **Light Play studio** and **1-2 lights** - one studio works well for a group of 4-5 students.
- **Cloth or ribbon** - mesh with a pattern looks cool.
- **Masking tape**
- **Transparencies** and **dry erase markers** - these work great for creating slides or drawing pictures
- **Solid objects** or **card stock** to create solid silhouettes
- **Dichroic film** - this is a really dynamic iridescent film that changes color based on the angle if incident light, and it's used in making jewelry and small kits of colors are available through places like Etsy or on Amazon

Students will work in groups to take everyday objects and place them in front of an LED lamp to create colorful, creative scenes projected on a translucent screen, learning about the properties of light and shadows. This is a fresh take on the idea of a diorama, and each group is encouraged to tell a story about their scene.

Making and tinkering can sometimes be pigeonholed into describing learning about circuits or 3D printing or designing small craft projects. But sharing stories and engaging in our whimsical and playful nature is also important!



POINTER: Don't limit the kids to the props at hand - have them draw and cut out some from paper, use classroom items or bring things from home for a show and tell theme.

Explore

CREATE A STORY

Have the students work in groups of 3-6 and spend at least 30 minutes developing a story to share with the class at the end.

Keep the lights on for the first 10-15 minutes, then turn them off so the kids can explore what the scenes will look like when it is dark. Alternatively, have 10 minutes on to work, 5 off to see how their studio will look in the dark, 10 more minutes of light, 5 of dark, etc.

The most important idea to get across in preparing students for this activity is to encourage them to create a scene that tells a story or expresses an idea. For reticent students or those that get stuck, a prompt can be helpful. Something like, "What do the northern lights look like?", "Tell us about how your route to school looks during a certain season.", "What do you think the desert looks like?"

When each group is ready to present, gather the class together and have them visit each studio to hear the story and see the studio presentation of their classmates. This part should be done with the lights off entirely!

Explain and Expand

Have students share their stories and scenes with the class.
Here are a few questions to ask:

- What is a shadow? How are shadows created? How is this different indoors vs outdoors? What about when the lights are off in the classroom?
- How many shadows are made on the screen when you add a second light into your studio? What would happen if you added a third?
- Explain the difference between opaque, translucent, and transparent.
- How can you make shadows larger and smaller on the screen? Why does this work?
- What do you think makes the dichroic film change colors of light so much just by being flexed and bent?

Evaluate

Here are a few questions to ask during reflection:

- Could you make something like these light studios at home? What would you need to do this?
- What are some things you can think of that would cast an interesting shadow?
- Can you tell what something is just by looking at its silhouette? What about if it changes profile/orientation or proximity to the screen?
- How do our eyes see light? What other kinds of light are there besides visible light?

Full online instructions for this activity can be found at:
www.instructables.com/id/Light-Play-Studios-in-the-Classroom

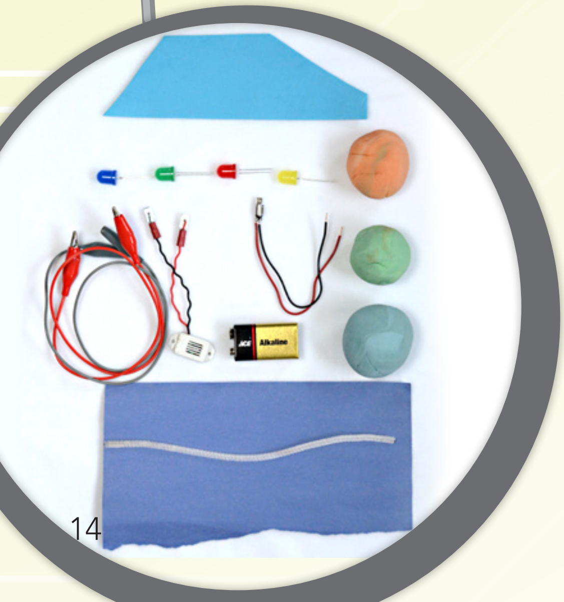
ACTIVITY 6: **SQUISHY CIRCUITS**

Make interesting creatures that light up using play-doh.

Time Needed: 1 class period
Grade Recommendation: 3rd-8th

SUPPLIES

- **Play-doh** (homemade or store-bought)
- **9-Volt batteries**
- **Alligator clips** or **wires** or **9V battery snaps** (Digi-Key part#BS6I-MC-ND, digikey.com)
- **LEDs** - the larger 10mm variety are great (Evil Mad Scientist Ultra-Bright 10mm, evilmadscientist.com) but any regular 3V LED will work
- **Paper**, **craft foam**, **wood**, **plastic**, **etc**. - anything that is an electrical insulator will work
- **Pipe cleaners** or **insulated wire** (16-20 AWG would be fine)
- **Optional:** 3V piezo buzzers, vibrating motors, or any other exciting component that is safe that operates at 3V
- **Optional:** it is helpful to solder and/or crimp male disconnect terminals to the leads of components like the battery snaps, motor and buzzer wires



Engage

Circuits work because of electrons flowing through them to complete a full loop, which is a complete circuit. They flow when there is a difference in electrical potential between two points, which we talk about as charge. If there is a more positive charge, the electrons will flow towards it to try and achieve equilibrium.

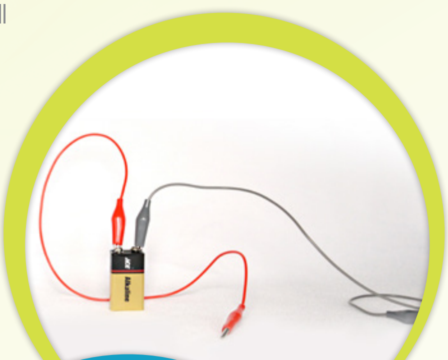
We'll be creating circuits out of conductive materials and using insulators to get the electricity to flow where we want it to. This is a good way to engage the students about the class of materials we call electrical conductors and their counterpart, insulators. Conductors of electricity are materials that electricity will readily flow through - this includes materials like metal and water that have electrolytes them. There are more exotic things like graphene sheets and such, but these two classes cover a large part of what kids will be familiar with when it comes to conductors.

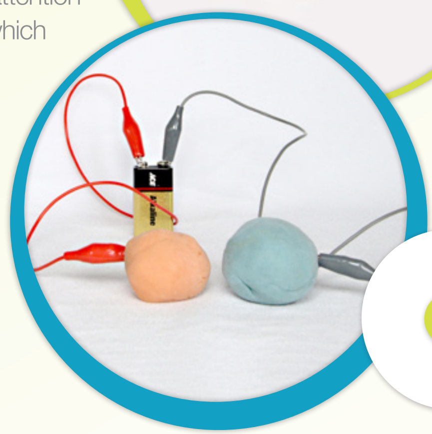
Insulators are materials that electricity does not easily flow through. There are many more different materials that are insulators than conductors, so challenge the kids to come up with the goofiest insulator. Wood, paper, rubber, plastic, fabric and glass, etc. are all insulators.

Explore

HOOK UP THE BATTERY

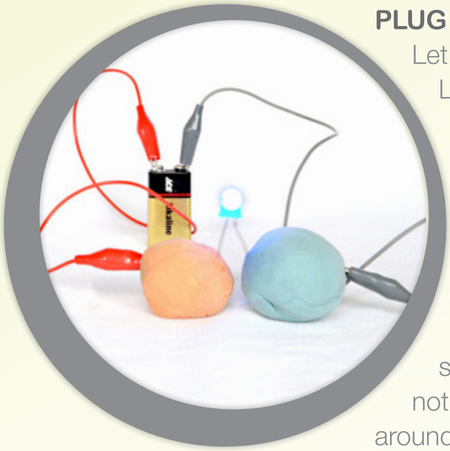
Once you've gathered your materials, get out some play-doh and make two balls about the size of a golf ball. Attach either two alligator clips to the battery or the battery snap. Pay attention to which clip is the positive and which is the negative - polarity is very important for these circuits! Once your battery is hooked up, stick one of the leads into one of the balls of dough, and the other in another ball. You have a partial circuit here, but we need to close the loop by adding a component.





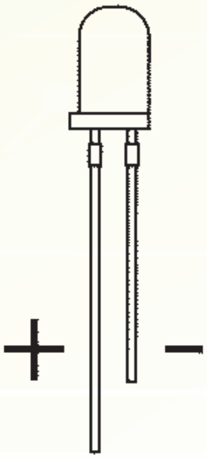
Conductors, insulators, and resistance are all central to this innovative exploration of electric circuits. Participants create sculptures using play-doh (which is conductive), wires or pipe cleaners, and a variety of insulators. Each creature incorporates an LED or buzzer, challenging the artist to create a design that doesn't short-circuit.

SAFETY TIP: There are two important safety considerations to address with this activity. The first is that if you short the 9V battery for too long, it will overheat and start smoking. DON'T leave two balls of play-doh with the leads connected touching each other for too long - this is a short circuit and will overheat the battery. Also, DON'T touch the legs of the LED directly to the alligator clips or the terminals of the battery. LEDs use 3V to operate, and our battery puts out 9V. If you do this, the LED will burn out and could potentially explode when heated.



PLUG IN AN LED

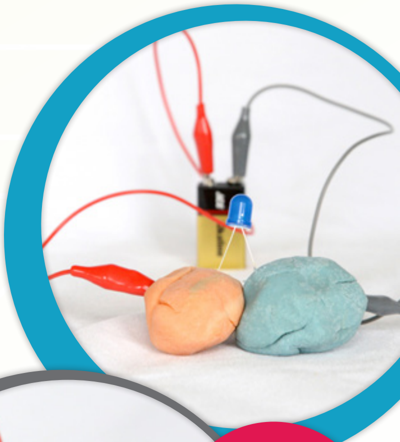
Let's learn how to "plug in" the LED properly to our circuit. LED stands for Light Emitting Diode. A diode is an electrical component that only allows electricity to flow in one direction through it. When electricity is flowing the proper direction through an LED, it lights up! When it is flowing the opposite direction, nothing happens. So, how do you tell? LEDs have two legs on them: the longer leg is the positive lead, and the shorter leg is the negative. So, make sure that the long leg of the LED is connected to the positive ball of play-doh, and the shorter is connected to the negative. If you plug in your LED and nothing happens or you can't tell which leg is longer, simply turn it around to see if this is the problem.



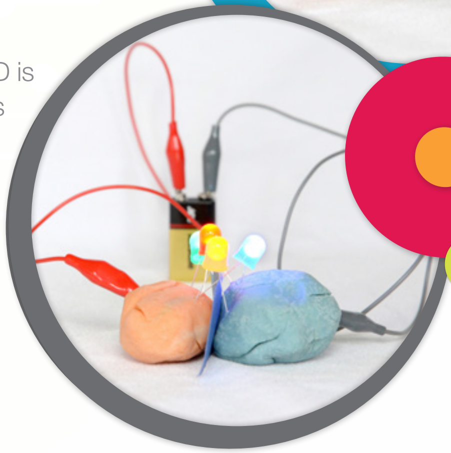
The picture above shows the LED working and properly connected for this test circuit.

HOW DOES THIS WORK?

Why does our LED that likes 3V not explode when connected to the play-doh, but gets damaged if hooked up directly to 9V? Well, the play-doh is conductive because of the water and salt in it, but it does not conduct all of the 9V to the LED. All conductors have a little bit of electrical resistance: some of the current that flows through the LED is resisted by the play-doh. There are other ingredients in there like flour, oil, and cream of tartar that are insulators, so play-doh has a relatively high resistance as compared to copper or just a cup of salt water. When the electricity flows through the play-doh, the resistance of the material brings the voltage down to 3V for the LED, and everyone is happy.



To dig a little further into this, push the two balls of play-doh together once your LED is lit up. (It's okay to do this for a short time.) The LED will go out, as shown above. It's helpful to tell kids that electricity is very "lazy" - it will take the easiest way it can to make a completed circuit. When the two balls are separated, there is technically an insulator in between them - air. To complete the circuit, the electrons have to flow all the way up through the LED, light it up, and go back down into the other ball of play-doh. When the two are pushed together, the electrons can flow easier through the play-doh vs the LED, so they do that instead. They take a shorter path to complete the circuit, which is why it's called a short circuit.



ACTIVITY 6: SQUISHY CIRCUITS

If you put a piece of paper, wood, foam, etc. in between the balls of play-doh and push them together, your LEDs will still light up. Try adding more LEDs to the circuit - what happens to the brightness of each LED as you do this?

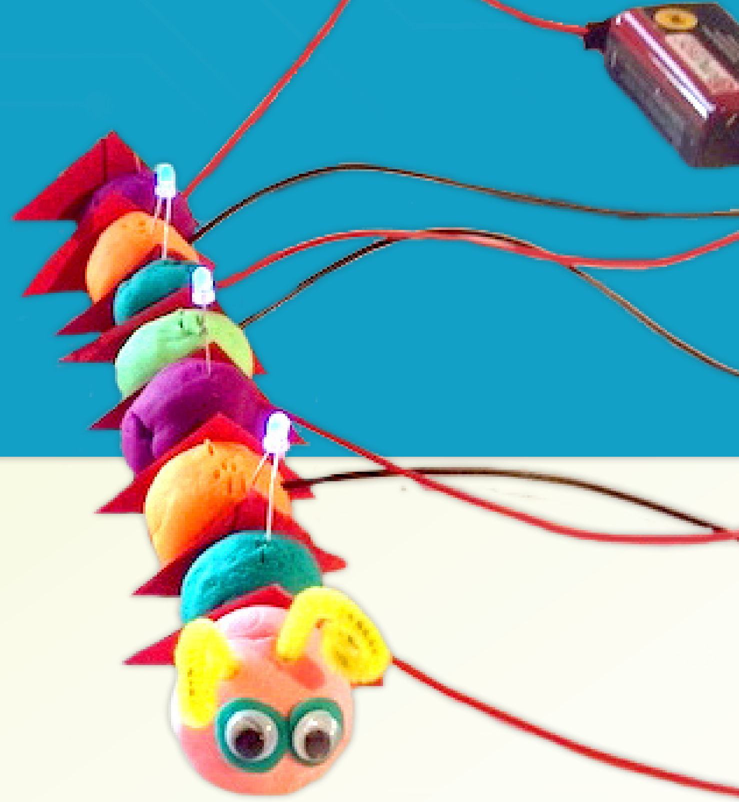
Lastly, most items that are insulators are really just materials that have a high resistance to electricity - electricity can still travel through them, but it takes a lot more current to overcome the high resistance of the material. This means that electricity can travel through air (think of lightning and static electricity) or melt through the insulation on a wire, it just has to have a lot of current.

MAKING MORE COMPLICATED CIRCUITS AND CREATURES

Now that we've got the very basic principles down for this, it's easy to expand to make more complicated circuits or experiment with other components. Try the piezo buzzer - what happens if you plug it in with reverse polarity? What about a motor?

The pipe cleaners are another great additional tool for this activity - they are essentially an insulated wire with fluffy plastic on the outside and flexible steel on the inside. You can use pipe cleaners to jump between balls of play-doh. If it's not working, strip some of the fluff off of the ends of the pipe cleaner. Remember, though, that you always have to have a ball of play-doh to plug into or you'll be putting 9V into the LED.

The best part of this activity is making your own creature - we've seen everything from snakes and ponies to castles to hamburgers with red LED ketchup!



Explain and Expand

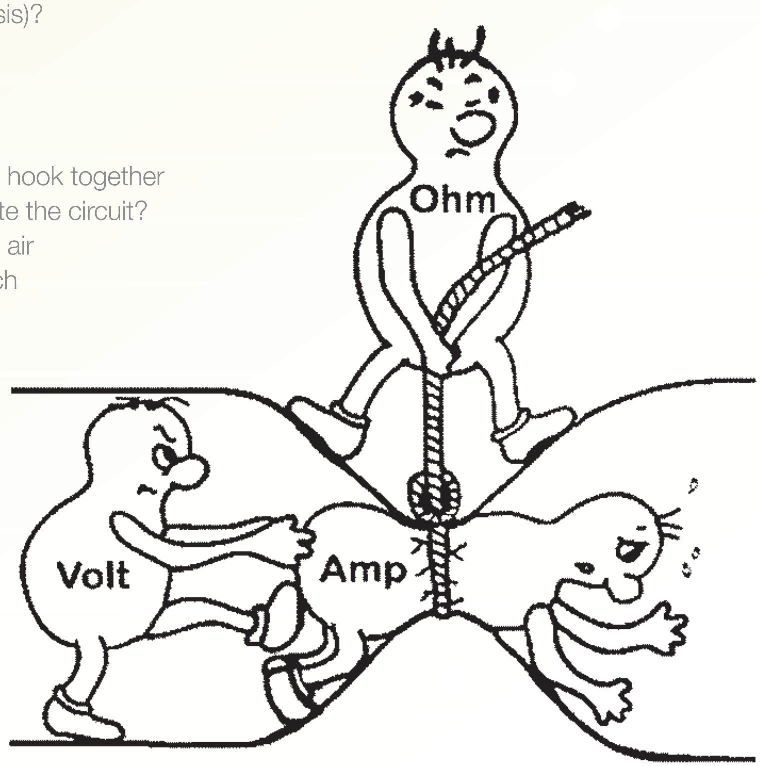
Have the students share their creatures with the rest of the class. Here are a few questions to ask:

- What is a circuit, and what does it mean for a circuit to be open or closed?
- What happens when you add more components to the circuit ? Why?
- Why do you think a battery will overheat when short circuited?
- What things do you need to create the simplest circuit you can think of? What about a more complex circuit?
- What other materials like play-doh do you think would work for this activity? Bananas? Pickles?
- As these circuits are left connected for a bit, the negative terminal tends to get a black film on it. Why do you think this happens (hint: it has to do with the salt content and electrolysis)?

Evaluate

Here are a few questions to ask during reflection:

- How many balls of play-doh do you think you could hook together before the resistance would be too great to complete the circuit?
- How is it that static electricity can travel through the air (shocking your sibling or friend right before you touch them directly, for example) when air is a resistor?
- What is resistance in a circuit? See image at right for a graphical illustration of Ohm's law as it pertains to volts, amps, and ohms.

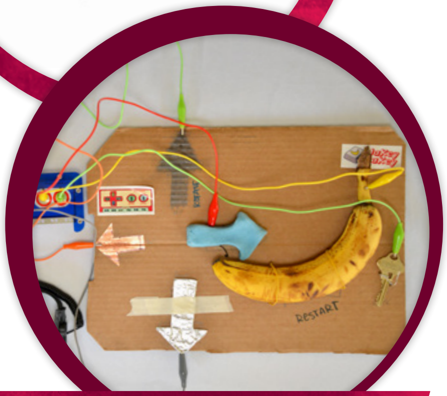


FULL ONLINE INSTRUCTIONS for this activity can be found at:
www.instructables.com/id/Squishy-Circuits-in-the-Classroom

ACTIVITY 7: MAKEY MAKEY

Anything conductive can be a computer key with this award-winning circuit kit!

Time Needed: 1 class period
Grade Recommendation: 2nd-12th



SUPPLIES

You don't need much to make this activity work, but it's helpful to have a variety of items on hand.

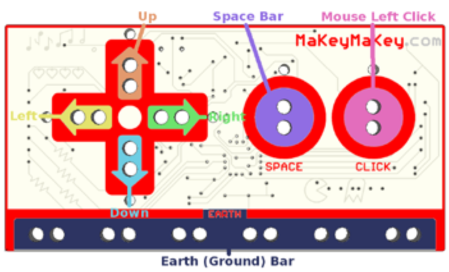
- **Makey Makey Kit** - comes with 7 alligator clips, Makey Makey board, USB cable, jumper wires, & instructions
- **Conductive materials** - anything conductive will work, really.
- **Bananas** (though celery is a better option that doesn't get as gross)
- **Copper tape** - if it's an option, get the conductive adhesive version (Sparkfun part# PRT-13828, sparkfun.com)
- **Graphite** - artist's pencils type 6B are best, but No. 2 pencils are okay
- **Aluminum foil**
- **Play-Doh** - homemade or store bought
- **A friend or classmate** (more on that later)
- **Insulators** like paper, cardboard, masking tape, etc.
- **A computer with a USB port and working internet connection** or Scratch installed and no internet
- **Optional: ESD** grounding bracelet to attach to your wrist for the ground connection. You can purchase one of these or simply make your own with an alligator test lead and some aluminum foil.

Engage

Makey Makey is an incredibly fun and innovative tool for teaching kids about conductivity and electric circuits. It is very easy to set up and play with, while also being incredibly versatile and encouraging experimentation and play.

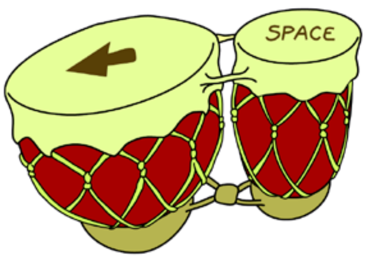
While these instructions will focus on using Makey Makey to create a controller for playing video games, there are many other uses and all sorts of creative devices that it can be used in to interact with a computer. Think of what you might create on your own!

How Makey Makey works is simple: the board is sending out a small amount of electricity on the different keys, and when the circuit is completed between that key and the ground bar, it tells the computer that that is a key press. The beauty of the design is that you can use anything conductive to achieve this - bananas, play-doh, metal, other people, etc.



Explore

HOOK UP AND TEST

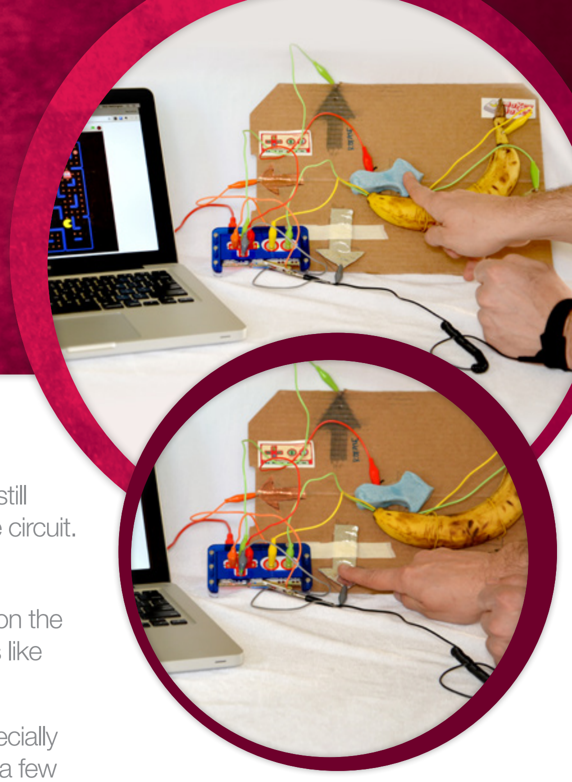


Before making a controller, it's helpful to hook everything up and test it out to see if it will work. Simply plug in the USB cable to an available port on your computer, and plug the other end into the Makey Makey. These use the drivers for gene keyboards and mice, so there are no programs to install. If you have issues with connectivity, see the Makey Makey quick start guide for details.

Go to the Makey Makey Apps website (http://www.makeymakey.com/apps) and pick something simple like Bongos. You can either hook up test leads to each of the directions and keys (Up, Down, Left, Right, Space, Click) or just press them with your fingers. Here's where the circuitry comes in - the bar on the bottom of the board is the Earth (Ground) Bar. To complete a circuit for the Makey Makey to register a key press, you have to connect one of the keys indicated above to the ground bar. So, hold the ground bar and just touch the Left button or Space with the Bongos app and it will play one of those two sounds. Yay, everything is working right!

Even another person can be one of the buttons on your keyboard. High fives are a great way to do this, with one person holding a lead attached to a key, and the other holding a lead attached to the ground bar.

With a blend of digital and low-tech items, participants create a computer controller using items that are conductive. This controller can interface with simple games like Mario Bros. or Tetris, make music, control a camera, and much more.



A great activity to do with a large class is to get them all to stand in a circle and hold hands. One person on one end of the circle touches a key, and on the other end the person touches the ground board. The most we've done is 32 people, and everything still worked fine! In this scenario, the electricity travels through each person to complete the circuit.

MAKE A CONTROLLER AND GET PLAYING!

Now it's time for the real fun - making your own controller for a game. All of the games on the Makey Makey Apps site are kid-friendly and optimized for the Makey Makey, but others like Dance Dance Revolution, Mario Brothers and Pac-Man work well too.

It is recommend to mount your controller on a piece of paper or cardboard. This is especially important if you are working on a metal surface so you don't get a short circuit. Having a few cardboard boxes on hand is a great way to add some variety to this activity - instead of a 2D mounted controller, make one that is 3D.

It's also helpful to label which items press which key, as it's hard to remember if you're in the middle of an intense game of Pac-Man if the banana is up or down, or if a ball of aluminum foil is left or right.

The possibilities of controller design are endless, so don't prime the students to make one exactly like the one shown above. It can be a hat, a box that has a metal ball rolling around in it, etc.

POINTER: If things are not working, it's likely that one of the test leads has come loose either on the Makey Makey or on the conductor that you've attached it to. Also, it's important to remember that you are completing the circuit, not just pressing the button on the Makey Makey, so the ground bar needs to be a part of the circuit.

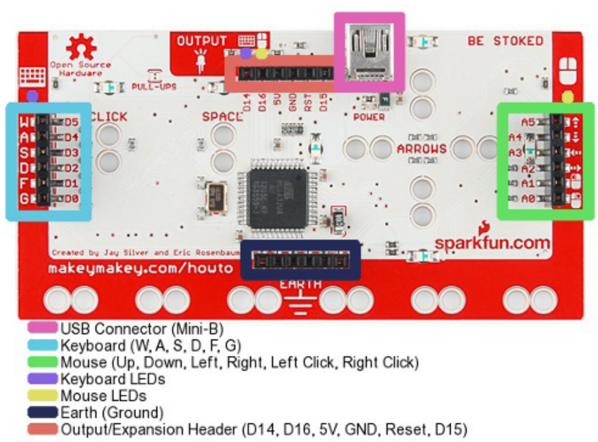
If the game you are playing needs more keys than the ones on the front face, you're in luck - the extra jumper cables supplied with the kit can be plugged into the back of the Makey Makey for additional keys. See the image at right for which ones will work.

Lastly, if you are working with kids who are familiar with Scratch, it is very easy to write your own game or Scratch program to interact with the Makey Makey.

Explain and Expand

Have your students share their controller with the class.
Here are some questions to ask:

- What is a circuit, and what does it mean for a circuit to be open or closed?
- What other materials do you think would work for this activity? Pickles? Kiwi fruit? Cheese?
- Sometimes you can trick the Makey Makey into thinking a key has been pressed even though you are not touching ground by building up a good static charge. What is going on here?



Evaluate

Here are some questions to ask during reflection:

- What is something exotic that you think would work well as a button key?
- What will happen if you attach an insulator to test lead that is connected to the Makey Makey? Will it work?
- Can you think of a non-computer game that you could create using the Makey Makey? (Example: a door alarm that alerted someone when a door was opened).

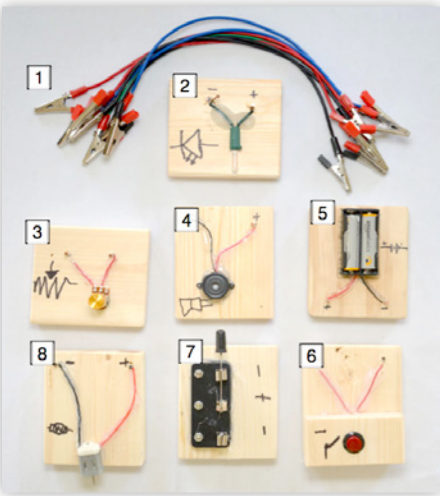
Full online instructions for this activity can be found at:
www.instructables.com/id/Makey-Makey-in-the-Classroom

ACTIVITY 8: CIRCUIT BLOCKS

Create your own programmable electronic components!

SUPPLIES

Time Needed: 2-3 class period
Grade Recommendation: 5th-12th



1. Alligator clips - any will do, these beefy ones are made to last.
2. LED - make sure the + and - are labled properly.
3. Potentiometer - like a volume knob.
4. Piezo speaker - make sure this one is internally driven (ones labeled ED in our set are for a separate use).
5. Battery Block.
6. Momentary Switch
7. Knife Switch
8. Motor

You'll need the blocks shown below.
Here's a brief description of what each does:

- **Alligator clips** - used to connect each block to other blocks in the set. Any will work. The ones shown were made with thicker gauge wire (16 AWG audio speaker) and larger clips for durability.
- **LED block** - made from a string of LED christmas lights. Ensure that the (+) and (-) legs are labeled properly on this one. LEDs are a diode, which means that the electricity has to flow through them the proper direction: the (+) has to be attached to the positive side of the battery and (-) to the negative side.
- **Potentiometer:** this is a variable resistor. When the resistance is high, less electricity is flowing through the circuit. When lower, more. So, when the volume is turned all the way up on a speaker or speed on a motor, the resistance is lowest. When the speaker has the lowest volume or lowest speed on the motor, the resistance is at its highest through the potentiometer.
- **Piezo speaker -** this is a little buzzer. Make sure for this project you are using the one that is NOT labeled "ED": those are for a different project. These, like the LEDs, need to be hooked up with (+) to positive and (-) to negative.
- **Battery:** plain enough, this powers the whole thing.
- **Motor:** a little DC motor. This can be hooked up either direction; changing the polarity of how it is hooked up will change the rotational direction of the motor.
- **Knife switch** - looks like something right out of Frankenstein! These switches are a way to hook up two separate components to the same battery, or just make an on/off switch that stays on/off for a component.
- **Momentary switch:** this is a simple pushbutton switch. When it's depressed, it allows current to flow through the circuit. When it is not pushed, it breaks the circuit. A great setup is to put it in line with a speaker and have the kids make Morse code.

Engage

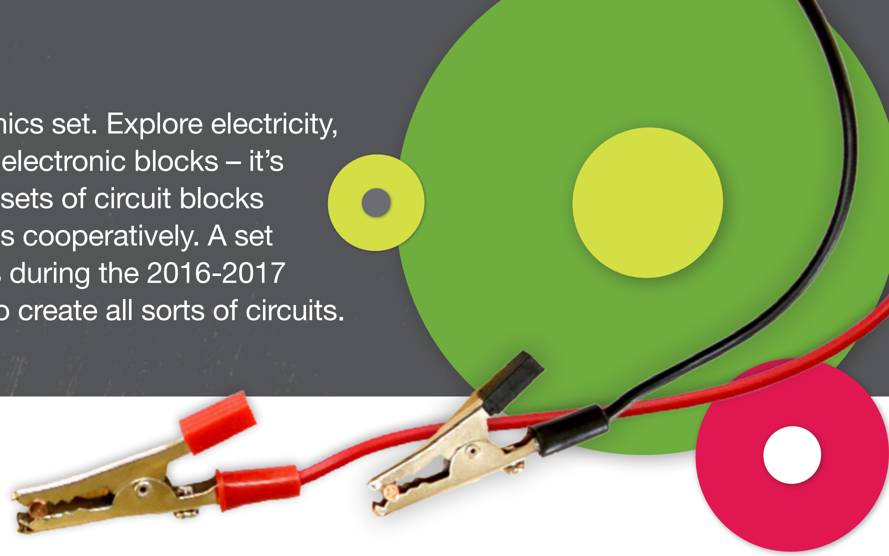
Learning about circuits and electricity can be an intimidating task - it seems so complicated! This activity involves the use of a modular set of electronic components that are easy to hook up to each other. The circuit combinations possible with a few of these components are almost endless, and any electronic component that you can glue onto a block of wood will work: take apart some old toys and add some of their working bits to this set, for example.

For full instructions on how to make a set of circuit blocks (or add new ones), visit the Snapguide from Learning Technologies at the Science Museum of Minnesota (http://snapguide.com/guides/make-circuit-blocks/)

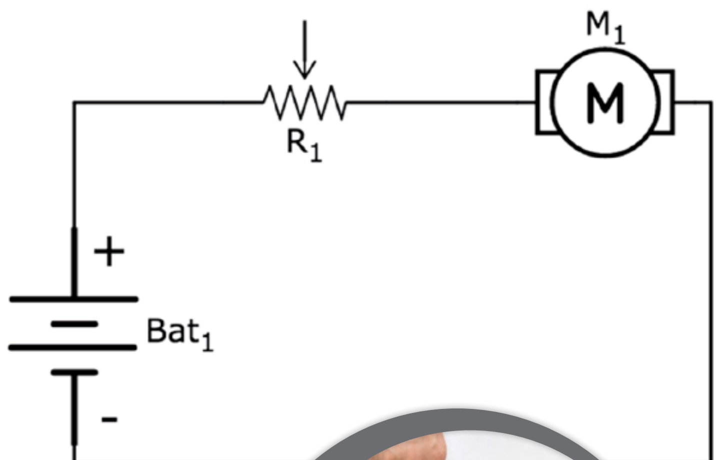
SAFETY TIP:

NEVER make a circuit that doesn't have a load on the battery (LED, motor, speaker, etc) - this is short circuiting the battery and will ruin the batteries, potentially causing them to overheat and smoke. It's unlikely they will catch on fire, but it is possible. A switch (momentary or knife) is NOT a load on the batteries. If the batteries do get shorted, disconnect them immediately and set them aside for a bit. If they remain that way for too long, the batteries will become unusable, so throw them away.

Build the tools and parts of a modular electronics set. Explore electricity, circuits, and programming by making a set of electronic blocks – it's like LEGOs for electricity. Students will make sets of circuit blocks in groups of two or three and assemble circuits cooperatively. A set of these blocks were made by the 5th graders during the 2016-2017 school year and can be mixed and matched to create all sorts of circuits.



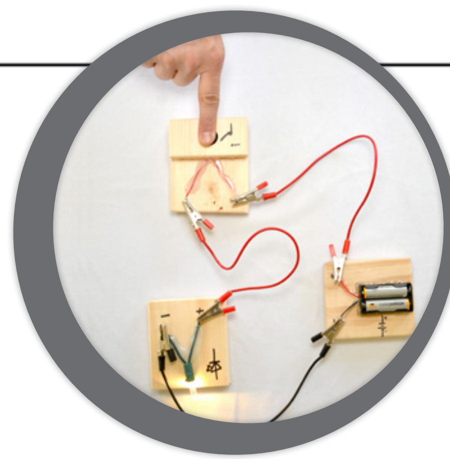
CIRCUIT SYMBOLS



A great extension to playing around with and building circuits in this activity is learning about circuit symbols and diagrams. Electrical engineers and hobbyists all use circuit diagrams to be able to replicate someone else's circuit - it's a universal way to communicate how components are hooked together. Circuit diagrams scale from showing how to hook up something as simple as a light bulb to as complex as how to build a supercomputer.

Each component should be labeled with the internationally recognized circuit symbol - that way, you can set out a diagram and challenge the kids to set up the circuit using the symbols to see what it does! See the appendix for symbols and diagrams you can photocopy.

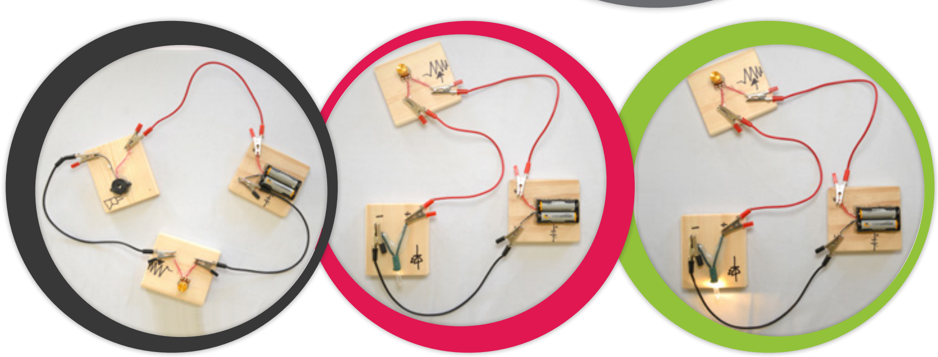
CIRCUIT 1: BEEP BEEP BOOP



This simple circuit is a great way to get started. A momentary switch and any of the load components (speaker, LED, motor) will allow you to switch on and off the current to the component. Make some Morse code, light up a dance party, etc. Hook up multiple components in line with the battery and see what happens when more of them are powered on.

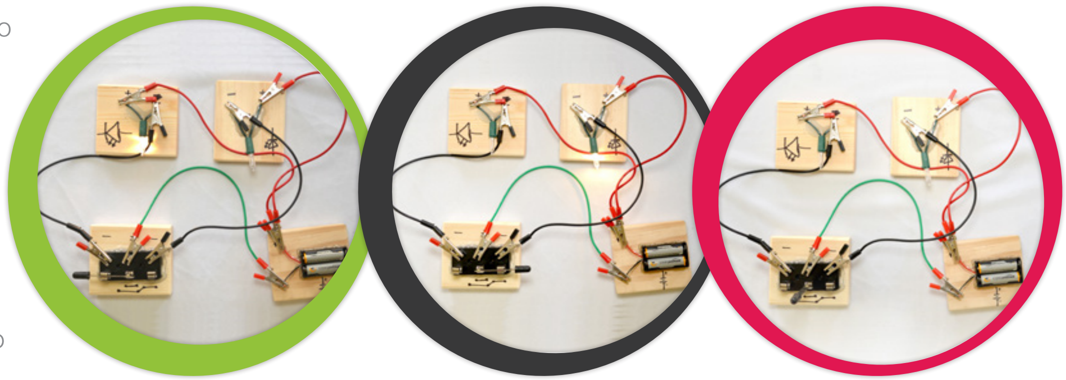
CIRCUIT 2: PUMP UP THE VOLUME

Play with the potentiometer. This component changes the resistance through the circuit: higher resistance impedes the flow of electricity, making the light dimmer, motor slower, or speaker weaker. Lower resistance allows these components to work at a higher brightness, speed, or volume. What happens when the resistance is all the way up?



ACTIVITY 8: **CIRCUIT BLOCKS**

CIRCUIT 3: THE KNIFE SWITCH



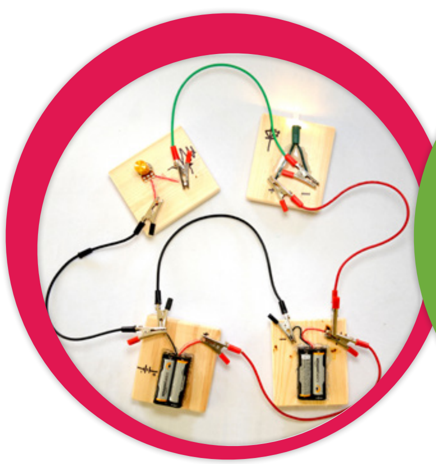
The knife switch block tends to give kids trouble, and it is not immediately intuitive how to hook it up. Basically, it connects the middle contact to either of the two side contacts. See at right for how to make it power two separate blocks. You can alternate between the two by putting the knife down on either contact. Multiple components can be added in series or parallel on either contact.

CIRCUITS 4 AND 5: SERIES AND PARALLEL CIRCUITS

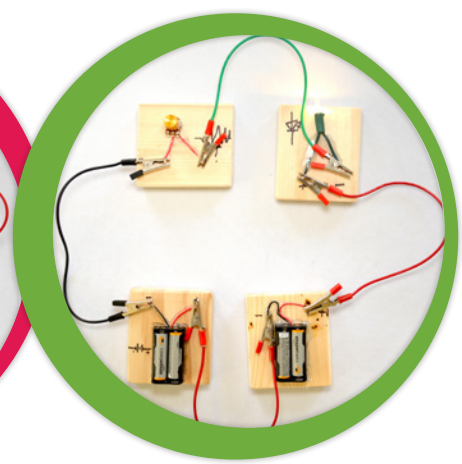
The concept of series and parallel circuits is a fundamental one to get across to kids. How batteries are hooked up to a circuit changes their output voltage and current, which has an impact on how the circuit will behave. The same goes for components: if they are hooked up in series vs. parallel, they will behave differently. The typical example is Christmas lights: old style ones had all the bulbs hooked up in series, meaning that if one single bulb burned out, the whole string would shut off because it is breaking the circuit. You had to go along and find the burnt out one and replace it - a huge pain! Modern lights are hooked up in parallel: each bulb is essentially creating its own circuit with the power source. When one bulb goes out, the rest will stay lit, and it's much easier to find and replace burnt out bulbs.

In the below photos, the batteries are hooked up in series in one photo and parallel in another. When they are hooked up in series, the voltage of each battery pack is added together. Each individual AA battery puts out 1.5 volts. A battery pack has two of those batteries essentially hooked end-to-end in series, so each battery pack puts out 3 volts. If you hook two battery packs up in series, that generates 6 volts, which is too much for the LED and the speaker, but probably okay for the motor. In the example, a potentiometer is hooked into the circuit to limit the voltage to the LED so it doesn't burn out.

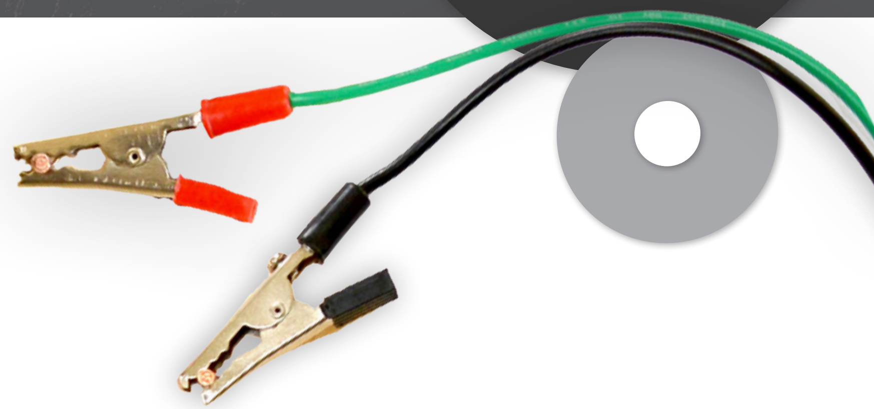
When the batteries are hooked up in parallel, the output voltage is the same - 3 volts. However, we added more battery capacity into the circuit, so our LED batteries will last twice as long.



PARALLEL CIRCUIT



SERIES CIRCUIT



Explain and Expand

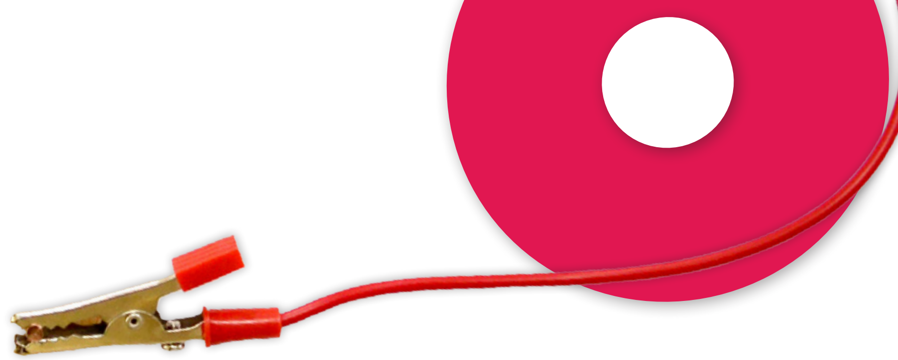
Have the students share the circuits they made with the class.
Here are just a few questions to think about when facilitating this activity:

- What is a circuit, and what does it mean for a circuit to be open or closed?
- What happens when you add more components to the circuit without adding another battery? Why?
- What is resistance in a circuit?
- Why do you think a battery will overheat when short circuited?
- What things do you need to create the simplest circuit you can think of? What about a more complex circuit?

Evaluate

Here are some questions to ask during reflection:

- What other electrical components would work great as a circuit block?
- How many blocks do you think you could attach together? Would you connect them in series, parallel, or a mix of the two?
- Can you create a circuit of your own and draw a circuit diagram so that someone else could replicate it?



Full online instructions for this activity can be found at:
www.instructables.com/id/Circuit-Blocks-in-the-Classroom

Time Needed: 1 class period
Grade Recommendation: K-12th

Engage

Forced perspective photography is a great way to get kids thinking creatively and engaged in making fun scenes and stories. They will do amazing things when you hand them a camera (in addition to taking a billion selfies). There is also a lot of math and science content in this activity in terms of thinking about distance, proportionality, and the way our brains perceive the world.

This is a fun and light activity and is best done outside when the weather is nice. It is possible to do inside, but the effect is much greater in a wide open space such as a field or playground.

SUPPLIES

- **The Polaroid Z2300 Instant Print cameras** - cell phone or digital cameras work just as well
- **Polaroid ZINK refills for the camera**
- **SD Card for the camera**
- **Props of any sort -** paper cutouts are great to have kids color or they can draw their own
- If you do cutouts, popsicle sticks and tape or glue are a must so that your hand doesn't show up in the photographs
- A wide open space outside or large interior space (a gym would work well)

Explore

HOW TO WORK THE POLAROID Z2300 CAMERA

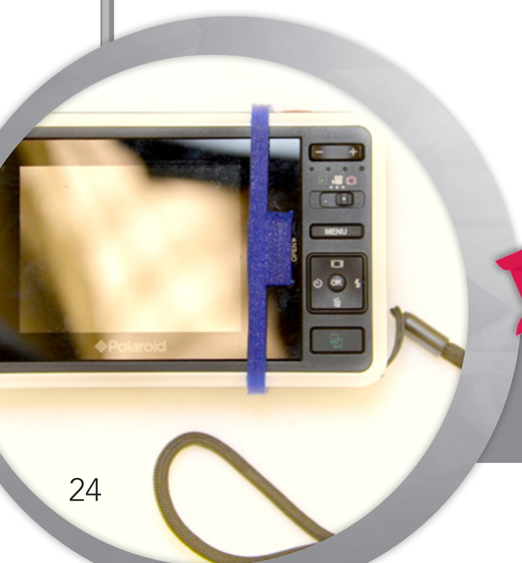
For classroom facilitations it's very important that you charge the cameras before using them. One downside to these cameras is the printing feature uses a lot of battery, so charge the cameras between each class and during any other breaks if you'll be using them a lot.

See the camera's manual for further instructions, but here's a quick rundown of how to use it and some pitfalls to avoid.

To take photos, turn the camera on using the power button on the top. Ensure that the Playback/Video/Photo button selection switch is underneath the red camera symbol. Get your photo lined up and press the zoom button to zoom in/out as desired. The photo you are taking is shown on the LCD screen on the back. Press the large red button on the top to take your photo once you are ready. T ake multiple photos! It would be hard to fill a 2GB SD card in a class period, so take lots of photos to be able to choose the best to print.

1 Shutter release button

1 Wide/Tight Zoom
2 Video, playback, photo taking selector
3 Menu selection switch and OK button
4 Print photo button
5 Screen
6 3D-Print strap to prevent accidental opening of back

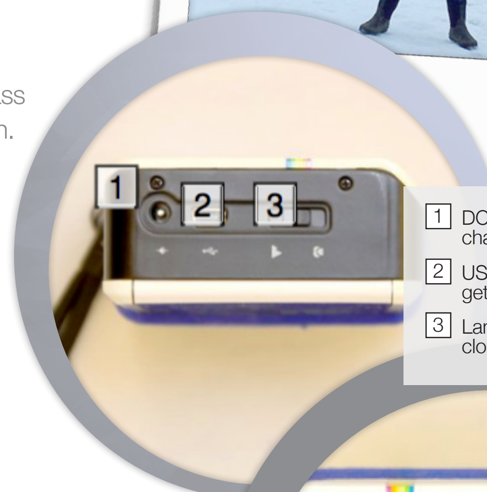


POINTER: Make sure that students use the wrist strap at all times, they will definitely drop the camera if they do not!

Trick your brain while exploring the relationship between distance and perceived size.

Students can print, draw, or sculpt items and place them strategically in front of the camera to tell an interesting narrative or simply make something whimsical. The use of instant-print cameras adds novelty and ensures that all students can participate with or without a smartphone. This activity is a rewarding way to challenge and hone spatial reasoning skills.

Take all your photos at once, then plan to print them at the end of the class period or when you're inside and don't have as much glare on the screen. When you are satisfied that you have a shot or two that will work well to print, push the print button (this works in both camera and playback modes). It will allow you scroll through the photos: select which photo to print by pushing the print button again, and choose how many copies to print (the default is 1). It'll ask if you want to print this one: select OK and it will start the process.



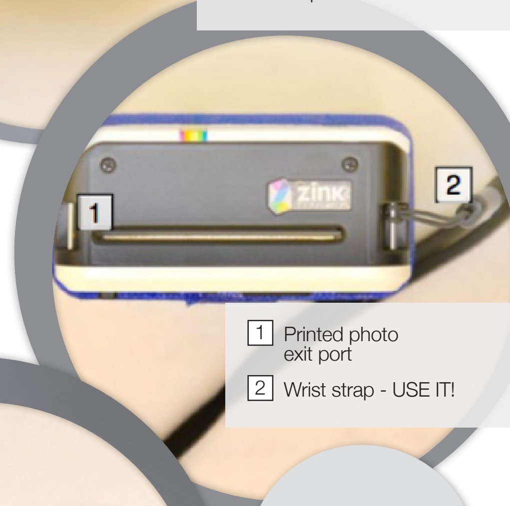
1 DC Power jack to charge camera

2 USB connector to get photos onto PC

3 Landscape vs closeup selection

The printed picture will come out of the side. Do not pull on it as it's printing! If the printing takes a long time or the colors are very faded, it's likely the battery is low.

To add more ink sheets, slip off the 3D printed band and push the open button up. The sheets come in packages of 10 with a blue card that tells the camera some calibration aspects of that batch of sheets - it says it is necessary, but it's actually not (though you will get better quality photos if you use it). Additionally, some cameras need to have that sheet primed a little bit to feed through, so push it a little bit into slot on the side nearest the buttons and the camera will do all of the work from there.



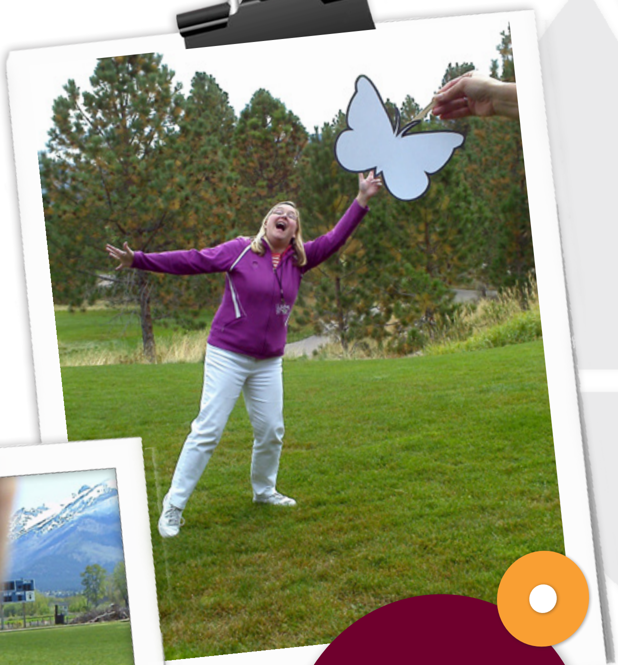
1 Printed photo exit port

2 Wrist strap - USE IT!

When you insert the film package, ensure that the shiny side of the film is facing you. The back is printed with the word "ZINK" all over it. Also, don't put more than 10 sheets into the camera at one time.

It is very easy to accidentally open the back of the Z2300 camera. A thick rubber band or piece of tape will work well to solve this. The indicated 3D-printed strap covers the switch as well as keeps the whole thing closed.

ACTIVITY 9: FORCED PERSPECTIVE PHOTOGRAPHY



Getting the Perfect Shot

Setting up your shot is the most important part of forced perspective photography. Really, any photograph that you take in which you use the distance between objects to vary their size in proportion to each other is forced perspective. Important concepts to take away from this activity are foreground, background, and proportionality. If you put something twice as far away as something else, it will look twice as small. The inverse is true as well.

There are other things that affect how you judge distances. Your brain gets clues from how objects overlap, how they interact with the background, or whether things are in focus. Controlling for these things can make the forced perspective trick work better. These are good considerations when thinking about how to compose a shot.

For actually taking the photos, have the kids work in groups of at least 3 - one is the photographer, one student does the foreground work, and the other does the background work. Don't have them get so far away from each other when doing the actual photo taking that they can't hear each other, and have them plan their composition before heading outside to take photos.

POINTER: Have the kids take all their photos at once, then print after coming back inside or at a later time.

Explain and Expand

Have the students share their photos with the rest of the class. Here are some questions to ask during facilitation:

- How do we use forced perspective when drawing or painting something on a two-dimensional surface to give it the appearance of something with depth?
- Why do our brains perceive this size difference?
- What other props might you use to create a scene or story using forced perspective photography? Try it at home!

Evaluate

Here are some questions to ask during reflection:

- How would this technique be useful in the film and photography industry?
- Can you think of any famous photos or paintings that use forced perspective in their composition?

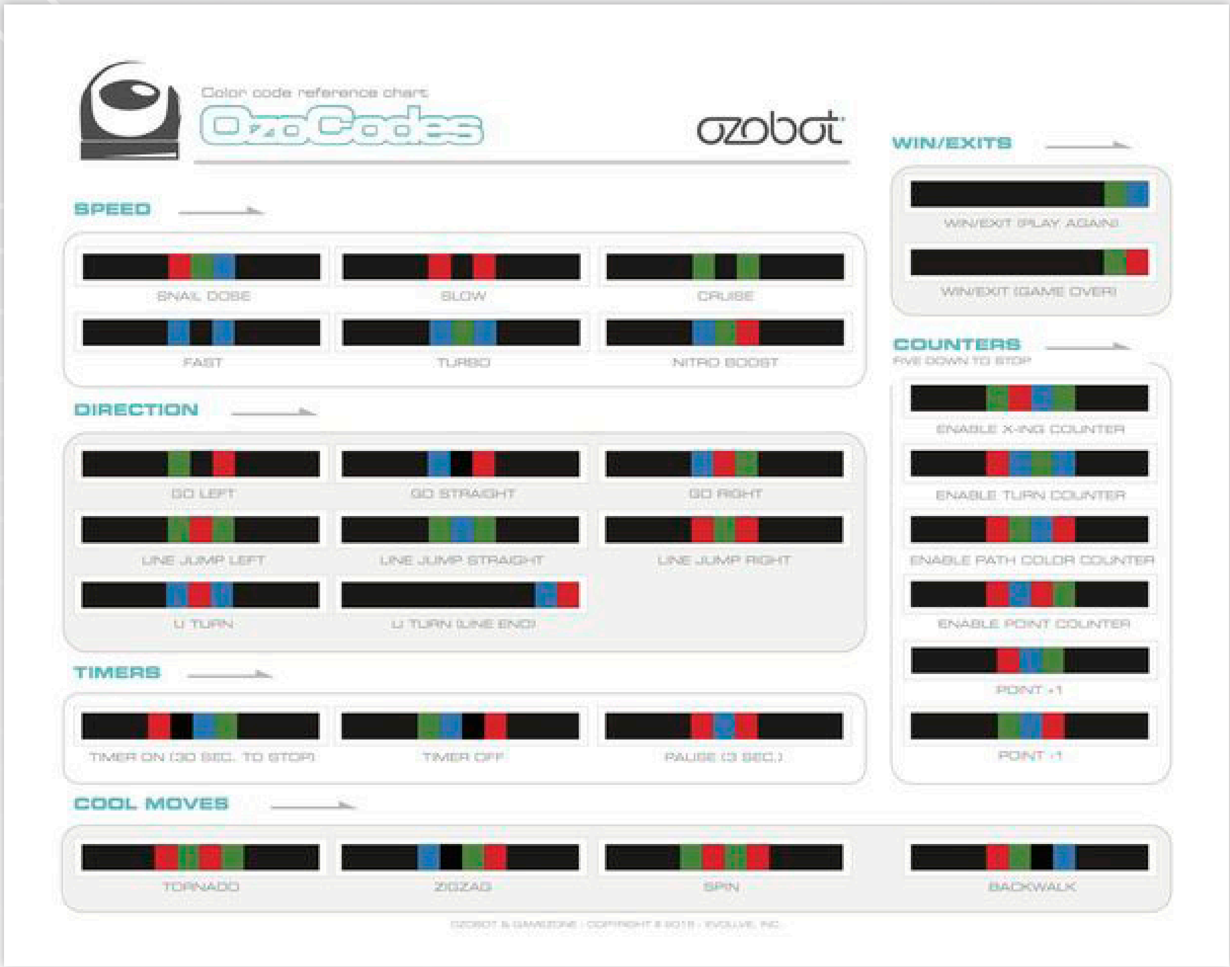
Full online instructions for this activity can be found at:
www.instructables.com/id/Forced-Perspective-in-the-Classroom-with-the-Polar

Appendix
SUPPORT DOCUMENTS

Ozobots
- Ozocodes
- Ozobots Instruction Sheets

Ziplines
- Zipline Speed Calculator

Circuit Blocks
- Circuit Symbols

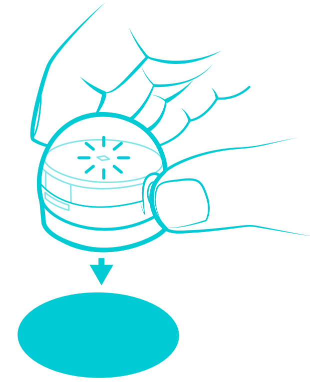


Tips: Calibration

1

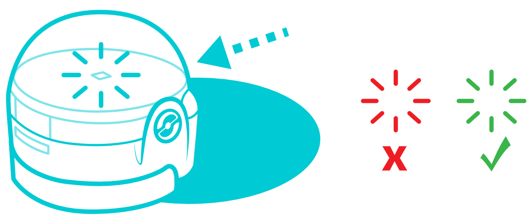
Hold down the power button on Ozobot for 2 seconds until the LED light turns white.

2

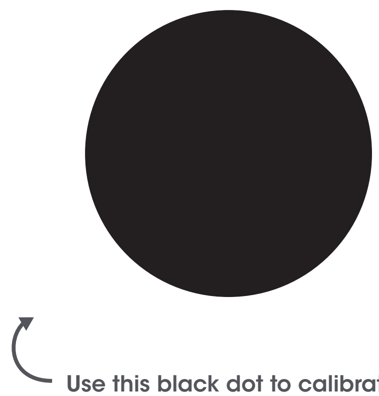


Quickly Place Ozobot in the middle of the black calibration dot.

3

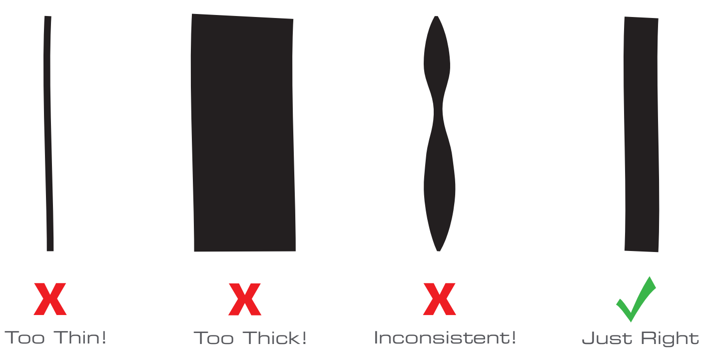


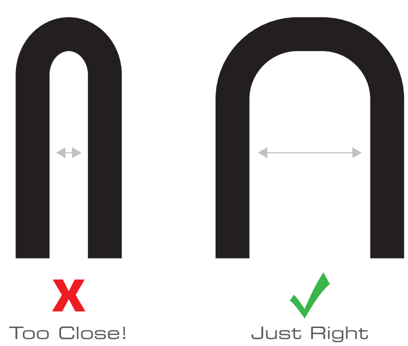
Ozobot will move forward and blink green, which means it has successfully calibrated. Start over if Ozobot blinks red.

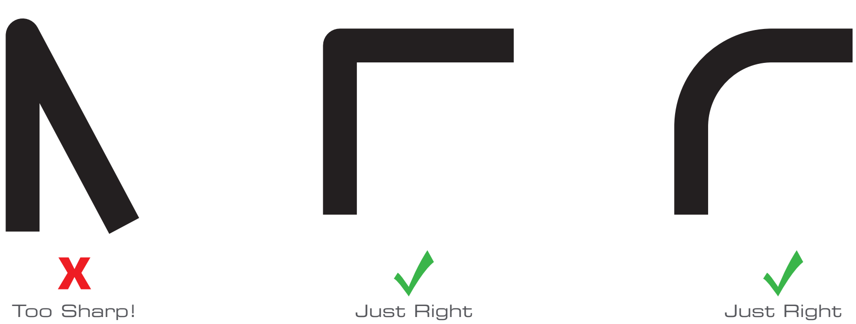


Use this black dot to calibrate.

Tips: Drawing Lines







Name:_________________ **Zipline Speed Calculator**

1. How far did your racer travel? ____________**Inches**
2. How long was the flight of your racer? _________**Seconds**
3. Divide the distance of your flight by the number of seconds.

(For example, 100 inches / 2.3 seconds).

Write that number here:__________**Inches per Second**

4. Multiply the number in step 3 by 0.05681.
5. Write that number here: __________**Miles per hour** Whoa, that's fast!

Name:_________________ **Zipline Speed Calculator**

1. How far did your racer travel? ____________**Inches**
2. How long was the flight of your racer? _________**Seconds**
3. Divide the distance of your flight by the number of seconds.

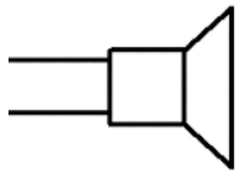
(For example, 100 inches / 2.3 seconds).

Write that number here:__________**Inches per Second**

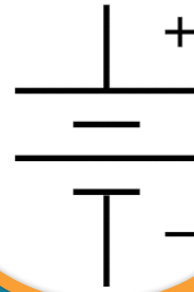
4. Multiply the number in step 3 by 0.05681.
5. Write that number here: __________**Miles per hour** Whoa, that's fast!

Circuit SYMBOLS

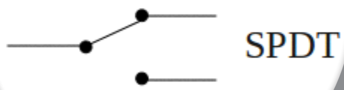
Piezo Speaker



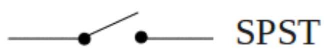
Battery



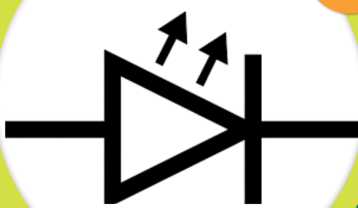
Knife Switch



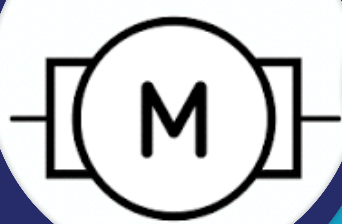
Momentary Switch



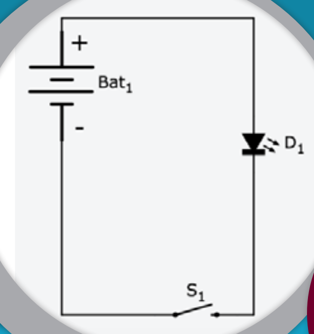
LED

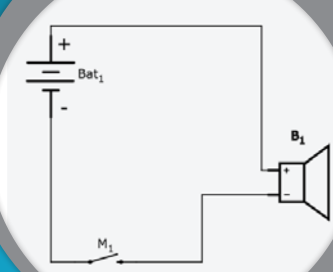


Motor

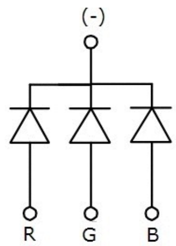


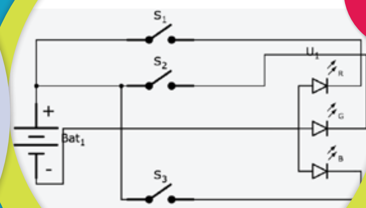
Potentiometer

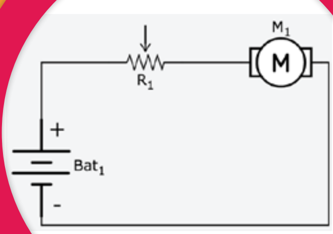


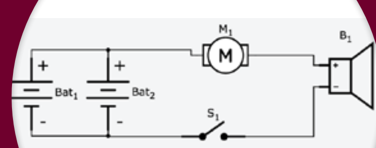


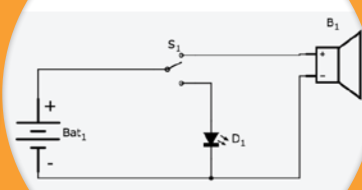
RGB LED











NGSS Standards ADDRESSED

SCIENCE & ENGINEERING PRACTICES:

Planning and Carrying Out Investigations
Asking Questions and Defining Problems
Developing and Using Models
Analyzing and Interpreting Data
Constructing Explanations and Designing Solutions

K-2

K-PS2: Motion and Stability: Forces and Interactions

K-PS2-1. Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object.

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 pull.

2-PS1: Matter and its Interactions

2-PS1-3. Make observations to construct an evidence-based account of how an object made of a small set of pieces can be disassembled and made into a new object.

K-2-ETS1: Engineering Design

K-2-ETS1-1. Ask questions, make observations, and gather information about a situation people want to change to define a simple problem that can be solved through the development of a new or improved object or tool.

K-2-ETS1-2. Develop a simple sketch, drawing, or physical model to illustrate how the shape of an object helps it function as needed to solve a given problem.

K-2-ETS1-3. Analyze data from tests of two objects designed to solve the same problem to compare the strengths and weaknesses of how each performs.

K-2nd	PS1: Matter and its Interactions	PS2: Motion and Stability: Forces and Interactions		EST1: Engineering Design		
	2-PS1-3	K-PS2-1	K-PS2-2	K-2-ETS1-1	K-2-ETS1-2	K-2-ETS1-3
Bouncy Rockets				X	X	
Ozobots						
Zipline Racers		X	X		X	X
Circuit Blocks	X					
Forced Perspective						
Hovercrafts		X	X	X	X	
Light Play						
Squishy Circuits						X
Makey Makey						

3-5

3-PS2: Motion and Stability: Forces and Interactions

3-PS2-1. Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

3-PS2-2. Make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion.

4-PS3: Energy

4-PS3-1. Use evidence to construct an explanation relating the speed of an object to the energy of that object.

4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.

4-PS3-4. Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.

4-PS4: Waves and their Applications in Technologies for Information Transfer

4-PS4-2. Develop a model to describe that light reflecting from objects and entering the eye allows objects to be seen.

4-PS4-3. Generate and compare multiple solutions that use patterns to transfer information.

5-PS1: Matter and Its Interactions

5-PS1-3. Make observations and measurements to identify materials based on their properties.

5-PS2: Motion and Stability: Forces and Interactions

5-PS2-1. Support an argument that the gravitational force exerted by Earth on objects is directed down.

3-5-ETS1: Engineering Design

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.

3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

3rd-5th	PS1: Matter and Its Interactions	PS2: Motion and Stability: Forces and Interactions			PS3: Energy			PS4: Waves and their Applications in Technologies for Information Transfer		ETS1: Engineering Design		
	5-PS1-3	3-PS2-1	3-PS2-2	5-PS2-1	4-PS3-1	4-PS3-2	4-PS3-4	4-PS4-2	4-PS4-3	3-5-ETS1-1	3-5-ETS1-2	3-5-ETS1-3
Bouncy Rockets		X	X	X							X	X
Ozobots									X		X	X
Zipline Racers		X	X	X	X		X			X	X	X
Circuit Blocks	X					X			X		X	
Forced Perspective								X				
Hovercrafts											X	X
Light Play								X				
Squishy Circuits	X					X	X				X	X
Makey Makey	X					X						

Middle School

MS-PS2: Motion and Stability: Forces and Interactions

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.

MS-PS3: Energy

MS-PS4: Waves and Their Applications in Technologies for Information Transfer

MS-PS4-3. Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals.

MS-ETS1: Engineering Design

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

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-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

MIDDLE SCHOOL	PS2: Motion and Stability: Forces and Interactions		PS4: Waves & Their Applications in Technologies for Information Transfer	ETS1: Engineering Design			
	MS-PS2-3	MS-PS2-5	MS-PS4-3	MS-ETS1-1	MS-ETS1-3	MS-ETS1-3	MS-ETS1-4
Bouncy Rockets				X			
Ozobots			X				
Zipline Racers					X	X	X
Circuit Blocks	X		X	X	X	X	
Forced Perspective							
Hovercrafts					X		
Light Play							
Squishy Circuits	X	X			X	X	
Makey Makey	X			X	X	X	