# AKA SCIENCE

Fun Physics: Forces & Motion
Grades 4-6

AKA Science is funded by our generous community partners.
portland children's levy · aws elemental · First Tech federal credit union · Genentech

# Fun Physics: Forces & Motion (Grades 4-6)

## Welcome to AKA Science!

Physics is the study of matter, motion, and energy. Physics explores forces such as heat, light, sound, pressure, density, gravity, and electricity, and the way that they affect objects. By studying physics, we can understand much of the world around us, from the tiniest atomic particles to the mind-boggling vastness of our galaxy. We observe physics in action every day; when we're riding in a car, watching tv, seeing an airplane in the sky, observing a construction site, or running at the gym. There is so much to discover in the great world of Physics!

Over the next 8 weeks, you will put the properties of physics to the test by launching catapults, mastering coin tricks, and connecting electrical circuits! Power up for fun as you make magic of magnets, build a drag racer, and make a boat paddle itself! Sink a diver in a bottle, send a balloon rocket zooming, and design a marble speed track!

## BEFORE YOU START:

- **Please be sure the take-home supply advisories are put into the hands of your students' caring adults.**
- **NOTHING from the AKA Science kit should go in anyone's mouth, nose, eyes, or ears.** Mystery substances can be harmful, and even familiar substances can be contaminated. **If a student ingests a non-food product, call Poison Control: 1-800-222-1222 or 911.** Make sure you consult with your Site Coordinator about any issues.
- **Reserve about 15-30 minutes prior to class starting to prep materials** (see "Prep Steps" section below. If you don't have access to your classroom in advance, see if your site can provide a cart or tray.
- **Newspaper is helpful for covering desks.** A small bundle is in your kit. If it gets used up, you may want to grab a free newspaper to replenish your supply.
- **Be thoughtful about your strategy for handing out supplies.** To minimize spills and accidents, don't give students more supplies than they need for each step of an activity, and gather back supplies when they're no longer being used.

# Fun Physics: Forces & Motion (Grades 4-6)

- **You don't have to do all the activities.** You may not have time to do every activity in the curriculum with your class—and that's okay! It's up to you which activities to shorten, lengthen, or skip if needed.

- **Make time for- and encourage students to use their Lab Notebooks** to plan, record, and reflect on their observations as you go.

- **We all make mistakes!** Assure your students that mistakes are learning opportunities and in science, it's how discoveries are made. It might take some time, but you will learn how to do this, you will get better at this, and you will eventually overcome challenges that arise. You can do hard things!

  **If an experiment didn't work, we encourage you to debrief with students and reflect. Here are some example prompts:**

  - ✓ *What happened today that made you try hard?*
  - ✓ *What can I learn from this?*
  - ✓ *What other strategies or improvements can I try next time?*
  - ✓ *What do I need to get info about or work on before I try this again? Where could I get advice or help from?*
  - ✓ *How could I safely try this experiment in a different way?*
  - ✓ *What did I do today that I am proud of? What are my goals for the next class?*

## HELPFUL "*FUN PHYSICS: FORCES & MOTION* VOCABULARY:

- **Physics:** The study of matter, motion, and energy. Physics explores forces such as heat, light, sound, pressure, density, gravity, and electricity, and the way that they affect objects.
- **Properties:** Characteristics of matter that enable us to differentiate one material from another, including qualities like strength, stretchiness or absorbency.
- **Friction:** The resistance of motion when one object rubs against another.
- **Potential Energy**: A form of energy that has the potential to do work but is not actively doing work or applying any force on any other objects.
- **Kinetic Energy:** The energy an object has because of its motion.
- **Density:** A physical property that measures how closely packed together a substance's particles are.
- **Matter:** Anything that takes up space and can be weighed.
- **Energy:** The force that causes things to move and work. It may exist in potential, kinetic, thermal, electrical, chemical, nuclear, or other various forms.
- **Force:** A push or pull on an object. A force can make an object move, speed up, slow down, stay still, or change shape. Common forces include gravity, friction, tension, electrical force, magnetic force, spring force, and applied force.
- **Gravity:** The force by which a planet or other body draws objects toward its center.
- **Pressure:** The physical force exerted on an object.

# Fun Physics: Forces & Motion (Grades 4-6)

## Class 1: Gravity Showdown

| Supplies | # |
|---|---|
| Aluminum pie pans (small) | 16 |
| Binder clips (large) | 16 |
| Butcher paper (sheets, white) | 1 |
| Cups (8oz paper) | 16 |
| Index cards | 16 |
| Marbles (small) | 16 |
| Markers (various colors, washable) | 1 |
| Notebooks | 16 |
| Paper (8.5inx11in sheets, white) | 16 |
| Paper (half-sheets, white) | 32 |
| Paper clips (jumbo) | 16 |
| Pencils | 16 |
| Pennies | 48 |
| Rubber bands (size 33) | 16 |
| Tape (rolls, Scotch) | 1 |

| | |
|---|---|
| Worksheets: "Dear Parents" AKA Science Take-Home Supplies Advisory (half-sheet) | 16 |
| Worksheets: Consent for Publicity Form | 16 |
| Worksheets: Magnet Take-Home Permission Slip | 16 |
| Worksheets: Pre-Survey | 16 |
| Worksheets: Survey Answers | 1 |

### Prep (prior to class) — Time: 15-30 Minutes

- **General:** Ask your Site Coordinator about the best way to send home the Take-Home Supplies Advisory.
- **General:** Ask your Site Coordinator if they want to send home the Magnet Take-Home Permission Slips.

### Activity One – Set the Tone — Time: 5 Minutes

| Supplies | # | Supplies | # |
|---|---|---|---|
| Butcher paper (sheets) | 1 | Markers (dark blue, washable) | 1 |
| Tape (roll, Scotch) | 1 | | |

**Goal:** To set the tone by establishing class agreements.

**Procedure:**

1. Gather students in a circle and facilitate an introductory icebreaker (e.g., name + kind of animal they would like to be for a day).
2. Using marker and butcher paper, facilitate a discussion among students to establish a set of class rules that they can all agree on.

   Example questions:
   - ***We have limited supplies in class. How can we share?***
   - ***How do we safely use science supplies?***
   - ***What is appropriate/inappropriate behavior in class?***
   - ***How do we want to be treated in class?***
   - ***How can we be our best selves in class?***
   - ***What happens if someone breaks one of our agreements?***
   - ***What are the clean-up procedures?***


3. Once rules are established, have students sign with their name or something that is unique to them (like a stamp pad and thumb print, or a symbol, etc.) directly onto the paper.

### Activity Two – Pair & Share — Time: 10 Minutes

| Supplies | # | Supplies | # |
|---|---|---|---|
| Pencils | 16 | Worksheets: Survey Answers | 1 |
| Worksheets: Pre-Survey | 16 | Lab notebooks | 16 |

**Goal**: To engage students' thinking and questioning related to the day's activities.

**Procedure:**

1. Prepare a quiet space for students to give them a physical area to think. The space can be an area set aside from the activity area, where students sit in a circle to ponder the *Pair & Share* question.
2. Make lab notebooks and pencils available.
3. Ask students one or more *Pair & Share* questions:
    - ***What is science?*** *(There are many possible answers, but a good one might be, "Learning about the world.")*
    - ***What is physics?***
    - ***How does physics relate to your life?***
    - ***What is a force?*** *(A force is a push or pull on an object. A force can make an object move, speed up, slow down, stay still, or change shape. Common forces include gravity, friction, tension, electrical force, magnetic force, spring force, and applied force.)*
    - ***What is a motion?*** *(A change with the time, position, or orientation of object or matter.)*
    - ***What is one thing about force or motion you are curious about?***
4. Ask students to discuss their ideas with their neighbor before inviting students to share what they came up with. This is a "challenge by choice" opportunity and no one is required to share with the class if they are not comfortable.
5. After the discussion, **administer the pre-survey** to students.
6. Read each question aloud so all students understand each question.
7. Collect completed surveys.
8. Let students know you'll be discovering the answers with them in the coming weeks.
9. **Submit the completed surveys to Site Manager/Coordinator.** These need to go to your Manager/Coordinator as soon as possible so they don't get lost. At the end of the term, you'll be submitting the students' post-surveys as well.

## Activity Three – Coin Tricks — Time: 20 Minutes

| Supplies | # | Supplies | # |
|---|---|---|---|
| Cups (8oz paper) | 16 | Paper clips (jumbo) | 16 |
| Index cards | 16 | Pennies | 48 |

**Goal**: To demonstrate that an object at rest stays at rest until a force acts on it, using pennies and stacks of pennies.

**Source**: https://bit.ly/3wYqhVx

**Survey Connection: This activity is linked to the following survey question:**

★

**Q.** What is the force that pulls all objects toward the earth?

**A. Gravity.**

**Background:**

Newton's First Law (INERTIA) says that an object at rest wants to stay at rest. In this activity you'll be using pennies to experiment with inertia. You'll see Newton's First Law in action when you flick the index card sideways off the cup—or flick it sideways from in between some pennies—the pennies don't move sideways. Why? The pennies want to stay still because they were already still. The only force that can act on the pennies is gravity, which pulls them downward.

The same is true when you flick the bottom penny out from the stack of pennies. The flick from the paper clip is enough energy to move the bottom penny sideways out of rest, but it doesn't move the other pennies sideways.

The pennies on your elbow are a little trickier. They are at rest, then you take them out of rest by moving your elbow out from under them. However, it takes gravity a little time and effort to pull them out of rest and downward. If you swing your hand fast enough, you can rely on their inertia (wanting to stay still) to catch them before gravity has a chance to pull them all the way down to the ground!

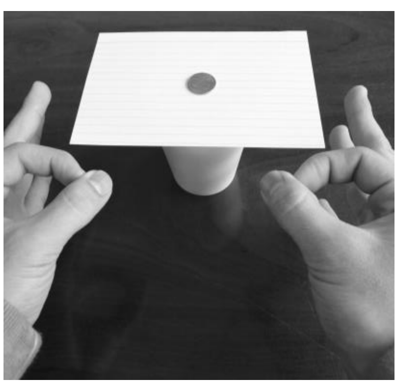
How do you overcome inertia and move an object from rest? You apply a force, of course! The one you used to move the index card and the bottom penny in the stack is called the "APPLIED FORCE" because you (a person!) applied it. (https://bit.ly/3jv8XUZ)

**Procedure:**

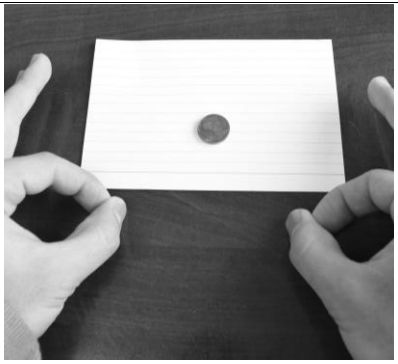
1. Give each student an 8oz paper cup, three pennies, and an index card.
2. Have students place the index card over the mouth of the cup and place one penny in the middle of the index card.
3. Ask students: ***What do you think will happen to the penny if we flick the index card off the top of the cup? Let's find out!***
4. Have students flick the index card away from themselves and off the top of the cup. Use two hands (one positioned at each corner on one of the long sides of the index card) then flick with both pointer fingers straight ahead. The motion of index card should be parallel to the table (see photo at left).
5. Allow students to practice flicking the card until they see a reliable result.

   Discussion Prompts:
   - ***Where does the penny go?***
   - ***Is that what you predicted?***
   - ***Why did this happen?***
   - ***If the penny wants to stay still, why does it fall into the cup?***

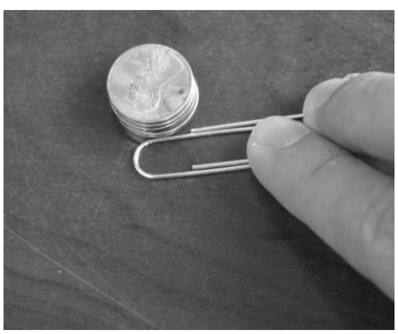
6. Tell students:



Coin Tricks. Place one hand at each bottom corner of the index card and flick the card straight forward. The penny should fall into the cup.



Coin Tricks. Place an index card on a stack of 2 pennies, then place a penny on the index card directly above the stack of pennies. Flick the index card forward as before.



Coin Tricks. Swipe the paper clip along the surface of the table so the edge of the paper clip strikes the edge of the bottom penny.

- ***According to Newton's First Law of Motion, an object at rest tends to stay at rest until a force acts on it. This is called <u>inertia</u>. When we say, "at rest," we mean the object is still—not that it's sleeping! The penny stays still when the index card moves sideways because it started still and wants to stay still.***
- ***Once the card is gone, the penny has no surface to rest on, and gravity pulls it down. <u>Gravity</u> is the force that pulls all objects toward the earth. It's the reason you walk on the ground instead of floating through space!)***

7. <u>Have students</u>:
   a. Set the cup aside and place one penny on the table (ideally near the edge of the table).
   b. Place the index card over the penny. (Ideally, place it so that one of the long edges of the index card hangs very slightly off the edge of the table.)
   c. Stack the other two pennies directly above the penny that's under the index card.

8. <u>Ask students:</u> ***We know that a penny at rest will want to stay at rest. So, what do you think will happen if you flick the index card out from between these resting pennies? Try and see!***

9. As with the cup, have students line up one hand at each corner of the index card, then flick the card out from between the pennies (see top photo at left).
10. Allow students to repeat until they see a reliable result.

    <u>Discussion Prompt:</u>
    - ***What happens?*** *(The index card flies out and the pennies fall into a stack.)*

11. Have students work together to try using different numbers of pennies above and below the card to see which combinations are successful.
12. <u>Ask students:</u> ***You just flicked an index card out from a stack of pennies, but can you flick a <u>penny</u> out from a stack of pennies? How would you do that?***

13. Pair students. Give each pair two jumbo paper clips (one per student).
14. Have each pair combine their pennies into a stack that is six pennies tall.
15. <u>Ask students:</u> ***Can you use your paper clip to flick the bottom penny out from the stack? What do you think will happen to the stack of pennies?***

16. Have students take turns trying to flick the bottom penny out from the stack.
17. After students have tried their own methods, show students that if they swipe the edge of the paper clip against the bottom penny in

Coin Tricks. Place penny on elbow and quickly swing your hand down.

the stack, that penny will shoot out and leave the rest of the stack upright (see middle photo at left).

18. Allow students to take turns trying that technique.

    <u>Discussion Prompts:</u>
    - ***Why does the stack stay standing after you knock out the bottom penny?***
    - ***How is this like the index card in the stack of pennies?*** *(Again, according to Newton's First Law, an object at rest—in this case, the stack of pennies—will stay at rest unless acted upon. Since you're only hitting the bottom penny, the rest of the stack remains still/at rest!)*

19. Have students return to individual work and retrieve three pennies each.
20. <u>Ask students:</u> ***Do you think you can react faster than the pull of gravity?***
21. Have students lift one arm up and back so their elbow is pointing straight forward (like a waiter carrying a tray but extended back so the whole forearm is parallel to the ground—see bottom photo at left).
22. Have students balance a penny on top of their elbow and cup their palm.
23. <u>Ask students:</u> ***If you swing your hand down quickly, do you think you can catch the penny?***

<u>**TIPS**</u>:
- **You may need to demonstrate the motion for students.**
- **It helps to do this activity in an open area** (or have students take turns) so that flying pennies don't hit anyone.

24. Allow students to experiment with a quick motion, swinging their hand forward and down to grab the penny. This may take a few tries. ***Speed is key!*** It may help to avoid looking and just go by feel.
25. Once students have mastered one penny, have them add another penny on top of the first and try again. Students can work up to a stack of three pennies.

    <u>Discussion Prompts:</u>
    - ***Is it easier to catch one penny, two pennies or three pennies?*** *(Surprisingly, it should only be a little harder to catch three pennies than it is to catch one.)*
    - ***What allowed you to catch the pennies in midair?***

26. <u>Tell students:</u> ***Newton's First Law of Motion – INERTIA! The pennies are at rest until your elbow moves out from under them. At that point, gravity pulls them out of rest, and they fall straight down. If your arm is moving fast enough, your fingers end up directly below the pennies and you can catch them before they hit the ground!***

## Activity Four – Pie Pan & Tablecloth Trick Time: 15 Minutes

| Supplies | # | Supplies | # |
|---|---|---|---|
| Aluminum pie pans (small) | 16 | Paper (8.5inx11in sheets, white) | 16 |
| Binder clips (large) | 16 | Paper (half-sheets, white) | 32 |
| Cups (8oz paper) | 16 | Rubber bands (size 33) | 16 |
| Marbles (small) | 16 | | |

**Goal**: To demonstrate that an object at rest stays at rest until a force acts on it by learning the secret behind the magician's tablecloth trick.

**Source:** http://bit.ly/3Ygq5MI & http://bit.ly/3ZIFgoR

**Survey Connection:**

★ **Q.** What is the force that pulls all objects toward the earth?
**A. Gravity.**

**Background:**

Remember that Newton's First Law is about inertia—an object at rest stays at rest until something acts on it. In this activity, when you hit a pie pan, your hand forces the pan and tube to fly sideways. Why doesn't the paper ball go flying sideways as well? Because it is at rest and wants to stay at rest! It only moves downward because gravity pulls it down once it has nothing to rest on.

With the tablecloth trick, when you try pulling the paper from under the tube, the friction between the two is enough to overcome the tube's inertia and make the tube fall over. When you karate chop the paper, your hand forces the paper to move down and out from underneath the tube very quickly. There is much less friction from the paper, and less force on the tube. There isn't enough force to overcome the tube's inertia, so it stays still while the paper moved.

This is the same trick magicians use when they pull a tablecloth off a table full of dishes. Can you think of another way to use this trick? (https://bit.ly/3wYqhVx)

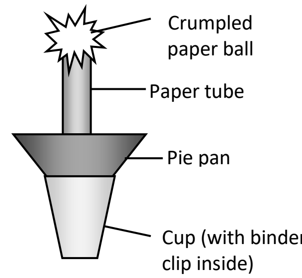
**Procedure:**

1. Ask students: ***You've learned that INERTIA (Newton's First Law) works on pennies. Do you think it also works with bigger objects? Let's find out!***

2. Give each student two half-sheets of paper, a rubber band, a small pie pan, and a large binder clip.

Pie Pan & Tablecloth Trick. Chop the pie pan sideways so the paper ball falls into the cup.

3. <u>Have students</u>:
    a. Roll one half-sheet of paper into a short cylinder (about the diameter of a golf ball) and put a rubber band around it so that it makes a paper tube.
    b. Fold the silver parts of the large binder clip against the black base. Put the binder clip in the cup with the black base at the bottom.
    c. Center the pie pan over the cup opening.
    d. Crumple the other half-sheet of paper into a ball (see diagram at right).
    e. Place the paper tube upright in the center of the pie pan, then balance the paper ball on the top opening of the tube.



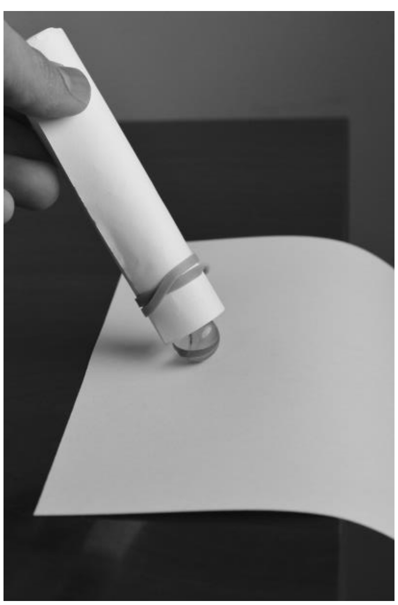

4. <u>Ask students:</u> ***What do you think will happen to the ball if you knock the pie pan sideways? Let's try!***

5. Have students use a quick (yet gentle) sideways chop with one hand to knock the pie pan out of the way (see top photo at left). A short chop that only touches the pie pan works best. The motion of the pie pan should be parallel to the table, and the hand should rebound back after the chop (to get out of the way).
6. Allow students to practice the motion until they see a reliable result.

    <u>Discussion Prompts:</u>
    - ***What happens?*** *(The ball falls into the cup.)*
    - ***Why?***

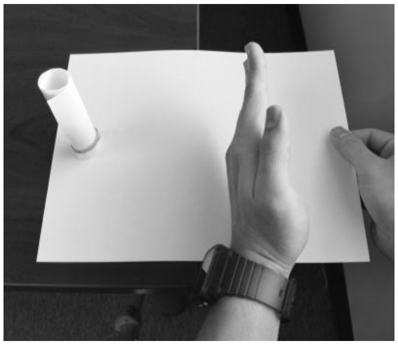
7. <u>Tell students:</u> ***Just like the penny on top of the index card, the ball was at rest—so it didn't want to move. When the pie pan and paper tube got knocked out of the way, there was a split second where the ball still didn't move…until gravity pulled it straight down***

8. Set aside all the supplies except for the paper tube (with rubber band around it).
9. Give each student a sheet of 8.5inx11in paper and a small marble.
10. <u>Ask students:</u> ***Have you ever seen the magic trick where a magician pulls a tablecloth out from underneath a table full of plates and glasses—but nothing falls or breaks? Do you think we could use INERTIA to perform our own magic trick?***



Pie Pan & Tablecloth Trick. Roll the half-sheet of paper into a tube and secure it with a rubber band. Place the tube upright with the marble inside the bottom of the tube.

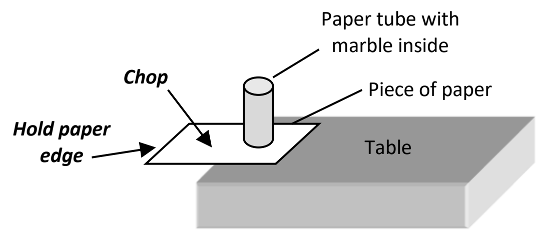
11. <u>Have students</u>:
    a. Lay the paper flat on the table, with about half of it hanging off the edge.
    b. Place the tube upright on the table on top of the sheet of paper.



Pie Pan & Tablecloth Trick. Hold the hanging edge of the paper with one hand and karate the chop the paper with the other. The tube should remain standing.

   c. Slide the rubber band around the tube down toward the bottom of the tube, to help weigh the tube down.
   d. Place the marble inside the paper tube (see bottom photo at left).

Discussion Prompt:
***What do you think will happen if you pull the piece of paper out from underneath the paper tube?***




12. Have students pull the full sheet of paper out sideways from underneath the paper tube.

Discussion Prompts:
- ***What happened?*** *(The tube fell over.)*
- ***How can we use INERTIA to keep the paper tube from falling over?***

13. Have students reset the paper, marble, and tube. Hold the loose edge of the paper level with the table. With the other hand, give it a sharp downward karate chop (see diagram above and photo on next page).

Discussion Prompt:
- ***What happened?*** *(The paper tube should have stayed standing.)*

14. Students may need to try a few times to keep the tube upright. The key is to chop the paper quickly *down*, not pull it sideways.
15. For more of a challenge, have students try to keep the tube upright without using the marble. For less challenge, leave more of the paper hanging off the table.

Discussion Prompt:
- ***Why does it work?***

16. Tell students: ***At low speed, the force of friction between the paper and tube was stronger than the tube's inertia, so the tube fell over. With the downward chop, though, the paper moved faster. At high speed, the tube's inertia was greater than the force of friction, so the tube stayed still.***

## Activity Five – Daily Debrief Time: 5 Minutes

| Supplies | # |
|---|---|
| Worksheets: Take-Home Supplies Advisory (half-sheet) | 16 |
| Lab Notebooks | 16 |
| Pencils | 16 |
| Worksheets: Consent for Publicity Form | 16 |

**Goal:** To draw today's activities together through a thoughtful question and give students an opportunity to ask their own questions.

**Procedure:**

1. Encourage students to reflect on what they learned in today's class and what new questions they might have.
2. Allow students a few seconds to think. Have them discuss their thoughts and questions with a partner, then share with the rest of the class and/or write down in their lab notebook.
3. If needed, feel free to offer prompts like:
   - ***What do you think would happen if we changed one thing about today's activities (for example: materials, speed, temperature, etc.)?***
   - ***If you could investigate (explore) one more thing about today's activities, what would you like to find out?***

4. If time allows, ask the following question:
   - ***How do you feel inertia when riding in a car?"*** *(Inertia says non-moving objects want to stay still and moving objects want to keep moving. The jerk you feel when the car starts suddenly is because your body wants to stay in place as the car is moving. The jerk you feel when the car comes to a stop is because your body wants to continue moving, but the seatbelt keeps you from moving forward.)*

**Clean up:** Make sure students help clean the room before they leave.

**What to save:** Remember to save all the items in the "SAVE" column of the "WHAT TO SAVE" table (see next page).

| Materials used | # | SAVE | Materials used | # | SAVE |
|---|---|---|---|---|---|
| Aluminum pie pans (small) | 16 | 0 | Paper clips (jumbo) | 16 | 0 |
| Binder clips (large) | 16 | 16 | Pencils | 16 | 16 |
| Butcher paper (sheets, white) | 1 | 1 | Pennies | 48 | 0 |
| Cups (8oz paper, "coffee") | 16 | 16 | Rubber bands (size 33) | 16 | 0 |
| Index cards | 16 | 0 | Tape (rolls, Scotch) | 1 | 1 |
| Marbles (small) | 16 | 16 | Worksheets: "Dear Parents" AKA Science Take-Home Supplies Advisory (half-sheet) | 16 | 0 |
| Markers (various colors, washable) | 1 | 1 | Worksheets: Magnet Take-Home Permission Slip | 16 | Check with Site Coordinator |
| Notebooks | 16 | 16 | Worksheets: Consent for Publicity Form | 16 | 0 |
| Paper (8.5inx11in sheets, white) | 16 | 0 | Worksheets: Pre-Survey | 16 | 16 |
| Paper (half-sheets, white) | 32 | 0 | Worksheets: Survey Answers | 1 | 1 |

**<u>What goes home</u>:** Pie pan, index card, paper tube, paper ball, jumbo paper clip & 3 pennies per student

**Notes about sending supplies home from AKA Science:**

- Let students know that they'll get to take home various AKA Science supplies over the course of the term—however, they won't take home *all* of the supplies, and they won't necessarily take home supplies after *every* day of class.
- **Instruct students that they should <u>never</u> put AKA Science supplies in their mouths, eyes, ears, or noses, or use them in a way that could hurt anyone.**
- Please use your judgment about sending supplies home with students. If the "WHAT GOES HOME" section includes a supply item that you don't think your students can handle safely while unsupervised, **don't send it home.**
- *Reminder re Magnet Permission Slips: If they don't want to deal with the permission slips, it's no problem—it just means you'll give the magnets to the Site Coordinator at the end of the term instead of having students take them home. When you get to Class 7, feel free to tell students that the magnets have to stay at the site.*

# Fun Physics: Forces & Motion (Grades 4-6)

## Class 2: Climb & Dive

| Supplies | # |
|---|---|
| Aluminum roasting pans | 2 |
| Bottled water (16oz bottles) | 16 |
| Crayons (box) | 1 |
| Cups (20oz plastic) | 4 |
| Newspaper | 1 |
| Nuts (metal hexagons) | 32 |
| Paper clips (regular size) | 64 |
| Paper towels (rolls) | 1 |
| Pencils | 16 |
| Pennies | 16 |
| Pipe cleaners (full size) | 16 |
| Pipe cleaners (half-pieces) | 16 |
| Popsicle sticks (jumbo) | 16 |
| Rubber bands (size 33) | 16 |
| Scissors (site provides) | 16 |
| Straws (bendy tip, striped, full size) | 16 |
| Straws (1in pieces) | 32 |
| Tape (rolls, masking or blue painter's) | 1 |
| Tape (rolls, Scotch) | 4 |
| Water (oz) | 40 |
| Yarn (5ft pieces) | 16 |

**Printed Materials**

| | |
|---|---|
| Worksheets: Climbing Creatures (half-sheets on cardstock) | 16 |
| Worksheets: Pre-Survey | any left |

### Prep (prior to class) — Time: 15-30 Minutes

- **Act. 4**: Fill four 20oz cups three-quarters full of water (don't use the bottled water for this).
- **NOTE:** Newspaper is provided as needed to help protect surfaces from messes.

### Activity One – Pair & Share — Time: 10 Minutes

| Supplies | # | Supplies | # |
|---|---|---|---|
| Pencils | 16 | Worksheets: Survey Answers | 1 |
| Worksheets: Pre-Survey | 16 | Lab notebooks | 16 |

**Goal**: To engage students' thinking and questioning related to the day's activities.

**Procedure:**

1. Prepare a quiet space for students to give them a physical area to think. The space can be an area set aside from the activity area, where students sit in a circle to ponder the *Pair & Share* question.
2. Make lab notebooks and pencils available.
3. Ask students one or more *Pair & Share* questions:
   - ***When do you use balance (or see things balancing) in your everyday life?*** *(Riding a bike, walking on a balance beam, standing on one leg, looking at birds perched on telephone wires.)*
4. Ask students to discuss their ideas with their neighbor before inviting students to share what they came up with. This is a "challenge by choice" opportunity and no one is required to share with the class if they are not comfortable.
5. After the discussion, **administer the pre-survey** to any students who haven't already been surveyed. Collect completed surveys.
6. **Submit the completed surveys to Site Manager/Coordinator.** These need to go to your Manager/Coordinator as soon as possible so they don't get lost. At the end of the term, you'll be submitting the students' post-surveys as well.

### Activity Two – Tightrope Balancer — Time: 15 Minutes

| Supplies | # |
|---|---|
| Nuts (metal hexagons | 32 |
| Pipe cleaners (full size) | 16 |
| Popsicle sticks (jumbo) | 16 |

**Goal**: To observe how changing an object's center of gravity affects its balance using a popsicle stick and a pipe cleaner with weights on the ends.

**Source**: https://bit.ly/3I29cAd

**Survey Connection:**

★ **Q.** What is the force that pulls all objects toward the earth?
**A. Gravity.**

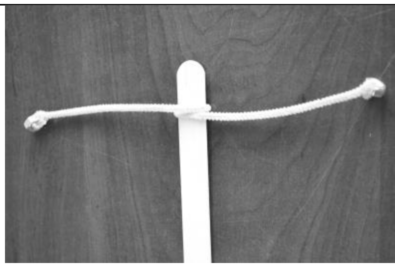
**Background:**

In this experiment, the main force you will be working with (and against) is gravity! At first, when you try to balance the Tightrope Balancer at one end of the popsicle stick, the problem is that gravity is pulling down on the entire figure at once, but your fingertip can only support one side of it. That's where the secret of the "center of gravity" comes in! By changing the placement of weight in Tightrope Balancer's arms, you will be able to shift the center of gravity toward one end of the popsicle stick. When you put your finger under that new center of gravity, the entire Tightrope Balancer can balance at one end of the stick.

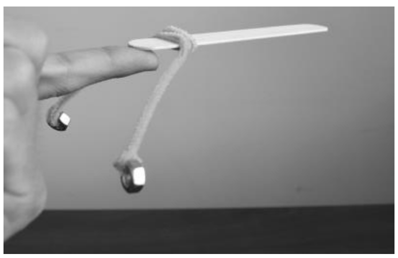
Everything has a center of gravity! On humans, it's usually somewhere near your hips. When scientists try to find the center of gravity in an object, they have to use difficult calculations—but they also use familiar concepts like symmetry. An object is symmetrical if there's a place where you can split it in half and have one half be the mirror image of the other (i.e., the same size and shape, just flipped). Did you notice that your balance bird is symmetrical? Where could you cut it in half so that both halves would be the same size and shape? (https://bit.ly/3JHLD0Q)

**Procedure:**

1. Have students try to balance on one foot.
2. Ask students:
   - ***What happens when you try to balance?***
   - ***How does your body move?***
   - ***Do you have to make some changes in the way you're standing in order to balance?*** *(Many people hold their arms out to their sides to balance, shifting their bodies and tilting their arms as needed. Rumor has it that you can place a finger on your bellybutton to help keep still!)*
3. Give each student: two metal nuts, one full-size pipe cleaner, and one jumbo popsicle stick.

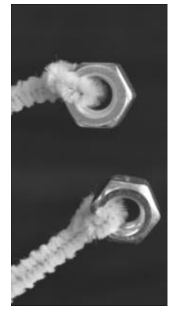


Tightrope Balancer. Wrap each pipe cleaner "arm" one full rotation around the popsicle stick.



Tightrope Balancer. Create a "Y" shape with the stick and the popsicle stick "arms" so that one end of the Tightrope Balancer perches on a fingertip. (The "arms" will naturally dip below the stick.)

4. Have students:
   a. Slip one end of the pipe cleaner into a metal nut and tightly loop the end of the pipe cleaner to lock the nut in place. Repeat for the other nut on the other end of the pipe cleaner (see photo).
   b. Fold the pipe cleaner in half, gently. There should be an equal distance from each nut to the center of the pipe cleaner.
   c. Place the flat part of the jumbo popsicle stick on the fold that marks the midpoint of the pipe cleaner, about an inch from one end of the popsicle stick. Make sure the popsicle stick is pressed flat against the pipe cleaner (see photo).
   d. Wrap one side of the pipe cleaner tightly around the stick until it loops back to where it started. Repeat for the other side of the pipe cleaner in the opposite direction. The "arms" of the pipe cleaner will be shorter, but each nut should still be an equal distance from the popsicle stick (see top photo at left).



Tightrope Balancer. Left photo: Wrap each end of the pipe cleaner around a metal nut. Right photo: Put the popsicle stick directly on the midpoint of the pipe cleaner.

5. Ask students: ***You've just built a Tightrope Balancer! How can you get it to balance on just one finger?***

6. Allow students time to explore points of balance on the stick.
7. Tell students: ***Every object has a point where it will balance—a point where its weight is equally distributed on all sides. That point is called its center of gravity because it's the center where gravity pulls down on all the parts of the object equally!***

   Discussion Prompts:
   - ***What worked the best?*** *(Placing a finger under or near the pipe cleaner probably had the best results.)*
   - ***Does the Tightrope Balancer work if you put your finger under the popsicle stick in the inch of space between the pipe cleaner and the end of the stick?*** *(No!)*
   - ***Why not?*** *(Because that's not where its center of gravity is.)*
   - ***Do you think you could change its center of gravity by adjusting the pipe cleaner "arms?" Try it!***

8. Guide students through bending and rearranging the pipe cleaner "arms" until they can get the Tightrope Balancer to balance with a fingertip under the inch of space between the pipe cleaner and the end of the stick. The best way is to push the arms forward (toward

the nearest end of the stick), so the arms and stick form a "Y" shape when the stick is flat on a surface. When the stick is balanced on a fingertip, the weight of the nuts will naturally pull the arms down below the stick.

Discussion Prompts:

- ***How can the whole thing balance on such a small point?*** *(The metal nuts at the ends of the pipe cleaner add extra weight to the arms. By moving the arms and changing where that weight is, you can change the Tightrope Balancer's center of gravity.)*
- ***Would the Tightrope Balancer balance on its tip if it weighed the same all over?*** *(No—it wouldn't balance on its tip, since its weight would be spread out too much. The center of gravity of an evenly-weighted object is at its middle.)*
- ***How far can you tip the Tightrope Balancer over until it falls off your finger?***
- ***Can you get the longer end of the popsicle stick to stand straight up with the short end on your fingertip? Try it!***

9. Allow students time to experiment with tipping the Tightrope Balancer and rearranging its arms to create new centers of gravity.

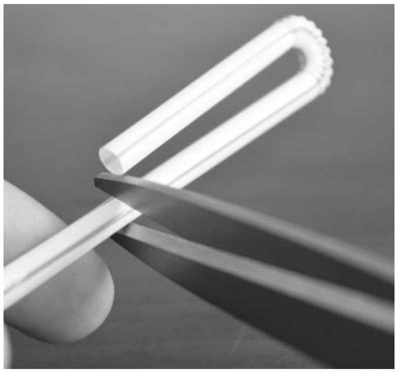
## Activity Three – Cartesian Diver Time: 15 Minutes

| Supplies | # | Supplies | # |
|---|---|---|---|
| Aluminum roasting pans | 2 | Paper towels (rolls) | 1 |
| Bottled water (16oz bottles) | 16 | Rubber bands (size 33) | 16 |
| Cups (20oz plastic) | 4 | Scissors (site provides) | 16 |
| Newspaper | 1 | Straws (bendy tip, striped, full size) | 16 |
| Paper clips (regular size) | 64 | Water (oz) | 40 |

**Goal**: To demonstrate that applied force can change pressure and cause motion using a straw-and-rubber-band Cartesian diver.

**Source**: https://bit.ly/3lQyElc

**Background:**
Why does the diver float when you put it in the bottle? There is a tiny bubble of air trapped in the bent straw. That is enough to make the diver less dense than the water, so it floats at the top. When you squeeze the bottle, you put pressure on the water and everything inside the bottle—including the air bubble. The extra pressure makes the air bubble inside the straw smaller, which changes the density of the diver. Now that the diver is denser than the water, it sinks to the bottom. When you let go of the bottle, you remove the pressure on the diver and it is able to float back to the top. It's all about balancing the forces of gravity, which pulls the diver down, and buoyancy, which helps the diver float!



Cartesian Diver. Cut the long side of the straw so there's an equal length of straw on both sides of the bend.

Cartesian Diver. Wrap a rubber band around the straw openings to create the diver.

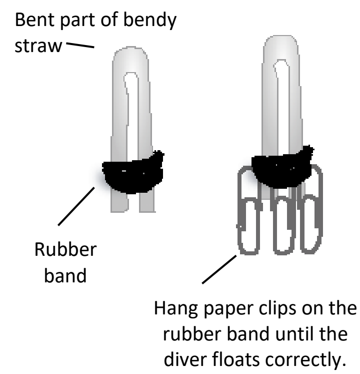
Cartesian Diver. Add paper clips to the rubber band until the top of the diver barely floats above the surface of the water in the cup.

What else uses density to move? A submarine uses density to dive and then come back up to the surface. A submarine has ballast tanks that can be filled with water to make it sink, or with air to make it float. By adjusting how much air or water is in the tanks, you can determine exactly how deep the submarine goes. (http://bit.ly/3L3aqgi)

**Procedure:**

1. Ask students:
   - ***What happens when you drop a stone in water?*** *(It sinks.)*
   - ***What happens when you drop a piece of foam in water?*** *(It floats.)* ***Do you think there are any objects that could both sink and float in water? Let's find out!***

2. Put students in four groups. Give each group a 20oz cup filled three-quarters full of water. Make scissors available.
3. Give each student a rubber band, four paper clips, and a striped bendy straw.
4. Place two aluminum roasting pans in an accessible space for students, preferably on or near a sink.
5. Have students:
   a. Bend the bendy part of their straw over so the short side of the straw almost touches the long side.
   b. Cut the long side of the straw to make it the same length as the short side. There should be an equal length of straw on both sides of the bend (see top photo at left).




   c. Wrap a rubber band around the bottom of the bent straw piece several times. The rubber band should be near the straw openings, away from the bent part. This is now the "diver" (see middle photo at left).
   d. Test to see if the diver floats by putting it in the cup of water. The goal is to have the tip of the diver (the bent part of the straw) bobbing just above the surface of the water (see bottom photo at left & diagram above).
   e. If more than the tip is sticking out above the water, add paper clips one at a time by hanging them onto the rubber band. Each paper clip should hang down away from the bent part of the straw, making the diver look a bit like an octopus (see diagram above). **Test the diver after adding each paper clip until it floats correctly.**

6. When students are ready, assign them to one of the two aluminum roasting pans. Give each student an unopened water bottle.
7. Have students:
   a. Remove the label from their water bottle and throw it away.

Cartesian Diver. Pour water from the 20oz cup to top off the water in the bottle. (The diver is inside the bottle, and the bottle is sitting in the roasting pan to avoid a mess.)

Cartesian Diver. When you squeeze the bottle, the diver should sink to the bottom. When you release the sides of the bottle, the diver should float back up to the top.

b. Hold their water bottle over the pan (to catch any overflow), remove the cap, carefully put their diver in the bottle. (Students may need to take turns to share the pan).
c. Add water from the 20oz cup if needed to top off the water bottle (you may want to pour the water for students—see top photo at left).
d. Screw the cap back on the water bottle tightly. The water bottle should be as full as possible before putting the cap back on. The diver should float inside the bottle (see bottom photo at left).

**<u>TIP</u>:** • **The Cartesian Diver works best when the bottle is full to the brim.**

<u>Discussion Prompts:</u>
- ***Does the diver sink or float?*** *(It floats.)*
- ***Do you think you could get it to sink? How?***

8. Have students firmly squeeze and hold the sides of the bottle, then release.

<u>Discussion Prompts:</u>
- ***What happened?*** *(The diver sank down when the sides were squeezed, then floated back up when the sides were released.)*
- ***Why does this happen?*** *(When the sides of the bottle are squeezed, the air inside the bottle is compressed, which affects the diver's buoyancy.)*

## Activity Four – Climbing Creature Time: 20 Minutes

| Supplies | # | Supplies | # |
|---|---|---|---|
| Crayons (box) | 1 | Straws (clear, 1in pieces) | 32 |
| Pencils | 16 | Tape (rolls, blue painter's or masking) | 1 |
| Pennies | 16 | Tape (rolls, Scotch) | 4 |
| Pipe cleaners (half-pieces) | 16 | Worksheets: Climbing Creature (half-sheets on cardstock) | 16 |
| Scissors (site provides) | 16 | Yarn (5ft pieces) | 16 |

**<u>Goal</u>**: To understand how friction changes with direction by making a piece of cardstock "climb" up string.

**<u>Source</u>**: https://bit.ly/3Zlk4iH

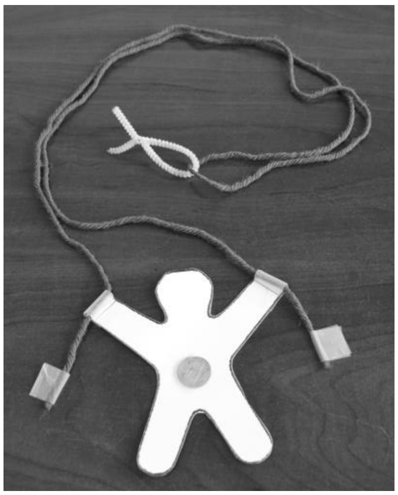
**<u>Survey Connection</u>**

★ **Q.** What is the force that pulls all objects toward the earth?
**A. Gravity.**

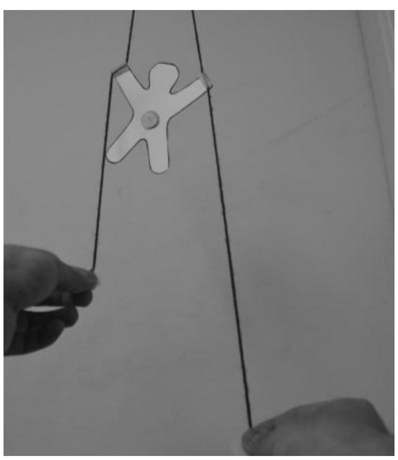
# Fun Physics: Forces & Motion (Grades 4-6)

## Class 2: Climb & Dive

Climbing Creature. Tape a 1in straw piece sideways on each “hand” (don’t tape over the straw openings).



Climbing Creature. Fully assembled.



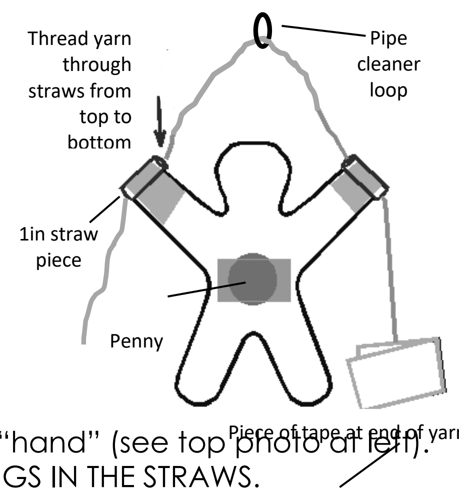
Climbing Creature. Pull one end of the yarn, then the other, to make the creature climb up the yarn.

**Background:**

Friction is a “stopping” force. Whenever two things rub against each other, friction is the force that makes it harder for them to move. The amount of friction depends on which things are rubbing together. Have you ever slid on a hardwood floor in socks? You probably couldn’t slide the same way while wearing tennis shoes! Socks have less friction, so they make it easier to slide.

Your Climbing Creature uses friction to climb up the yarn. When you pull one side of the yarn, the creature tilts. This makes the yarn slide smoothly through the straw on one side, but it creates a bend in the other yarn near the straw on the other side. The bend creates friction between the yarn and the straw, which holds the creature in place. When you pull the yarn on the other side, the creature tilts the other way, so the bend is released, and the creature moves up—and a new bend is created in the yarn on the other side. It’s just like if you were to climb up a wall by holding on with one hand (the bent string) and reaching up with the other hand (the straight string). (https://bit.ly/3XhPAwv)

**Procedure:**




1. Give each student a Climbing Creature worksheet, a penny, a 5ft piece of yarn, a half-piece of pipe cleaner, and two 1in straw pieces. Make crayons, scissors, pencils, and tape available.
2. Have students:
   a. Color and cut out the Climbing Creature from the worksheet.
   b. Tape a straw piece sideways on the end of each “hand” (see top photo at left). DON’T TAPE OVER THE OPENINGS IN THE STRAWS.
   c. Tape the penny in the middle of the creature (like a belly button).
   d. Twist the half-piece of pipe cleaner into a loop.
   e. Thread the yarn through the pipe cleaner loop and pull it through so the loop is in the middle of the piece of yarn.
   f. Thread the ends of the yarn through the straws, so the pipe cleaner loop is above the creature’s head, and each end of the yarn is threaded through one straw piece from top to bottom. The ends of the yarn should hang downward (see middle photo at left and diagram above).
   g. Put a piece of tape on each end of the yarn so the creature won’t slide off.
3. Ask students: ***How do you think you can make the Climbing Creature move up the yarn?***
4. Pair students.
5. Have one student hold a pencil so the eraser points at their partner.

6. Have the other student slide their Climbing Creature's pipe cleaner loop onto the pencil. The Climbing Creature should hang down near the ends of the yarn.
7. Have the student who's not holding the pencil use one hand to gently pull down on one piece of tape, then use the other hand to pull down on the other piece of tape, alternating back and forth (like milking a cow or turning a steering wheel back and forth). As the creature climbs, have the student pulling on the pieces of tape move their hands outward to keep the yarn taut (see bottom photo at left).
8. Have students switch roles and repeat.
9. Ask students: ***Why do you think the Climbing Creature is able to defy gravity and move up the string?*** *(The angle of the straws creates friction against the yarn, which lets the creature climb.)*

## Activity Five – Daily Debrief — Time: 5 Minutes

| Supplies | # |
|---|---|
| Worksheets: Take-Home Supplies Advisory (half-sheet) | any left |
| Lab Notebooks | 16 |
| Pencils | 16 |

**Goal:** To draw today's activities together through a thoughtful question and give students an opportunity to ask their own questions.

**Procedure:**

1. Encourage students to reflect on what they learned in today's class and what new questions they might have.
2. Allow students a few seconds to think. Have them discuss their thoughts and questions with a partner, then share with the rest of the class and/or write down in their lab notebook.
3. If needed, feel free to offer prompts like:
    - ***What do you think would happen if we changed one thing about today's activities (for example: materials, speed, temperature, etc.)?***
    - ***If you could investigate (explore) one more thing about today's activities, what would you like to find out?***

4. If time allows, ask the following question:
    - ***What are some ways we can stop a force (or slow it down) using another force?"*** *(Parachutes slow down the effect of gravity by creating drag, brakes on a car use friction to stop acceleration, baseball gloves use leather cushion to stop a ball.)*

**Clean up**: Make sure students help clean the room before they leave.

**What to save**:

| Materials used | # | SAVE | Materials used | # | SAVE |
|---|---|---|---|---|---|
| Aluminum roasting pans | 2 | 2 | Popsicle sticks (jumbo) | 16 | 0 |
| Bottled water (16oz bottles) | 16 | 0 | Rubber bands (size 33) | 16 | 0 |
| Crayons (box) | 1 | 1 | Scissors (site provides) | 16 | 16 |
| Cups (20oz plastic) | 4 | 4 | Straws (clear, 1in pieces) | 32 | 0 |
| Newspaper | 1 | 0 | Straws (bendy tip, striped, full size) | 16 | 0 |
| Nuts (metal hexagons) | 32 | 0 | Tape (rolls, masking or blue painter's) | 1 | 1 |
| Paper clips (regular size) | 64 | 0 | Tape (rolls, Scotch) | 4 | 4 |
| Paper towels (rolls) | 1 | 1 | Water (oz) | 40 | 0 |
| Pencils | 16 | 16 | Worksheets: Climbing Creatures | 16 | 0 |
| Pennies | 16 | 0 | Worksheets: Pre-Survey | any left | any new |
| Pipe cleaners (full size) | 16 | 0 | Yarn (5ft pieces) | 16 | 0 |
| Pipe cleaners (half-pieces) | 16 | 0 | | | |

**What goes home**: Tightrope Balancer, Climbing Creature & Cartesian Diver

*(Review safety guidelines with students: the water in the bottle is not for drinking; the water bottle cap should be screwed on tightly before taking the bottle home; small items should always be kept away from children ages 3 and younger to avoid the risk of choking)*

# Fun Physics: Forces & Motion (Grades 4-6)

## Class 3: Action/Reaction

| Supplies | # |
|---|---|
| Balloons (9in) * | 33 |
| Fishing line (ft) | 32 |
| Foam tubing (grooved track, 6ft pieces) | 4 |
| Marbles (small) | 20 |
| Pencils | 16 |
| Popsicle sticks (jumbo) | 16 |
| Scissors (site provides) | 16 |
| Stir sticks | 16 |
| Straw pieces (2in, "for axles") * | 32 |
| Straws (clear, full size) | 10 |
| Tape (rolls, masking or blue painter's) | 1 |
| Wheels (small, wooden) | 64 |

| | |
|---|---|
| Worksheets: Pre-Survey | any left |

### Prep (prior to class) Time: 15-30 Minutes

- **Act. 3 (OPTIONAL):** Cut sixteen 2in straw pieces ("for axles") in half. You'll make thirty-two 1in pieces.
- **Act. 4:** Cut eight straws in half.
- **Act. 5a:** Cut two straws in half.
- **Act. 5b (SUGGESTED):** Prepare the fishing line for balloon rockets (see Steps 2-4 in Activity 5.)

***Your kit contains an extra balloon and sixteen extra 2in straw pieces "for axles."** Please bring the extras to class in case they're needed.

### Activity One – Pair & Share Time: 10 Minutes

| Supplies | # | Supplies | # |
|---|---|---|---|
| Pencils | 16 | Worksheets: Survey Answers | 1 |
| Worksheets: Pre-Survey | 16 | Lab notebooks | 16 |

**Goal**: To engage students' thinking and questioning related to the day's activities.

**Procedure:**

1. Prepare a quiet space for students to give them a physical area to think. The space can be an area set aside from the activity area, where students sit in a circle to ponder the *Pair & Share* question.
2. Make lab notebooks and pencils available.
3. Ask students one or more *Pair & Share* questions:
    - ***Do you know what a reaction is?*** *(It's something that happens as result of something else.)*
    - ***Let's see if you can figure out what reactions happen as a result of these actions: throwing a basketball down at the floor*** *(the ball hits the floor and bounces back up);* ***blowing on a white dandelion*** *(the seeds fly into the air);* ***pushing a toy car*** *(the car rolls forward).*
    - ***Can you think of any other actions and reactions?***

4. Ask students to discuss their ideas with their neighbor before inviting students to share what they came up with. This is a "challenge by choice" opportunity and no one is required to share with the class if they are not comfortable.
5. After the discussion, **administer any remaining pre-surveys** to any students who haven't already been surveyed. Collect completed surveys.
6. **Submit the completed surveys to Site Manager/Coordinator.** These need to go to your Manager/Coordinator as soon as possible so they don't get lost. At the end of the term, you'll be submitting the students' post-surveys as well.

## Activity Two – Newton's Cradle

**Time: 5 Minutes**

| Supplies | # |
|---|---|
| Foam tubing (grooved track, 6ft pieces) | 4 |
| Marbles (small) | 20 |

**Goal:** To demonstrate that every action causes an equal and opposite reaction by knocking marbles into each other on a foam track.

**Source:** *The Science of Forces* by Steve Parker

**Survey Connection:**

★

**Q.** Fill in the blank: For every action, there is an equal and opposite ______________.

**A. Reaction.**

**Background:**

Newton's Third Law of Motion says: "For every action there is an equal and opposite reaction"—but what does that mean, exactly? You will demonstrate what it means in this activity! When your action is pulling one marble back and letting it go, the reaction is one marble shooting out the other side. When your action involves two marbles, so does the reaction! Each of your actions has an equal and opposite reaction.

This activity is such a good demonstration of Newton's Third Law that there's a standard version of it called "Newton's Cradle." The more common version features a row of metal balls that hang from thin wires. You can see one at OMSI or a science store! (*The Science of Forces*, Steve Parker)

**Procedure:**

1. Ask students: ***Do you think that for every action, like jumping, pushing, or rolling, there's an equal reaction? How can we test that?***
2. Put students in four groups.
3. Give each group a piece of foam track and three marbles.
4. Have one student make the foam track into a loop by crossing one end over the other with the groove on the inside. Hold the loop so the ends are crossed at the top, and the smooth part of the loop is resting on the table (see photo at left).
5. Have another student put three marbles in the groove at the bottom of the loop.
6. Have another student press one finger down on the center marble to hold it still.
7. Ask students: ***If we hold the center marble in place, what do you think will happen if we push one of the other marbles up the track then let it roll back down? Let's try it!***
8. Have the fourth student push one of the marbles almost midway up the side of the track, then release. Make sure the other student is still

Newton's Cradle. Have one student hold the foam track to form a loop.


Newton's Cradle. While one student holds the center marble still, have another student push marbles up one side of the track, then release them so they hit the center marble.

holding the center marble in place with their finger (see photo on next page).

Discussion Prompts:

- ***What happened?*** *(The center marble remained still, but the third marble rolled up the other side of the track!)*
- ***Can you control how far the third marble goes if you change the release point of the first marble? Try it!***

9. Have students switch roles (one person holding the track loop, one person holding the center marble, one person pushing and releasing the first marble, one person observing) and repeat the experiment. Students should vary the release point of the first marble and see a corresponding change in the third marble (e.g., the higher the release point on the first marble, the higher the third marble travels).
10. Ask students: ***What do you think will happen if we add one marble to each side (to make a row of five marbles)? Will we see the same effect?***

11. Give each group two more marbles. Have students place one new marble on each side of the original three marbles.
12. Ask students: ***If we push one marble up on one side and let it go, how many marbles do you think will shoot out from the other side? Try it!***

13. You may want to have students switch roles again and try the experiment. With one person still holding the central marble still, have another push one of the farthest marbles up the ramp then release it.

Discussion Prompts:

- ***How many marbles shot out of the other side?*** *(Only one!)*
- ***What do you think will happen if we send two marbles down to hit the center marble?***

14. You may want to have students switch roles and repeat the experiment, this time pushing two marbles up one side of the track and releasing them.

Discussion Prompt:

- ***What happens?*** *(Two marbles shoot up the other side!)*

15. Allow students to continue experimenting if they wish.
16. OPTIONAL: You can add two marbles from another group for a total of seven marbles on one track as a demonstration. Holding the central marble still, if you release three marbles from one side, three marbles will shoot out the other side.

## Activity Three – The Wheels on the Bus Go Time: 10 Minutes

| Supplies | # | Supplies | # |
|---|---|---|---|
| Scissors (site provides) | 16 | Tape (rolls, blue painter's) | 1 |
| Stir sticks | 16 | Tape (rolls, masking) | 1 |
| Straw pieces (2in, "for axles") | 16 | Wheels (small, wooden) | 64 |

**Goal**: To create an axle using a stir stick and wooden wheels.

**Source**: Hands on Science Outreach & Tyler Oshiro, AKA Science

**Survey Connection:**

**Q.** Fill in the blank: For every action, there is an equal and opposite _____________.
**A. Reaction.**

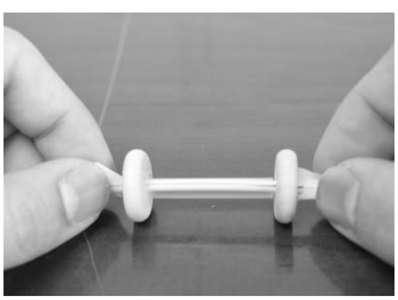
**Background:**

Trying to roll two wheels together is difficult when they're not connected! To make two wheels move at the same speed in the same direction, you joined them together with an axle. Axles connect two wheels together and can stabilize both of them.

There are two types of axles: "fixed axle" and "fixed wheel." In a fixed axle type, the axle stays still, and the wheels can turn freely around it. This is like the first part of the experiment, when you held the ends of the stir stick (the axle), and each wheel was able to turn. These types of axles can be found in smaller vehicles like skateboards! Each wheel on a skateboard turns on its own.

The other kind of axle is a "fixed wheel" axle. In a fixed wheel type, the wheels are attached to the axle and can't move on their own, so the entire axle has to turn inside of a space called a bearing. This is like the second part of the experiment, when the wheels were stuck to the stir stick (the axle) and you had to hold the clear piece of straw (the bearing) so the entire axle could turn inside it. These types of axles can be found in larger vehicles like cars. The wheels don't turn on their own—the axle turns, and the wheels attached to the axle turn with it.

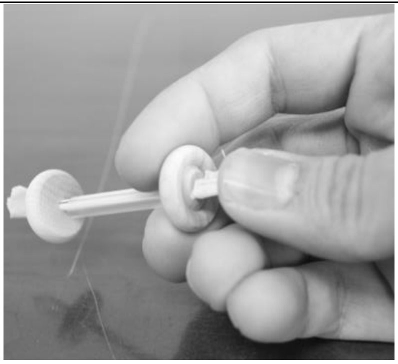
Almost anything you can think of with wheels has one or more axles—from wagons, to strollers, to roller skates, to cars! Although axles are definitely useful for helping multiple wheels move together, sometimes an axle is also needed when there's only one wheel to stabilize. For example, hamster wheels, Ferris Wheels, and windmills all have an axle in the center that they turn around. Even rolling pins and pinwheels turn on an axle! (Anthony, David A. (2007). The horse, the wheel, and language: how Bronze-Age riders from the Eurasian steppes shaped the modern world.)



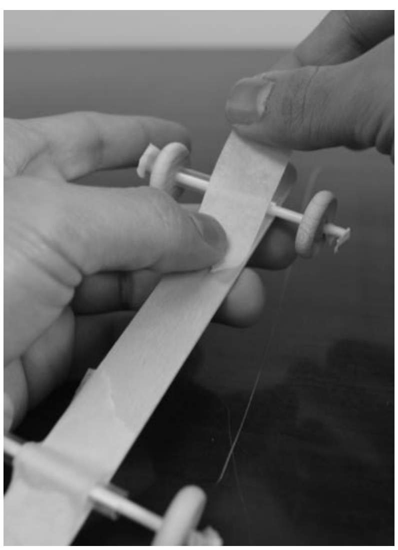
Wheels on the Bus Go. Hold the two ends of the stir stick to roll the wheels together.

**Procedure:**

1. Ask students: ***Think about the wheels on a car or bus. Are they connected or do they spin by themselves?*** *(They're usually connected.)* ***Why do you think they're connected?***


Wheels on the Bus Go. Push the wheels so they stick on the masking tape ends of the stir sticks.


Wheels on the Bus Go. Hold the wheels by the clear straw piece to roll the wheels in sync.


Balloon Racer. Tape the 1in straw pieces onto the jumbo popsicle stick to create a basic car.

2. Give each student a small wooden wheel.
3. <u>Ask students:</u> ***What happens if you roll a wheel across the table (or floor) by itself?***

4. Have students try rolling one of their wheels by giving it a gentle push.

   <u>Discussion Prompts:</u>
   - ***Did it roll smoothly?***
   - ***How long did it stay standing?*** *(Probably not very long.)*

5. Give each student another wooden wheel.
6. <u>Ask students:</u> ***How could you get these two wheels to work together? Can you make them go the same direction and speed if you roll them across the table (or floor)? Try it!***

7. Allow students to experiment with rolling the wheels side by side in the same direction, by giving each of them a gentle push at the same time.

   <u>Discussion Prompts:</u>
   - ***How well did the wheels stay in sync?*** *(Probably not very well.)*

8. <u>Ask students:</u> ***Do you think we could make the wheels work together better if we connect them? Let's try!***

9. Give each student a stir stick and a 2in piece of straw (or two 1in pieces of straw if you cut them as prep). Make scissors, masking tape, and painter's tape available (both types of tape work).
10. <u>Have students:</u>
    a. Cut the stir stick in half.
    b. Cut the 2in piece of straw in half to make two 1in pieces (if not prepped).
    c. Insert one half-piece of stir stick into one 1in piece of straw.
    d. Add a wheel to each end of the stir stick.
    e. Place a small piece of masking tape on each end of the stir stick to keep the wheels from falling off. Try to avoid getting tape on the wheels so they can still turn freely.

11. Have students hold the ends of the stir stick and try rolling the wheels forward (see top photo at left).
12. <u>Tell students:</u> ***The stir stick that connects the wheels is called an axle! An <u>axle</u> is a pole that goes through the center of one or more wheels. The axle stabilizes the wheels and helps them move together.***

13. <u>*Ask students:*</u> ***If we stick the wheels to the stir stick, will they still roll? Let's find out!***

14. Have students push the wheels outward along the stir stick so the masking tape forces them to stick in place (see middle photo at left). If the wheels still spin individually, add some tape from the stir stick onto each wheel to hold the wheel in place. The wheels should not turn freely after this step.
15. Ask students: ***How can you make the wheels move forward by holding the ends of the stir stick? What happens if you hold the middle of the clear straw and try rolling the wheels forward?***

16. Give students time to test these two different methods of rolling the wheels.

    Discussion Prompt:
    - ***What's the difference between holding the stir stick directly and holding the clear piece of straw around it?*** *(When you hold the stir stick directly, you have to roll it between your fingers to make the wheels go forward since the wheels can't turn by themselves. When you hold the clear piece of straw, you can just push the straw forward—the stir stick can turn in the space inside the clear straw, and the wheels move along with it.)*

17. Give each student two more wheels.
18. Have students use the other half-piece of stir stick and the other 1in piece of straw to create another set of wheels on an axle.

## Activity Four — Balloon Racer — Time: 20 Minutes

| Supplies | # | Supplies | # |
|---|---|---|---|
| Balloons (9in) | 16 | Straws (clear, full size) | 8 |
| Popsicle sticks (jumbo) | 16 | Tape (rolls, blue painter's) | 1 |
| Scissors (site provides) | 16 | Tape (rolls, masking) | 1 |
| Stir sticks* | 16 | Wheels (small, wooden) * | 64 |
| Straw pieces (2in, "for axles")* | 16 | | |

***Each student should have already created 2 axles with wheels in the previous activity.**

**Goal**: To demonstrate that every action causes an equal and opposite reaction by building a small balloon-powered vehicle.

**Source**: https://bit.ly/3HFgAQF

**Survey Connection:**

**Q.** Fill in the blank: For every action, there is an equal and opposite _____________.

**A. Reaction.**

**Background:**

Remember, Newton's Third Law says: "For every action, there is an equal and opposite reaction!" So, what's the action and what's the reaction here? Let's think about the first ACTION that allowed the balloon racer to have power: blowing up its balloon engine! We shoved air into a stretchy space (the balloon) so that the balloon was pressing on the air inside it. Then, when we allowed the air to escape, it forced its way through the opening that aimed out the back of the racer. The REACTION was the racer shooting forward away from the forceful, escaping air!

Since every action-reaction pair has to be equal, you might have noticed that blowing up the balloon a lot resulted in a longer ride and blowing up the balloon just a little resulted in a shorter ride. The REACTION of the air escaping was equal to the ACTION of you forcing the air inside!

Do you think real racecars could be powered by balloons? Probably not—they're too heavy! Instead, they turn fuel into energy that moves the car forward. We'll learn more about energy in a later class. (https://bit.ly/3HFgAQF)

**Procedure:**

1. Ask students: ***We've learned about axles and wheels. How can we use them to create a self-powered vehicle? Let's find out!***

2. Have students retrieve their axles with wheels from the previous activity. (Each axle is a half-piece of stir stick inside a clear 1in straw piece with a wheel on each end, and each student should have two axles.)
3. Give each student a jumbo popsicle stick and a pencil. Make scissors, masking tape and painter's tape available (both types of tape work).
4. Have students write their name on their popsicle stick.
5. Have students tape their axles to the jumbo popsicle stick. Tape each clear straw piece perpendicular to the popsicle stick, close to one end of the stick (see top photo at left).
6. Flip the popsicle stick over so the axles are underneath the stick.

   Discussion Prompts:
   - ***What did you just build?*** *(A car!)*
   - ***You can push your car to make it roll, but is there a way to get the car to move by itself?***
   - ***Do you think we could use air power? Let's try!***

7. Give each student a balloon and a half-straw piece (from prep).
8. Have students:
   a. Cut the stiff ring of the balloon neck off.
   b. Insert the tip of the half-straw piece into the neck of the balloon.
   c. Tape the neck of the balloon around the end of the half-straw piece. Make sure the seal is snug (see bottom photo at left).

Balloon Racer. Tape the balloon neck around a half piece of straw.

Balloon Racer. Blow up the balloon through the straw, then place a finger over the straw opening to keep the balloon inflated. Release to watch the racer go!

d. Tape the half-straw piece along one flat side of the popsicle stick, on the side opposite the wheels. The open end of the straw should hang slightly off the back of the car, and the balloon should rest near the middle of the popsicle stick.

9. <u>Ask students:</u> ***If we blow up the balloon and then let the air out, which way will the car move? Will it go toward the opening of the straw, or toward the back of the balloon? Let's make a hypothesis (best guess that we will then test.)***

10. Have students blow the balloon up through the straw, then pinch the straw shut. The racer works best if the balloon is only inflated to about the size of two fists (see photo at left).
11. Have the class set their cars down on a smooth surface and watch them go!

<u>Discussion Prompts:</u>
- ***Was your hypothesis correct?***
- ***What happened?*** *(The car became a balloon-powered racer! It moved in the opposite direction of the air coming out of the end of the straw.)*
- ***Why?*** *(Newton's Third Law! For every action, there is an equal and opposite reaction.)*

12. Allow students to experiment with more or less air in the balloon. Is the reaction always equal to the action? (Yes!)

## Activity Five – Balloon Rocket — Time: 15 Minutes

| Supplies | # | Supplies | # |
|---|---|---|---|
| Balloons (9in) | 16 | Scissors (site provides) | 1 |
| Fishing line (ft) | 32 | Tape (rolls, blue painter's) | 1 |
| Straws (clear, full size) | 2 | | |

**<u>Goal</u>**: To observe an action/reaction sequence by making a balloon-and-straw "rocket" travel along a piece of fishing line.

**<u>Source</u>**: *Physics for Every Kid* by Janice Van Cleave

**<u>Survey Connection:</u>**

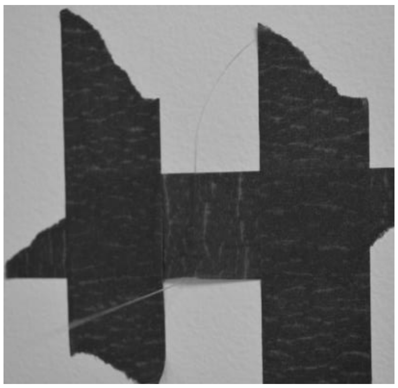
★ **Q.** <u>Fill in the blank</u>: For every action, there is an equal and opposite ______________.
**A. Reaction.**

**<u>Background:</u>**
Just like the balloon racers, balloon rockets work because of Newton's Third Law. As you may have guessed, the action and the reaction in this

activity are similar to the balloon racer. The only difference is that this time, the balloon zooms forward on a line instead of pushing a car on wheels.

Which balloon vehicle seemed more powerful to you? If the rocket seemed more powerful, then it's most likely because of 2 factors: 1) the rocket straw moving against the fishing line encountered less friction than the racer wheels moving against the desk or floor, and 2) the rocket had less weight to move than the racer (just the straw versus the wheels and axles on the popsicle stick).

Did you know that octopi move like balloons? Since an octopus lives in the ocean, it uses jet propulsion—taking in water then shooting it backwards—to move itself forward, just like you did with your balloon! Other animals that use jet propulsion: squid, cuttlefish, and dragonfly nymphs! http://bit.ly/41XwdfF, https://bit.ly/3lc4BeM



Balloon Rocket. Place one piece of painter's tape perpendicular to the fishing line. Place two pieces of tape parallel to the line (one on each side of the line).

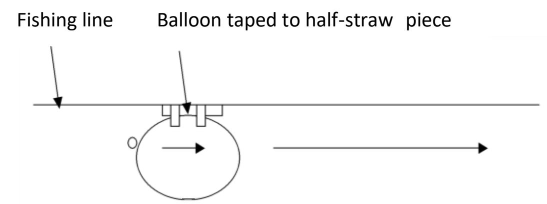
Balloon Rocket. Attach the balloon to the half-straw piece on the fishing line with two pieces of painter's tape. Pinch the balloon neck shut until you're ready to let the balloon rocket fly along the fishing line.

**Procedure:**

******* Steps 2-4 are suggested as prep for the Class Leader to prepare the fishing line:

1. Ask students: ***In the previous activity, you built a car that was powered by a balloon. It worked because every action causes an equal and opposite reaction. Can we use that same idea to make a different rocket-powered vehicle? Let's try!***
2. *** Unravel the 32ft fishing line gently (so it doesn't get knotted).
3. *** Cut the fishing line so you can string several pieces taut across your space, parallel to the ground. You can make four 8ft pieces *or* two 16ft pieces. *(Note: the longer the fishing line, the harder it will be to keep taut.)*
4. *** For each line:
   a. Thread a half-straw piece onto the line.
   b. Tape the ends of the line to vertical surfaces so the line is fairly taut.
      - Smooth, unpainted surfaces are ideal. In a pinch, you can string the line between desks, have two students hold the line stretched between them, or tape one end and hold the other.
      - To secure each end, place a piece of painter's tape perpendicular to the length of the line, then add two pieces of tape parallel to the line on both sides of the first piece of tape (see top photo).
   c. Place two pieces of painter's tape onto each half-straw piece. The pieces of tape should be perpendicular to the straw, with the sticky side facing down and the ends of the tape hanging loose off the piece of straw. These will stay on the straw for repeated uses (see bottom photo at left).
5. Ask students: ***How do you think we could get a balloon to move on this contraption?***

6. Give each student a balloon.
7. Have students blow up the balloon and DON'T TIE IT. Instead, twist the neck and pinch it shut to make sure the air can't escape.




8. For each piece of fishing line, make sure the half-straw piece with tape is near one of the ends of the line.
9. Have the first student(s) tape the body of their inflated balloon to the underside of the straw on the line (you may want to be in charge of this step). The balloon should be parallel to the line, with its neck pointed toward the closest endpoint.
10. Ask students: ***This activity will let us see action and reaction in a controlled way. What do you think will happen when you let go of the balloon? Let's find out!***

11. Have students let go of the balloon (see diagram above and bottom photo at left).
12. Allow students to repeat the experiment until every student gets a turn (the length of time will depend on number of lines set up). You can also allow students to turn their balloons around and see if they work in the opposite direction.

    Discussion Prompt:
    - ***So what was the action, and what was the equal and opposite reaction?*** *(Action: when we released the neck of the balloon, the sides of the balloon pushed the air out of the balloon. Reaction: the air inside the balloon also pushed back against the balloon, with equal force in the opposite direction, which made the balloon move.)*

## Activity Six – Daily Debrief — Time: 5 Minutes

| Supplies | # |
|---|---|
| Worksheets: Take-Home Supplies Advisory (half-sheet) | any left |
| Lab Notebooks | 16 |
| Pencils | 16 |

**Goal:** To draw today's activities together through a thoughtful question and give students an opportunity to ask their own questions.

**Procedure:**
1. Encourage students to reflect on what they learned in today's class and what new questions they might have.

2. Allow students a few seconds to think. Have them discuss their thoughts and questions with a partner, then share with the rest of the class and/or write down in their lab notebook.
3. If needed, feel free to offer prompts like:
   - ***What do you think would happen if we changed one thing about today's activities (for example: materials, speed, temperature, etc.)?***
   - ***If you could investigate (explore) one more thing about today's activities, what would you like to find out?***

4. If time allows, ask the following question:
   - ***Can you think of some other ways we use air as a source of Power?*** *(Windmills for mechanical power, wind turbines for electrical power, sailboats, blowing out birthday candles, etc.)*

**Clean up**: Make sure students help clean the room before they leave.

**What to save**:

| Materials used | # | SAVE | Materials used | # | SAVE |
|---|---|---|---|---|---|
| Balloons (9in) | 33 | 0 | Stir sticks | 16 | 0 |
| Fishing line (ft) | 32 | 32 | Straw pieces (2in, "for axles") | 32 | 0 |
| Foam tubing (grooved track, 6ft pieces) | 4 | 4 | Straws (clear, full size) | 10 | 0 |
| Marbles (small) | 20 | 20 | Tape (rolls, blue painter's) | 1 | 1 |
| Pencils | 16 | 16 | Tape (rolls, masking) | 1 | 1 |
| Popsicle sticks (jumbo) | 16 | 0 | Wheels (small, wooden) | 64 | 0 |
| Scissors (site provides) | 16 | 16 | Worksheets: Pre-Survey | any left | any new |

**What goes home**: Balloon Racer

*(Review safety guidelines with students: balloons and small items should always be kept away from children ages 3 and younger to avoid the risk of choking)*

# Fun Physics: Forces & Motion (Grades 4-6)

## Class 4: Electricity!

| Supplies | # |
|---|---|
| Batteries (AA, 1.5-volt)* | 9 |
| Foil sheets (large rectangles)* | 16 |
| Foil squares (2inx2in)* | 16 |
| Light bulbs (small, 1.5-volt)* | 8 |
| Paper clips (regular size) | 16 |
| Pencil lead (thin pieces)* | 24 |
| Pencils | 16 |
| Pennies | 16 |
| Rubber bands (size 33) | 16 |
| Scissors (site provides) | 8 |
| Tape (rolls, black electrical) | 1 |
| Tape (rolls, blue painter's) | 1 |
| Tape (rolls, masking) | 1 |
| Tape (rolls, Scotch) | 4 |
| Wire (insulated with stripped ends, 1ft pieces) | 8 |

| | |
|---|---|
| Worksheets: Circuit Game (printed on cardstock) | 16 |

**GENERAL NOTE: This class isn't designed to have a take-home item.**

**You have 2 options:**

- You can emphasize that today's activities provide a cool in-class experience (using electricity!), but for safety reasons, students will have to wait until the next class to receive a take-home item.
- You can swap one of the electricity activities with a different activity from another class that includes a take-home item (for instance, an activity from Class 2, "Pendulum Drop" from Class 6, or "Rolling on the River" from Class 8).

## Prep (prior to class)

- None

***Your kit contains one extra battery & eight extra pieces each of foil squares, foil sheets, and pencil lead.** Please bring the extras to class in case they're needed.

## Activity One – Pair & Share Time: 10 Minutes

| Supplies | # | Supplies | # |
|---|---|---|---|
| Pencils | 16 | Lab notebooks | 16 |

**Goal**: To engage students' thinking and questioning related to the day's activities.

**Procedure**:

1. Prepare a quiet space for students to give them a physical area to think. The space can be an area set aside from the activity area, where students sit in a circle to ponder the *Pair & Share* question.
2. Make lab notebooks and pencils available.
3. Ask students one or more *Pair & Share* questions:
   - ***Look around the room – how many things can you name that use electricity?"*** *(Lights, computer, overhead projector, etc.)*
4. Ask students to discuss their ideas with their neighbor before inviting students to share what they came up with. This is a "challenge by choice" opportunity and no one is required to share with the class if they are not comfortable.

## Activity Two — Circuit Flashlight Time: 15 Minutes

| Supplies | # | Supplies | # |
|---|---|---|---|
| Batteries (AA or C, 1.5-volt) | 8 | Scissors (site provides) | 8 |
| Light bulbs (small, 1.5-volt) | 8 | Tape (black electrical, roll) | 1 |
| Pencils | 8 | Wire (insulated with stripped ends, 1ft pieces) | 8 |

**<u>Goal</u>**: To create a simple circuit using an AA battery, wire, and a small light bulb.

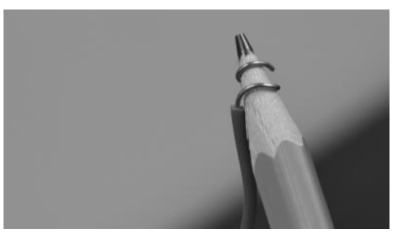
**<u>Source</u>**: *101 Great Science Experiments* by Neil Ardley

**<u>Background:</u>**

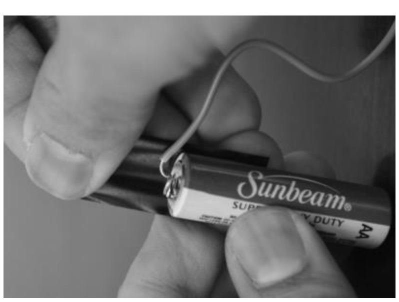
What makes it possible for you to turn a light bulb on? Electricity is a form of energy created by tiny, charged particles called electrons. When the electrons move, they create an electric current. For an electric current to flow, there has to be a loop that connects all the pieces—called a <u>circuit</u>. In a complete circuit, the end meets the beginning without interruptions.

In your experiment, the electric current will begin at the flat (-) end of the battery, flow through the wire into the metal grooves of the light bulb, then out the bottom of the bulb and into the (+) nub of the battery. If any of these parts aren't touching, the circuit isn't complete, and the current of electricity won't flow!

Did you know there's an animal that can produce electricity like a battery? Electric eels can produce a lot of electricity (up to 500 volts!) and they use this ability for hunting and self-defense. https://bit.ly/3ZVTa0M, https://bit.ly/3myFQkx.



Circuit Flashlight. Wrap one end of the wire around a pencil tip to make a small coil




**<u>Procedure</u>:**

1. <u>Ask students:</u> ***Light bulbs turn on when you flip a switch, but do you know what makes them work? Let's find out!***

2. Pair students. Give each pair one AA battery, a 1ft piece of wire, a pencil, and a small light bulb. Make scissors and electrical tape available.
3. Have pairs use the wrap one end of the wire around a pencil tip to create a small spiral spring (see photo at far left).
4. Place the wire spring against the flat (-) end of the battery (see left photo below).
5. Have pairs help each other use electrical tape to secure the wire spring onto the flat (-) end of the battery.

**<u>TIPS</u>:**
- **To use the electrical tape effectively, <u>stretch it out</u> as you tape it down:**
  - Start by attaching one end of the tape to the side of the battery.
  - Pull the other end of the tape tight over the area where the wire spring meets the flat (-) side of the battery.
  - Attach the tape to the other side of the battery.

Circuit Flashlight. One end of the wire is taped to the flat (-) end of the battery, and the other end is wrapped around the grooves at the base of the light bulb. You're ready to complete the circuit!


Circuit Flashlight. Holding the wire securely around the base of the light bulb, touch the bottom of the bulb to the (+) nub of the battery.

6. <u>Ask students:</u> ***How can we use the battery and the wire to turn on the light bulb? Will it work if we connect the light bulb directly to the (+) nub of the battery? Try it!***

7. Have pairs student touch the base of the light bulb to the (+) nub of the battery.
8. <u>Ask students:</u> ***Did it work?*** *(No.)* ***What if we connect the light bulb to the free end of the wire, without doing anything else? Try it!***

9. Have pairs wrap the free end of the wire around the grooves at the base of the light bulb, but don't do anything else.
10. <u>Ask students:</u> ***Did it work?*** *(No.)* ***Electricity flows like water. A battery needs a connected loop, called a circuit, to release a flow of electricity that will turn the light bulb on. How can we create a connected loop with the materials we have?***

11. Have pairs wrap the free end of the wire around the base of the light bulb. Make sure the wire doesn't touch the silver circle at the bottom of the bulb.
12. Have pairs pinch the wrapped wire against the base of the bulb to secure it in place (see top photo at left).
13. <u>Ask students:</u> ***What do you think will happen if you touch the bottom of the light bulb (attached to the wire) to the (+) nub of the battery? Try it!***

14. Have one student in each pair hold the battery with the (+) nub exposed. Have the other student pinch the wire around the base of the bulb, then touch the bottom of the bulb to the (+) nub of the battery (see bottom photo at left).

    <u>Discussion Prompt:</u>
    - ***What happened?*** *(The light bulb turned on!)*

**<u>WARNING</u>: Tell students they should never connect a wire directly from one end of a battery to the other end of the battery.** (The battery can overheat.)

**<u>WARNING</u>: Don't allow students to hold the light bulb in contact with the battery for more than 20 seconds at a time.** (The wire will gradually heat up.)
If desired, you can help students use electrical tape to tape the wire onto the light bulb so students aren't touching the wire directly. If you do this, you'll need to make sure the tape <u>only</u> touches the silver metal grooves, <u>not</u> the bottom of the bulb, or the light bulb won't work.

15. Have students in each pair switch roles. If students are having trouble getting their light bulb to turn on, make sure one end of the wire is taped securely to the flat (-) end of the battery and the other end of the wire is wrapped securely around the grooves at the base of the light bulb.

Discussion Prompts:

- ***What happens when the light bulb with the wire wrapped around it isn't touching the battery?*** *(The light bulb turns off.)*
- ***Why?***

16. Tell students: ***The circuit needs to be complete for electricity to flow from the battery. Touching the bulb to the battery completes that circuit, allowing electricity to flow through the wire to turn the light bulb on!***

17. Keep the wire attached to the battery and light bulb for the next activity.

## Activity Three – Conductors & Resistors Time: 10 Minutes

| Supplies | # | Supplies | # |
|---|---|---|---|
| Batteries (AA, 1.5-volt) | 8 | Rubber bands (size 33) | 16 |
| Foil squares (2inx2in) | 8 | Scissors (site provides) | 8 |
| Light bulbs (small, 1.5-volt) | 8 | Tape (rolls, black electrical) | 1 |
| Paper clips (regular size) | 16 | Tape (rolls, blue painter's) | 1 |
| Pencils | 16 | Tape (rolls, masking) | 1 |
| Pennies | 16 | Wire (insulated with stripped ends, 1ft pieces) | 8 |

**Goal:** To compare objects that can and cannot complete an electrical circuit using common household conductors and insulators.

**Source:** *Physics for Kids: 49 Easy Experiments with Electricity and Magnets*, Robert W. Wood

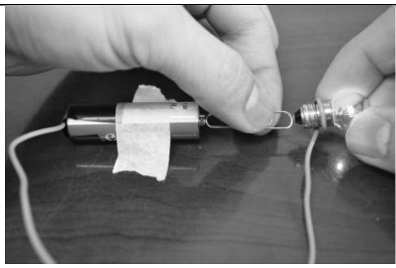
**Background:**

You are learning that metal objects can complete a circuit and turn on a light bulb. Electricity travels in a flow of charge known as an electrical current. "Conductors" like metal let that charge flow through them. They conduct the electricity from one point to another. "Insulators" like rubber and wood stop the flow.

Conductors and insulators are really important for keeping you safe when you work with electricity! One important conductor is a lightning rod. A lightning rod is a metal rod placed at the top of a building. The rod is connected by a wire that goes all the way to the ground. When lightning hits the rod, the electricity flows through the conductor and safely into the earth, instead of hitting the building. One important insulator is rubber. Electricians will often use rubber gloves and shoes to avoid getting accidentally shocked! https://bit.ly/3ZYSgRr

**Procedure:**

1. Ask students: ***In the last activity, we learned that a circuit needs to be complete to release the electricity in a battery and turn on a light***



Conductors & Resistors. Place the test object—in this case, a paper clip—between the (+) nub of the battery and the bottom of the light bulb. The battery should be taped to the table. One end of the wire should be taped to the flat (-) end of the battery, and the other should be wrapped around the base of the bulb. Touch the test object to the (+) nub of the battery and the bottom of the light bulb to complete the circuit.

***bulb. We saw how a wire can complete a circuit, but are there other things that can complete a circuit? Let's find out!***

2. Keep students in pairs. Make sure pairs still have their battery with the wire and light bulb attached (from the previous activity). Keep the electrical tape on hand in case students need to reattach their wire to the battery.
3. Have students tape their battery to the table so the flat (-) end is on the left and the (+) nub is on the right.
4. Make sure one end of the wire is still taped securely to the flat (-) end of the battery, and the other end is wrapped securely around the base of the light bulb.
5. Give each pair a foil square, a paper clip, a pencil, a penny, and a rubber band. Make masking and painter's tape available for the next steps (both types will work).
6. Have students create a hypothesis (a prediction or best guess about what will happen) about which of these objects will complete the circuit. Explain that ***scientists make hypotheses to help them test things intentionally and observe results accurately.***

7. Have pairs try adding different items to the circuit. To do this, have one student hold the test object so it touches the exposed nub (+) of the battery. Have the other student hold the light bulb so the bottom of the bulb that would normally touch the (+) nub of the battery touches the object instead. This creates a complete circuit (see photo at left).

> **WARNING: Sometimes a question comes up about connecting two batteries as part of a single circuit.** However, this would create a risk of the light bulb exploding because the bulbs are designed for 1.5 volts and a single battery is already 1.5 volts. **Please use only one battery per circuit.**

8. Allow pairs to test the foil square, the paper clip, the pencil, the penny, and the rubber band. If time allows, students can also test other objects from the kit or other items they have with them.

   Discussion Prompt:
   - ***Which objects completed the circuit?*** *(The foil square, the paper clip, and the penny.)*
   - ***Did you notice anything they have in common?*** *(They're all metal objects.)*
   - ***Why do you think that is?***

9. Tell students: ***Electricity flows when electrons—tiny little charged particles—move along a material. There are some materials through which electrons can travel more freely than others. These materials are considered good "conductors" of electricity. The opposite of a conductor is an insulator, such as the rubber band and wood of the pencil. However, you may have noticed that the metal part of the pencil near the eraser will conduct electricity!***

10. Have students detach the battery from the table. Keep the wire attached to the battery and light bulb and keep the foil square handy for the next activity.

## Activity Four – Pencil Lead Dimmer    Time: 5 Minutes

| Supplies | # | Supplies | # |
|---|---|---|---|
| Batteries (AA, 1.5-volt) | 8 | Tape (rolls, black electrical) | 1 |
| Light bulbs (small, 1.5-volt) | 8 | Tape (rolls, Scotch) | 4 |
| Pencil lead (thin pieces) | 24 | Wire (insulated with stripped ends, 1ft pieces) | 8 |
| Scissors (site provides) | 8 | | |

**Goal:** To learn that some objects can be both conductors and insulators by using a piece of pencil lead as a "dimmer switch."

**Source:** *Physics for Kids: 49 Easy Experiments with Electricity and Magnets*, Robert W. Wood

**Background:**

Some materials are conductors, others are insulators—and as you just learned, some are both! Pencil lead is made up of graphite, which scientists call "a variable resistor." Graphite *varies* in how much it *resists* the flow of electricity! The more graphite an electrical current has to pass through, the less current actually gets through. As the light bulb receives less current, the light gets dimmer.

Actual "light dimmers" are also called "rheostats." They use the same principle as the pencil lead to change the amount of current that flows to a light bulb. That makes it possible to change the brightness of a room with a dimmer switch, just like you did in your experiment! https://bit.ly/3mE1vYG

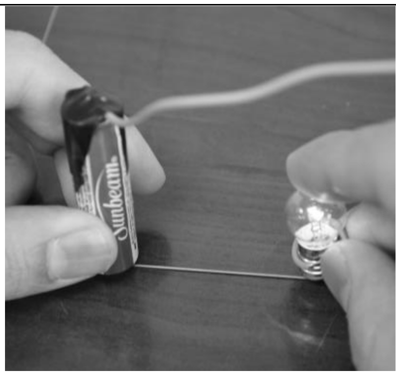
**Procedure:**

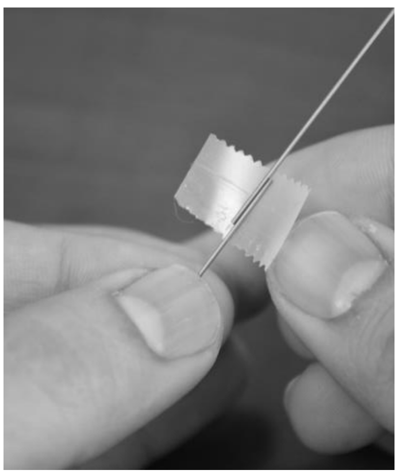
****Note:** If you're running short on time, you may want to do this activity as a demonstration.

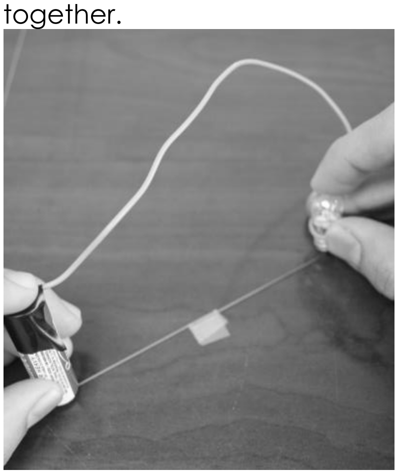
Pencil Lead Dimmer. Detach the wire spring from the flat (-) end of the battery and tape it to the (+) nub of the battery. The flat (-) end of the battery will be left exposed.

1. Tell students: ***You've learned the difference between a conductor (which allows electricity to flow through it), and an insulator (which blocks electricity). Let's see if you can guess whether an object you haven't tested yet is a conductor or an insulator.***

2. Keep students in pairs. Make sure pairs still have their battery with one end of the wire taped to the flat (-) end of the battery, and the other end of the wire wrapped around the grooves in the light bulb base. Make electrical tape available.
3. Have students detach the wire from the (-) flat side of the battery and tape it to the (+) nub of the battery (see top photo at left).
4. Give each pair one piece of pencil lead (the type found in a mechanical pencil).


Pencil Lead Dimmer. With the flat (-) end of the battery resting on one end of the lead, touch the base of the light bulb to different sections on the lead.


Pencil Lead Dimmer. Overlap the ends of the two pieces of lead and tape them together.


Pencil Lead Dimmer. Repeat the activity with the taped-together, double-length piece of lead.

5. Ask students: ***Do you think this pencil lead will be a conductor or an insulator? Let's test it!***

6. Have students form a hypothesis before they start testing.
7. Have pairs lay the piece of pencil lead on the table. Have one student hold the battery upright (with the wire coming off the top) and gently place the (-) flat end of the battery on top of one end of the piece of lead.
8. Ask students: ***What do you think will happen if you touch the bottom of the light bulb to the part of the lead that's closest to the battery? Let's make a hypothesis!***

9. While one student holds the battery upright on the lead, have the other student pinch the wire around base of the light bulb and touch the bottom of the bulb to the section of lead closest to the bottom of the battery. The lightbulb should turn on.
10. Ask students: ***What do you think will happen if you touch the bulb to a part of the lead farther from the battery?***

11. Have students pinch the base of the bulb and touch the bottom of the light bulb to the middle of the section of lead (see bottom photo at left).
12. Repeat for the section of lead farthest from the battery.

    Discussion Prompts:
    - ***What happens?*** *(The light bulb is brightest when touched to the section of lead closest to the battery. When touched to the far end of the lead, it still turns on, but it's less bright.)*
    - ***Why?***

13. Tell students: ***The lead is between a conductor and insulator! It conducts well when the electricity only has to travel through a small part of it but conducts poorly when the it has to travel farther.***

14. Ask students: ***What will happen if we make the piece of lead even longer? Let's try it!***

15. Give each pair another piece of lead. Make Scotch tape available.
16. Have pairs gently connect the two pieces of lead with Scotch tape. The best method is to slightly overlap the ends of the pieces of lead on a piece of tape, then fold the tape tightly around the connection. Make sure the two overlapped pieces of lead are touching within the taped section (see photo at left).
17. Have students repeat the activity with the new, double-length piece of lead (see bottom photo at left).

    Discussion Prompt:
    - ***What happens?*** *(The bulb dims even further along the longer section of lead.)*

## Activity Five – Circuit Game Show  Time: 20 Minutes

| Supplies | # | Supplies | # |
|---|---|---|---|
| Batteries (AA, 1.5-volt) | 8 | Scissors (site provides) | 8 |
| Foil sheets (large rectangles) | 8 | Tape (rolls, black electrical) | 1 |
| Foil squares (2inx2in) | 8 | Tape (rolls, Scotch) | 4 |
| Light bulbs (small, 1.5-volt) | 8 | Wire (insulated with stripped ends, 1ft pieces) | 8 |
| Pencils | 16 | Worksheets: Circuit Game (printed on cardstock) | 8 |

**Goal**: To explore an application of an electrical circuit by creating a paper and foil game show card.

**Source**: Nicole Howe, AKA Science

**Background:**

As you learned in the conductors and resistors activity, aluminum foil is a conductor of electricity! That means an electrical current can flow through it. In your circuit game, you will create one complete circuit and one incomplete circuit! The top patch of foil makes a complete circuit with the battery when you touch the light bulb to it, which causes the light bulb to turn on. The bottom patch of foil (from the 2inx2in square) isn't touching any other conductors or even the battery, so it can't allow electricity to flow!

Real switches like game show buzzers and light switches use this same principle. Flipping the switch or hitting the buzzer completes the circuit. Until the circuit is complete, the light bulb won't turn on and the buzzer won't buzz! http://bit.ly/3JpKCKk

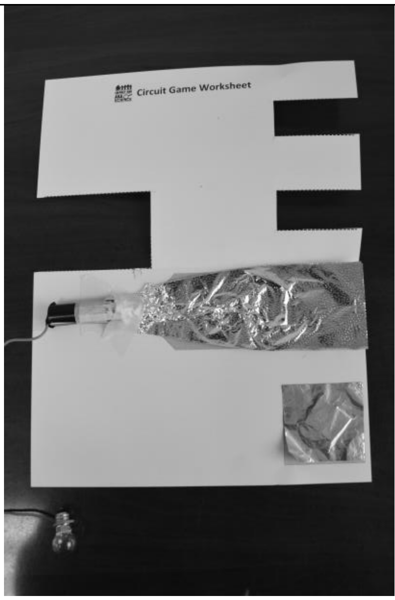
**Procedure**:

1. Ask students: ***How could we use what we learned about circuits to make a game?***

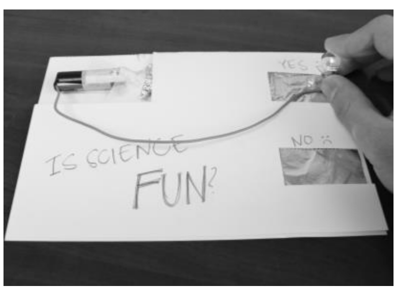
2. Keep students in pairs. Make sure pairs still have their 2inx2in square of foil. Also, make sure they still have their battery with one end of the wire taped to the flat (-) end of the battery, and the other end of the wire wrapped around the grooves in the light bulb base.

   Alternative to working in pairs: each kit comes with enough materials for each student to make their own Circuit Game, but they will have to share the green wires. You can have all students build their own games and share wires between pairs to test the games.

3. Give each pair a Circuit Game worksheet and a rectangular sheet of foil. Make scissors, Scotch tape, and pencils available. Keep electrical tape on hand.
4. Have pairs:

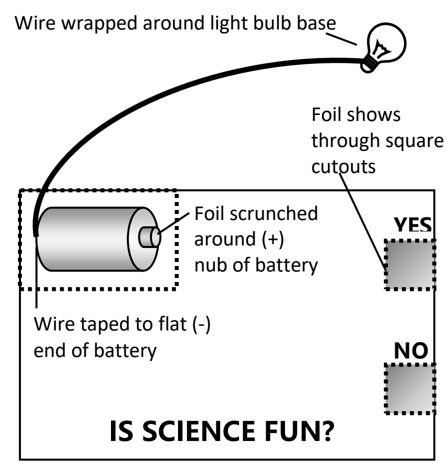



Circuit Game Show. This image shows the worksheet with the rectangles cut out and the battery and foil pieces taped in place. The left side of the long piece of foil is scrunched and taped around the (+) nub of the battery.




Circuit Game Show. Fold the worksheet in half and touch the bottom of the light bulb to each of the two exposed pieces of foil. The light bulb should turn on when it comes in contact with the top patch of foil (labeled Yes or True).

a. Cut out the three rectangles with dotted lines labeled "Cut out from edge of page." Each rectangle should be cut from the edge of the cardstock.
b. Fold the worksheet in half hamburger-style (bring the short top and bottom edges together) with the diagram inside. Unfold the worksheet.
c. Tape the battery to the section labeled "Tape Battery Here." The (+) nub should be facing inward (per the diagram on the worksheet).
d. Tape the foil square to the section labeled "Tape **2"x2"** Foil Here."
e. Fold the long rectangular foil sheet in half hot dog-style (bringing the long edges together). Lay it on the section labeled "Tape Foil Here," starting from the right edge of the worksheet. Trim the left side of the foil in line with the middle of the battery. Tape the foil to the worksheet. (The foil should cover the entire gray section of the worksheet, from the right edge of the worksheet to the battery, *leaving extra foil near the battery*.)
f. Scrunch the extra foil that's next to the battery around the (+) nub of the battery. Press the foil firmly so it stays on securely.
g. Tape the foil around the (+) nub of the battery (top photo at left).
h. Make sure the 2inx2in square of foil and the long rectangle of foil aren't touching.
i. Fold the worksheet in half along the crease you made previously. The only things that should be visible after folding are the battery and two patches of foil.




Top of the completed game (folded over the bottom half, where the battery & foil are taped)

j. Write a Yes/No or True/False question to the left of the foil and below the battery (see diagram above). Write the correct answer (Yes/True) above the top patch of foil. Write the wrong answer (No/False) above the bottom patch of foil.
k. To test the game, touch the bottom of the light bulb to each patch of foil. The light bulb should turn on when it comes in contact with the top patch of foil (labeled Yes or True—see bottom photo at left).

l. Have pairs try each other's games. If possible, ask someone who isn't part of the class to try the students' games (since they won't know the top patch of foil always makes the light turn on).

| | |
|---|---|
| **TIP:** | • If the light bulb doesn't light up when it touches the Yes/True patch of foil, help students attach the wire and foil more securely to the battery, and make sure the wire is wrapped securely around the light bulb base. |

Discussion Prompts:

- ***What happens when you touch the light bulb to the top (Yes/True) patch of foil?*** *(You complete the circuit of electricity from the battery, through the wire, through the light bulb, along the long piece of foil, and back to the battery. Completing the circuit makes the light bulb turn on.)*
- ***What happens when you touch the light bulb to the bottom (No/False) patch of foil?*** *(Nothing happens because the circuit isn't complete.)*

5. Have students detach the battery from the Circuit Game worksheet.

## Activity Six – Daily Debrief    Time: 5 Minutes

| Supplies | # |
|---|---|
| Worksheets: Take-Home Supplies Advisory (half-sheet) | any left |
| Lab Notebooks | 16 |
| Pencils | 16 |

**Goal:** To draw today's activities together through a thoughtful question and give students an opportunity to ask their own questions.

**Procedure:**

1. Encourage students to reflect on what they learned in today's class and what new questions they might have.
2. Allow students a few seconds to think. Have them discuss their thoughts and questions with a partner, then share with the rest of the class and/or write down in their lab notebook.
3. If needed, feel free to offer prompts like:
   - ***What do you think would happen if we changed one thing about today's activities (for example: materials, speed, temperature, etc.)?***
   - ***If you could investigate (explore) one more thing about today's activities, what would you like to find out?***
4. If time allows, ask the following question:
   - ***If you could invent a device that uses electricity, what would you invent?***

**Clean up**: Make sure students help clean the room before they leave.

**What to save**:

| Materials used | # | SAVE | Materials used | # | SAVE |
|---|---|---|---|---|---|
| Batteries (AA, 1.5-volt) | 9 | 9 | Scissors (site provides) | 8 | 8 |
| Foil sheets (large rectangles) | 16 | 0 | Tape (rolls, black electrical) | 1 | 1 |
| Foil squares (2inx2in) | 16 | 0 | Tape (rolls, blue painter's) | 1 | 1 |
| Light bulbs (small, 1.5-volt) | 9 | 9 | Tape (rolls, masking) | 1 | 1 |
| Paper clips (regular size) | 16 | 16 | Tape (rolls, Scotch) | 4 | 4 |
| Pencils | 16 | 16 | Wire (insulated with stripped ends, 1ft pieces) | 8 | 8 |
| Pencil lead (thin pieces) | 24 | 0 | Worksheets: Circuit Game (printed on cardstock) | 16 | 0 |
| Pennies | 16 | 16 | Worksheets: Pre-Survey | any left | any new |
| Rubber bands (size 33) | 16 | 16 | | | |

**What goes home**: Nothing*

***If you had every student complete a Circuit Game, those worksheets can go home without the battery, light bulb, and wire.***

# Fun Physics: Forces & Motion (Grades 4-6)

## Class 5: Energy Racers

| Supplies | # |
|---|---|
| Beads (plastic, pony) | 16 |
| Beads (wood, large center hole) | 8 |
| Crayons (box) | 1 |
| Cups (8oz paper) | 32 |
| Fishing line (5ft pieces) | 16 |
| Lids (for 8oz cups) | 32 |
| Paper clips (regular size) | 20 |
| Pencils | 16 |
| Pennies | 16 |
| Popsicle sticks (mini) | 16 |
| Rubber band chains (size 33) | 16 |
| Rubber bands (size 16) | 16 |
| Scissors (site provides) | 16 |
| Spools (wooden, 1in) | 16 |
| Straws (clear, full size) | 32 |
| Tape (rolls, blue painter's) | 1 |
| Tape (rolls, masking) | 1 |
| Tape (rolls, Scotch) | 4 |
| Washers (small) | 32 |

### Prep (prior to class) — Time: 15-30 Minutes

- **Act. 2 & Act. 3 (OPTIONAL):** Remove the straw wrappers before giving straws to students.
- **Act. 3 (OPTIONAL):** You could assemble each of the sixteen bead/washer/rubber band chain combos as prep. Students would make the cups in reverse order.

### Activity One – Pair & Share — Time: 10 Minutes

| Supplies | # | Supplies | # |
|---|---|---|---|
| Pencils | 16 | Worksheets: Survey Answers | 1 |
| Worksheets: Pre-Survey | 16 | Lab notebooks | 16 |

**Goal**: To engage students' thinking and questioning related to the day's activities.

**Procedure**:

1. Prepare a quiet space for students to give them a physical area to think. The space can be an area set aside from the activity area, where students sit in a circle to ponder the *Pair & Share* question.
2. Make lab notebooks and pencils available.
3. Ask students one or more *Pair & Share* questions:
   - ***What is energy?*** *(The ability to make things happen. It's not created or destroyed—just transferred from one form to another.)*
4. Ask students to discuss their ideas with their neighbor before inviting students to share what they came up with. This is a "challenge by choice" opportunity and no one is required to share with the class if they are not comfortable.

### Activity Two — Spool Racer — Time: 20 Minutes

| Supplies | # | Supplies | # |
|---|---|---|---|
| Pennies | 16 | Straws (clear, full size) | 16 |
| Popsicle sticks (mini) | 16 | Scissors | 16 |
| Rubber bands (size 16) | 16 | Tape (rolls, Scotch) | 4 |
| Spools (wooden, 1in) | 16 | Washers (small) | 16 |

**Goal**: To observe how rubber bands can store up potential energy and convert it to kinetic energy by building a spool racer.

**Source**: https://bit.ly/3JsDxZy

**Survey Connection:**

**Q.** When you stretch out a rubber band or pull back a catapult, what are you storing up?
**A. Potential energy.**

**Q.** Fill in the blank: For every action, there is an equal and opposite _____________.
**A. Reaction.**

**Background:**

Energy is always changing into different forms! Potential energy is energy that can be used in the future. When you wind the rubber band, you're using kinetic energy (the motion of winding) to store up potential energy in the rubber band. If you keep twisting the rubber band, you can store up even more potential energy.

After you let go of the rubber band, the potential energy turns into kinetic energy! Kinetic energy is the energy of motion, and it allows the spool racer to move across the floor. The spool stops moving once the stored potential energy has all been converted into kinetic energy and used up. (Chemistry and Physics for Nurse Anesthesia: A Student-Centered Approach (2nd edition) by Shubert, David, Leyba, John pg. 97-98), Interactive Science for Inquiring Minds Volume B, Volume 2 by Tho Lai Hoong, Tho Mun Yi, & Josephine Fong pg. 5)

**Procedure:**

1. Ask students:
   - ***What happens when you stretch a rubber band and then let it go?*** *(It springs back to its original shape—and in some cases, flies through the air.)*
   - ***What do we call the energy that's stored in the rubber band when you stretch it out?*** *(POTENTIAL ENERGY. Potential energy is energy that's stored up for future use.)*
   - ***What do we call the energy that's released as the rubber band springs back?*** *(KINETIC ENERGY. Kinetic energy is the energy of motion.)*
   - ***Do you think we use a rubber band's ability to store potential energy and release kinetic energy to make something move? Let's try!***


Spool Racer. Insert a penny into the rubber band loop on one side of the spool. Tape both to the spool.

2. Give each student a spool, a size 16 rubber band, a washer, a penny, a straw, and a mini popsicle stick. Make Scotch tape and scissors available.
3. Have students:
   a. Thread the rubber band through the hole of the spool until it pokes through the other side (use the straw to push it through). This will create two rubber band loops sticking out from the spool (one on each end).
   b. Hold one rubber band loop and insert the straw into the other loop to prevent the rubber band from sliding back inside the spool.

Spool Racer. Hold the spool sideways. Line up the popsicle stick handle so that it's facing toward you with the flat side up. Wind the handle and let the spool roll!

c. Insert a penny into the rubber band loop that doesn't have the straw. Make sure the penny is centered on the flat outer part of the spool and the rubber band is lying flat. Pull the loop with the straw to tighten the rubber band over the penny.
d. Put a piece of tape over the rubber band and penny to hold them in place. Press the tape down around the rim of the spool to smooth it out as much as possible.
e. Remove the straw from the other rubber band loop and thread a washer onto the loop. (One side of the washer is flatter than the other—make sure the flatter part is facing the spool.) Push the washer against the flat outer part of the spool and pull the rubber band tight so the loop sticks out of the spool and washer.
f. Slide the tip of the mini popsicle stick through the rubber band loop. The longer end of the popsicle stick is now a "handle."
g. Hold the spool sideways in one hand. Line up the popsicle stick handle so that it's facing toward you with the flat side up (see photo at left).
h. Use a finger at the outer edge of the handle to wind it forward around the washer 10-15 times. Place the spool racer on the floor with the wound-up handle pointed toward you. Let it go.

Discussion Prompts:

- ***What happens?*** *(The spool rolls along the floor by itself!)*
- ***How does it work?***
- ***What kind of energy is the spool racer using?***

4. Tell students: ***Winding the rubber band with the handle builds up potential energy. When you let go of the handle, the rubber band starts to unwind, and the stored potential energy is converted to kinetic energy, making the spool move. It's like a rubber band motor!***

5. Allow students to experiment with the spool racer.

**TIPS:**
- **Don't overwind the handle** (20 rotations is a good limit). If the rubber band gets overwound, it gets stuck inside the spool, and the spool can't move.
- **If the spool stops moving too soon**, try pulling the handle away from the spool to undo any kinks in the rubber band.
- **Make sure the rubber band has fully unwound before rewinding it.** You may need to pull the handle away from the spool to physically unwind it.

6. Ask students: ***Do you think the spool racer will work with something other than the mini popsicle stick? Let's find out!***

7. Have students remove the mini popsicle stick and insert the tip of the straw into the rubber band loop. Use the long side of the straw as the "handle" to wind the rubber band.

8. Have students experiment with the new version of the spool racer. If desired, students can experiment with cutting the straw to different lengths to see how it affects the spool racer's performance.

## Activity Three — Drag-Racing Cups Time: 25 Minutes

| Supplies | # | Supplies | # |
|---|---|---|---|
| Beads (plastic, pony) | 16 | Rubber band chains (size 33) | 16 |
| Crayons (box) | 1 | Straws (clear, full size) | 16 |
| Cups (8oz paper) | 32 | Tape (rolls, masking, or blue painter's) | 1 |
| Lids (for 8oz cups) | 32 | Washers (small) | 16 |
| Paper clips (regular size) | 20 | Pencils | 16 |

**Goal**: To observe how rubber bands can store up potential energy and convert it to kinetic energy by building a set of "drag-racing" coffee cups.

**Source**: http://bit.ly/3ZYBD8p

**Survey Connection:**

★

**Q.** When you stretch out a rubber band or pull back a catapult, what are you storing up?
**A. Potential energy.**

★

**Q.** Fill in the blank: For every action, there is an equal and opposite _____________.
**A. Reaction.**

**Background:**

Just like with the spool racer, you'll be using a rubber band to convert potential energy into kinetic energy. For our drag-racing cups, however, we make a bigger vehicle, so we need a whole chain of rubber bands instead of just one! Also, with more power and bigger wheels, we are able to store more potential energy and see more kinetic energy come out of it! The drag-racing cups travel much farther than the tiny spool racers. Does this remind you of a certain law of physics? Maybe Newton's Third Law, which says that for every action, there's an equal and opposite reaction?

Real drag-racers need a lot more power to move a lot more weight a lot faster. They can reach speeds of over 300 miles an hour! That's more than 5 times an average freeway speed. http://bit.ly/3ynjkxU

**Procedure:**

1. Ask students: ***We just created potential energy by twisting rubber bands and storing their energy. When we released them, the potential energy turned into kinetic energy to make the spool racer move. Do you think we could make a different kind of rubber band motor – maybe a bigger, more powerful one? Let's try!***


Drag-Racing Cups. Create a hole in the bottom of both coffee cups.

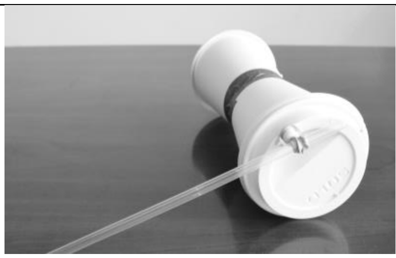

Drag-Racing Cups. Thread the rubber band chain through the holes in the cups.

2. Give each student a rubber band chain, two coffee cups, and a pencil. Make masking tape and painter's tape available (both types will work).

**TIPS**: In case a rubber band chain breaks and you need to make a new chain: To link two rubber bands together, lay them on a flat surface with the left one overlapping the right one slightly in the middle. Take the left side of the right rubber band and fold it over the right side of the left rubber band, then pull it under the farthest right part of the right rubber band. Pull to tighten. Repeat to add one more rubber band to the chain.

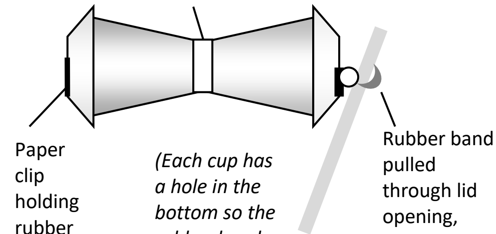
3. Have students:
   a. Poke a hole in the center of the bottom of each cup. Use the pencil to widen the holes to about the diameter of a quarter (centered on the bottom—see top photo at left).
   b. Tape the cups together, bottom to bottom, with a strip of painter's or masking tape that runs all the way around the bottoms of both cups. The holes should line up. (Students may want to help each other line up the bottoms of the cups and tape the cups together.)

4. Give each student two lids, a paper clip, a washer, a pony bead, and a straw. Make four extra paper clips available for students to share (pull the outer end of each clip out slightly so that it can be used to poke a rubber band through a bead).
5. Have students:
   a. Pull one end of the rubber band chain through the drinking hole in one of the lids, so a little bit hangs outside the top of the lid.
   b. Hook the paper clip through the part of the rubber band that's outside the lid.
   c. Tape the paper clip to the top of the lid (on the outside) to hold the rubber band in place.
   d. Put the taped lid on one of the cups.
   e. Run the rubber band chain through the middle of both cups (see bottom photo at left). Use a pencil to pull the chain through the holes in the bottoms of the cups into the second cup.
   f. Pull the free end of the rubber band chain through the hole in the second lid (from the bottom of the lid to the top).


Drag-Racing Cups. Finished product from the washer-bead-straw side.


Drag-Racing Cups. Finished product from the paper clip side.

g. Put the lid on the second cup, keeping the end of the rubber band pulled through. (Students may want to help each other in pairs with this step and the next one.)
h. Thread a washer onto the end of the rubber band. Push the washer against the lid, creating a rubber band loop sticking out of the washer.
i. Thread a pony bead onto the rubber band, next to the washer. (Students may want to share the slightly unbent paper clips to poke the rubber band through the pony bead.)




j. Insert the tip of the straw into the rubber band loop, next to the bead (see the diagram above and the top and middle photos at left).
k. Wind up the racer by holding the cups sideways in one hand and spinning the straw around the bead. (You can place one finger at the long end of the straw and make circles with your hand to guide the straw around.)
l. Set the cups down on their sides (ideally on a flat surface) with the long end of the wound-up straw pointed toward you. Let the cups go.

Discussion Prompts:

- ***What happened?*** *(The cups rolled forward!)*
- ***Why does it work?***

6. Tell students: ***When you wound the straw around the bead, you were also winding up the chain of rubber bands inside the cups. This stored up potential energy in the chain of rubber bands. When you released the straw, the rubber band chain started to unwind, which converted the stored potential energy into kinetic energy that made the cups move.***

## Activity Four — Zoom Bead

**Time: 5 Minutes**

| Supplies | # |
|---|---|
| Beads (wood, large center hole) | 8 |
| Fishing line (5ft pieces) | 16 |
| Tape (rolls, masking, or blue painter's) | 1 |

**Goal:** To observe how kinetic energy can be transferred using a zooming bead.

**Source**: https://bit.ly/3DRUeu0

**Survey Connection:**

**Q.** Fill in the blank: For every action, there is an equal and opposite _____________.

**A. Reaction.**

**Background:**

Forces, as you have learned, are all around us, acting in different directions. With your Zoom Bead, you learned that an applied force in one direction can cause motion in a different direction! By using kinetic energy to pull your hands apart, you created tension on your side of the fishing lines, which resulted in a push on your end of the bead. This caused the bead to move towards your partner's side, where there was less tension.

In some ways, this is similar to what you observed with Newton's Cradle. When you hit one marble against another marble, the kinetic energy of the moving marble got transferred directly to another marble, causing it to move.

As cool as the Zoom Bead is, though, it's probably not useful on a large scale. Think about it: how long would the fishing lines have to be—and how far apart would you need to spread them—to send a wagon zooming along a road, or a jet zooming into the sky?

**Procedure:**

1. Ask students: ***In today's activities, you used kinetic energy (winding a rubber band) to store up potential energy. When you released that potential energy, it turned back into kinetic energy that made things move. Do you think you could quickly and directly transfer kinetic energy from one object to another? Let's find out!***

2. Pair students. Give each pair two 5ft pieces of fishing line and one wooden bead. Make masking tape and painter's tape available (both types will work).
3. Have students thread both pieces of fishing line through the hole in the bead.
4. Have students place one piece of tape on each of the four ends of the fishing line, and a second piece of tape a few inches in front of the first piece, for eight pieces of tape total (see top photo at left).

Zoom Bead. Place two pieces of masking tape or painter's tape on each of the ends of the fishing line.

Zoom Bead. Pull your hands apart to make the zoom bead shoot forward along the fishing line.

Zoom Bead. Have students hold the fishing lines taut between them and alternate who spreads their hands apart to make the bead move.

*(The inner pieces of tape on the fishing line are to protect students' fingers as the wooden bead zooms back and forth.)*

5. Have pairs spread out in the room. In each pair, one student should hold the two pieces of fishing line threaded through one side of the bead, and the other student should hold the two ends of the fishing line threaded through the other side of the bead.
6. Have students hold their ends of the line by the pieces of tape closest to the ends, with one line in each hand. (The second set of tape should be a few inches in front of their fingers when holding the line.)
7. Have students stretch the lines taut between them. Slide the bead so that it's closer to one student than the other.
8. Ask students: ***How can you send the bead from one side to the other while holding the taped ends of the line (without touching the bead directly)?***

9. Allow students to experiment. The most effective way to send the bead zooming is for the student on the receiving end to hold their lines close together while the student closest to the bead quickly pulls their hands apart to separate the lines (see bottom two photos at left). Students can alternate whose hands are close together and who pulls their hands apart to send the bead back and forth.

## Activity Five – Daily Debrief — Time: 5 Minutes

| Supplies | # |
|---|---|
| Worksheets: Take-Home Supplies Advisory (half-sheet) | any left |
| Lab Notebooks | 16 |
| Pencils | 16 |

**Goal:** To draw today's activities together through a thoughtful question and give students an opportunity to ask their own questions.

**Procedure:**

1. Encourage students to reflect on what they learned in today's class and what new questions they might have.
2. Allow students a few seconds to think. Have them discuss their thoughts and questions with a partner, then share with the rest of the class and/or write down in their lab notebook.
3. If needed, feel free to offer prompts like:
   - ***What do you think would happen if we changed one thing about today's activities (for example: materials, speed, temperature, etc.)?***
   - ***If you could investigate (explore) one more thing about today's activities, what would you like to find out?***

4. If time allows, ask the following question:

- ***Think of some other ways you could harness rubber band power. What's the coolest thing you could make?"***

**Clean up:** Make sure students help clean the room before they leave.

**What to save:**

| Materials used | # | SAVE | Materials used | # | SAVE |
|---|---|---|---|---|---|
| Beads (plastic, pony) | 16 | 0 | Rubber bands (size 16) | 16 | 0 |
| Beads (wood, large center hole) | 8 | 8 | Scissors (site provides) | 16 | 16 |
| Crayons (box) | 1 | 1 | Rubber band chains (size 33) | 16 | 0 |
| Cups (8oz paper) | 32 | 0 | Spools (wooden, 1in) | 16 | 0 |
| Fishing line (5ft pieces) | 16 | 16 | Straws (clear, full size) | 32 | 0 |
| Lids (for 8oz cups) | 32 | 0 | Tape (rolls, masking or blue painter's) | 1 | 1 |
| Paper clips (regular size) | 20 | 4 | Tape (rolls, Scotch) | 4 | 4 |
| Pencils | 16 | 16 | Washers (small) | 32 | 0 |
| Pennies | 16 | 0 | Popsicle sticks (mini) | 16 | 0 |

**What goes home:** Spool Racer (with mini popsicle stick and straw) & Drag-Racing Cups

*(Review safety guidelines with students: rubber bands should not be launched at people or pets; small items should always be kept away from children ages 3 and younger to avoid the risk of choking)*

| Supplies | # |
|---|---|
| Binder clips (large) | 16 |
| Binder clips (medium) | 16 |
| Cotton balls | 32 |
| Pencils | 16 |
| Pennies | 80 |
| Popsicle sticks (jumbo) | 16 |
| Rubber bands (size 33) | 32 |
| Spoons (plastic) | 32 |
| String (1.5ft pieces) | 16 |
| Tape (rolls, blue painter's) | 1 |
| Tape (rolls, masking) | 1 |
| Tape (rolls, Scotch) | 4 |

## Prep (prior to class)

- None

## Activity One – Pair & Share Time: 10 Minutes

| Supplies | # | Supplies | # |
|---|---|---|---|
| Pencils | 16 | Lab notebooks | 16 |

**Goal**: To engage students' thinking and questioning related to the day's activities.

**Procedure**:
1. Prepare a quiet space for students to give them a physical area to think. The space can be an area set aside from the activity area, where students sit in a circle to ponder the *Pair & Share* question.
2. Make lab notebooks and pencils available.
3. Ask students one or more *Pair & Share* questions:
    - ***What are some ways you can launch an object farther and/or faster than you could throw it?*** *(Bow and arrow, slingshot, cannon, pitching machine, darts, etc.)*

4. Ask students to discuss their ideas with their neighbor before inviting students to share what they came up with. This is a "challenge by choice" opportunity and no one is required to share with the class if they are not comfortable.

## Activity Two — Levers Time: 10 Minutes

| Supplies | # | Supplies | # |
|---|---|---|---|
| Pencils | 16 | Popsicle sticks (jumbo) | 16 |
| Pennies | 64 | Tape (rolls, Scotch) | 4 |

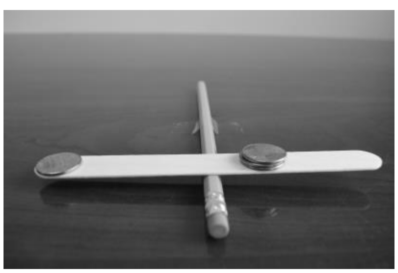
**Goal**: To observe that the longer a lever is, the stronger it is, using a popsicle stick balanced on a pencil with pennies as weights.

**Source**: Hands on Science Outreach

**Background:**

Levers are a type of simple machine. A lever is a bar that moves around a fixed point called a fulcrum. Using a lever involves some weight or resistance that needs to be moved, and an effort to move the weight. By using a lever, you could lift an object (like a baby elephant) that you normally wouldn't be able to lift by taking advantage of the longer arm=stronger arm rule!

There are three types of levers. A Class 1 lever is a seesaw, just like you created with your popsicle stick. The fulcrum is in between the weight and the force being used to move the weight. The other two classes of levers have the fulcrum at one end instead of in the middle, and the weight is either closer than the applied force (Class 2) or farther from the applied force (Class 3). Class 2 levers need less effort to lift the weight and Class 3 levers need more effort to lift the weight. Some examples of levers in your everyday life are a balance scale (Class 1), a wheelbarrow (Class 2), and your forearm (Class 3)! (https://bit.ly/3llgZAi)



Levers. Place a popsicle stick across a taped-down pencil. To balance three pennies with one, move the stack of three pennies closer to the fulcrum and the single penny further from the fulcrum.

**Procedure:**

1. Ask students: ***Imagine you're at the playground, and you meet a baby elephant! The baby elephant is heavier than you.***
   - ***How could you lift it up?*** *(If students are stuck, encourage them to think about a teeter-totter or seesaw.)*
   - ***What type of simple machine is a seesaw?*** *(A lever.)*

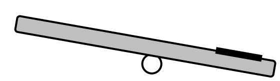
2. Give each student a pencil and a jumbo popsicle stick. Make tape available.

3. Ask students: ***How can you make a lever (or seesaw) with these materials? Let's try!***

4. Have students:
   a. Tape the pencil onto the table with the eraser pointing straight toward them. Make sure the pencil lays flat.
   b. Place the popsicle stick across the pencil, perpendicular to the pencil.
   c. Adjust the popsicle stick until it balances on the pencil.

5. Tell students: ***A lever is a stiff bar that pivots—or moves back and forth—on a support. The point where the bar moves back and forth is called the "fulcrum."***
   - ***In the see-saw lever you made, which part is the bar that moves back and forth?*** *(The popsicle stick)*
   - ***Where is the fulcrum?***
   - ***The fulcrum is the point where the popsicle stick meets the pencil. When the popsicle stick is balanced without any weight on it, the fulcrum is in the center of the stick.***

Side view of a popsicle stick laid across a taped-down pencil, with a penny weighing down one side:



6. Give each student 4 pennies.
7. Have students place a penny at one end of the stick:

   Discussion Prompts:
   - ***What happened?*** *(The popsicle stick became off-balanced.)*
   - ***How can you change the position of the popsicle stick to balance the penny?***

8. Allow students time to readjust the popsicle stick (without moving the penny!) so that it balances again with a penny on one end. (Hint: they need to shift the side with the penny closer to the pencil.)

Discussion Prompts:
- ***How did you balance the penny?*** *(By shifting the popsicle stick and changing the position of the fulcrum!)*
- ***What would happen if you added a penny to the other side of the popsicle stick? Let's try!***

9. Have students add a second penny to the other end of the popsicle stick.

   Discussion Prompts:
   - ***What happened?***
   - ***Is the popsicle stick balanced?***

10. Allow students time to adjust the popsicle stick so it balances with a penny on each end.

    Discussion Prompts:
    - ***Does the popsicle stick balance at the same point as it did when no pennies were on it?*** *(Yes, in the center.)*
    - ***What would happen if you moved one of the pennies closer to the pencil? Would the popsicle stick still balance? Try it!***

11. Have students shift one of the pennies to halfway between the pencil and the end of the popsicle stick.

    Discussion Prompts:
    - ***Is your lever still balanced?*** *(No.)*
    - ***Could you balance it by adding more weight? Try it!***

12. Allow students to add another penny on top of the penny that's halfway between the pencil and the end of the popsicle stick. They may need to shift the stack of two pennies slightly to achieve balance again.

    Discussion Prompts:
    - ***Did it take more or less weight to balance out the longer arm of the lever?*** *(It took more weight to balance out the longer arm.)*
    - ***Does that mean the longer arm can lift more or less weight than the shorter arm? Is the longer arm stronger or weaker?*** *(Longer arm=stronger arm! The longer arm is able to lift two pennies while the shorter one is only lifting one.)* ***Knowing that, do you think you can balance a stack of 3 pennies on one side with one penny on the other side, just by changing where the pennies are placed on each side and shifting the location of the fulcrum?***

13. Have students place three pennies on one side and one penny on the other. Allow them to experiment with shifting the pennies and popsicle stick to get their lever to balance (see photo at left). Takeaway: the longer arm is the stronger arm!
14. Ask students: ***So, if you were to set up a lever to lift a baby elephant, where would you set up the fulcrum? Would you want it to be in the middle, like a seesaw?***

15. Tell students (depending on responses to the above questions): ***Your side would need to be longer in order to balance the elephant's heavier weight. The fulcrum would need to be closer to the elephant, so that its side would be shorter. In other words, you would need a longer lever—a stronger lever—to lift the elephant's heavier weight.***

16. Leave the taped-down pencils and popsicle sticks set up for the next activity.

## Activity Three – Lever Launch     Time: 5 Minutes

| Supplies | # | Supplies | # |
|---|---|---|---|
| Cotton balls | 16 | Popsicle sticks (jumbo) | 16 |
| Pencils | 16 | Tape (rolls, Scotch) | 4 |

**Goal**: To experiment further with lever arm length by using a popsicle stick and pencil to launch a cotton ball.

**Source**: Hands on Science Outreach

**Survey Connection:**

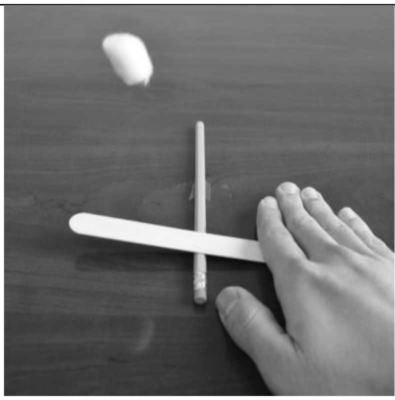
**Q.** Fill in the blank: For every action, there is an equal and opposite ____________.
**A. Reaction.**

**Q.** What is the force that pulls all objects toward the earth?
**A. Gravity.**

**Background:**

As you build your lever launch, you'll notice that by making the cotton ball arm as long as possible, you increase the distance the cotton ball is pushed by the popsicle stick. When the cotton ball arm is relatively short, the popsicle stick can only push the cotton ball upward by about an inch. When the cotton ball arm is as long as possible, the end of popsicle stick is able to lift up by several inches, giving the cotton ball a bigger upward push! That fits with what you learned about "longer arm = stronger arm." (https://bit.ly/3llgZAi)

**Procedure:**


Lever Launch. With the cotton ball on one side of the popsicle stick, bring your hand down on the other side to launch the cotton ball. Repeat with different lengths of popsicle stick on each side of the fulcrum.

1. Ask students: ***You just learned that you can use a lever to lift an object up. Do you think you can use a lever to lift an object up so fast that it flies into the air? Let's find out!***

2. Give each student a cotton ball. Make students have their popsicle stick and their pencil taped down to the table from the last activity.
3. Have students place their cotton ball on one side of the popsicle stick, then shift the popsicle stick so the cotton ball is as close to the pencil as possible, but still weighs its end of the popsicle stick down.
4. Ask students: ***In the last activity, you learned that a longer arm is a stronger arm. Do you think that this cotton ball on the short arm of the popsicle stick will fly high into the air? Let's see!***

5. Have students (in a controlled fashion!) bring their hand down onto the upturned end of the popsicle stick as if they were giving it a low five (see photo at left).

   Discussion Prompts:
   - ***What happened?*** *(The cotton ball flew into the air, but not very high.)*
   - ***If we make the cotton ball arm slightly longer, do you think the cotton ball will fly higher or lower?***

6. Have students shift the popsicle stick over slightly so the middle of the popsicle stick is on the fulcrum. Have them repeat step 3.

   Discussion Prompts:
   - ***Did the cotton ball fly higher or lower?*** *(Higher.)*
   - ***Why?*** *(The longer arm is the stronger arm! We made the arm holding the cotton ball longer, so it was stronger when launching the cotton ball.)*
   - ***Can we confirm our observations by making the cotton ball arm as long as possible?***
   - ***Should this be the lowest or highest jump?*** *(The highest!)*

7. Have students shift the popsicle stick over so most of it is on the side with the cotton ball and just a small part (about an inch) is on the other side of the pencil. Have them repeat step 3.

   Discussion Prompts:
   - ***Did your experiment confirm your hypothesis?*** *(Yes! The cotton ball flew the highest this time.)*
   - ***Why did that happen?***

8. Tell students: ***In the last activity, we learned that it takes less weight—or less force—to use the longer arm of a lever to move something on the shorter end. The reverse is also true! You have to apply more force to the shorter end of a lever to move something on the longer arm…but if you're able to use more force, you can make the object***

***on the longer arm move faster and farther! Your hand is much heavier and more powerful than the weight of a cotton ball, so you could make the lever arm as long as you wanted and still be able to launch the cotton ball. Your launcher uses the power of the longer arm in a special way: you have to apply more force to the shorter arm—but because you can do that, the cotton ball on the longer arm moves faster and flies higher!***

9. If time allows, let students experiment with placing the cotton ball closer to or farther from the pencil (without shifting the popsicle stick), changing where they hit the popsicle stick with their hand, and any other variables they'd like to test. Throughout their experimentation, they should see if they can ever violate the rule "the longer arm is the stronger arm." (Hint: nope.)

## Activity Four – Cotton Ball Catapult — Time: 20 Minutes

| Supplies | # | Supplies | # |
|---|---|---|---|
| Binder clips (medium) | 16 | Rubber bands (size 33) | 32 |
| Cotton balls | 32 | Spoons (plastic) | 32 |
| Popsicle sticks (jumbo) | 16 | Tape (rolls, masking or blue painter's) | 1 |

**Goal**: To use a basic understanding of a lever arm to create a catapult using office supplies (binder clips, rubber bands, plastic spoons, and popsicle sticks).

**Source**: https://bit.ly/3lboXf6

**Survey Connection:**

★ **Q.** When you stretch out a rubber band or pull back a catapult, what are you storing up?
**A. Potential energy.**

★ **Q.** Fill in the blank: For every action, there is an equal and opposite ____________.
**A. Reaction.**

★ **Q.** What is the force that pulls all objects toward the earth?
**A. Gravity.**

**Background:**

A catapult is used to launch items (like cotton balls!) toward a target. A catapult is a special kind of lever. Some catapults use a springing action, which makes them a Class 3 lever. Other types of catapults, like a trebuchet, use weights to be more energy efficient, so they're considered a Class 1 lever. The binder clip you'll use for your catapult has a springing action, so it's a Class 3 lever (which is a different type of lever than you used in the "Lever Launch" activity).

Did you know that catapults were first used in battle around 400 B.C.? Because a spring-style catapult was less energy efficient, it was used to smash through walls. The Class 1 trebuchet, however, was powerful enough to hurl objects over walls!

You can see the physics concept of a spring-action lever at work in a diving board. Where do you get the biggest bounce from the board? At the very edge, of course, where the lever arm is the longest and the strongest! (https://bit.ly/3lkLfLD)

**Procedure:**

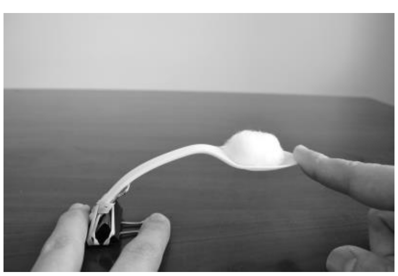
1. Ask students: ***In the last activity, you used a popsicle stick lever to launch a cotton ball. This is a basic form of a catapult! A catapult is a machine that uses a lever to launch an object. Do you think you could create an even better catapult using different supplies? Let's try!***

2. Give each student two plastic spoons, a medium binder clip, and two size 33 rubber bands. Make sure they still have their jumbo popsicle stick and cotton ball from the previous activity. Make scissors, masking tape and painter's tape available (both types of tape work).
3. Give students time to explore using the supplies to launch their cotton ball.
4. After students have tried their own methods for a few minutes, show students how to create a basic catapult model (see photo at left).
5. Have students:
   a. Line up the bottom of the spoon handle with the outside of the mouth of the binder clip. The spoon should be centered on the binder clip so that the back of the spoon handle leans against the silver part of the clip.
   b. Attach the handle of one spoon to the binder clip using one of the rubber bands. The rubber band should be wrapped around the spoon and binder clip multiple times to hold the spoon in place securely. One option is to attach the spoon to the binder clip with the rubber band in a crisscross or 'X' shaped pattern.
   c. Set the flat base of the binder clip on a table so the spoon sticks almost straight up.
   d. Place the cotton ball into the bowl of the spoon (students may need to bend the spoon back slightly to hold the cotton ball).
   e. With one hand on the base of the binder clip, use the other hand to pull the bowl of the spoon backwards then release (see top photo at left). You may want to have students take turns launching their catapults.

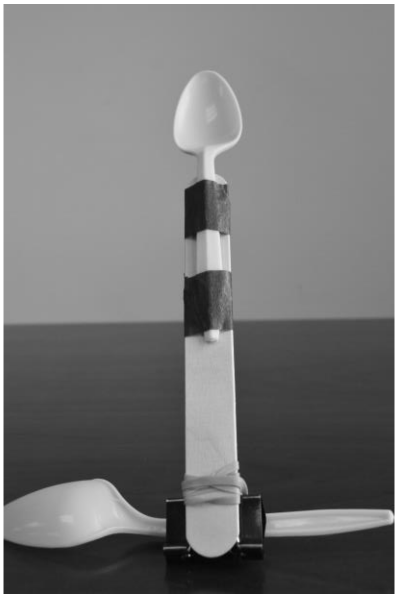
Discussion Prompts:

- ***What happens?*** *(The catapult launches the cotton ball into the air!)*

Cotton Ball Catapult. Basic model of a catapult.



Cotton Ball Catapult. Load the catapult with a cotton ball and pull it back by the bowl of the spoon. Release to launch the cotton ball.



Cotton Ball Catapult. Example of a modified catapult. Note that the spoon is sturdily secured to the popsicle stick.

- ***How is that like the lever experiment you did?*** *(The spoon acts like the lever arm and stores potential energy when it's pulled back. When it's released, it springs forward and launches the cotton ball!)*
- ***Can you modify your catapult to launch your cotton ball higher and/or further? Remember, a longer arm is a stronger arm!***

6. Allow students to explore modifying their basic catapult with the additional spoon, the popsicle stick, and the rubber band. Ask them to test their catapults gently for now so that they're not constantly chasing their cotton balls all over the classroom.
7. As students are making their modifications, remind them that they don't have to use all the supplies. Also, if students want to make a longer catapult arm—for instance, by adding the popsicle stick in addition to the spoon—the entire arm needs to be as stiff as possible, meaning that supplies have to be overlapped and taped together in a sturdy way (see bottom photo at left).
8. Have students do a full test of their catapult. You can hold a competition for the highest cotton ball and the farthest cotton ball.
9. If time allows, students can compare launching a normal cotton ball to launching a cotton ball with pieces of tape wrapped around it. The extra mass and reduced drag of the taped-up cotton ball should result in a farther launch.

## Activity Five – Pendulum Drop — Time: 15 Minutes

| Supplies | # | Supplies | # |
|---|---|---|---|
| Binder clips (large) | 16 | String (1.5ft pieces) | 16 |
| Pennies | 16 | Tape (rolls, masking or blue painter's) | 1 |

**Goal:** To observe that the shorter a pendulum is, the faster it swings, using a penny attached to string as a pendulum.

**Source**: https://bit.ly/3DPPqFt

**Survey Connection:**

**Q.** What is the force that pulls all objects toward the earth?
**A. Gravity.**

**Background:**

The device you created is a penny pendulum. A pendulum is a weight that swings from a pivot or fixed point—in this case, your finger. Playground swings are an example of a pendulum. Usually, as a pendulum swings back and forth over time, it gets slower, and its swing gets lower due to friction.

In our activity, when you let go of the penny, gravity started to pull the binder clip down, which made the penny pendulum shorter and shorter as the penny got closer to your finger. As the penny pendulum got shorter, it swung faster and faster. In the blink of an eye, the force of acceleration got so great that the penny pendulum started swinging high enough to wrap all the way around

Did you know that Galileo was one of the first scientists to study the properties of pendulums? According to his student Viviani, Galileo first noticed a swinging chandelier hanging from the ceiling, which led him to define the swinging pendulum. Pendulums were used as early as the second century, such as the seismoscope pendulum designed in the second century by a Chinese scientist named Zhang Heng. A common type of pendulum is a metronome, which keeps track of the speed of music. (https://bit.ly/3I7PKIM, http://bit.ly/3I7xB7F)

Pendulum Drop. Finished product with a penny taped to one end of the string and a large binder clip tied to the other end.

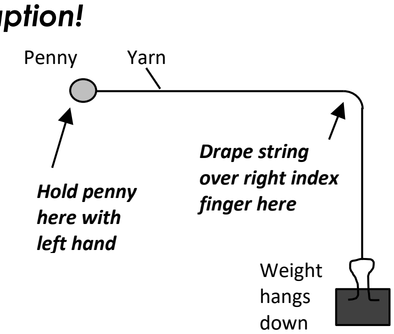
**Procedure:**

1. Ask students: ***Have you heard of a pendulum before? How does it work?*** *(It's just a weight swinging back and forth!)* ***Let's make one!***

2. Give each student a penny, a piece of string, and a large binder clip. Make masking tape and painter's tape available (both types will work).
3. Have students tape the penny to one end of the string.
4. Have students stand up and hold the free end of the string about a foot in front of them, so that the end with the penny hangs straight down.
5. Have students pull their penny to one side (keeping the string taut), then release it. Watch the penny swing back and forth.
6. Ask students: ***What do you think will happen to the penny's swinging if we change the length of the string? Will it swing faster or slower? Let's make a hypothesis!***

7. Have students pull their penny to one side, then release it. While the penny is swinging, have them pinch part of the string lower than where their other hand holds the end of the string. Then, have them pinch closer and closer to the penny to observe how the speed of the penny changes.

   Discussion Prompts:
   - ***Does a shorter string make the penny swing faster or slower?*** *(Shorter string = faster swing!)* ***Let's see how we can use that knowledge to create a tricky contraption!***
8. Have students:
   a. Tie or tape the binder clip to the end of the string opposite the penny (see photo). Stand up for the next step.
   b. Hold the penny in their left hand. While holding the penny, extend their right index finger and put it under the string halfway toward



Pendulum Drop. Hold the penny in one hand and let the string drape over your other finger. Release the penny and watch it wrap around your finger!

the binder clip. The string should hang over their finger; the binder clip should hang straight down below their finger (see diagram).

Discussion Prompt:

- ***What do you think will happen if you let go of the penny?*** *(The weight of the binder clip is heavier than the penny. It seems like gravity would pull the binder clip down—along with the penny, since they're connected by the string—and both would hit the ground.)*

9. Have students let go of the penny (see photo at left).

Discussion Prompt:

- ***What happened?*** *(Instead of falling, the penny on the string wrapped itself around your finger, causing the binder clip to hang suspended in midair!)*

10. Have students try changing the placement of their finger along the string.

## Activity Six – Daily Debrief Time: 5 Minutes

| Supplies | # |
|---|---|
| Worksheets: Take-Home Supplies Advisory (half-sheet) | any left |
| Lab Notebooks | 16 |
| Pencils | 16 |

**Goal:** To draw today's activities together through a thoughtful question and give students an opportunity to ask their own questions.

**Procedure:**

1. Encourage students to reflect on what they learned in today's class and what new questions they might have.
2. Allow students a few seconds to think. Have them discuss their thoughts and questions with a partner, then share with the rest of the class and/or write down in their lab notebook.
3. If needed, feel free to offer prompts like:
   - ***What do you think would happen if we changed one thing about today's activities (for example: materials, speed, temperature, etc.)?***
   - ***If you could investigate (explore) one more thing about today's activities, what would you like to find out?***

4. If time allows, ask the following question:
   - ***What are some things we could launch using a catapult? How big would the catapult have to be?***

**Clean up**: Make sure students help clean the room before they leave.

**What to save**:

| Materials used | # | SAVE | Materials used | # | SAVE |
|---|---|---|---|---|---|
| Binder clips (large) | 16 | 0 | Rubber bands (size 33) | 32 | 0 |
| Binder clips (medium) | 16 | 0 | Spoons (plastic) | 32 | 0 |
| Cotton balls | 32 | 0 | String (1.5ft pieces) | 16 | 0 |
| Pencils | 16 | 16 | Tape (rolls, masking or blue painter's) | 1 | 1 |
| Pennies | 80 | 64 | Tape (rolls, Scotch) | 4 | 4 |
| Popsicle sticks (jumbo) | 16 | 0 | | | |

**What goes home**: Pendulum Drop & Cotton Ball Catapult

*(Review safety guidelines with students: binder clips on strings should not be swung at other people; catapults should not be aimed at people or pets; students should be careful not to pinch their fingers in the binder clips; small items should always be kept away from children ages 3 and younger to avoid the risk of choking)*

| Supplies | # |
|---|---|
| Cups (9oz paper) | 16 |
| Magnets (ring-shaped) | 16 |
| Nuts (metal hexagons) | 32 |
| Paper clips (regular size) | 16 |
| Pencils | 16 |
| Pennies | 64 |
| Scissors (site provides) | 16 |
| String (6in pieces) | 16 |
| Tape (rolls, masking or blue painter's) | 1 |
| Yarn (1ft pieces) | 4 |
| Yarn (2ft pieces) | 16 |

| | |
|---|---|
| Worksheets: Post-Survey | 16 |
| Worksheets: Survey Answers | 1 |

### Prep (prior to class)

- No activity prep.
- Please reserve 15 minutes at the end of class for Post-Surveys.

### Activity One – Pair & Share — Time: 10 Minutes

| Supplies | # | Supplies | # |
|---|---|---|---|
| Pencils | 16 | Lab notebooks | 16 |

**Goal**: To engage students' thinking and questioning related to the day's activities.

**Procedure:**

1. Prepare a quiet space for students to give them a physical area to think. The space can be an area set aside from the activity area, where students sit in a circle to ponder the *Pair & Share* question.
2. Make lab notebooks and pencils available.
3. Ask students one or more *Pair & Share* questions:
    - ***Where can you find magnets in your everyday life?*** *(On the refrigerator, on the white board, inside most electronic devices like cell phones, computers, etc.)*
4. Ask students to discuss their ideas with their neighbor before inviting students to share what they came up with. This is a "challenge by choice" opportunity and no one is required to share with the class if they are not comfortable.

### Activity Two — Floating on Air — Time: 15 Minutes

| Supplies | # | Supplies | # |
|---|---|---|---|
| Magnets (ring-shaped) | 16 | Scissors (site provides) | 16 |
| Paper clips (regular size) | 16 | String (6in pieces) | 16 |
| Pencils | 16 | Tape (rolls, masking, or blue painter's) | 1 |

**Goal**: To learn about magnetic fields by making ring magnets float on top of each other and causing a paper clip to float in the air near a magnet.

**Source**: Lisa Pitts, OHCC & https://bit.ly/3lhSXpM

**Survey Connection**

**Q.** What is the force that pulls all objects toward the earth?
**A. Gravity.**

**Background:**
As you'll observe in this activity, when the paper clip is very close to the magnet, it gets pulled toward the magnet, even without touching it directly. A magnetic field is the invisible space around a magnet in which a

magnet can exert a force! Within the magnetic field, other magnets can be attracted or repelled, and metals like paper clips can be pulled toward the magnet.

In your experiment, the magnetic field causes the paper clip to store up potential energy. When the string is cut, the paper clip flies toward the magnet and sticks to it. The paper clip's potential energy is converted into kinetic energy (energy in motion.)

Did you know that some species of sharks can detect magnetic fields? Scientist are creating a fake kelp field made of magnets that stops sharks from wanting to enter parts of the ocean where there are a lot of humans in the water. This method is better than nets because it leaves sharks unharmed. (https://bit.ly/3T2bHWW, https://bit.ly/3J4xI34)

**Procedure:**

1. Give each student a ring magnet.
2. Ask students: ***Do you think the magnet will stick to some things in the room? Let's find out!***

3. Give students instructions about areas of the room to avoid if you're in someone else's space. Allow students to try to get the magnet to stick to things in the room.

**WARNING: Don't allow students to use the magnets near computers! Magnets should also be kept away from cell phones, credit cards & pacemakers.**

Discussion Prompts:
- ***What happened?***
- ***What did the magnet stick to?***

4. Tell students: ***Magnets are pulled toward certain types of metals, particularly iron, nickel, and cobalt. This pull is called magnetic attraction. The area around a magnet where you can feel the pull is called a magnetic field.***

Floating on Air. Stack two ring magnets on a pencil so one floats above the other.

5. Pair students. Give each pair a pencil.
6. Have pairs stand their pencil upright on the table, then stack their ring magnets on the pencil (so the pencil sticks up through their centers—see photo at left).

Discussion Prompts:
- ***What happened?*** *(Either the magnets stuck together, or the top magnet floated above the bottom magnet.)*
- ***If your top magnet didn't float, can you make it float? Try it!***

7. If a pair's top magnet didn't float, flip it over and slide it back onto the pencil.

Discussion Prompts:
- ***Does it matter which direction you stack the rings?*** *(Yes.)* ***Why?***

Floating on Air. The paper clip will levitate if held within the magnet's magnetic field. (Scotch tape is pictured instead of masking or painter's tape so that the magnet is visible.)

- ***Why does the top magnet float when one side is facing down, but stick to the other magnet when the other side is facing down?***
- ***Why doesn't gravity hold the top magnet down?*** *(The repelling force is stronger than the force of gravity for the ring magnets!)*

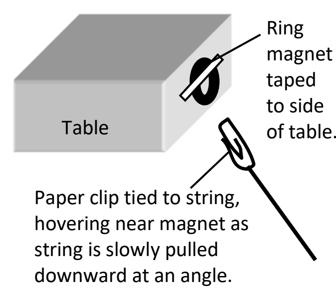
8. <u>Tell students:</u> ***Every magnet has two opposite sides: a North Pole and a South Pole. The <u>magnetic field</u> of a magnet is strongest at its poles. Opposite poles attract, which pulls them toward each other and makes them stick together. But if two poles are the same, they repel each other, which means they push each other away. North Poles stick to South Poles but repel other North Poles.***

9. <u>Ask students:</u> ***Could you float more than one magnet at a time? Let's find out!***

10. Put students in four groups. Have them combine their magnets on one pencil.

11. <u>Ask students:</u> ***You just used magnets to make other magnets float above them. Can you use a magnet to make a paper clip float in the air? Let's find out!***

12. Give each student a 6in piece of string and a paper clip. Make sure each student has their ring magnet from the previous activity. Make scissors, masking tape and painter's tape available (both types of tape work).




13. <u>Have students</u>:
    a. Tie the paper clip to one end of string.
    b. Tape the magnet flat against the side of a table or desk.
    c. Place the tip of the paper clip against the magnet (so that it sticks to the magnet) and let the free end of the string hang down.
    d. Grasp the free end of the string (the one without the paper clip).
    e. SLOWLY and GENTLY, pull the free end of string downward, angled outward from the table. Pull just until the paper clip detaches from the magnet but remains suspended in the air near the magnet (see diagram above and photo at left).

<u>Discussion Prompts:</u>

- ***What keeps the paper clip floating?***

14. Tell students: ***The paper clip is within the magnet's magnetic field, so it is pulled to the magnet, even without touching it directly. The paperclip has POTENTIAL ENERGY – energy stored up to move if the string gets cut or the magnet moves closer or father away.***

15. Pair students. Have one student make the paper clip float while the other student carefully cuts the string (without jarring the string and disturbing the paper clip.)

    Discussion Prompts:
    - ***What happened?***
    - ***Why did the paper clip fly to the magnet instead of falling to the ground?***

16. Tell students: ***The paper clip flew to the magnet and stuck because its potential energy was converted into KINETIC ENERGY – the energy of motion, and it flew to the magnet instead of falling to the ground because the paper clip was still in the magnet's magnetic field. The magnetic force attracting the paperclip was stronger than the downward pull of gravity.***

17. Have students remove the string from their paper clips (slide the string along the paper clip until it slips off). Keep the paper clips handy for the next activity.

## Activity Three – Magnet Chain & Stack Time: 10 Minutes

| Supplies | # |
|---|---|
| Magnets (ring-shaped) | 16 |
| Nuts (metal hexagons) | 32 |
| Paper clips (regular size) | 16 |

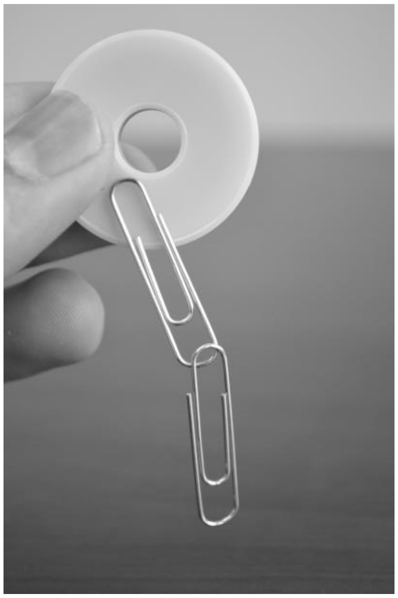
**Goal**: To observe that magnets can temporarily magnetize metals using a ring magnet, metal nuts, and paper clips.

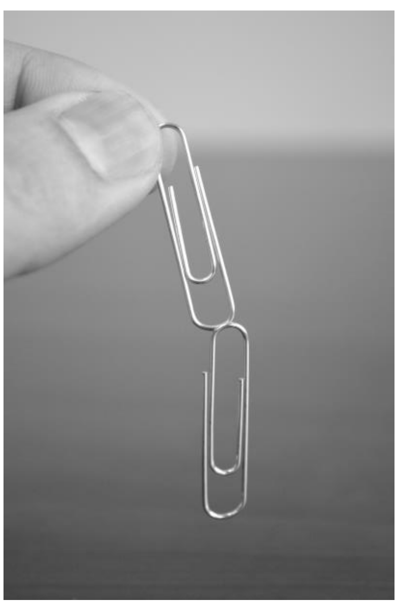
**Source**: http://bit.ly/3F7RNo0

**Background:**

Many magnets are strong enough to make metal objects become magnetic—as long as the metal objects stay in contact with the magnet. If the magnet is strong enough, the metal objects may still be magnetic for a little while even when they're no longer touching the magnet. The ability of a magnet to magnetize a metal is called "induction." As you saw in the experiment, induction can be achieved by keeping the metal object in contact with one of the poles on the magnet. It can also be achieved using an electric current (but that's a more advanced technique).

It's pretty cool that magnets can cause metal objects to temporarily act like magnets. Usually, metal objects aren't magnetic themselves—they're just attracted to magnets. However, if you heat a piece of iron to a high enough temperature—called the Curie Point—the iron will actually lose its ability to be attracted to a magnet, let alone the ability to act like one! (Physics for Kids: 49 Easy Experiments with Electricity and Magnetism by Robert W. Wood, https://bit.ly/3HMz4yQ)


Magnet Chain & Stack. Touch a second paper clip to the paper clip that's on the magnet. The second paper clip is magnetized without directly touching the magnet.


Magnet Chain & Stack. After slipping the first paper clip off the magnet, the second paper clip should remain attracted to the first paper clip.

**Procedure**:

1. Ask students: ***In the previous activity, you learned that magnets attract metals, which means that metals like to stick to magnets. Do you think you can make a metal object to stick to another metal object using magnetic force?***

2. Pair students. Make sure each pair has two paper clips and at least one magnet.
3. Ask students: ***You already know that a paper clip will stick to a magnet. If a paper clip is stuck to a magnet, do you think you could get a second paper clip to stick to the first one, without letting it touch the magnet directly? Try it!***

4. Have pairs add one paper clip to one magnet.
5. While one student holds the magnet with the paper clip on it, have the other student touch a paper clip to the end of the first paper clip (see top photo at left).

   Discussion Prompt:
   - ***What happened?*** *(The second paper clip sticks to the first paper clip as if it's magnetic!)*

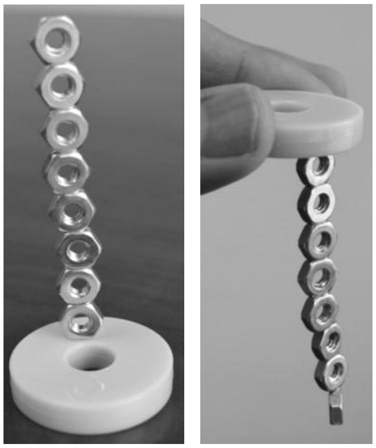
6. Ask students: ***What do you think will happen if we take the first paper clip off the magnet? Will the second paper clip still stick to it, or will it fall off? Try it!***

7. Have students hold the paper clip that's touching the magnet, with the second paper clip dangling freely.
8. Have students gently slide the first paper clip off the magnet and hold it in midair (see bottom photo at left).

   Discussion Prompts:
   - ***What happened?*** *(The second paper clip is still stuck to the first paper clip!)* ***Is the paper clip a magnet now?***
   - ***What would happen if you pulled the paper clips apart, then touched them together again?***
   - ***Would they still be magnetic?***

9. Allow students to experiment with separating and rejoining the paper clips. They can also explore touching the one or both paper clips to the magnet before trying to connect them to see whether that matters (hint: it does!).

   Discussion Prompts:



Magnet Chain & Stack. Stack metal nuts upwards or downwards on a magnet.

- ***Do the paper clips stay magnetic forever?*** *(No.)*
- ***Why not?***

10. Tell students: ***If a magnet is strong enough, it can give a metal object magnetic properties for a short time. Soon, though, the metal object returns to its normal, non-magnetic state. However, as long as a metal is directly touching a magnet, the magnetic force from the magnet will make the metal magnetic as well.)***

11. Ask students: ***The ability of a magnet to make metals magnetic is called "induction." Can we use induction to overcome other forces, like gravity? Let's try!***

12. Put students in four groups.
13. Give each group eight metal nuts. Keep the nuts away from the magnets in preparation for the next step. (Tip: if you think students will giggle at the phrase "stack the nuts," you may want to call them "hex nuts.")
14. Ask students: ***Without using magnets, how high can you stack the nuts edge-to-edge on the table if you take turns placing them one at a time? Try it!***

15. Have students take turns adding nuts to the stack, standing the nuts on top of each other to make the highest possible tower. Have students count the number of nuts in the final stack. (Tip: if students don't seem to find the task challenging, you might want to give them a time limit.)

    Discussion Prompts:
    - ***How hard was it to stack the nuts?***
    - ***What happens if you try to move your stack sideways?*** *(The stack falls down.)*
    - ***Do you think it would be easier or harder if you built your stack of nuts on top of a magnet?***

16. Have students stand the first nut up on its edge on one magnet, then continue the stacking process, taking turns adding nuts to the stack. Again, have students count how many nuts they can stack (see photo at left).

    Discussion Prompts:
    - ***Was it easier or harder to stack the metal nuts on the magnet?*** *(Easier.)* ***Could you feel the pull of the magnet through the metal nuts?*** *(Yes.)*
    - ***Did the pull get stronger or weaker as the stack got higher?*** *(Weaker.)*
    - ***What happens if you try to move your stack by sliding the magnet sideways on the table?*** *(The stack stays standing!)*

17. Allow students to experiment with repeating the stacking process. They may want to add additional magnets or nuts or try making different shapes.
18. OPTIONAL: Allow students to try stacking their nuts upside down! Have one student hold the magnet while other students add nuts from the bottom.

## Activity Four — Swinging Magnet Time: 10 Minutes

| Supplies | # | Supplies | # |
|---|---|---|---|
| Magnets (ring-shaped) | 16 | Yarn (1ft pieces) | 4 |
| Tape (rolls, masking or blue painter's) | 1 | | |

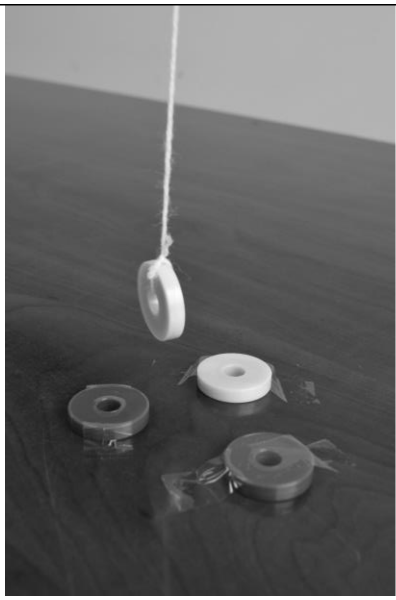
**Goal:** To observe how magnetic forces can act at a distance by allowing a free-swinging magnet to be swayed by fixed magnets.

**Source:** *Physics for Kids: 49 Easy Experiments with Electricity and Magnets*, Robert W. Wood

**Background:**
In this activity, you'll observe your magnet swinging all over the place when it gets near the triangle of magnets. Why does it do that? Each magnet has a magnetic field. When you tape the three magnets in a triangle, their magnetic fields overlap. Some areas where the fields overlap have the effect of repelling—or pushing away—another magnet, and other areas have the effect of attracting—or pulling—another magnet. When you swing the hanging magnet over the tops of the taped magnets, the hanging magnet gets pushed and pulled in crazy patterns by the different overlapping magnetic fields. (https://bit.ly/3YlDSCj)

**Procedure:**
1. Ask students: ***Earlier today, you learned that the force of a magnetic field can act on metals at a distance, like when your paper clip floated in the air near your magnet. Can magnets also act on other magnets at a distance? Let's find out!***

2. Keep students in four groups. Make sure each group has four magnets (if you have fewer than 16 students, you may need to hand out additional magnets).
3. Give each group a 1ft piece of yarn and make tape available (both types will work).
4. Have students tape three of their magnets flat on the table so they form a triangle. There should be about one to two inches of space between each of the three taped magnets.
5. Have another student tie or tape the 1ft piece of yarn to the fourth magnet.
6. Ask students: ***What do you think will happen if we let the fourth magnet dangle over the three taped magnets? How will the dangling magnet react? Try it!***



Swinging Magnet. Dangle a magnet from a piece of yarn above three taped-down magnets. (Scotch tape is pictured instead of masking or painter's tape so that the magnets are visible.)

7. Have one student hold the free end of the yarn, letting the magnet hang down about an inch above the three taped magnets (see top photo at left).
8. Allow the other students to take turns gently pushing the hanging magnet so it swings above the taped magnets.

   Discussion Prompt:
   - ***What happened?*** *(The hanging magnet zigzags wildly in the area above the taped magnets.)*
   - ***What makes the magnet move?*** *(Magnetic forces are pushing and pulling the hanging magnet as it moves in and out of the magnetic fields of the taped magnets.)*

9. Have students switch roles and repeat the experiment.

## Activity Five — Centripetal Force    Time: 10 Minutes

| Supplies | # | Supplies | # |
|---|---|---|---|
| Cups (9oz paper) | 16 | Yarn (2ft pieces) | 16 |
| Pennies | 64 | Pencils | 16 |

**Goal:** To observe centripetal force by swinging a cup of pennies in a circle.

**Source:** https://bit.ly/3JRbnrH

**Survey Connection:**

★ **Q.** What is the force that pulls all objects toward the earth?
**A. Gravity.**

**Background:**

Have you ever felt like you were being pushed or pulled in a car when it made a sharp turn? That's because the flipside of Newton's First Law (an object at rest will stay at rest unless a force acts on it) is that an object in motion will continue in the same direction unless a force acts on it. When your car takes a turn, it's changing directions and requires a force to do so. You're feeling the inertia of your body that wants to continue in the same direction being pushed in a new direction.

Now, imagine riding in a car that's constantly driving in circles. You would constantly feel that force pressing you against the outer side of the car as your body wants to continue in the straight path it's not allowed to take. That's what's happening to the penny in your cup! The constant change in direction keeps the penny from traveling in the straight direction it wants to. Instead, centripetal force pushes the penny against the far edge of the cup. That force is so strong that it can overcome gravity, which is trying to pull the penny toward the ground.

If you've ever wondered why roller coasters can flip upside down and no one falls out, now you know! Centripetal force keeps people pushed into their seats—and of course, there are seat belts just in case. (https://bit.ly/3YhUVVz)

**<u>Procedure</u>:**

1. <u>Ask students:</u> ***Earlier today, we learned that magnetic forces can sometimes overcome the force of gravity. What is another invisible force that can overcome gravity? Let's find out!***

2. Pair students.
3. Give each pair two paper cups, two 2ft pieces of yarn, and two pencils.
4. <u>Have students:</u>
   a. Use a pencil to poke two small holes across from each other near the rim of their paper cup (leave a little space under the rim for ease of poking).
   b. Thread the piece of yarn through the holes in the top of the cup and bring the ends of the yarn together above the opening of the cup.
   c. Tie the two ends of the yarn together to form a handle (like the handle of a bucket). (See bottom photo at left, though yours might look different). Pull the yarn through so the knot is as far as possible from the cup.

Centripetal Force. Thread the yarn through the holes in the paper cup and tie the two ends into a knot.

5. Give each pair of students a penny. Have them put the penny in one of the cups.
6. <u>Ask students:</u> ***What would happen if you turned the cup upside down?***

7. Have students turn the cup upside down.

   <u>Discussion Prompts:</u>
   - ***What happened?*** *(The penny fell out and hit the floor.)*
   - ***Why did that happen?*** *(Gravity pulled the penny toward the earth.)*
   - ***How could you prevent the penny from falling out of the cup when you turn the cup upside down? Let's find out!***

8. Have one student in each pair put the penny back in the cup.
9. Hold the knotted ends of the yarn handle bunched together in one hand. The cup should hang down, weighted by the penny.
10. Have the students who are holding the cups spread out so they each have at least a 2ft circle around them. Have the other students from each pair stand to one side of the room for this round of the experiment.
11. Ask students: ***What do you think will happen if you swing the cup around in a circle (like a Ferris wheel)? Will the penny fall out when the cup is upside down, or will something else happen? Let's try it!***


Centripetal Force. Swing the cup (with pennies inside) around by the yarn handle.

12. Let students try swinging the cup around in a smooth circular motion. It may take a little practice (see photo at left).

    Discussion Prompts:
    - ***What happens?*** *(As long as the cup is swung in a smooth circle, the penny stays in the bottom of the cup!)*
    - ***Is there a force acting on the penny? Let's watch closely!***

13. Have students switch roles. Allow the second group of students to swing the cup around in a circle.

    Discussion Prompts:
    - ***Can you see the force keeping the penny in the cup?*** *(No.)*
    - ***Why not?***

14. Tell students: ***The force that keeps the penny in the cup is called CENTRIPETAL FORCE. It's created when things are swung in a circle. Centripetal force pushes away from the center of the circle—in this case, it forced the penny to the bottom of the cup, which kept it from falling out of the cup. What do you think will happen if we add more pennies to the cup?***

15. Give each pair three more pennies (so that each pair has four pennies total).
16. Have students repeat the activity with additional pennies in the cup.

    Discussion Prompts:
    - ***What happened?*** *(The pennies still stayed in the cup!)*
    - ***Could you feel any difference between swinging one penny and swinging four pennies?*** *(You could probably feel centripetal force pushing outward around the circle more strongly with four pennies.)*

## Activity Six – Daily Debrief Time: 5 Minutes

| Supplies | # |
|---|---|
| Worksheets: Post-Survey | 16 |
| Lab Notebooks | 16 |
| Pencils | 16 |

**Goal:** To draw today's activities together through a thoughtful question and give students an opportunity to ask their own questions.

**Procedure:**

1. Encourage students to reflect on what they learned in today's class and what new questions they might have.

2. Allow students a few seconds to think. Have them discuss their thoughts and questions with a partner, then share with the rest of the class and/or write down in their lab notebook.
3. If needed, feel free to offer prompts like:
   - ***What do you think would happen if we changed one thing about today's activities (for example: materials, speed, temperature, etc.)?***
   - ***If you could investigate (explore) one more thing about today's activities, what would you like to find out?***

4. If time allows, ask the following question:
   - ***What could you use magnets and centripetal force for in your daily lives? Or what kind of invention could you create using those two forces?***

5. Give each student a **Post-Survey** worksheet. Make pencils available.
6. Read each survey question aloud for the students and allow a few seconds to think about the question. Have students write their answers on the surveys.
7. Collect the surveys then have students discuss their answers with a partner. Review the correct answers aloud with students.
8. **SAVE STUDENTS' POST- SURVEYS TO GIVE TO YOUR SITE MANAGER.** Please ensure all names are legible on the surveys and, if not, write them in.

**Clean up:** Make sure students help clean the room before they leave.

**What to save:**

| Materials used | # | SAVE | Materials used | # | SAVE |
|---|---|---|---|---|---|
| Cups (9oz paper) | 16 | 0 | String (6in pieces) | 16 | 0 |
| Magnets (ring-shaped) | 16 | 16 | Tape (rolls, masking or blue painter's) | 1 | 1 |
| Nuts (metal hexagons) | 32 | 32 | Worksheets: Post-Survey | 16 | 16 |
| Paper clips (regular size) | 16 | 16 | Worksheets: Survey Answers | 1 | 1 |
| Pencils | 16 | 16 | Yarn (1ft pieces) | 4 | 0 |
| Pennies | 64 | 0 | Yarn (2ft pieces) | 8 | 0 |
| Scissors (site provides) | 16 | 16 | | | |

**What goes home:** Centripetal Force cup & 4 pennies per student.

*(Review safety guidelines with students: cups should not be spun around while standing close to other people; small items should always be kept away from children ages 3 and younger to avoid the risk of choking)*

- REMINDER: If your Site Coordinator sent home Magnet Take-Home Permission Slips, remind students to get them signed and bring them back by the final class.

# Fun Physics: Forces & Motion (Grades 4-6)

## Class 8: Forces Finale

| Supplies* | # |
|---|---|
| Aluminum roasting pans | 2 |
| Cups (20oz plastic) | 4 |
| Foam tubing (grooved track, 6ft pieces) | 8 |
| Magnets (ring-shaped) | 16 |
| Marbles (small) | 16 |
| Newspaper | 1 |
| Paper clips (regular size) | 16 |
| Paper towels (rolls) | 1 |
| Pencils | 16 |
| Popsicle sticks (notched, "skill sticks") | 32 |
| Rubber bands (size 16) | 16 |
| Rubber bands (size 33) | 16 |
| Straw paddles (taped together, "for boats") | 3 |
| Straw pieces (2in, "for boats") | 64 |
| Tape (rolls, blue painter's) | 1 |
| Tape (rolls, masking) | 1 |
| Tape (rolls, Scotch) | 4 |
| Vials (small plastic, with lid) | 16 |
| Water (oz) | |

**If you have leftover kit supplies, bring them for Activity 3: Marble Coaster*

| | |
|---|---|
| Worksheets: Post-Survey | any left |

## Prep (prior to class) Time: 15-30 Minutes

- **Act. 2**: *Staying inside*: fill two roasting pans just over halfway with water. *Going outside*: fill two roasting pans less than halfway with water (for easy carrying) & fill four 20oz cups with water.
- **Act. 2c (optional):** Prep the Size 16 rubber bands for students. (See Act. 2, Step 2a.)
- **Act. 3 (optional):** Bring leftover kit supplies for *Marble Coaster*.
- **GENERAL:** If your Site Coordinator sent home Magnet Take-Home Permission Slips, ask them which students returned a signed form.

## Activity One – Pair & Share Time: 10 Minutes

| Supplies | # | Supplies | # |
|---|---|---|---|
| Pencils | 16 | Lab notebooks | 16 |

**Goal**: To engage students' thinking and questioning related to the day's activities.

**Procedure:**
1. Prepare a quiet space for students to give them a physical area to think. The space can be an area set aside from the activity area, where students sit in a circle to ponder the *Pair & Share* question.
2. Make lab notebooks and pencils available.
3. Ask students one or more *Pair & Share* questions:
   - ***How do boats stay afloat? How do they move in water?***
4. Ask students to discuss their ideas with their neighbor before inviting students to share what they came up with. This is a "challenge by choice" opportunity and no one is required to share with the class if they are not comfortable.
5. **Give post-surveys to any students who haven't already done one.**

## Activity Two — Rolling on the River Time: 20 Minutes

| Supplies | # | Supplies | # |
|---|---|---|---|
| Aluminum roasting pans | 2 | Popsicle sticks (notched, "skill sticks") | 32 |
| Cups (20oz plastic) | 4 | Straw paddles (taped together, "for boats") | 3 |
| Newspaper | 1 | Straw pieces (2in, "for boats") | 64 |
| Paper clips (regular size) | 16 | Tape (rolls, Scotch) | 4 |
| Paper towels (rolls) | 1 | Vials (small plastic, with lid) | 16 |
| Rubber bands (size 16) | 16 | Water (oz) | |
| Rubber bands (size 33) | 16 | | |

**Goal**: To observe how rubber bands can store up potential energy and convert it to kinetic energy by building a small paddlewheel boat.

**Source:** Hands On Science Outreach

**Background:**

So far, you've built a spool racer, drag-racing cups, and in this activity a boat—all using rubber bands! When you build a boat, you will learn that rubber bands can store potential energy, then release that same energy as the kinetic energy of motion! Does that same concept work here? Of course! This time, though, instead of making an object roll, the rubber band turns a paddle that pushes the water under the boat.

Do you remember how forces can be balanced? In your boat, the downward pull of gravity is balanced by the buoyant force of water—that's what keeps the boat afloat!

There's one more concept at work here. Remember that for every action, there's an equal and opposite reaction. In this case, the action is winding the straw paddle, and the reaction is the paddle turning and causing the boat to move. This rubber band boat is a great reminder of many of the concepts you've learned so far! (https://bit.ly/3YyDorW, https://bit.ly/3ldiro7)

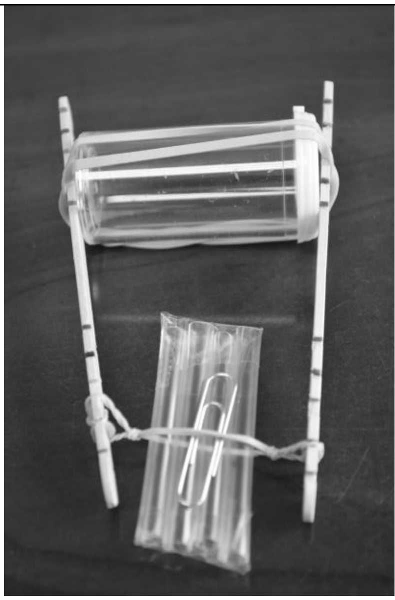
**Procedure:**

**TIPS:**
- **If you can go outside for this activity,** great! Just fill the roasting pan(s) partway with water (up to a point that won't spill easily for carrying). Have four students each carry a 20oz cup of water to add to the pan(s) outside. Each pan should be slightly more than half full of water to do the activity.
- **If it's not possible to go outside**, you'll want to bring newspapers to class to cover the floor under the pans of water. The water often splashes out, and newspaper will help minimize the mess.

1. Ask students: ***In an earlier class, you used rubber bands to power a spool racer and drag-racing cups. Do you think you can use a rubber band to power a boat as well?***

2. Give each student a vial with a lid on, two notched popsicle sticks ("skill sticks"), one size 16 rubber band, four 2in straw pieces, one regular paper clip, and one size 33 rubber band. Make Scotch tape available.
3. Start with the body of the boat. Have students:
   a. Tie two knots in the size 16 rubber band to divide it into three equal parts (see the rubber band near the paper clip in the photo on the next page).
   b. Make sure the vial has a lid on it and the lid is pressed firmly in place.
   c. Place the vial sideways between the skill sticks, so that the first skill stick is pressed flat against the lid of the vial, and the second skill stick is pressed flat against the bottom of the vial. The sticks will be parallel.
   d. Position the vial two notches in from the end of the parallel skill sticks, so that the vial and sticks form a lopsided letter "H."

Rolling on the River. Create a "straw paddle" by taping together four 2in straw pieces, then taping across the tops and bottoms of the straws. (There are three pre-made samples in your kit.)



Rolling on the River. Finished "boat." Note that the paper clip is inserted between the rubber band and the top of the "straw paddle."

   e. Wrap the size 33 rubber band around the skill sticks and vial *twice* to keep the vial in place.
   f. Slip the outer loops of the size 16 rubber band onto the free ends of the skill sticks (one loop goes around each skill stick on the end farthest from the vial).

4. Ask students***: For the rubber band to power the boat, it needs something to push the water under it. Do you think you can make something that will push against the water?***

5. Show students the pre-made straw paddles. Place them around the room as examples. (Note: If a few students end up struggling to make their own straw paddles, you can have them use the pre-made examples for their boats.)
6. Have students:
   a. Place the four 2in pieces of straw so they form an even row with their long sides touching.
   b. Tape the straw pieces together, then tape across the tops and bottoms of the straws. This creates a "straw paddle" (see top photo at left).
   c. Insert the straw paddle into the center gap in the size 16 rubber band.
   d. Slide the regular size paper clip into the same gap in the rubber band so it lies flat on top of the straw paddle (see bottom photo at left).

7. Split the class in half and assign each group to one of the roasting pans.
8. If you decide to stay indoors, put down newspaper or paper towels on the floor, then give each group a roasting pan filled halfway with water. If you go outdoors, you'll need to bring the pans of water with you. You can fill them partway indoors, then have students carry cups or other containers to bring the water level in the pans just past halfway full before you begin the activity.
9. Ask students: ***Now that you have your boat, how can you store energy in it so it will move forward when you put it in water? Remember, rubber bands can store potential energy when they're stretched or twisted, then convert it back to kinetic energy!***

10. Wind up the "straw paddle" by taking the side of the paddle farthest from the vial, pushing it upward (toward the vial), then circling it down and back up again. Repeat 10-15 times to wind up the rubber band. Make sure students hold the paddle in place after turning it to store that potential energy!
11. Have students take turns placing their boat in the water (at one end of the roasting pan, *with the vial at the back of the boat*) and releasing the "straw paddle." It helps to make sure the paddle is fully immersed in the water before letting it go to minimize splashing. (The boat should travel at least one length of the pan. Students may need to adjust how close the vial is to the end of the skill sticks if the boat isn't traveling that far.)

Discussion Prompts:

- ***What happened to your boat?*** *(It moved across the water!)*
- ***Which part of the boat had potential energy that was released to make the boat move?*** *(The twisted rubber band).*
- ***Could you change which direction the boat moves?*** *(Yes, by twisting the rubber band the opposite way.)*
- ***How is the paddle on a paddleboat like a wheel? How is it different?***

## Activity Three — Marble Coaster　　Time: 30 Minutes

| Supplies | # | Supplies | # |
|---|---|---|---|
| Cups (20oz plastic) | 4 | Pencils | 16 |
| Foam tubing (grooved track, 6ft pieces) | 8 | Tape (rolls, masking or blue painter's) | 1 |
| Marbles (small) | 16 | | |

**Goal**: To apply students' cumulative knowledge of forces and motion to engineer a grooved track for a marble to roll along.

**Source**: http://bit.ly/3ZWs5KS

**Background:**

Building a marble coaster really applies all the concepts you learned about in AKA Science! Your marble coaster is a great example of potential and kinetic energy. By starting the marble high up on a ramp, you make sure the marble has enough potential energy to convert into the kinetic energy needed to roll through your course.

Will you add a loop into your track? You'll probably have to consider the size of the loop to make sure there is enough centripetal force to keep your marble from falling down! Will you add a turn to your track? You probably must tilt the track because inertia keeps the marble moving straight when you want it to turn! Will you add a jump to your track? You probably have to make sure your marble has enough kinetic energy to leap into the air!

Engineers are people who apply physics to create machines and other contraptions. There are many different kinds of engineers, from people who work on traffic patterns, to people who harness nuclear power, to people who design roller coasters! Now that you've had your first taste of the engineering process, see if you can apply it in your life. All you need to do is design, test, and most importantly, retest! Good luck, and don't forget to use what you've learned about the physics of forces and motion!

**Procedure:**

1. Ask students: ***Over the past several weeks, you learned about gravity, electricity, magnetism, kinetic and potential energy, friction, balance, and inertia. Can you use some of these concepts to create a marble coaster? Let's try taking it step by step!***

Marble Coaster. Create a steep starting ramp by taping the grooved track from a wall to a table, or from a table to the floor.

Marble Coaster. Connect the two pieces of track by smoothly taping over the junction.

Marble Coaster. Loop example.

2. Put students in four groups. Give each group four marbles, a 20oz cup (emptied out from the previous activity), and two 6ft pieces of grooved foam track. If you have leftover supplies from your kit, make them available as building materials.

   Discussion Prompt:
   - ***To create a good start to get your marble rolling, you're going to have to convert a good source of potential energy into kinetic energy. How can you do that?***

3. Guide students through using painter's tape to attach one end of a piece of track to a vertical surface in the classroom. *(Smooth, unpainted surfaces are ideal.)* The higher the piece of track is taped, the better start it will give the marble. Students should tape the other end of the piece of track to a flat, horizontal surface like a table or the floor (see top photo at left).
4. Have groups test their starting track. The marble should pick up speed as it travels down the ramp. It should stay in the groove of the track.

   Discussion Prompt:
   - ***Now that you have a good start, what else can you do with your coaster?*** *(Students may want to create a loop, a turn, or a jump. See below for tips on these.)*

5. Before you allow students to engineer additions to their marble coasters, prepare them with these tips:
   a. Test often! Engineers often find that something doesn't work the way they thought, and they have to change something to make it work. Before you build your entire coaster, make sure each part of it works the way you think it will! (You may want to use the 20oz cup to catch the marble at the end of the track, so it doesn't roll too far away.)
   b. Make sure the connections between pieces of track are smooth (see middle photo at left).
   c. Keep up your marble's energy! Every obstacle will use up some of the kinetic energy created by the initial roll down the ramp. If your marble is running out of energy, start your coaster higher, make your obstacles smaller (so they use up less energy), or build in ways for the marble to pick up more energy.

6. Guide students through adding obstacles to their coaster using these tips:
   a. For loops, remember that centripetal force pulls away from the center of a circle. Make sure the marble is moving fast enough, so it stays in the track and doesn't fall out. If the loop is too wobbly, the marble will lose momentum, so you may need to reinforce the loop by taping it to firm objects like

popsicle sticks (if you have any leftovers) or pencils. Also, smaller loops will waste less momentum, so the marble doesn't need as much speed going in (see bottom photo on previous page).

b. For turns, you may notice that the marble will want to continue in a straight line and may jump out of the track. To correct for this, tilt the track slightly sideways (i.e., bank it) to keep the marble in the groove (see top photo at left).

c. For jumps, remember that the marble needs a lot of kinetic energy to overcome the pull of gravity. If the ramp is too high, the marble will lose a lot of its energy and won't be able to jump. Keep the ramp as short as possible for maximum height on the jump (see middle photo at left).

7. After about 20 minutes, have groups take turns demonstrating their marble coasters (see bottom photo at left). You may also ask students to share the challenges they faced building their coasters and how they overcame them—just like real engineers learn from each other!
8. OPTIONAL: For a fun bonus, you can combine the four groups into two and help students connect their separate coasters to create two mega-coasters. The best way to do this is to set up one group's initial ramp so it flows from a wall onto a table, then connect the next group's coaster so the initial ramp flows from the table to the floor (to build momentum). That way, you can just add the start of the second group's coaster to the end of the first group's coaster.

Marble coaster. Turn example.

Marble Coaster. Jump example.

Marble Coaster. Full coaster.

## Activity Four – Wrap-Up! Time: 5 Minutes

**Clean up:** Make sure students help clean the room before they leave.

**What to save**:

★ ***ALL COMPLETED STUDENT PRE- & POST-SURVEYS***

**Please stack each student's completed Pre & Post Survey on top of each other, then give the whole stack to your Site Coordinator or Manager right after the last class so they don't get lost in the shuffle. They will submit the surveys to AKA Science.**

**What goes home**:

***ALMOST* EVERYTHING!***

***Never send students home with items that they can't be expected to use safely while unsupervised.** For this particular unit, **don't** send home batteries, light bulbs, wires or loose nuts with *any* students.

# Fun Physics: Forces & Motion (Grades 4-6)

## Class 8: Forces Finale

***Remember to submit students' Pre/Post Surveys to your Site Coordinator/Manager!***

- **Please <u>only</u> send magnets home with students for whom the Site Coordinator/Manager has confirmed that a signed permission slip is on file.** *(Review safety guidelines with students: magnets should not be handled roughly because they can chip or break; they should be kept away from small children, computers, cell phones, credit cards & people with pacemakers; magnets are a particular risk around small children, because in addition to being a choking hazard, swallowed pieces of magnets can pinch the digestive tract and cause serious medical problems)*

- If some students have permission to take home magnets—but other students don't—feel free to send home other extra items from the kit with the students who aren't taking magnets (so they don't feel left out).

- From Class 8, you can cut the pieces of foam tubing in half and send a 3ft piece home with each student, along with a marble and students' boats. *(Review safety guidelines with students: marbles should not be handled roughly because they can chip or break, and they should not be thrown at people or pets; small items should always be kept away from children ages 3 and younger to avoid the risk of choking)*

- **<u>For leftover supplies that aren't possible to send home with students</u>:**
  - Please ask if the site has a use for them. If so, the site can keep them!
  - If there are some supplies the site can't use, we're happy to put them back in our inventory! You're welcome to bring the leftover supplies to the next Class Leader training, drop them at our office, etc.

- **Questions?** Contact Kathryn Sechrist: ksechrist@impactnw.org
  *Thanks for your help – and thanks for teaching AKA Science!*

AKA Science is funded by our generous community partners.

We acknowledge that the land on which AKA Science operates is the traditional, unceded territory and homeland of the Multnomah, Wasco, Cowlitz, Kathlamet, Clackamas, Bands of Chinook, Tualatin, Kalapuya, Molalla tribes and many others whose communities gathered and thrived along these two great rivers.

# Fun Physics: Forces & Motion (Grades 4-6)

## NGSS - Next Generation Science Standards aligned with this curriculum.

- **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 a pull.
- **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.
- **1-PS4-4**
  - Use tools and materials to design and build a device that uses light or sound to solve the problem of communicating over a distance.
- **2-PS1-2**
  - Analyze data obtained from testing different materials to determine which materials have the properties that are best suited for an intended purpose.
- **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.
- **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.
- **3-PS2-3**
  - Ask questions to determine cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other.
- **3-PS2-4**
  - Define a simple design problem that can be solved by applying scientific ideas about magnets.
- **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.
- **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-PS3-3**
  - Ask questions and predict outcomes about the changes in energy that occur when objects collide.
- **4-PS3-4**
  - Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.
- **5-PS2-1**
  - Support an argument that the gravitational force exerted by Earth on objects is directed down.