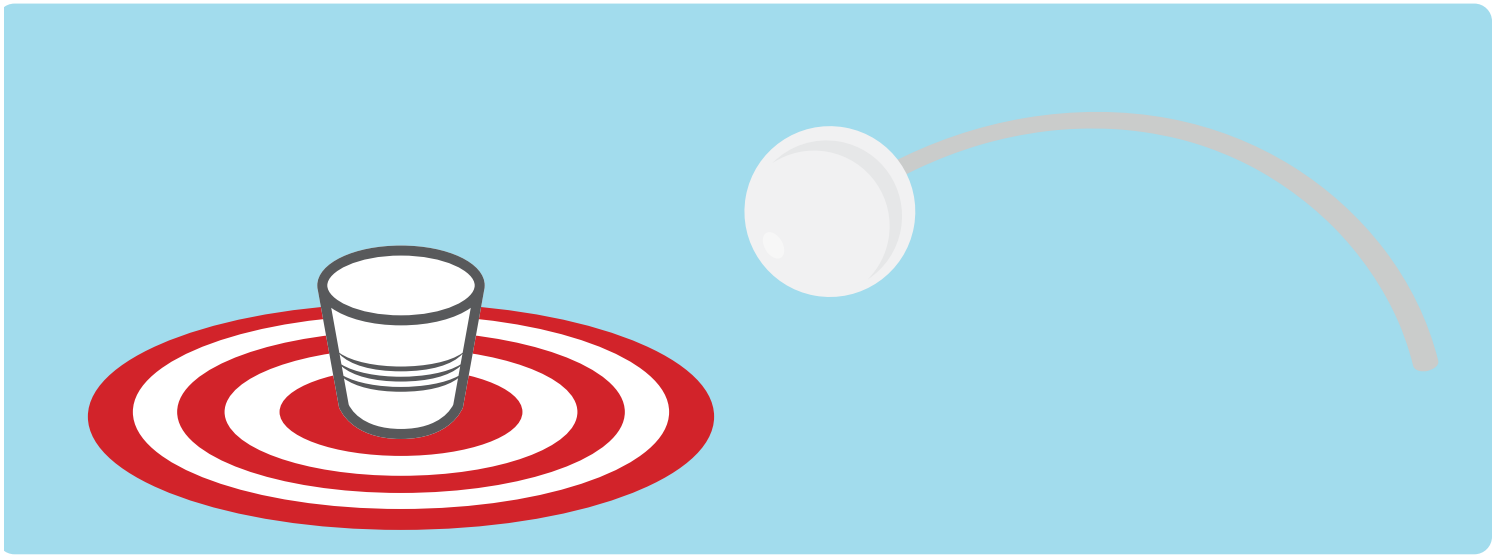
LESSON

Circle of Pong

Grade Levels: 2-12
Duration: 65 min

Students use their knowledge of energy and forces to place a ball in the center of a 6 foot diameter circle. As students iterate through this design challenge, they gain first-hand experience using the Innovation Design Process.



Outline

Frame the Activity	20 min total
Activate Prior Knowledge	10 min
Introduce Design Challenge	10 min
Design Challenge	**35 min total**
Prototype: Build and Test	20 min
Share Solutions	15 min
Closing	**10 min total**
Debrief	10 min

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Concepts/Skills

Gravity, potential energy, kinetic energy, innovation design process

Objectives

Students will:

- Design, build, and test a device that delivers a ball into a cup.
- Make design considerations based on concepts of potential and kinetic energy

Lab Connection:

Physics of Roller Coasters
Advanced Physics of Roller Coasters

Materials and Preparation

Materials

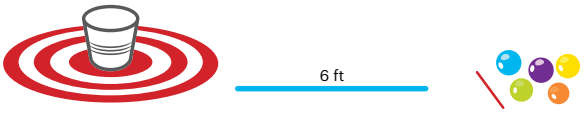
(per class of ~32 students)					*(1 per group)*
Items to create reach and structure *(30-40 items)*	**Items that can enable motion** *(60-80 items)*	**Items that can stick, grip, grab, or scoop** *(30-40 total)*	**Items that can stick, grip, grab, or scoop** *(30-40 total)*	**Fasteners** *(60-80 items)*	**Tools** *(1 set)*
□ Cardboard □ Cardboard tubes □ Craft sticks □ Index cards □ Paint sticks	□ Clothespins □ Rubber bands □ Springs □ Straws □ String or yarn	□ Funnels □ Hooks □ Paper cups or bowls □ Plastic baskets	□ Binders □ Cardboard □ Cardboard tubes □ Craft sticks □ Food containers □ Poster board □ Rulers □ Wooden skewers	□ Binder clips □ Paper clips □ Pipe cleaners (chenille stems) □ Rubber bands □ String □ Tape	□ Hole punch □ Ruler or yardstick □ Scissors □ Tape

Tip: Don't use glue and limit the use of tape. This allows for faster iteration, more reuse of materials, and less mess.

Test Area Supplies

- A 6 foot (1.83 m) diameter circle clearly marked on the ground.
  - Use a plastic tablecloth, string, tape, etc.
- A cup placed in the center of the circle.
- 1 ball per team for students to test with; the ball needs to fit in the cup.
  - Ping pong ball, rubber ball, foam ball, marble, etc.

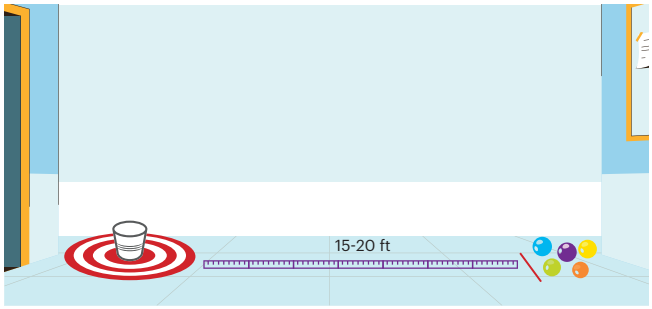
Sample Testing Setup



Advanced Test Area Supplies

- Consider setting up the testing zone circle outside or in a hallway to give teams more space to test.
  - Use a tape measure to mark the distance from the cup every few feet out to 15-20 feet (4.57-6.1 m).
- A cup placed in the center of the circle.
  - The smaller the cup, the harder the challenge.
- 1 ball per team for students to test with; the ball needs to fit in the cup.
  - Ping pong ball, rubber ball, foam ball, marble, etc.

Advanced Testing Setup



Preparation

1. Set up the testing zone.
   - Place the circle in a spot that students can access to test as often as they want.
   - Place a cup in the center of the circle. Be sure to tape it down so it is always in the same spot.
2. Gather materials and set up so teams have access to all the items. Group materials by type so teams can peruse and choose based on their ideas.
3. Plan to have students form teams of 3-4.

Lab Connection

Circle of Pong builds on the connection between potential and kinetic energy that students explore in the **Physics of Roller Coasters** and **Advanced Physics of Roller Coasters** Labs at The Tech Interactive. The student-built roller coasters focused on gravitational potential energy that transforms into kinetic energy as the ball rolls down a hill. In this next step of energy exploration, students will focus on finding different ways to store and then transfer energy to a ball to deliver it to a target.

Check out the **Explore Design Challenge Learning page** for tips on how to help learners become creative problem solvers. Here you can find a variety of Tech Tips, videos and downloadable resources.

Frame the Activity

Define the Problem *(10 min)*

1. Let students know that in this lesson they will be exploring energy. Energy can be in the form of potential energy (stored) or kinetic energy (motion). Have students discuss in their teams what they already know about energy.
   - If students attended the **Physics of Roller Coasters** or **Advanced Physics of Roller Coasters** Labs at The Tech Interactive have them discuss some of these questions:
     - *Where were potential and kinetic energy present in your roller coaster?*
     - *How were you able to transform potential energy into kinetic energy?*
     - **Advanced Physics of Roller Coasters:**
       - *Was there anything special about the amount of energy you could have at one time?*
2. Lead a discussion around the connections between potential energy and kinetic energy.
   - *What are ways that energy can be stored? Are there any examples in the room right now?*
   - *What are ways that we can increase the stored energy?*
   - *How can potential energy help move an object?*
   - *How might kinetic energy be related to potential energy?*
   - *Are there real life devices that use both potential and kinetic energy?*
   - *How does the device transform them back and forth?*

- *Does the device move something? (e.g., A roller coaster has both types of energy and delivers people in a cart around a track using hills.)*

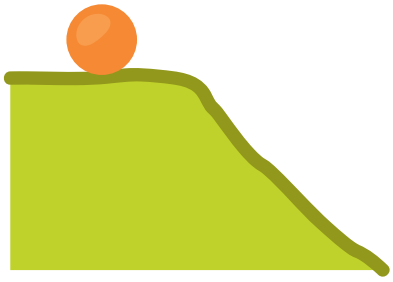
3. For advanced engineers:
   - *How does conservation of energy apply to transforming potential energy to kinetic energy?*
   - *What are examples of how Newton's first law of motion applies to an object?*
4. Let teams know that they will be focusing on storing energy and converting it into another type to deliver an item.

For Beginning Engineers

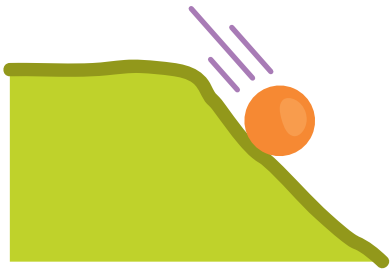
For students who are new to studying energy it can be helpful to present graphics or videos that showcase how potential and kinetic energy are related and how energy can be transformed from one type to another.

Energy: The capacity to do work. Appears in many forms, all of which are either kinetic or potential.

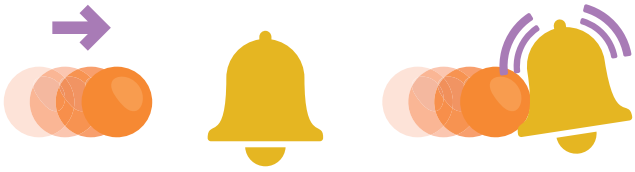
Potential energy (stored energy)



Kinetic energy (energy of motion)



Energy cannot be destroyed. But it can be transferred from one object to another or even transformed from one form to another.



Introduce the Challenge *(10 min)*

1. Introduce the design scenario:

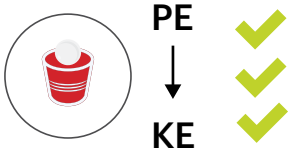
The U.S. Geological Survey (USGS) has hired your engineering team to help them deliver a small piece of equipment to the center of a lava flow or volcano. You can't launch the device by touching it, you can't get close to the lava flow, and it needs to be precise every time. Can you use your knowledge of physics and engineering to help them out?

Additional story options

Depending on your class, you can link the story to other science topics or other learning units.
For example:

- *Teams are asked to deliver a device that takes weather measurements. It needs to travel along the same path multiple days in a row to accurately take data for the area.*
- *You and your friend live next door to each other and want to send notes back and forth. You want to send the notes through each other's windows. Can you design a device that will help your note land in your friends room through the window?*

2. Introduce the constraints and criteria for success. Have teams discuss how they will be using potential and kinetic energy to create their devices.

Design Problem	Deliver a ball into a cup in the middle of a six foot (1.83 m) diameter circle.	
Criteria	• The ball must come to rest in the cup without bouncing on the ground. • The device should transform potential energy into kinetic energy to move the ball. • The device should work three times in a row.	
Constraints	• Only the materials provided may be used. • No human help — the ball cannot be moved or assisted by a team member. • The ball must start outside the circle — no body part may enter the area above the circle.	

For Advanced Engineers

Focus on materials testing.

- Challenge advanced engineers to test different materials to discover what items can store the most potential energy. Teams can try out multiple materials before building their final design.
- Consider providing a variety of potential energy storing items such as different sizes and shapes of rubber bands, springs, bungee cords, or more.
- Use the **Advanced Testing Set-up** so teams can step back to launch their device over the most distance possible.

Design Challenge Part 1

Prototype (Build and Test) *(20 min)*

1. Divide students into teams of 3-4 for the design challenge.
   - Consider using roles with students that align with careers such as design architect, civil engineer, and quality control inspector.
2. Allow teams a few minutes to examine the materials and then brainstorm ideas in their teams before building. Provide each team with their ball as well. Teams should be trying to answer some of the below while exploring the materials table:
   - *What items will store potential energy?*
   - *What items can be used to hold the ball?*
   - *What items can help transform the potential energy into kinetic energy?*
3. Have teams collect materials and begin building.

For Beginning Engineers

Provide more structure around selecting materials and getting started.

- Restrict teams to collecting only 10 items at the start.
- Teams must choose at least one item that can store potential energy and at least one item that can help transform the potential energy into kinetic energy.
- Have teams build for a few minutes before allowing material exchanges or new selections.

4. Encourage learners to test early and often, to discover areas for improvement.
5. During the prototyping time, support teams with open-ended questions to guide their process.

Prototype Questions

Just Starting Out

- *How are you determining which materials to use?*
- *How does your device store potential energy?*
- *What does your device do to transform the potential energy into kinetic energy?*
- *Where can you look for inspiration in the real world?*

Problem-Solving After Testing

- *How did your device perform during testing?*
- *Are you noticing a pattern from your tests so far? What can that tell you?*
- *What are some ideas you have to change your design?*
- *Did you notice something in another design that you want to try?*

Pushing Design Further

- *What can your team try to make this design more reliable?*
- *Could your team's device store energy in a different way?*

6. Encourage learners to use key vocabulary and concepts such as gravity or potential energy as they discuss and reflect on their testing.
7. Provide reminders of the time. As the prototype time comes to a close, encourage teams to test even if they do not feel their device is ready.

Share Solutions *(15 min)*

1. At the end of the time limit, have learners stop even if they haven't been able to complete their design (or iteration of their design).
2. Have each team demonstrate their device while sharing what they built and why.

Sharing Prompts

Possible sharing prompts could include:

- *Tell us about your device.*
- *How does your device transform potential energy into kinetic energy?*
- *What changes did you have to make while working?*
- *How were you able to ensure the ball would land in the cup?*
- *What changes could make it more reliable?*
- *Did any other teams inspire a part of your design after you saw them test? How did you incorporate the idea?*
- *What would you change or add if you had more time?*

3. Keep the sharing simple and focused. Have learners give each other positive feedback on their designs. Encourage them to tell the presenting team one thing they liked or noticed.

Debrief *(10 min)*

1. Have students reflect on what they learned from the building and iterating process and the larger engineering concepts and real-world applications.
2. Lead a short debrief with some of these questions.

Design Process

- *From what you observed, what makes devices more reliable?*
- *Did you notice anything that a lot of teams did while working? (e.g., a brainstorm, iterating after testing, changing their minds to try something new)*
- *What are some features that worked well in many devices? What are some features that did not work as well?*

Science Concepts

- *What similarities did you notice in how different devices transformed energy?*
- *What type of material was the most common to store potential energy?*
- *How might knowledge of potential and kinetic energy help other kinds of scientists or engineers?*
- *For advanced engineers:*
  - *How or where are conservation of energy and Newton's First Law of Motion related to this experiment?*

Career Connection: Roller Coaster Engineer

Designing and building roller coasters is a real world job where engineers can use physics concepts such as potential and kinetic energy to design fun rides for people to enjoy. To create fun roller coasters that keep their passengers safe, roller coaster engineers draw blueprints, use computer programs to calculate velocity and energy, and manage budgets for construction and maintenance. Roller coaster engineers might get degrees in mechanical engineering, structural engineering, or civil engineering.

To learn more about the science behind roller coasters and careers designing and building them check out the resources below.

- **Meet an Expert:** Meet Donnelly Williams, hear how he got into the field of roller coaster engineering, and learn what he loves about it. **"This Roller Coaster Engineer Creates World Famous Amusement Park Rides,"** True Calling, YouTube *(2:25 min)*
- **Research**: Learn more about the science behind roller coaster design and consider how an engineer might use this. **"The Real Physics of Roller Coaster Loops,"** Art of Engineering, YouTube (18:02 min)
- **Try it:** Get some inspiration from this backyard creation and think about how you might go about designing a small scale coaster. **"How This Guy Built a Roller Coaster in His Backyard,"** Wired, YouTube *(10:55 min)*

Activity Extension

Iteration is an important part of the design process.

- Provide students time to revisit and revise their designs based on their testing, feedback, and/or observations of other team's designs.
- With more time, have students extend their prototyping process by selecting a challenge from the **Challenge Cards** resource page.

Standards Connections

Next Generation Science Standards

Grade		Description
K-2	K-2-ETS1-2	Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.
2	2-PS1-2	Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.
3	3-PS2-2	Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.
4	4-PS3-4	Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.
6-8	MS-PS3-5	Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.
	MS-ES1-2	Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
9-12	HS-PS3-3	Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.
Related Standards		3-PS2-1, 5-PS2-1, 3-5-ETS1-3, 3-5-ETS1-2, MS-ETS1-1, MS-ETS1-3
Science and Engineering Practices		Asking Questions and Defining Problems Planning and Carrying Out Investigations
Cross Cutting Concepts		Patterns Cause and Effect Structure and Function

Vocabulary

- **Conservation of Energy:** Energy cannot be created or destroyed; it may be transformed from one form into another, or transferred from one place to another, but the total amount of energy never changes.
- **Elastic Potential Energy:** Potential energy due to tension — either stretch (rubber bands, etc.) or compression (springs, etc.)
- **Energy:** The ability to do work
- **Force:** An influence (push or pull) on a body or system, causing a change in movement or shape
- **Gravitational Potential Energy:** Potential energy due to elevated position. This depends only on vertical displacement and not the path taken to get there. The value is always relative to some reference level.
- **Kinetic Energy:** The energy of motion. An object in any form of motion has kinetic energy (e.g., running, walking, dancing, flying, etc.).
- **Mass:** The amount of matter that is contained by an object
- **Newton's 1st Law of Motion:** An object at rest tends to stay at rest and an object in motion tends to stay in motion with the same speed and in the same direction unless acted upon by an unbalanced force