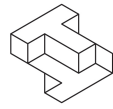


Circle of Pong

Design Challenge Learning



The Tech
Museum of Innovation

201 S. Market St.
San Jose, CA 95113
1-408-294-8324
thetech.org

Students use their knowledge of potential and kinetic energy, and explore forces of motion in order to place a ball in the center of a 6-foot diameter circle. As students iterate through this design challenge, they gain firsthand experience in the design process.

Grades 3-12

Estimated time: 45 minutes

Student Outcomes:

1. Students will be able to design and build a device that delivers a ping pong ball to a cup.
2. Students will be able to explain design considerations based on concepts of potential and kinetic energy, and forces.
3. Students will be able to utilize the three step design process to meet an engineering challenge.

Next Generation Science Standards

Grade 3-5: *Engineering Design* 3-5-ETS1-1, 3-5-ETS1-2, 3-5-ETS1-3

Grade 3: *Physical Science* 3-PS2-1, 3-PS2-2

Grade 4: *Physical Science* 4-PS3-1, 4-PS3-4

Grade 5: *Physical Science* 5-PS2-1

Grade 6-8: *Engineering Design* MS-ETS1-1, MS-ETS1-2, MS-ETS1-3, MS-ETS1-4; *Physical Science* MS-PS2-2, MS-PS3-1, MS-PS3-2, MS-PS3-5

Grade 9-12: *Engineering Design* HS-ETS1.1, HS-ETS1.2, HS-ETS1.3; *Physical Science* HS-PS2-1, HS-PS2-2, HS-PS3-2, HS-PS3-3

Common Core Language Arts-Speaking and Listening

Grade 3: SL.3.1b-d, SL.3.3, SL.3.4a

Grade 4: SL.4.1b-d, SL.4.4a

Grade 5: SL.5.1b-d, SL.5.4

Grade 6: SL.6.1b-d

Grade 7: SL.7.1b-d

Grade 8: SL.8.1b-d

Grade 9-10: SL.9-10.b-d, SL.9-10.2, SL.9-10.3, SL.9-10.4

Grade 11-12: SL.11-12.1.b-d, SL.11-12.2, SL.11-12.4

California Science Content

Grade 3: *Physical Science* 1.b, d; *Investigation and Experimentation* 5.a-b, d

Grade 4: *Investigation and Experimentation* 6.a, 6.c-d

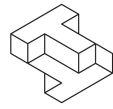
Grade 5: *Investigation and Experimentation* 6.a-c, 6.h

Grade 6: *Investigation and Experimentation* 7.a-b, 7.d-e

Grade 7: *Investigation and Experimentation* 7.a, 7.c-e

Grade 8: *Physical Science* 1.a-e, 2.a-g; *Earth Science* 4.e; *Investigation and Experimentation* 9.a-b

Grade 9-12: *Physics* 1.a-f, 2.a-g; *Earth Sciences* 1.a, 1.c, 1.f, 8.a-c, *Investigation and Experimentation* 1.a, 1.e, 1.g, 1.l-m



Vocabulary:

Familiarity with these terms and concepts will enhance students' experience in the activity

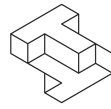
- **Elastic Potential Energy:** Potential energy due to tension – either stretch (rubber bands, etc.) or compression (springs, etc.).
- **Energy:** The ability to do work. Appears in many forms, all of which are either kinetic or potential.
- **Force:** A push or a pull. An influence on a body or system, causing or tending to cause a change in movement or shape.
- **Friction:** Forces resisting motion between one set of molecules and another due to electrical attraction and repulsion, usually between two solid surfaces; static before motion starts and kinetic during motion.
- **Gravitational Potential Energy:** Potential energy due to elevated position. *Note this only depends on vertical displacement and not the path taken to get it there. This value is always relative to some reference level.*
- **Inertia:** The tendency of matter to remain at rest if at rest, or if moving, to keep moving in the same direction, unless affected by an outside (or unbalanced) force.
- **Kinetic Energy (KE):** Energy of motion. Includes heat, sound, and light (motion of molecules).
- **Mass:** The amount of matter that is contained by an object.
- **Mechanical Energy:** Energy possessed by an object due to its motion or its stored energy of position. Mechanical energy can be either kinetic energy (energy of motion) or potential energy (stored energy of position).
- **Momentum:** The quantity of motion of a moving object, equal to the product of its mass and its velocity.
- **Newton's Law of Momentum Conservation:** The amount of momentum remains constant – momentum is neither created nor destroyed, but only changed through the action of forces.
- **Newton's law of 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.
- **Newton's Laws of Motion:**
 - **1st Law (Law of Inertia):** 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.
 - **2nd Law:** When an unbalanced force acts on a body, it is accelerated in the direction of the force; the magnitude of the acceleration is directly proportional to the force and inversely proportional to the mass of the body... $F=ma$.
 - **3rd Law:** Forces always occur in pairs. If object A exerts a force, F , on object B exerts an equal and opposite force, $-F$, on object A. Or "Every action has an equal and opposite reaction."
- **Potential Energy (PE):** Energy of position; energy that is stored and held in readiness. Includes chemical energy, such as fossil fuels, electrical batteries, and food we eat.
- **Torsion:** The twisting of an object due to an applied torque (the tendency of a force to rotate an object about an axis).

Resources:

- Kinetic and Potential Energy Comparison: Powered by Diffen, the website that allows you to compare anything, and includes an overview of kinetic and potential energy.
[www.diffen.com/difference/Kinetic Energy vs Potential Energy](http://www.diffen.com/difference/Kinetic_Energy_vs_Potential_Energy)
- PhET Interactive Simulations: Administered by the University of Colorado Boulder, the website provides a variety of interactive simulations for science and math. It includes simulations dealing with motion, energy, power, and work. <https://phet.colorado.edu>

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Design Challenge Process:

The Design Challenge Process is designed so students reinforce their science, mathematics, social studies, and language arts content knowledge, through an open-ended process that results in an original, team-driven solution. Students are expected to take responsibility for assessing their own progress and incorporate peer feedback as they conceptualize and redesign their projects.

The process consists of three interconnected steps:

Conceptualize

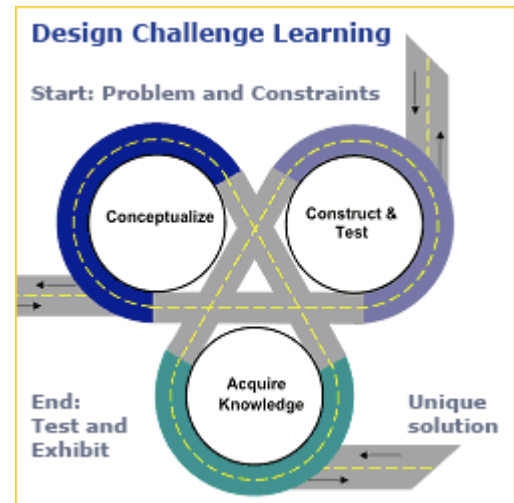
- Identify problem, materials, and constraints
- Brainstorm ideas and possible solutions

Construct and Test

- Select a solution
- Design and construct
- Prototype
- Redesign or modify
- Retest

Acquire Knowledge

- Research
- Share solutions
- Reflect and discuss



Through the try, fail, learn approach, students develop skills and habits of mind of Silicon Valley innovators: creativity, problem solving, design, collaboration, leadership, risk-taking, perseverance, and learning from failure.

Materials:

Materials can be limiting or inspirational to students! Have a wide variety of materials to promote a diversity of solutions. "Recycled items" are really useful: old mouse pads, wood scraps, boxes, cardboard tubes, strawberry baskets, etc.

Team Materials (2-3 Engineers):

- 5 cm of Tape
- 30 cm of 3-ply String
- 4 Rubber Bands
- 1 Dixie Paper Cup
- 1 Sheet of Copy Paper
- 2 Paperclips
- Brown Paper Lunch Bag (3" x 6-7")

Testing Supplies:

A plastic cup securely taped in the center of a large 6-foot diameter circle created out of tape, string, plastic tablecloth, butcher paper, etc. Students must place a ping pong ball into the cup while remaining outside of the circle (fully releasing the ball is not necessary). Note: The cup size can be altered depending on the age and ability level of the students. An 8oz. cup is much more difficult than a 16oz. cup.

- 8-16 oz Plastic Cup (depending on age range)
- Material to create 6 foot diameter circle

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Lesson Plan:

Introduction (5 minutes)

1. The United States and its territories encompasses 169 geologically active volcanoes that are monitored by the United States Geological Survey (USGS). In order to prevent loss of life and property, the USGS issues volcano warnings which requires real-time monitoring of volcanoes, their seismology, and gas, thermal, and surface deformation measurements.
2. What challenges do scientists have to overcome in order to monitor volcanoes? What tools do you think scientists use in order to overcome these challenges? (*Reference on Volcano Monitoring:* <http://volcanoes.usgs.gov/about/faq/faqmonitoring.php>)
3. Imagine if you had to deposit a small piece of equipment to the center of a lava flow. How would you do it? What science concepts would you use to help you achieve your mission?

The Challenge (20 minutes)

1. Introduce the Challenge: Devise a way to deposit a ping-pong ball into a paper cup that is located in the middle of a 6-foot diameter circle.
2. Introduce the Constraints:
 - Every person in the team must be actively involved in the placement of the ball.
 - The ping pong ball must start outside the circle and must come to rest inside the paper cup in the center of the circle.
 - Students may not touch the ping pong ball or reach into the 6-foot circle.
 - No part of anyone's body may extend into the imaginary cylinder that extends above the circle.
 - Only the provided materials may be used.
3. Build: Give students about 15 minutes to build and test. The instructor should ask open-ended questions to help guide students through the design process, but should also allow students space to tinker.
4. Testing: During the build time students should be able to test and iterate their designs freely. Students should build their device away from the testing site, and then bring their device over to the testing site in order to test. Teams may not build/iterate in at the test site! The setup for the test site is as follows:
 - Create a 6 foot diameter circle out of tape, string, butcher paper, or a circular table cloth.
 - Securely tape a cup (larger cups for an easier challenge, smaller cups for a more difficult challenge) to the center of the circle.
 - Teams test from along the outer edge of the circle and may not extend any body part into the imaginary cylinder that extends above the circle.

Demonstration and Reflection (20 minutes)

1. Demonstration: Have students demonstrate their devices one team at a time. If students have not completed their device, or their device did not function as expected, ask them *how the device would have worked*.
2. Reflection: Have each group of students explain their design strategy and how their device uses energy and force to place the ball in the cup. The instructor should ask leading questions to get at the science behind the designs.
 - Teaching Points:
 - Energy comes in many forms, and can be changed from one form to another.

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- Kinetic energy is the energy of motion, and potential energy is the stored energy of position.
- A force is a push or a pull. An object can have two or more forces that act on a single object including: gravity, elastic forces due to tension or compression, and friction.
- Force, energy, and work are related.
- Mass is a variable of energy.
- Newton's laws predict the motion of most objects.
- Questions:
 - Can you explain how your device stores potential energy?
 - Can you explain when your ping pong ball transforms potential energy into kinetic energy?
 - Can you identify the forces acting on your ball? Did you make use of any force(s)?
 - What was the most challenging aspect of your design?
 - Did you need to take into consideration the mass of your ball? How did the overall weight of your ball affect the design of your device?
 - What would happen if you used a heavier ball? What modifications would you need to make to your device to accommodate the heavier ball?
 - Why did you choose to...? How did you solve...?
 - How did your team work together? How could you improve your teamwork?
 - If you could have one more material what would it be?

Extensions

1. Repeat the Design Challenge with a ball of a different mass. How does this affect the performance of the device? Discuss how this change further supports Newton's 1st and 2nd Laws of Motion?
2. Repeat the Design Challenge and give the teams the additional material they requested or a selection of materials to add to their device? How does the change affect the performance?
3. Add a material to the team kits that connects with another unit that has been discussed such as electrical components or magnets.
4. Further explore potential and kinetic energy with the Design Challenge *Energy at Play*.