Circle of Pong

Description:
Students use their knowledge of potential and kinetic energy, and explore forces and motion to place a ball into the center of a 6-foot diameter circle.

Grade Levels: 3-12

Educational Outcomes:
1) Students will demonstrate their knowledge of Potential and Kinetic Energy.
2) Students will apply their knowledge forces to the design of their devices.
3) Students will get a first-hand experience of the design process that scientists and engineers undergo.

Estimated Time: 1 class session (40 minutes)

California Science Standards Connections:

Grade 3 - Physical Science:
1. Energy and matter have multiple forms and can be changed from one form to another.

Grade 6 - Physical Science:
3a. Students know energy can be carried from one place to another by heat flow or by waves, including water, light and sound waves, or by moving objects.

Grade 8 - Physical Science:
2. Unbalanced forces cause changes in velocity.
2 d. Students know how to identify separately the two or more forces that are acting on a single static object, including gravity, elastic forces due to tension or compression in matter, and friction.

Grades 9-12 - Physical Science:
1. Newton's laws predict the motion of most objects.
2. The laws of conservation of energy and momentum provide a way to predict and describe the movement of objects.

All Grades: Investigation and Experimentation: Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations.

The Tech Museum Connections:
Big Ball Machine – energy and motion, transfer of energy

Materials And Set-Up (Per Team Of 2-3):
You may use only the materials provided, including:

5 cm tape
30 cm 3-ply string
4 rubber bands
1 Dixie sized paper cup
1 sheet of copy paper
2 paperclips
Ping-pong ball
Small gift sized paper bag no bigger than 3" X 6 or 7 " (supplies can be distributed to teams in this bag)

Testing:
A paper/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 ping pong ball into cup while remaining outside of the circle (fully releasing ball is not necessary).
Please 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.

Teacher Notes:
This introductory Design Challenge is a great way to introduce students to the teamwork and process skills that are necessary for more involved Design challenges. Please view our Cup in the Cupboard Design Challenge Unit for a more thorough description of process and teamwork skill development, presented in a Design Challenge context.

Adapted from a lesson plan written by Bill Dunbar and Lydia Mongia

A. DESIGN CHALLENGE

Scenario:
Sometimes it is safe to keep your distance. Imagine if you had to deposit a small piece of equipment on an island located in the middle of a lava pit. How would you do it?

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.

Constraints
- Every person 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
- You may use only those objects found in your materials' kit
- You may not damage or destroy the ping pong ball

B. Design Challenge Demonstration and Reflection:

Demonstration: Have student teams demonstrate their devices one team at a time.

Reflection: Have each group of students explain their design strategy. Instructor should ask leading questions to get at the science behind the designs.

Note: It's ok if the device doesn't quite work. Students should be able to explain their thinking behind their design.

C. Teaching Points to guide Reflection Questions:

- Potential Energy is stored Energy that can be either gravitational (gravity) or elastic (rubber bands, springs...) for this particular challenge.
- Kinetic Energy is Energy in motion.
- Forces
- Teamwork

Questions to encourage Teaching Points:
- 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? Would this change make it easier or more difficult to place the ball in the cup? What modifications would you need to make to accommodate a heavier ball?
- Ask about specific aspects of their design as well. Why did you choose to use a ______ as part of your design strategy?
- How did your team work together? What challenges did you face as a team? How could you improve your teamwork?
- If you could have one more material (or more of one of the materials you were given), what would it be?

Teacher Notes:

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.

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 Law of Momentum Conservation:
The amount of momentum remains constant - momentum is neither created nor destroyed, but only changed through the action of forces.

Potential Energy: Energy that is stored. Tossing the ping pong ball into the air by triggering a device that has stored spring-like energy makes use of elastic potential energy. One way to think of it is that something with potential energy has the capability to do something. For example, a stretched rubber band has the capability to fly across the room, a relaxed rubber band does not.

Kinetic Energy: Energy of motion. When the ball is tossed into the air, potential energy is converted into kinetic energy. One way to think of this is something with kinetic energy is moving. For example, as the rubber band flies across the room it has kinetic energy.

D. CLEAN UP: REDUCE! RE-USE! RECYCLE!

Only throw away items that cannot be re-used. All items should be returned to the appropriate place.

E. POST ACTIVITIES:

- Repeat the Design Challenge but change the mass of the ball. How does this change affect the performance of the device? Discuss how this change further supports Newton's 1^{st} and 2^{nd} Laws of Motion.
- Participate in The Tech's *Energy at Play* lesson, to further explore potential and kinetic energy by designing a toy that will move a ball with stored energy.
- Participate in The Tech's *Motion Commotion* lesson, to explore potential and kinetic energy by designing a contraption with multiple steps to ring a bell.

RESOURCES

Conceptual Physics by Paul Hewitt. HarperCollins College Publishers, New York, NY. 1993.

Glenbrook South Physics website: http://www.glenbrook.k12.il.us/gbssci/phys/phys.html

Rutgers University Physics Education Resource website: http://www.physics.rutgers.edu/hex/visit/lesson/lesson_index.html

The Physics Classroom tutorial website: http://www.physicsclassroom.com/Default2.html

Please note:
This Design Challenge can also lend itself to a discussion about Newton's 2^{nd} Law of Motion.

Newton's 2^{nd} Law of Motion:
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.

Glossary & Concepts:

Physics Terms

- Elastic Potential Energy: Potential energy due to tension -- either stretch (rubber bands, etc.) or compression (springs, etc.).
- Energy: "Nature's way of keeping score." Measured in joules. Appears in many forms, most of which are ultimately derived from the sun or from radioactivity.
- Force: A push or pull. The force applied to a machine is called work input or effort force.
- 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. Gravitation potential energy = weight x height. 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. KE= ½ mass x velocity^2 = ½ mv^2 Note that small changes in speed can result in large changes of KE (it's speed squared!). Net force x distance = KE. Includes heat, sound, and light (motion of molecules). KE is a scalar quantity; it cannot be canceled.
- 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.
- Potential Energy (PE): Energy of position; energy that is stored and held in readiness. Includes chemical energy, such as fossil fuels, electric batteries, and the food we eat.

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, then object B exerts an equal and opposite force -*F* on object A" or "Every action has an equal and opposite reaction".