

Free Up the Ketchup!

Description:

Students demonstrate their knowledge of Newton's 1st Law of Motion with this introductory level Design Challenge.

Grade Levels: 6-12

Educational Outcomes:

- 1) Students will demonstrate their knowledge of Newton's 1st Law of Motion in the design of their device.
- 2) Students will apply their knowledge forces and motion 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 (45 minutes)

California Science Standards Connections:

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:

16 oz cup

Ping pong ball (with a piece of double stick tape adhered to it)

Double Stick Tape

Sticks or pieces of wood (balsa wood)

Cardboard

Rubber bands

Sponge material

Heavy mass (e.g., a wood block)

String

Light cardboard (from a box or manila folder)

Glue gun with sticks of glue

Unlimited supplies of weights such as: bolts, washers & screws

Other possible items: aluminum pie pan, toilet paper/ paper towel rolls

Testing:

Students test their devices on the official "sticky cup", which is a 16oz. cup containing an ping pong ball covered in double stick tape. **Please note:** It is advised to have a few back up balls in case the original loses its stick.

Teacher Notes:

Please note: You may need to tailor this lesson to fit the age and experience levels of your students. One way to alter it is by controlling the amount of double stick tape added to the ping pong balls (stickier for older students!).

A. DESIGN CHALLENGE

Scenario:

Your very young neighbor really enjoys eating his French fries with ketchup. Unfortunately, he sometimes has a hard time getting the last bits of ketchup out of the bottle.

Challenge

Using your knowledge of Newton's First Law, create a model of a device that will remove ketchup from the bottom of a bottle. Your model of the ketchup and bottle will be a ping pong ball that is stuck to the bottom of a cup.

Constraints

- You will not be able to test your device ahead of time with the cup that contains the sticky ball.
- You may not alter or modify the official test cup in any way.
- You will get two attempts to dislodge the sticky ball.
- You may not touch the device once the cup has been installed except to initiate the motion of the device with a light touch.
- You are not allowed to touch the ball or the cup once it is installed in the device you have created.
- The device itself may not come in direct contact with the ball until the ball has been freed from the cup.
- You must start your demonstration by explaining how Newton's First Law is relevant to the design.

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 and how their device demonstrates Newton's 1st Law of Motion. Instructor should ask leading questions to get at the science behind the designs.

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.
- Newton's 1st Law of Motion (Law of Inertia)

Questions to encourage Teaching Points:

- Can you explain how your device demonstrates Newton's 1st Law of Motion when it is used?
- Can you explain how your device stores potential energy?
- Can you explain when your ping pong ball transforms potential energy into kinetic energy?
- 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 dislodge the ball from 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?

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 1st Law of Motion.
- Participate in The Tech's *Motion Commotion* lesson, to further explore potential and kinetic energy as well as Newton's 3rd Law of Motion by designing a contraption with multiple action-reaction steps to ring a bell (go to: <http://www.thetech.org/learning/challenge/design/>).

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 2nd and 3rd Laws of Motion.

Newton's 2nd 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.

Newton's 3rd Law of Motion:

For every action, there is an equal and opposite reaction.

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. Gravitational 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. $KE = \frac{1}{2} \text{mass} \times \text{velocity}^2 = \frac{1}{2} mv^2$ 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".