

Double Toss

Description:

Students use their knowledge of potential and kinetic energy, and explore forces and motion as they work together to solve this introductory level Design Challenge.

Grade Levels: 6-12

Educational Outcomes:

- 1) Students will demonstrate their knowledge of Potential and Kinetic Energy.
- 2) Students will apply their knowledge forces and motion to design their devices.
- 3) Students will gain an understanding (and older students will apply their knowledge) of the concepts of acceleration, velocity, and momentum.
- 4) Students will get a first-hand experience of the design process that scientists and engineers use to solve problems.

Estimated Time: 1 class session (30-45 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:

1. The velocity of an object is the rate of change of its position.
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:

Innovation: Virtual Design – Design & Ride a Rollercoaster; Big Ball Machine – energy and motion, transfer of energy

Materials And Set-Up (Per Team Of 2-3):

| | |
|------------------------|--------------------------------------|
| 2 mousetraps* | 1 sheet of aluminum foil |
| 30 cm masking tape | 1 sheet of typing paper (8 1/2 X 11) |
| 50 cm string | 1 coat hanger |
| 4 rubber bands | 1 ping pong ball |
| 1 ruler (do not break) | |
| 1 paper cup (8-16 oz) | |
| 1 Skewer | |
| Paper plate | |

Testing materials-

Meter stick used to measure toss height

* A good way to ensure the safety of students when working with mousetraps is to glue two pieces of wood that are wider than student fingers to the base of the trap (positioned so that they will block the spring release arm from slamming down on fingers).

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 changing the height requirement for both tosses.

Students may want to use the furniture as part of their device. Since this isn't mentioned as a constraint, technically it's allowed (within reason and considering safety, of course). A good teaching strategy is to ask them "what do your constraints say?" If it's not specifically identified in the constraints, they are free to use whatever materials they'd like

Note: the definition of the word "toss" is purposely not given. This is part of the beauty of this design challenge. When asked, teachers are encouraged to not give a definition but to reflect back on students by asking them "what do you think?" "Does what you're describing define a toss?" And leave it up to the students to figure out.

A. DESIGN CHALLENGE

Challenge

Create a device that will toss a ball up at least 30 centimeters into the air, catch it and toss the ball up again at least 30 cm.

Constraints

- You may touch the device one time in order to trigger its motion, but you may not touch the mechanism or the ball again.
- The energy used to move the ball must come from the device and not from the human starter.
- You should be very careful with mousetraps! Any team caught playing with the mousetrap in an irresponsible way will be disqualified.
- You will get two attempts to demonstrate your device.

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 uses energy, forces, and motion to complete the task. 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 2nd Law of Motion $a = f/m$ (f = force, m = mass, a = acceleration)
- Newton's 3rd Law of Motion: action: reaction

Questions to encourage Teaching Points:

- Can you tell me how and where your ping pong ball stores potential energy? (*Device probably stores elastic potential energy at start and ball stores gravitational potential energy as it is tossed up, then additional elastic potential energy is stored for second toss*).
- Can you tell me where 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 your ball go faster or slower? What modifications would you need to make to accommodate a heavier ball?
- Can you identify where the "opposite reaction" occurs? What are the action-reaction forces that are working together?
- Ask about specific aspects of their design as well. Why did you choose to use a _____ as part of your design strategy?

Teacher Notes:

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.

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 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.



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:

- Provide students with the opportunity to redesign their devices.
- Change the mass of the ball. How does this change effect the acceleration, velocity and momentum of the ball and its interaction with the device?
- 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 (go to: <http://www.thetech.org/learning/challenge/design/>).
- 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 (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>

Teacher Notes:

Momentum: Mass in motion. An object's momentum is a combination of its mass and its velocity. The greater the mass, the greater the momentum. !

Velocity: Speed (how fast something is going = distance/time) with a directional component. In physics, it matters which way the ping pong ball is moving.

Acceleration: Change in velocity. How fast does something go from a standstill to a specific speed? Or from a specific speed to a standstill (called deceleration)? In automotive design, how fast a car goes from 0 to 60 miles per hour is an important statistic. That is acceleration. The longer something accelerates, the more change in velocity it has. A sports car can go from 0 to 60 mph in about 5 seconds. If you have the same acceleration for 10 seconds, the car will be going 120 mph.

Gravity: This is the force by which the earth pulls things back to it. (Technically, anything with mass has gravity, including an 8 year old. It is just too weak for us to feel its effects.) The gravitational force will always create the same acceleration.

Glossary & Concepts:

Physics Terms

- Acceleration: The rate at which an object changes its velocity. An object is accelerating if it is changing its velocity, both speeding up or slowing down.
- Air resistance: The friction that acts on something moving through air.
- 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. $KE = \frac{1}{2} \text{mass} \times \text{velocity}^2 = \frac{1}{2} mv^2$ 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.
- Velocity (speed): How fast an object is moving. The distance traveled over time.

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".