A Simple Soda Can Steam Engine

Conservation of Energy

Introduction

Phase changes are taught at just about every level of science education, K–college. Rarely, however, is it emphasized what an important role they have played historically in our technological development. The boiling of water, after all, was what first allowed us to take significant advantage of chemical energy, enabling us to convert the heat given off during an exothermic reaction into useful work. How wonderful then that one of the earliest and most fundamental steam engines can be replicated with an aluminum soda can!

Concepts

- Energy conversion
- Phase changes
- Newton's third law of motion

Materials

Water
Bunsen burner
Fishing swivel
Pin
Soda can, unopened
String
Support stand with ring clamp

Safety Precautions

Caution should be taken whenever dealing with flame. Keep all flammable materials away from the demonstration. The can becomes quite hot during this demonstration. Keep hands and face away from the steam coming out of the can. Use heat resistant gloves or allow the can to cool completely before removing it from the swivel. Wear chemical splash goggles and a chemical-resistant apron. Wash hands thoroughly with soap and water before leaving the laboratory. Follow all laboratory safety guidelines.

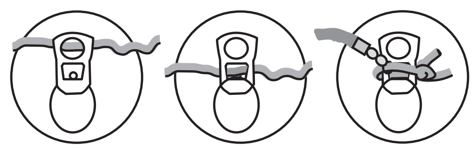


Figure 1.

Preparation

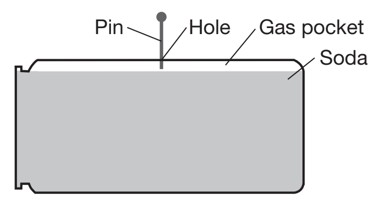


Figure 2.

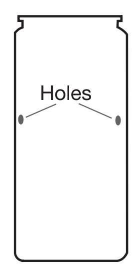


Figure 3.

1. Using an unopened soda can, gently slip a piece of string under the pull tab and pull it up so that it is wedged in over the rivet in the can's center.
2. Thread the string through a fishing swivel and tie the two loose ends of the string together (see Figure 1).
3. This step can get messy and should be done near a sink or even outdoors! Remove the soda can from the swivel and lay the soda can on its side. Push a pin in the side of the can about halfway up, and then withdraw the pin (see Figure 2). *Note:* If the can is kept horizontal and the hole is made on the very top of the curve, soda should not squirt out of the hole!
4. Empty as much of the soda as possible out of the can by shaking it with the pin-hole facing downward into a sink.
5. When shaking is no longer very effective, make a similar hole in the exact opposite side of the can—180° from the first slit (see Figure 3). Blow through this hole to force the remainder of the soda out of the can.
6. Insert the pin back into one of the holes, and then push the pin head to one side to make the hole tangential to the wall of the can. Repeat this step for the second hole, pivoting the pin head to the same side as for the first. See Figure 4 for a top view cross-section of these tangential holes.
7. Add 20–30 mL of water to the can. This may be done by any of a number of ways. Perhaps the simplest is just to hold the can down on its side at the bottom of a deep basin sink and let the water flow into one of the holes for about 10 seconds. Or, hold the can in a pan containing 3–4 cm of water, with one hole on bottom (submerged) and the other hole on top, and let the water leak in over the course of 5–10 minutes. Gently moving the can back and forth under water can speed up the process.

8. Attach a ring clamp to a support stand, and tie a length of string to the outside edge of the ring. Tie the other end to the fishing swivel about 1 cm below the ring, and cut off any extra string. Reattach the loop of string by sliding it under the pull tab as in Step 1 (see Figure 5).

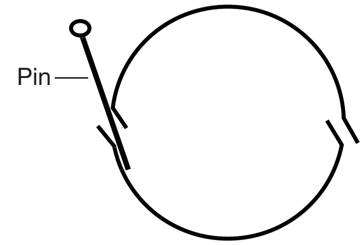


Figure 4.

Procedure

1. Establish a cool flame on a Bunsen burner and place it under the can, adjusting the ring height if necessary (see Figure 5).
2. Once the water inside starts boiling and the steam starts spurting out of the two slits, the can will begin spinning quite rapidly, and continue for several minutes. If the can begins to wobble, reduce the flame.

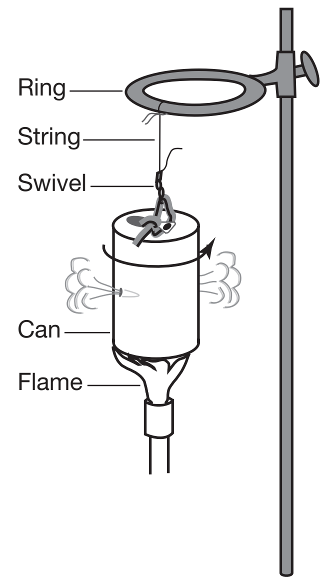


Figure 5.

Tips

- Diet sodas are preferable if this activity is being done inside, since they have less potential to create a sticky mess.
- To increase the duration of the spin, use more water, but expect a proportionately longer heat-up period.
- To make an engine that spins the other way, repeat the above procedure, but orient the holes in the other direction. In other words, instead of having the holes angled to the right, have them angled to the left.

Discussion

This activity demonstrates in a fun and very inexpensive way the conversion of chemical energy in the form of methane and oxygen (or ethanol and oxygen) into the thermal energy of the flame, which in turn can be converted into the mechanical energy of the spinning can, thanks to the phase change of water boiling. This, in turn, might be used to do useful work—perhaps some sort of spool placed over the can could coil up a thread as it is spun, which in turn might lift an object off the floor. Or perhaps the spinning engine could be used to turn a generator to convert the mechanical energy into electrical. Inasmuch as the can always spins counter to the direction the holes are pointing, this engine could also be used to illustrate that for every action force there is an equal and opposite reaction force.

Acknowledgments

Thanks to Ed Ginoza of Maui High School and Don Chaney of Baldwin High School in Kahului, HI for co-developing this activity with Bob Becker of Kirkwood High School, Kirkwood, MO.

Materials for *A Simple Soda Can Steam Engine* are available from Flinn Scientific, Inc.

Materials required to perform this activity are available in the *Hero's Engine—Demonstration Kit* available from Flinn Scientific. Materials may also be purchased separately.

Catalog No.	Description
AP7115	Hero's Engine—Demonstration Kit
AP8228	Support Stand, 24″ Rod
AP8232	Support Ring with Rod Clamp, 4″
AP4823	String, Ball, 75 g

Consult the Flinn Scientific website for current prices.

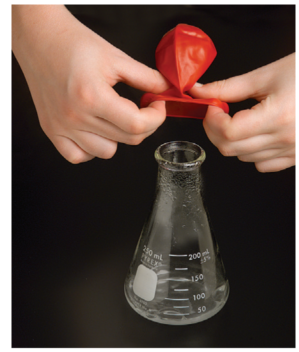
Balloon in the Bottle

Introduction

Heat some water in a flask, then attach a balloon, cool the flask, and watch as the balloon collapses into the flask. An easy-to-perform variation of the common *Crush the Can* demonstration of atmospheric pressure.

Concepts

- Pressure differential
- Vacuum



Materials

Erlenmeyer flask, borosilicate glass, 250-mL

Balloon, latex, 11-inch size (size to fit flask)

Hot plate or Bunsen burner

Ice bath or cold running water

Water, 25 mL

Safety Precautions

Always practice a demonstration before presenting it to students. Be careful of the hot glass and steam. Wear chemical splash goggles and heat-resistant gloves.

Procedure

1. Add approximately 25 mL of water to a 250-mL Erlenmeyer flask. Heat the water using a hot plate, Bunsen burner or other heat source.
2. As the water comes to a boil and steam begins to rise out of the flask, remove the flask from the heat. Quickly place the balloon over the mouth of the flask.
3. Place the flask under cold running water and the balloon will be pushed into the flask until it fills the entire flask. If the balloon stretches too much, it may break.

Tips

- Use a borosilicate (e.g., Pyrex®) flask with a heavy-duty rim. Do not use an economy-choice flask. Check the flask for chips or cracks before use.
- Stretch out the balloon by inflating and deflating it before using it.
- The demonstration works best if the balloon is centered on the opening when placed over the mouth of the flask. It also helps if the balloon is slightly pushed into the flask when it begins to collapse. If not, it may collapse onto itself and not get drawn into the flask. The demonstration will work without holding it under cold water, but it takes longer to cool the glass and condense the water vapor.
- A hard-boiled, shelled egg can also be used in place of the balloon. A larger flask may be needed depending on the size of the egg.

Discussion

The *Balloon in the Bottle* demonstration is an easy-to-perform variation of the common *Crush the Can* demonstration. Both demonstrations rely on the creation of a pressure differential caused by the condensation of water vapor inside a closed system. As the water vapor cools and condenses, the molecules move more slowly, and a partial vacuum is formed since no more air can enter the flask. The pressure outside the flask is still at atmospheric pressure (approximately 14.7 lb/in^2). This pressure difference will cause the balloon to be pushed into the flask. The balloon is not "sucked" into the flask—it is pushed in by the greater atmospheric pressure that exists outside the closed system. The balloon will continue to be pushed into the flask until the pressure inside the closed system is approximately equal to the atmospheric pressure.

NGSS Alignment

This laboratory activity relates to the following Next Generation Science Standards (2013):

Disciplinary Core Ideas: Middle School
- MS-PS1 Matter and Its Interactions
  - PS1.A: Structure and Properties of Matter
- MS-PS3 Energy
  - PS3.A: Definitions of Energy
  - PS3.B: Conservation of Energy and Energy Transfer

Disciplinary Core Ideas: High School
- HS-PS2 Motion and Stability: Forces and Interactions
  - PS2.A: Forces and Motion
- HS-PS3 Energy
  - PS3.A: Definitions of Energy
  - PS3.B: Conservation of Energy and Energy Transfer

Science and Engineering Practices
- Developing and using models
- Planning and carrying out investigations
- Constructing explanations and designing solutions

Crosscutting Concepts
- Cause and effect
- Scale, proportion, and quantity
- Energy and matter
- Stability and change

Reference

Shakhashiri, B. Z. *Chemical Demonstrations: A Handbook for Teachers in Chemistry;* University of Wisconsin: Madison; Vol. 2, pp 6–8.

Materials for *Balloon in the Bottle* are available from Flinn Scientific, Inc.

Catalog No.	Description
AP1900	Balloons, Latex, pkg/20
AP9802	Hot Plate, Flinn, 7″ × 7″
GP3045	Erlenmeyer Flask, Borosilicate Glass, 250-mL

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.

Bottomless Bottle

A Fluid Pressure Demonstration

Introduction

Use this old parlor trick to teach about the incompressibility of liquids and Pascal's law of equal pressure.

Concepts

- Pascal's law
- Incompressibility of liquids
- Pressure

Materials

Food dye (optional)
Glass bottle, tall with thin neck and wide body
Glass disposal container
Gloves, cotton (long enough to provide lower arm protection)
Rubber mallet
Safety glasses
Safety shield (optional)
Transparent tape
Water

Safety Precautions

Use caution when striking the top of the glass bottle with a rubber mallet. Strike the top squarely so the lip of the bottle does not crack. If the lip cracks, but the bottle's bottom does not fall out—do NOT hit the bottle again. Throw the bottle away and use a new bottle. Students observing the demonstration need to wear safety glasses. Students need to stand at least 10 feet away when the demonstration is performed. The bottle may crack in areas other than the bottom and broken glass may fly several feet from the demonstration site. Wear thick cotton or Playtex®-type latex gloves, a long-sleeved shirt or lab coat, and safety glasses. Practice this demonstration several times before performing in front of the class. A safety shield should be used if students do not have safety glasses available.

Preparation

1. Obtain an empty, clear glass bottle—beer, wine-cooler or sauce bottles work best. Glass soda bottles do not work as well.
2. Use hot soapy water to clean the bottle and remove any labels that may be on the bottle (especially if it once contained an alcoholic beverage).
3. Wrap transparent tape around the bottom of the bottle and half-way up the bottle (see Figure 1). This will help contain any broken glass once the bottom cracks out.
4. Fill the bottle about three-quarters to seven-eighths full with water so that the water level is in the neck of the bottle, just above the wider "body" part of the bottle (see Figure 1). Add food dye if desired.
5. Allow the water to sit for several minutes or longer so that some of the trapped air can escape.

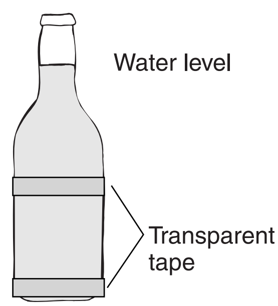


Figure 1.

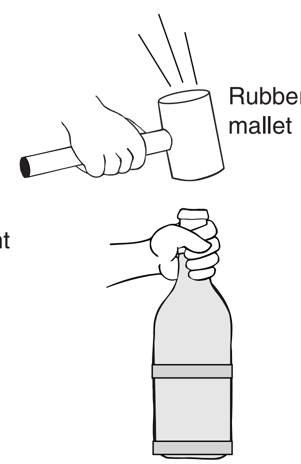


Figure 2.

Procedure

1. Obtain a rubber mallet, long cotton or Playtex-type gloves, safety glasses, and the partially filled, taped bottle.
2. Grip the neck of the bottle tightly with a gloved hand and hold it over a glass disposal container. *Caution:* Make sure everyone near the demonstration is wearing safety glasses!
3. Firmly strike the top opening of the bottle with the rubber mallet. Make sure the end of the rubber mallet strikes the opening squarely (see Figure 2). *(The bottom of the glass bottle should break and fall into the glass disposal container along with the water.) Caution:* If the bottom of the bottle does not "fall out" with the first blow, but the bottle's body or the lip cracks or chips—do NOT strike the bottle again. Use a new bottle.
4. Show the broken bottle to the class. *Caution:* Do NOT pass the bottle around to the class or allow the students to hold it.

There will be many sharp edges that could easily injure the students.

5. Dispose of or recycle the broken glass appropriately.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures, and review all federal, state and local regulations that may apply, before proceeding. It is recommended that this demonstration be done directly over a glass disposal container. Paper towels may be placed in the bottom of the container to absorb the water. If done over a garbage can, dispose of the broken glass properly.

Tips

- It is important to practice this demonstration several times before performing in front of the class to get a feel for how hard to strike the top of the bottle. It typically does not take a very hard hit to break the bottom out of the bottle. It may take two or three hits the first time.
- Large, flat-headed rubber mallets work the best.

Discussion

Blaise Pascal (1623–1662) is well known as a mathematician but he also performed many experiments involving pressure in fluids. One of the principles he developed to explain the properties of fluids is known as Pascal's principle or Pascal's law. *Pascal's law* states that pressure applied anywhere to a fluid is transmitted undiminished in all directions. This law serves as a basis and exploration for much of what is now known as *hydraulics*.

In the *Bottomless Bottle* demonstration, the force of the rubber mallet striking the top of the bottle causes the air inside the bottle's neck to compress slightly (because of inertia and the brief airtight seal around the bottle's opening). The compressed air travels through the bottle's neck as a shock wave (through compression and rarefraction) until the compression wave reaches the water level. At this point, the water will not compress. Instead, the force from the shock wave increases the pressure on the liquid. This pressure is then distributed equally to all points of the bottle holding the water. Pressure is equal to a force per unit area ($P = F/A$). Therefore, under constant pressure, a region of the container with a large surface area will experience a greater force compared to a region with a smaller surface area. The small force that is applied to the water in the narrow neck of the bottle (from the compressed air) multiplies into a much larger force in the wider "body" portion. Depending on the bottle dimensions (neck diameter versus bottom diameter), this force may increase by 5 to 20 times at the bottom of the bottle. This large force causes the bottom of the bottle to "pop" out.

An alternative explanation for the force that "pops" the bottom out has to do with cavitation. When the top of the bottle is struck with the mallet, the bottle moves downward. The water inside the bottle, however, does not move down due to inertia. This briefly creates a vacuum at the bottom of the bottle. As a result of the low pressure area, tiny bubbles of water vapor form. When the water does move down, the bubbles collapse, creating a shock wave. This rapid formation and implosion of bubbles is known as *cavitation*. The combined force of all the collapsing bubbles is enough to break away the bottom of the bottle.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12

Systems, order, and organization
Evidence, models, and explanation

Content Standards: Grades 5–8

Content Standard B: Physical Science, properties and changes of properties in matter, understanding of motions and forces, transfer of energy

Content Standards: Grades 9–12

Content Standard B: Physical Science, structure and properties of matter, chemical reactions, motions and forces, conservation of energy and increase in disorder

Acknowledgment

Special thanks to Todd Everson, Milwaukee School of Languages, Milwaukee, WI for providing the cavitation explanation for this activity to Flinn Scientific.

Materials for *Bottomless Bottle—A Fluid Pressure Demonstration* are available from Flinn Scientific, Inc.

Catalog No.	Description
AP6643	Bottomless Bottle Demonstration Kit
SE1041	Gloves, for rough/sharp materials
AP8829	Glass Disposal Container

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.

Discovering the Speed of Sound in Air

Introduction

Have you ever observed a carpenter hammering in a nail off in the distance? If you are far enough away from the carpenter, you will observe the hammer hit the nail before you hear it hit. It seems as though there is a delay in the time it takes for the sound to reach your ears. Why does this happen? How fast does sound travel? Discover the speed of sound with this activity!

Concepts

- Anti-node and node
- Frequency and wavelength
- Mechanical wave
- Longitudinal wave
- Standing wave
- Velocity

Background

Sound is a mechanical, longitudinal wave created by the vibrations of material objects. A mechanical wave requires a medium in order to propagate. In other words, for sound to travel, some type of substance must be present (solid, liquid, or gas). A substance is needed because sound travels by pushing molecules back and forth. If there are no molecules to move, sound will not propagate. This is why sound can not travel in a vacuum. Sound is also considered to be a longitudinal wave because it vibrates the particles in the medium back and forth along the direction of the wave propagation.

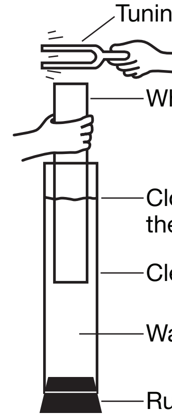


Figure 1.

The speed of sound is not a constant value and varies depending on the medium in which it travels. At 0 °C the accepted value for the speed of sound in air is 331 m/s. As the temperature of air increases, the speed of sound also increases because molecules in hot air move more rapidly and collide more often than molecules in cool air. The speed of sound also increases in substances having molecules that are packed tightly together. Therefore sound tends to have higher speeds in solids and slower speeds in liquids and gases. The reason for this is because molecules that are close together bump into each other more easily than molecules that are far apart.

The speed of sound can be calculated using Equation 1 below. According to this formula, if the frequency (f) and wavelength (λ) of a wave are known, the speed (v) can easily be calculated by multiplying the two values together. In this activity you will be using various tuning forks to determine the speed (v) of sound. When a tuning fork is set into motion, the sound produced will have a specific frequency and wavelength. The frequency of a tuning fork is printed directly on it. The wavelength, on the other hand, is not listed on the tuning fork, and must be determined in order to calculate the speed of sound.

$$v = f\lambda \qquad \textit{Equation 1}$$

v = speed (m/s)
f = frequency (Hz)
λ = wavelength (m)

The wavelength of a sound wave can be determined using an air-filled tube that is closed at one end. In this experiment, the air-filled tube is a piece of white PVC tubing placed in water. The water is used to close off the tubing at one end. See Figure 1. A tuning fork will be used to generate a sound wave over the open end of the white PVC tube. The length of the white PVC tube is altered by slowly lifting it out of the water. As the PVC tube is lifted, the length of the air-filled portion increases. At the appropriate length (this length varies for tuning forks of different frequencies), the sound wave travels through the air in the tube and reflects off the water at the closed end. The reflected wave then interferes with the incident waves generated by the source (the tuning fork), and a standing wave forms.

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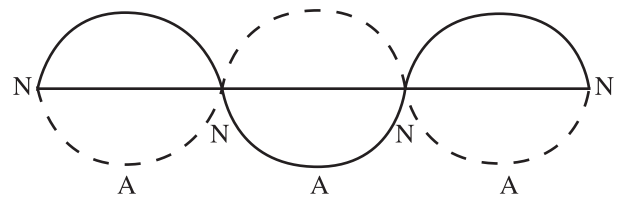
A *standing wave* is a pattern that results when two waves of the same frequency, wavelength, and amplitude travel in opposite directions and interfere with each other. A *node* is a point in a standing wave that always undergoes complete destructive interference and therefore is stationary. An *anti-node* is a point in the standing wave, halfway between two nodes, at which the largest amplitude occurs. See Figure 2. Because the amplitude is largest at an anti-node, the sound will be the loudest at this point. Figure 3 represents various standing waves that can be created in a close-ended column of air. When an anti-node is present at the open end, the sound will resonate or hum loudly.



N = node
A = anti-node

Figure 2.

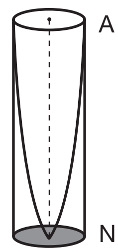
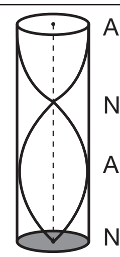
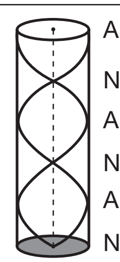
No. of Wavelengths Shown	Closed-end Air Column
¼ λ 1 quarter of a full wavelength	
¾ λ 3 quarters of a full wavelength	
⁵⁄₄ λ 1 full wavelength plus 1 quarter of a wavelength	

Figure 3.

The *Procedure* section of this lab lists the steps necessary to create a standing wave having only one node and one anti-node, as shown in the top section of Figure 3. Creating a standing wave with one node and one anti-node will mean that only ¼ of a complete wavelength is present inside the air-filled PVC tube. If the length (L) of the air-filled portion of the PVC tube is measured in meters, this will be the length of ¼ of one complete wavelength. In order to calculate one complete wavelength, the tube length (L) must be multiplied by 4. See Equation 2 below.

$$\lambda = 4L \qquad \textit{Equation 2}$$

λ = wavelength (m)

L = tube length (m)

Materials

Clamps, universal extension, 2
Clamp holders, 2
Graduated cylinder, 250-mL
Plastic tube, clear, 1" diameter, 2 ft
PVC tube, white, 1/2" diameter, 2 ft
Rubber stopper, solid, #6
Ruler, metric
Support stand
Tuning forks, set of 8
Tuning fork activator
Water, 250 mL

Safety Precautions

This lab is considered to be nonhazardous. Please follow all laboratory safety guidelines.

Procedure

1. Set up a support stand and attach one universal extension clamp to the top of the rod, and a second universal extension clamp to the bottom of the rod.
2. Plug the bottom of the clear plastic tube with a #6 rubber stopper.
3. Attach the clear plastic tube to the support stand using the universal extension clamps. See Figure 4. The rubber stopper should be resting on the base of the support stand.
4. Place the white PVC tube inside of the clear plastic tube.
5. Fill a large graduated cylinder with 250 mL of water.
6. Make sure the end of the clear plastic tube is completely sealed by pouring a small amount of water into the tube and watch for leaking. Vaseline® can be put around the edge of the stopper if leaking does occur.
7. Pour the 250 mL of water into the sealed plastic tube. The water should be near the top but not overflowing.

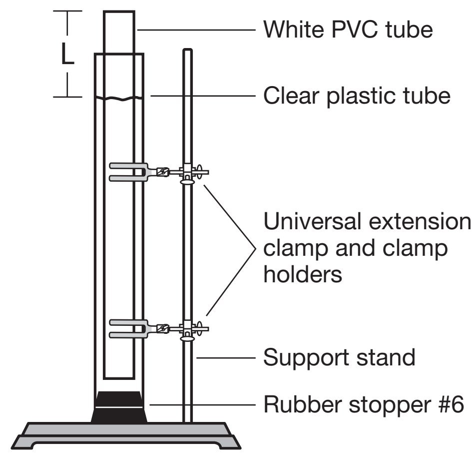


Figure 4.

8. Obtain a tuning fork that matches a frequency listed on the data table (see the next page).
9. Hit the tuning fork on a tuning fork activator.
10. Hold the tuning fork over the tube setup. Hold the white PVC tube with your free hand and slowly lift it out of the water while at the same time lifting the tuning fork. Make sure the tuning fork remains over the opening of the white PVC pipe (see Figure 1). Keep moving the tube and the tuning fork upward until a very loud humming noise is heard. The tube may hum the entire time, but at a certain point, it will get very loud.
11. Hold the tube in place at the spot where the sound resonates the loudest. Using a metric ruler, measure the length of the white PVC tube that is above the surface of the water. Measure the length (L) in centimeters, and record the length in both cm and meters on the data table.
12. Repeat steps 7–10 with the remaining tuning forks.
13. Using Equation 2 from the *Background* section, calculate the wavelength of sound for each tuning fork.
14. Using Equation 1 from the *Background* section, calculate the speed of sound in air for each tuning fork.

NGSS Alignment

This laboratory activity relates to the following Next Generation Science Standards (2013):

Disciplinary Core Ideas: Middle School
- MS-PS1 Matter and Its Interactions
  - PS1.A: Structure and Properties of Matter
- MS-PS3 Energy
  - PS3.C: Relationship between Energy and Forces
- MS-PS4 Waves and Their Applications in Technologies for Information Transfer
  - PS4.A: Wave Properties

Disciplinary Core Ideas: High School
- HS-PS1 Matter and Its Interactions
  - PS1.A: Structure and Properties of Matter
- HS-PS3 Energy
  - PS3.A: Definitions of Energy
- HS-PS4 Waves and Their Applications in Technologies for Information Transfer
  - PS4.A: Wave Properties

Science and Engineering Practices
- Developing and using models
- Analyzing and interpreting data
- Using mathematics and computational thinking
- Constructing explanations and designing solutions

Crosscutting Concepts
- Patterns
- Cause and effect
- System and system models
- Energy and matter in systems
- Structure and function

Tips

- This activity will only work for tuning forks with a frequency of 256 Hz or higher.
- If a clear plastic tube is not available, a large graduated cylinder may be used.
- Before the students do this activity, demonstrate how to properly lift the white PVC pipe out of the water while lifting the tuning fork. As this technique is demonstrated, have the students listen for the change in loudness of the sound. The students should be close during the demonstration because individuals who are far way commonly have trouble hearing the change in volume.
- PVC tubing of a different length and diameter may be used in place of the size suggested. If the length or diameter is changed, make sure to test it before the students perform the activity. Make sure that the tube length is longer than 0.35 m. This is because our sample data shows that the largest ¼ wavelength was 0.329 m from the tuning fork with a frequency of 256 Hz. If the tube is not longer than this amount, the 256 Hz tuning fork will not resonate when held over the tube.
- For further concept development, try the *Waves and Sound Student Laboratory Kit* (Flinn Catalog No. AP7014) and the *Open-Ended Resonance Tube Set* (Catalog No. 4616) available from Flinn Scientific.

Sample Data Table

Frequency (Hz)	Tube Length (cm)	Tube Length (m)	Wavelength (m)	Speed of Sound (m/s)	Average Speed of Sound (m/s)
256	32.9	0.329	1.316	336	334
288	29.5	0.295	1.180	339	
320	26.5	0.265	1.060	339	
341	24.7	0.247	0.988	337	
384	21.6	0.216	0.864	331	
427	19.4	0.194	0.776	331	
480	17.2	0.172	0.688	330	
512	16.2	0.162	0.648	331	

Materials for *Discovering the Speed of Sound* are available from Flinn Scientific, Inc.

Catalog No.	Description
AP7260	Disocvering the Speed of Sound in Air—Classroom Set
AP1037	Clamp, Universal Extension Clamp
AP8219	Clamp Holder
AP2228	Rubber Stoppers, Solid, #6
AP4685	Ruler, Metric, 12"
AP4550	Support Stand, Economy Choice
AP9242	Tuning Forks, Set of 8
AP6422	Tuning Fork Activator

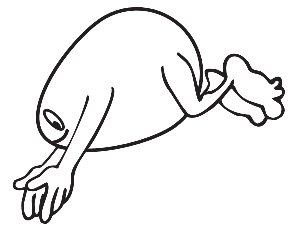
Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.

Diving Eggs

A Demonstration of Inertia

Introduction

Students experience the effects of inertia every day—riding in a car, playing sports, even when picking up their backpacks. Present a more dramatic demonstration of Newton's first law by safely dropping three raw eggs into glasses of water, without touching the eggs! Applause is guaranteed!



Concepts

- Balanced forces
- Inertia
- Newton's first law of motion

Materials

Eggs, raw, 3
Water, tap
Broom
Cardboard tubes, 3 (empty toilet paper tubes)
Demonstration tray or jelly roll pan
Drinking glasses, 3
Pie pan or pizza pan, sturdy aluminum
Table
Towel

Safety Precautions

Take care when handling raw eggs. Wash hands thoroughly with soap and water after handling eggs. Clean up spills immediately. Wear safety glasses. Observers should be a safe distance away from the trajectory of the pie pan. Follow all laboratory safety guidelines.

Procedure

1. Obtain three identical tall drinking glasses, large enough for an egg to fit in sideways.
2. Fill each glass about three-fourths full with tap water.
3. Place a demonstration tray or jelly roll pan 1 cm from the edge of a table. *Note:* The bottom of the tray must be completely flat.
4. Place two of the glasses in the tray next to the edge. The rim of the glasses should be near, but not extending over, the edge of the table.
5. Place the third glass between the other two, forming a triangle shape. See Figure 1.
6. Obtain a sturdy aluminum pie plate or a small aluminum round pizza pan.
7. Center the aluminum pan on top of the three glasses. The edge of the pan should extend slightly beyond the edge of the table.
8. Obtain three empty cardboard toilet paper tubes.
9. Stand the tubes vertically on the aluminum pan, centering one tube over each glass (see Figure 2).
10. Obtain three raw eggs. *Note:* For practice, hard boiled eggs may be used. Once the demonstration has been perfected, use raw eggs.
11. Balance one egg on top of each cardboard tube, laying the egg lengthwise across the top of the tube. Do not fit the narrow end of the egg into the tube; the egg should just rest on top (see Figure 2).
12. Obtain a broom and place the bristles on the floor by the table with the handle extending upward.
13. Holding on to the broom handle, and facing the egg setup on top of the table, step on the bristles of the broom with one foot.

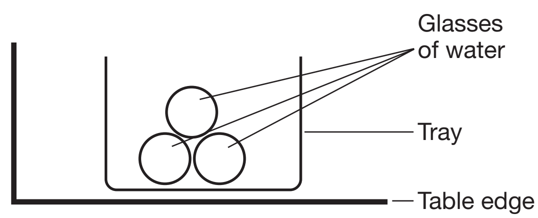


Figure 1. Overhead view

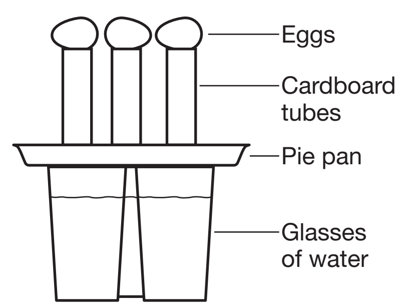


Figure 2.

Publication No. 10884
061616

14. Pull back on the broom handle like a lever. See Figure 3.
15. *Without letting go of the broom handle*, carefully test to see if the handle will hit the aluminum pan *between* the two closer glasses when the handle is released. If not, adjust the position of the broom accordingly. The handle should not hit any of the glasses or the tray.
16. Continuing to step on the bristles, pull the broom handle back.
17. Let go of the broom handle and watch as the eggs "dive" safely into the glasses of water.

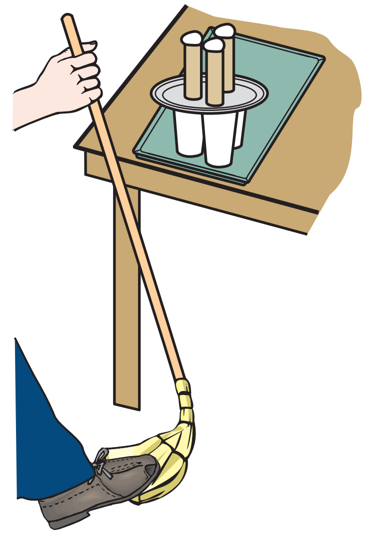


Figure 3.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory wastes. Eggs may be disposed of in the trash according to Flinn Suggested Disposal Method #26a. Egg whites and yolks from broken eggs may be disposed of down the drain with plenty of water according to Flinn Suggested Disposal Method #26b. If necessary, sterilize the glasses and demonstration tray with a 10% bleach solution, then rinse with water.

NGSS Alignment

This laboratory activity relates to the following Next Generation Science Standards (2013):

Disciplinary Core Ideas: Middle School
MS-PS2 Motion and Stability: Forces and Interactions
PS2.A: Forces and Motion
PS2.B: Types of Interactions

Disciplinary Core Ideas: High School
HS-PS2 Motion and Stability: Forces and Interactions
PS2.A: Forces and Motion
PS2.B: Types of Interactions

Science and Engineering Practices
Developing and using models
Planning and carrying out investigations

Crosscutting Concepts
Patterns
Cause and effect

Tips

- Practice with other objects before using raw eggs. Hard boiled eggs, rubber balls, or any other objects similar in size and mass may be used.
- Thin aluminum pie pans may dent with the force of the broom handle, resulting in a less elastic collision. These pans are not recommended for this demonstration.
- Diving Eggs is available from Flinn Scientific as a Super Value Kit, "Diving Eggs Inertia Challenge" (Catalog No. AP7419). The kit includes weighted plastic eggs for practice.
- Using clear drinking glasses allows students to see the eggs after they have dropped into the water. Large beakers may be used instead of drinking glasses.
- Videotape the demonstration, and then play it back in slow motion.

Discussion

Newton's first law of motion states that an object at rest tends to stay at rest unless a net force acts on it. This law is also known at the law of inertia. *Inertia* is the tendency of an object to resist change in motion. Inertia is directly related to mass—the greater the mass of an object, the greater its inertia. In the "Diving Eggs" setup, all the forces are balanced with all objects at rest. A net horizontal force is supplied by the moving broom handle. This force acts upon the aluminum pan, which then accelerates in the direction of the applied force. When the edge of the pan hits the cardboard tubes, the tubes accelerate in the direction of the force also. The eggs do not move with the tubes because of their greater inertia. Since no horizontal force acts on the eggs, however, once the force holding them up is gone, the only remaining force is gravity, and the eggs drop into the glasses of water.

Materials for *Diving Eggs* are available from Flinn Scientific, Inc.

Catalog No.	Description
AP7419	Diving Eggs Inertia Challenge—Super Value Kit
GP1025	Beaker, 400-mL

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.

How Fuses Work

Introduction

Students use electrical devices every day. An essential safety component of any electrical device is the fuse. Demonstrate what it means to “blow a fuse” and show why fuses are important safeguards against electrical fires.

Concepts

- Electrical circuit
- Fuses
- Ohm’s law
- Short circuit

Materials (for each demonstration)

Aluminum foil strip, 2 mm × 10 cm
Balloon
Connector cords with alligator clips, 4
Lamp receptacle
Lantern battery, 6-V
Miniature lightbulb, 6-V
Scissors
Support stand and clamp
Tape

Safety Precautions

Although latex (in balloons) is considered nonhazardous, not all health aspects of this substance have been thoroughly investigated. Latex may be an allergen. A 6-volt battery is not harmful, but small shocks are possible. Do not leave the short circuit wiring in place for more than 15 seconds. The battery can discharge quickly and the terminals and alligator clips can become very hot if connected for a longer duration. Disconnect the battery immediately once the balloon pops. When the balloon pops, be careful of flying particles. The demonstrator and all observers should wear safety glasses. Wash hands thoroughly with soap and water before leaving the laboratory. Follow all laboratory safety guidelines.

Preparation

1. Cut a narrow strip of aluminum foil, 2 mm × 10 cm for each demonstration. *Note:* Cut the aluminum very thin—less than 2 mm wide if possible. The ends may be slightly wider so they do not break when the alligator clips are attached.
2. Screw a 6-V miniature lightbulb into the lamp receptacle.
3. Set up a support stand and clamp. This will allow students a better view of the balloon “fuse.”

Procedure

1. Blow up a balloon, leaving it slightly underinflated. *Note:* Overinflating the balloon may increase the chance of an unexpected “pop” while completing the circuit or adjusting the foil strip.
2. Tie the open end of the balloon in a knot.
3. Tape a 2 mm × 10 cm strip of aluminum foil to the widest part of the balloon, leaving 2–3 cm of the aluminum strip free at each end (see Figure 1). Make sure the center portion of the foil strip between the two pieces of tape is flat against the balloon.
4. Place the knot of the balloon in the clamp and tighten the clamp to secure the balloon for better viewing.
5. Using three connector cords with alligator clips, connect a 6-V lantern battery, the lightbulb, and the aluminum strip in series (see Figure 2). Be sure the metal of the alligator clips is not touching any part of the balloon.

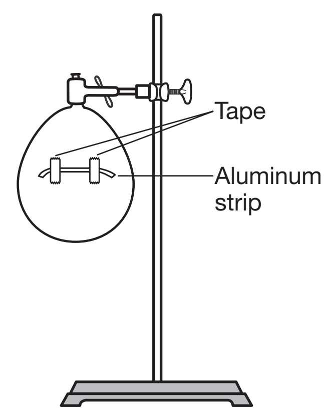


Figure 1.

6. The lightbulb should light, showing the circuit is complete.
7. Instruct students to “cup” their ears with their hands as protection from the loud “pop” of the balloon.
8. Standing away from the balloon, create a short circuit by attaching each end of a fourth connector cord to the clips on the lamp receptacle (see Figure 3). The bulb should go out or become very dim.
9. Make note of the time the short circuit was created. The balloon should burst in a few seconds. *Note:* Do not leave the

short circuit in place for more than 15 seconds. If the balloon does not burst, disconnect the wires from the battery first, and then check to make sure the aluminum strip is flat against the balloon. Adjust if necessary. Repeat steps 5–8.

10. Once the balloon pops disconnect the battery immediately.
11. Show students the broken aluminum strip.

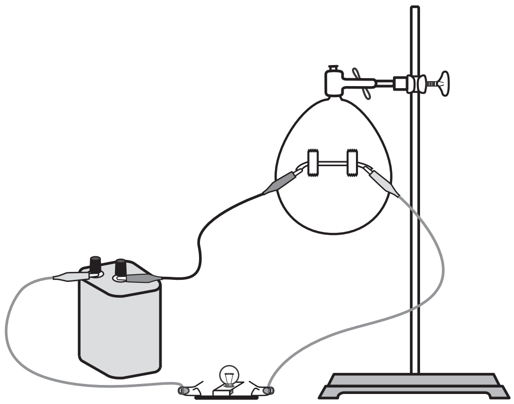


Figure 2.

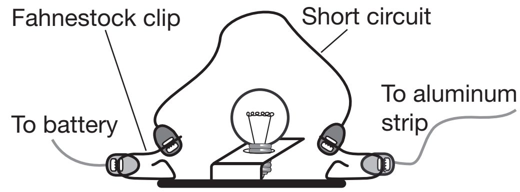


Figure 3.

NGSS Alignment

This laboratory activity relates to the following Next Generation Science Standards (2013):

Disciplinary Core Ideas: Middle School
MS-PS2 Motion and Stability: Forces and Interactions
PS2.A: Forces and Motion
PS2.B: Types of Interactions

Disciplinary Core Ideas: High School
HS-PS2 Motion and Stability: Forces and Interactions
PS2.A: Forces and Motion
PS2.B: Types of Interactions

Science and Engineering Practices
Asking questions and defining problems
Developing and using models
Planning and carrying out investigations
Analyzing and interpreting data

Crosscutting Concepts
Patterns
Cause and effect
Structure and function

Tips

- A size 0 solid rubber stopper may be used to seal the inflated balloon rather than tying a knot. The stoppered end of the balloon can be secured in the clamp.
- When the short circuit is produced, the alligator clips will heat up. If either clip is touching the balloon, the latex may melt in that spot and cause the balloon to pop, instead of the aluminum strip "wire" causing the balloon to pop. While the effect may seem the same, the aluminum strip may not break in the former example.
- Stand away from the balloon when connecting the wire for the short circuit—the balloon may pop very quickly!
- Four 1.5-V batteries connected in series may be used in place of a 6-V lantern battery. Two or three 1.5-V batteries may also work; however, the balloon will most likely take longer than 15 seconds to pop.
- It is important to disconnect the battery immediately after the balloon pops. Even though the circuit is no longer complete when the aluminum strip breaks, if any exposed metal parts of the system touch other metal to complete a circuit, current may flow and cause parts of the circuit to overheat.
- Always wear safety glasses when working with an inflated balloon. Even peeling off a piece of tape to make an adjustment in the aluminum strip may cause the balloon to burst.
- This activity is available from Flinn Scientific as a demonstration kit, *How a Fuse Works* (Catalog No. AP7365).

Discussion

A fuse (fusible link) is a device designed to stop the flow of current when a circuit overheats. A circuit may get too hot either by carrying a load greater than it was designed for or by a *short circuit*. A short circuit may occur when wires lose part of their insulation or become frayed and touch each other. The path of the current is shortened, resulting in less resistance in the circuit. Less resistance results in more current flowing through the circuit than was intended. This can cause damage to the circuit from overheating, and may eventually start a fire or cause an explosion.

Electrical devices in a home, business, vehicle, and even handheld devices are protected by fuses. The fuse is part of the circuit it is designed to protect. Most fuses include a filament with a lower melting point than the rest of the wiring in the circuit. When a circuit overload occurs, the filament melts and breaks, creating an open circuit. In this demonstration, the balloon assembly represents the low-melting-point filament. When the short circuit is established, the aluminum strip heats up, melting the balloon. As the balloon bursts, it breaks the thin aluminum strip, interrupting the circuit. To reestablish current, the "blown" fuse must be removed and a new one inserted in its place. Most household circuits today as well as some electrical devices (such as a hair dryer) are protected by a circuit breaker. A circuit breaker causes a temporary interruption to the current flow, and can be reset once the problem in the circuit has been corrected.

Materials for *How Fuses Work* are available from Flinn Scientific, Inc.

Catalog No.	Description
AP7365	How a Fuse Works—Demonstration Kit
AP1429	Lantern Battery, 6-V
A0019	Aluminum Foil, Household Type
AP6035	Lamp Receptacles, Economy Choice
AP6321	Connector Cords with Alligator Clips
AP9257	Miniature Lightbulb, 6.15-V

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.

Pressure Differential Bottle

Introduction

Blow up a balloon and have it stay inflated without tying it. Is it magic? Open up a world of understanding for your students regarding air pressure with this simple, clever device.

Concepts

- Atmospheric pressure
- Force

Materials

Bottle, 1-L PET

Balloon

Cork borer

Stopper/cork (optional)

Safety Precautions

Although the materials used in this demonstration are not considered hazardous, use caution especially when inflating or deflating the balloon. Latex (in balloons) may be an allergen. For proper hygiene, each person demonstrating the pressure differential bottle should use a separate balloon. Wear impact-resistant safety glasses for eye protection. Wash hands thoroughly with soap and water before leaving the laboratory. Follow all laboratory safety guidelines.

Preparation

A pressure differential bottle is a regular bottle with a secondary opening (see Figure 1). A pressure differential bottle is also known as a harbottle.

1. Obtain a 1-L PET plastic bottle.
2. Determine the size of the secondary opening (see *Tips* section).
3. Use a cork borer or drill to create the secondary opening on the side of the bottle near the bottom (see Figure 1).

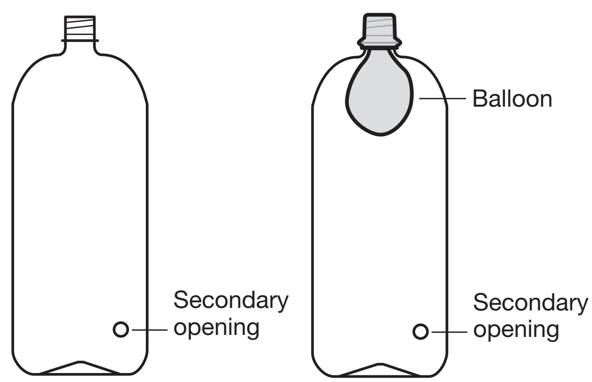


Figure 1. **Figure 2.**

Procedure

1. Obtain the pressure differential bottle from the *Preparation* step.
2. Place the balloon into the neck of the bottle and stretch the mouth of the balloon over the neck of the bottle (see Figure 2).
3. Blow up the balloon inside the bottle. Once the balloon is inflated, seal the secondary opening with a finger or stopper. The balloon will remain inflated even though the mouth of the balloon is unsealed.
4. Allow air into the secondary opening and the balloon will deflate.
5. *(Optional)* Try to blow up the balloon when the opening is sealed. It can't be done!

Disposal

The pressure differential bottle should be cleaned and then stored for reuse. If using a glass harbottle, store in proper packing materials to prevent breakage. Do not store the balloons inside the bottle. Dispose of used balloons at the end of each demonstration. Store unused balloons for future use.

NGSS Alignment

This laboratory activity relates to the following Next Generation Science Standards (2013):

Disciplinary Core Ideas: Middle School	Science and Engineering Practices	Crosscutting Concepts
MS-PS1 Matter and Its Interactions PS1.A: Structure and Properties of Matter MS-PS2 Motion and Stability: Forces and Interactions PS2.A: Forces and Motion MS-ESS2 Earth's Systems ESS2.A: Earth's Materials and Systems **Disciplinary Core Ideas: High School** HS-PS1 Motion and Its Interactions PS1.A: Structure and Properties of Matter	Asking questions and defining problems Planning and carrying out investigations Constructing explanations and designing solutions	Cause and effect Stability and change

Tips

- Traditional harbottles, Flinn Catalog No. AP7205, are made of glass and the secondary opening is sealed with a stopper when demonstrating its use. Plastic bottles can be designed to function as the traditional model by adding a secondary opening to the bottle.
- A 1-liter plastic bottle makes an ideal pressure differential bottle. Make the secondary opening on the side near the bottom of the bottle or on the bottom of the bottle. For best results, make the opening at least 0.5 cm in diameter. If sealing with a stopper, match the size of the opening to the mid-stopper diameter. Reference the *Flinn Scientific Catalog/ Reference Manual* to coordinate cork borer and stopper/cork sizes. The opening is best made by a drill or a cork borer. A piece of masking tape placed on the bottle when using the drill/cork borer can reduce slippage. *Please note:* The bottom of a plastic bottle is usually thicker than the sides so making the opening on the bottom of the bottle might require more effort.
- When working with the pressure differential bottle a stopper can be used to seal the secondary opening, however, a finger works well for sleight-of-hand "magic."
- As an inquiry activity give students a regular bottle and one with a secondary opening and two balloons. Challenge students to inflate the balloon and have it remain inflated without sealing the mouth of the balloon.
- Air pressure accounts for many principles seen every day such as weather, flight, breathing, vacuums, and pumps. Have students research an everyday air pressure system.

Discussion

Air has mass, takes up space, and exerts pressure, even though it is not seen. So the question remains: when the balloon is blown up inside the bottle containing a secondary opening and the opening is then sealed, why does the balloon stay inflated? Why doesn't the air rush out of the mouth of the balloon?

The balloon expands into the bottle because of a difference in air pressure. When air is blown into the balloon, the air pressure inside the balloon increases and the balloon expands forcing air out of the secondary opening. (If there is no secondary opening or the opening is sealed, it is difficult if not impossible to overcome the air pressure inside the bottle to blow up the balloon. This can be demonstrated.) When the air is pushed out of the pressure differential bottle's secondary opening due to the expanding balloon, the resulting air pressure inside the bottle around the balloon is lowered and is less than atmospheric pressure. If the secondary opening of the bottle is then plugged with a finger or stopper before removing your mouth from the balloon, the air pressure is not allowed to equalize. Therefore, the air pressure in the bottle around the balloon remains lower than the pressure inside the balloon and the balloon stays inflated. When the secondary opening is unplugged, the higher air pressure outside the bottle will push air into the secondary opening to equalize the pressure in the bottle. As the air pressure increases around the balloon, the air inside the balloon is pushed out of the balloon's mouth until the balloon deflates. The air pressure is again equal both inside and outside the deflated balloon.

Materials for *Pressure Differential Bottle* are available from Flinn Scientific, Inc.

Catalog No.	Description
AP7205	Harbottle, Glass
AP1900	Balloons, 12″ Round, Latex, 20/pkg
AP7669	Plastic Soda Bottle, 1-L
AP8326	Cork Borer, Set of 6

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.

Simple Block and Tackle Pulley Demonstration

Introduction

How much easier is it to lift a heavy object using a pulley system? Use this simple broomstick-pulley system to effectively demonstrate why a block and tackle pulley system is so useful.

Concepts

- Pulleys
- Simple machines
- Mechanical advantage

Materials

Broom handle (or dowel rod), 1 to 1½″ diameter (or ¾″ PVC pipe), 2–3 feet long, 2

Rope, strong, 25 feet long

Student volunteers, 3

Safety Precautions

Please follow normal laboratory safety guidelines. Wear cloth gloves when holding the handles to avoid rope abrasions. Clear out the demonstration area to remove objects that could be tripped over. Do not jerk on the rope. Pull the rope gently with an even force.

Procedure

1. Select three student volunteers.
2. Assign two volunteers as broom-handle holders and the other as the rope puller.
3. Have the two broom-handle holders wear gloves and stand about 5 to 6 feet apart and extend their arms to hold the broom handles parallel to the floor at waist level.
4. Securely tie one end of the rope to the middle of one of the broom handles.
5. Wrap the rope around the middle of the other broom handle (see Figure 1) and give the free end to the rope puller. The rope puller should stand behind, and slightly to the side of one of the holders, so that the rope will be pulled perpendicular to the length of the broom handles. The free end of the rope should go under the arms of the broom-handle holder so that the rope is pulled parallel to the ground as well (see Figure 2).
6. Have the two broom handle holders try as hard as they can to prevent the broom handles from coming together as the rope puller pulls on the rope. Can the single rope puller draw the two broom handle holders together? What is the mechanical advantage of this pulley system?

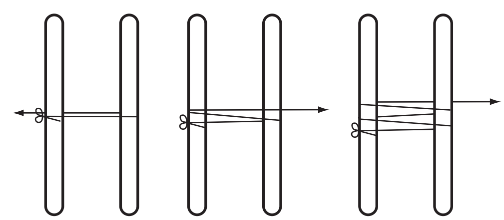


Figure 1.

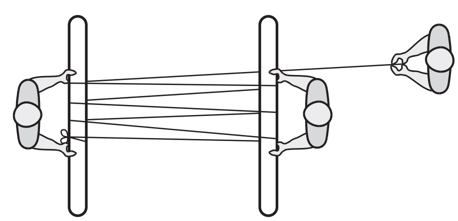


Figure 2.

7. Repeat steps 5 and 6 several times. For each new trial wrap the rope around the broom handles a different number of times (see Figure 1). How much more difficult is it for the holders with each new trial? How much easier is it for the puller? What is the mechanical advantage of the puller as a new loop is added to the pulley system? How close are the broom handle holders drawn together compared to the amount of rope pulled by the rope puller during each new trial?

Tip

- The purpose of this activity is to show how to increase the mechanical advantage of a pulley, not a contest of strength. Pulling too vigorously on the rope or jerking back on the handles may result in injury. The rope puller should take care to pull the rope evenly and straight, and avoid rubbing the rope against the hands of the other two volunteers. As a safety precaution, the volunteer handle holders may wear cloth gloves, available from Flinn Scientific (Catalog No. SE1030), to avoid abrasions from the rope.

Discussion

Pulleys are used extensively when heavy objects need to be lifted, especially in cranes in shipping and construction areas. Pulleys are one of six types of *simple machines* used to easily change the direction and/or the magnitude of an applied force. (The lever and fulcrum, inclined plane, wheel and axle, wedge, and screw are the five other types of simple machines.) How does a pulley decrease the amount of force necessary to lift an object? The advantage of a pulley is its ability to change the number of "ropes" lifting an object. This gives a lifter a greater mechanical advantage. *Mechanical advantage* is a ratio of the output force compared to the input force. The greater the mechanical advantage is for a system, the greater the output force is compared to the input force. The greater the mechanical advantage, the easier it is to do the work. For a block and tackle pulley system, the mechanical advantage is determined by the number of support ropes that are lifting the object (see Figure 3). Therefore, the more times the rope is wrapped around the broom handles, the greater the mechanical advantage is for the puller.

However, a pulley does not give something for nothing. A block and tackle pulley system gives a high mechanical advantage, but the sacrifice is that the applied force must be carried over a longer distance compared to the distance the lifted object actually moves. Ideally, due to the conservation of energy, the work in must be equal to the work out. *Work* is defined as a force times a distance. Therefore, even though a pulley (or any simple machine) makes it easier to lift a heavy object, the total amount of work necessary to lift the object will be equal. A smaller force will be used over a larger distance in order to lift a heavy object a short distance.

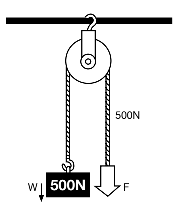
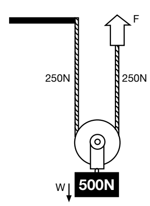
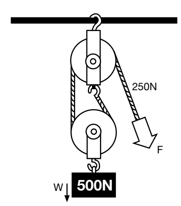
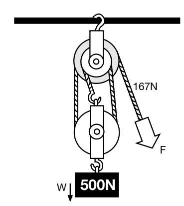
Mechanical Advantage	1	2	2	3
Pulley Setup				

Figure 3.

Alignment to the NGSS

This laboratory activity relates to the following Next Generation Science Standards (2013):

Disciplinary Core Ideas: Middle School
- MS-PS2 Motion and Stability: Forces and Interactions
  - PS2.A: Forces and Motion
- MS-PS3 Energy
  - PS3.A: Definitions of Energy
  - PS3.B: Conservation of Energy and EnergyTransfer
  - PS3.C: Relationship Between Energy and Forces

Disciplinary Core Ideas: High School
- MS-PS2 Motion and Stability: Forces and Interactions
  - PS2.A: Forces and Motion
- MS-PS3 Energy
  - PS3.A: Definitions of Energy
  - PS3.B: Conservation of Energy and EnergyTransfer
  - PS3.C: Relationship Between Energy and Forces

Science and Engineering Practices
- Asking questions and defining problems
- Developing and using models
- Planning and carrying out investigations

Crosscutting Concepts
- Patterns
- Cause and effect
- Scale, proportion, and quantity
- Systems and system models

Reference

Bilash, B. *A Demo A Day: A Year of Physical Science Demonstrations;* Flinn Scientific: Batavia, IL, 1997; p 262.

Simple Block and Tackle Pulley Demonstration is available as a Physical Science Demonstration Kit from Flinn Scientific, Inc.

Catalog No.	Description
AP6890	Human Block and Tackle Demonstration
SE1030	Terrycloth Gloves

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.

Singing Tube Demonstration

Introduction

Mysteriously play an organ pipe without an organ! This demonstration uses heated air to produce vibrations inside a long tube. The vibrations, in turn, produce standing sound waves with a unique tone, or timbre (tăm′ br)—the same concept that produces sound from an organ pipe.

Concepts

- Sound waves
- Open-ended resonance tubes
- Wind
- Organ pipes

Materials (for each demonstration)

Metal tube, 2″ dia. × 17″
Metal wire disks, 2½″ diameter, 3
Bunsen burner, or portable laboratory burner
Heat-resistant gloves, or oven mitts
Paper clip, metal
Pliers, needle-nose, with wire cutters

Safety Precautions

The edges of the metal wire disks are sharp. Please handle with care. Follow normal Bunsen burner safety guidelines. The metal tube and wire disks will get hot while in the burner flame. Wear heat-resistant gloves and safety glasses when performing this demonstration.

Preparation

1. Obtain the metal wire disks. Handle them very carefully.
2. Carefully bend one of the disks into a bowl shape (similar to a watch glass shape). Put pressure on the center of the disk with your thumbs and then evenly bend the edges of the disk with your fingers to form a bowl. See Figure 1. Be very careful not to cut yourself on the wire edges.
3. Form a bowl shape that has a slightly larger diameter than the inside diameter of the metal tube. If the wire disk is bent too much, it can be flattened out and adjusted to the proper diameter.
4. Repeat steps 2 and 3 for the two remaining wire disks.
5. Place one disk on top of the other to make a stack of three disks.
6. Obtain a metal paper clip and needle-nose pliers with wire cutters.
7. Straighten out the paper clip.
8. With the wire cutters, clip off a 1–2 cm paper clip piece.
9. Insert this paper clip piece through the center of the wire disk stack so that it goes through all three disks. See Figure 2.
10. Use a needle-nose pliers to bend the inserted paper clip piece into a “C” shape to secure the wire disks together. See Figure 2.

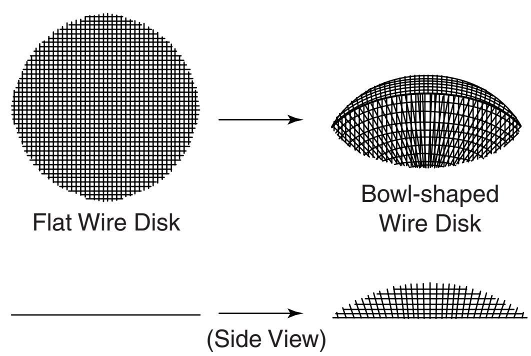


Figure 1.

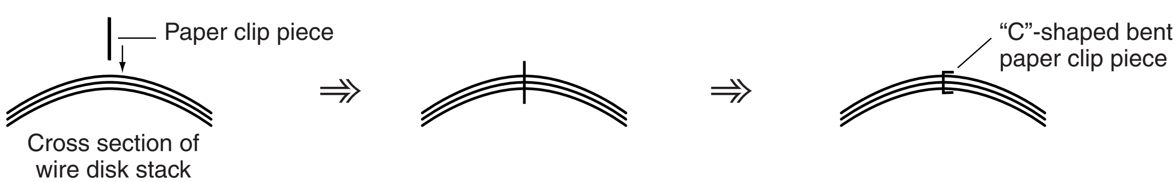


Figure 2.

11. Insert the curved end of the wire disk “stack” into the end of the metal tube, opposite to the label. See Figure 3. Carefully push and “massage” around the edges of the stack evenly in order to slide the disks into the tube so that they remain parallel with the tube opening. (When you look inside the tube, there should be no gaps between the disks’ edges and the wall of the tube.) The friction between the wall of the tube and the edges of the disks should keep them secure inside the tube. If the disks are loose or fall out, remove them and flatten them out slightly to increase their diameter so they fit snugly inside the tube. If the wire disks are pushed in crookedly, use pliers to remove them completely and begin again. Proceed slowly in order to keep the wire disks parallel with the opening of the tube.

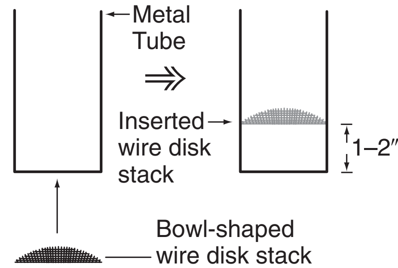


Figure 3.

12. Once the wire disks are inside the tube opening squarely, slide them down the tube so that they are about 1–2″ from the end of the tube. See Figure 3.
13. Set up a Bunsen burner or portable laboratory burner on a demonstration table.

Procedure

1. Light the Bunsen burner and adjust it to obtain a blue flame.
2. Wearing heat-resistant gloves or oven mitts, hold the metal tube at one end and position the other end of the metal tube vertically over the Bunsen burner flame to directly heat the wire disks inside the tube. See Figure 4.
3. Heat the wire disks for 10–15 seconds. Swirl the tube slightly to evenly heat the entire disk surface.
4. Remove the tube from the Bunsen burner flame and continue to hold it vertically. In a few seconds, a loud tone will begin to reverberate from the tube. The sound will last for several seconds (10–30 sec.), depending on how quickly the wire disks cool.
5. When the sound disappears, repeat steps 16–18 as often as necessary to reheat the wire disks and reproduce the sound.

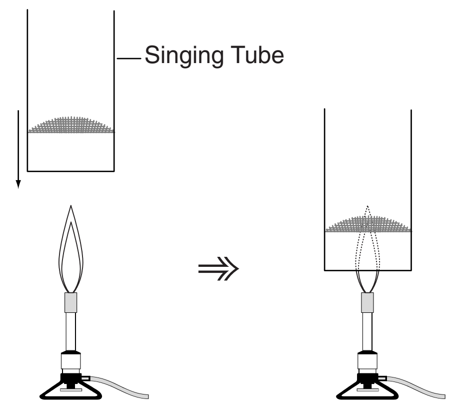


Figure 4.

6. **After the initial demonstration, perform this variation:** After heating the wire disks, remove the tube from the burner flame and immediately tip the tube 90° so that it is parallel to the floor. Notice that no sound resonates from the tube!
7. Quickly, but steadily, rotate the tube to the vertical position. The sound gradually increases in volume as the tube rotates towards the vertical position. (This should be done in 5–10 seconds—before the wire disks cool off.)
8. Discuss the observations with your students.

Disposal

The materials are completely reusable and should be saved for future demonstrations.

Tips

- Do not allow the metal tube to get too hot. The heat may scorch the tube label, heat-resistant gloves, and/or lab table it is stored on between trials.
- The Singing Tube can be silenced quickly, if it is too loud, by turning it horizontally, or by covering one of the ends (preferably the cool end).
- Pretend to pour sound into a beaker, or from a beaker into the tube. When the Singing Tube is “singing,” begin to pour the “contents” of the tube into a beaker by rotating the tube 90°, with a beaker at the top opening of the tube. As the tube rotates, the “singing” decreases and makes it appear as if you are emptying the sound from the tube into a beaker. Reverse the process by pretending to pour sound into the tube. Start with a heated tube held horizontally and then quickly, but steadily, rotate it to the vertical position as you hold the lip of a beaker near the “top” of the rotating tube. The volume of the “singing” increases, simulating the act of pouring sound into the tube.

Discussion

The open tubes in this demonstration act in a similar manner to the flue-type organ pipe (see Figure 5). In a flue-type organ pipe, a stream of air is directed against a sharp edge in an opening of the pipe. The sharp edge creates turbulent, complicated swirls of air which set up vibrations in the air column. The vibrations that are at the correct resonance frequency of the pipe (depending on the length of the pipe, the design of the pipe, and the air temperature) will resonate and produce a very loud tone. The tone is not a specific fundamental frequency, but it is a combination of the different harmonics that the column will allow. The fundamental frequency is usually the most prominent frequency in a resonating column. The shorter the pipe, the higher the vibrational frequency must be to produce resonation inside the column. Therefore, a short column will produce a higher pitch than a long column.

The Singing Tube is an example of an open-ended resonating air column. When the metal wire disks are heated, and then removed from the heat source, the metal will retain the heat for a time. This heated metal will heat the nearby surrounding air, which then rises through the tube. As the hot air rises, cooler air from the room will flow into the tube from the bottom and through the wire mesh. When the air flows through the wire mesh it becomes turbulent. The swirling turbulent air sets up vibrations inside the tube, and the correct vibrational frequencies will begin to resonate loudly inside the tube to produce a note, just as in the organ pipe. When the tube is tilted parallel to the ground, the heated air does not rise through the column to cause a large inflow of cooler air through the wire mesh. Without the rush of cool air through the tiny holes, no vibrations, and therefore no sounds, are produced.

NGSS Alignment

This laboratory activity relates to the following Next Generation Science Standards (2013):

Disciplinary Core Ideas: Middle School
MS-PS4 Waves and Their Applications in Technologies for Information Transfer
PS4.A: Wave Properties

Disciplinary Core Ideas: High School
HS-PS4 Waves and Their Applications in Technologies for Information Transfer
PS4.A: Wave Properties

Science and Engineering Practices
Asking questions and defining problems
Developing and using models
Constructing explanations and designing solutions

Crosscutting Concepts
Patterns
Energy and matter
Structure and function
Stability and change

Acknowledgment

Flinn Scientific would like to thank David Katz, Pima Community College, Tucson, Arizona, for providing us the idea for this demonstration.

Reference

Tipler, Paul A. *Physics for Scientists and Engineers,* 3rd Ed., Vol. 1; Worth Publishers: New York, 1990; pp 452–457.

The *Singing Tube Demonstration* is available as a demonstration kit from Flinn Scientific, Inc.

Catalog No.	Description
AP6312	Singing Tube Demonstration Kit
AP6305	Triple Singing Tubes

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.

Standing Wave Generator

Introduction

Teachers can demonstrate a standing wave by using a centrifuge device with a simple attachment. The discussion of wavelength and amplitude will become much more concrete as students see these principles for themselves!

Concepts

- Properties of waves
- Wavelength
- Nodes
- Antinodes
- Frequency
- Amplitude

Materials

Battery, D size
Bracken's Demonstration Spinner
Candle or burner
Cotton cord
Paper clip or dissection needle
PVC elbow
PVC pipe, long
PVC pipe, short, with cup hook
Ring stand
Soda bottle cap
Strobe light (optional)
Swivel, hole and latch
Swivel, two holes

Safety Precautions

Make sure hooks are firmly connected before operating the centrifuge. Do not touch the motor axle while rotor is spinning. Remove the battery from Bracken's Demonstration Spinner when not in use and during storage.

Procedure

1. Thread one end of the cotton cord through the 2-hole swivel and tie.
2. Melt a hole in the center of the flat surface of the cap (see Figure 1) using a heated straightened paper clip or dissection needle. (A candle or burner may be used to heat the paper clip.) The motor axle of the centrifuge device should fit snugly through this hole.
3. Melt a second hole on the side of the bottle cap.
4. Place the cap, flat side down, on the axle of Bracken's Demonstration Spinner through the center hole.
5. Tie the loose end of the cord through the hole of the swivel with the hole and latch. Clip the latch of the swivel to the hole on the side of the bottle cap.
6. Attach the PVC elbow to the two PVC pieces as shown in Figure 2.
7. Place the 2-hole swivel onto the cup hook (see Figure 2).
8. Slide the long PVC piece over the rod of the ring stand.
9. Turn on the motor and observe the wave pattern in the cotton cord.
10. Vary the number of nodes by changing the tension on the rope. This is easily done by holding and raising the PVC pipe assembly to tighten the rope.

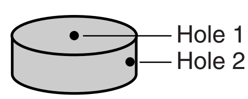


Figure 1. Cap

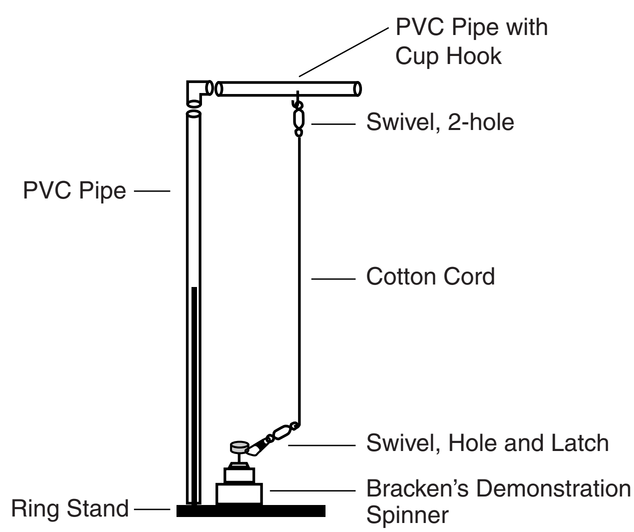


Figure 2. Setup

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Tips

- Bracken's Demonstration Spinner, Flinn Catalog No. AP6202, is required and sold separately.
- Properties like frequency, wavelength, nodes, and antinodes can be discussed using this wave generator.
- A strobe light can be used with this demonstration to "fool" our eyes. If the strobe light is properly adjusted, the spinning rope will appear motionless! This should be done in a dark room. Be advised that the use of strobe lights can trigger epileptic seizures in some people—take all necessary precautions.
- A video presentation of the *Standing Wave Generator* activity is available through the Flinn Scientific Web site (www.flinnsci.com) in *Electron Configuration*, part of the Flinn Scientific—Teaching Chemistry™ eLearning Video Series.

Discussion

All traveling waves follow the *principle of superposition*. That is, when two or more waves meet at the same location the waves overlap with each other and add together to instantaneously create a new wave form. However, the original wave patterns are not lost. Instead, they travel through each other, interact with superposition, and then emerge with the same original shape.

The superposition of two or more waves creates two types of interference—constructive interference and destructive interference. *Constructive interference* occurs when two or more waves combine at the same location and instantaneously produce a wave form with a larger amplitude than any of the original waves. *Destructive interference* occurs when two or more waves combine at a given location to instantaneously produce a wave with a lower amplitude than any of the original waves. When two continuous waves traveling in opposite directions with the same frequency interact with each other, an interesting wave form can be created. If the waves are the correct frequency, a *standing wave* is produced. A standing wave form is the result of constructive and destructive interference of waves that interact in such a way to make the peaks (antinodes) and valleys (nodes) of the wave remain fixed in space.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Systems, order, and organization
Evidence, models, and explanation

Content Standards: Grades 5–8
Content Standard B: Physical Science, understanding of motions and forces

Content Standards: Grades 9–12
Content Standard B: Physical Science, motions and forces

Acknowledgment

Flinn Scientific would like to thank Jeff Bracken, chemistry teacher at Westerville North High School in Westerville, Ohio for sharing this original idea. Jeff would like to thank his student lab assistant, Ben Swanger, for his valuable assistance in creating this demonstration.

Reference

Tipler, Paul A. *Physics for Scientists and Engineers*, 3rd Ed., Vol. 1; Worth Publishers: New York, 1990; pp 414–424.

The *Standing Wave Generator* is available as a demonstration kit from Flinn Scientific, Inc.

Catalog No.	Description
AP6161	Standing Wave Generator
AP6202	Bracken's Demonstration Spinner
AP1425	Battery, Replacement, D size
AP5720	Stroboscope

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.