# 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 | Cork borer |
| Balloon | 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).

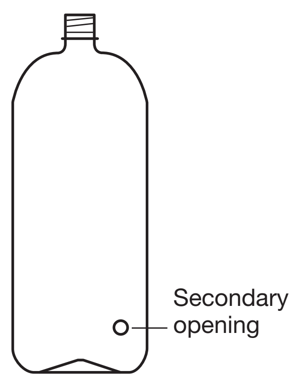


**Figure 1.**

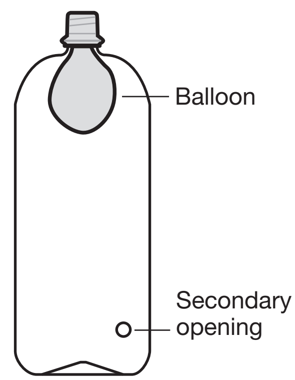


**Figure 2.**

## 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**
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

**Science and Engineering Practices**
Asking questions and defining problems
Planning and carrying out investigations
Constructing explanations and designing solutions

**Crosscutting Concepts**
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

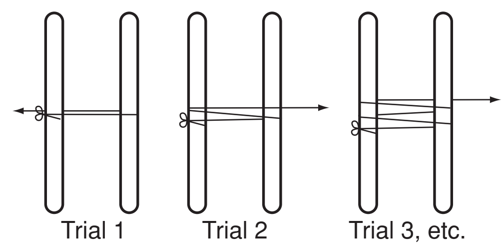


**Figure 1.**

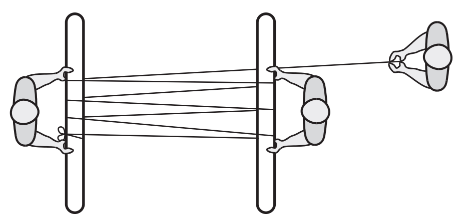

**Figure 2.**

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?
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?



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## 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.

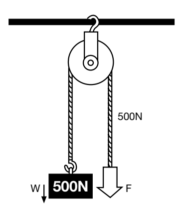
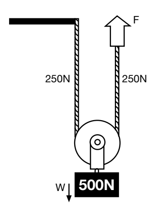
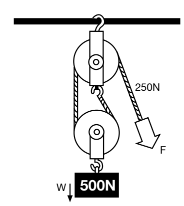
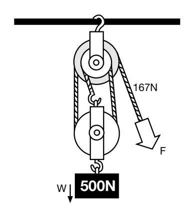
| Mechanical Advantage | 1 | 2 | 2 | 3 |
|---|---|---|---|---|
| Pulley Setup |  |  |  |  |



**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 |

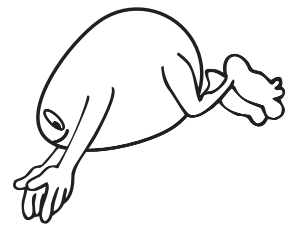
Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.

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

## *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

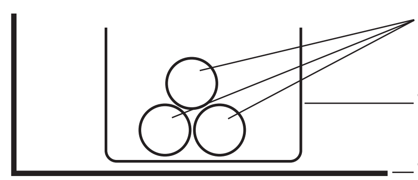



**Figure 1.** Overhead view

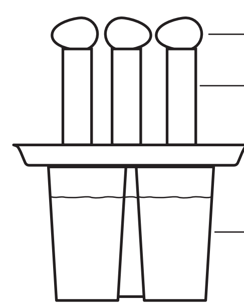



**Figure 2.**

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.

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.

# 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.

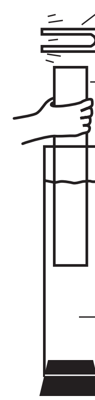


**Figure 1.**

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 ($\lambda$) 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)
$\lambda$ = 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.

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.

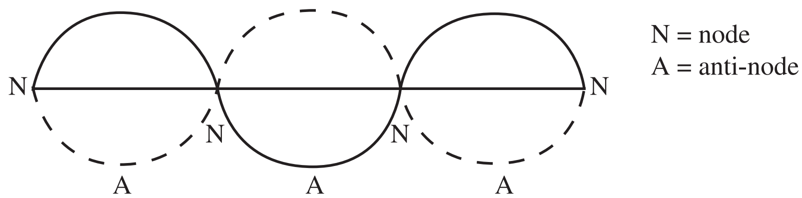



**Figure 2.**

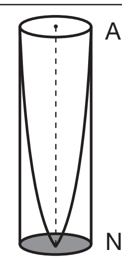
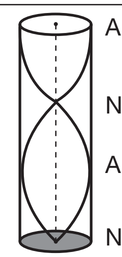
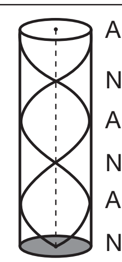
| No. of Wavelengths Shown | Closed-end Air Column |
|---|---|
| ¼ λ<br>1 quarter of a full wavelength |   |
| ¾ λ<br>3 quarters of a full wavelength |   |
| ⁵⁄₄ λ<br>1 full wavelength plus 1 quarter of a wavelength |   |

**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.

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

$\lambda$ = 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.

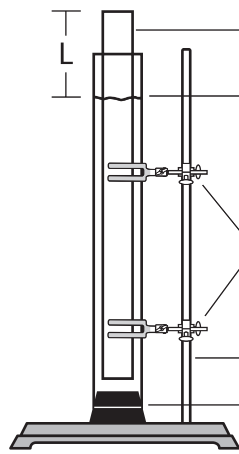



**Figure 4.**

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.

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# Build Your Own Spinning Pyramid

## Introduction

What makes a merry-go-round spin? What about a ceiling fan or a boat propeller? All these objects require a source of energy to cause them to spin. You may have correctly answered that electrical energy or electricity is what makes a merry-go-round, a ceiling fan, or a boat propeller rotate; however, there are other energy sources that can be used to make objects spin, such as wind and steam.

**Figure 1.** Windmills are powered by the kinetic energy of winds.

In this investigation, you will build a spinning pyramid that spins due to the movement of hot air. The challenge of this investigation is to optimize the design of the spinning pyramid to make it spin faster and continuously!

## Concepts

- Air Convection
- Energy Conversion
- Heat Transfer
- Kinetic Energy
- Motion
- Rotational Motion

## Background

Wind is the natural movement of air relative to Earth's surface. Wind is something that can be easily experienced because we can feel it on our skin, blowing away our hair, and making water waves form in oceans or lakes. But why does air move at all causing winds?

Air is composed of various gases, mainly nitrogen and oxygen; when the air temperature increases due to the heat coming from the sun, its gas molecules move at higher speeds and the air expands. Heat makes the air less dense or lighter than cooler air, and thus hot air tends to rise to higher altitudes in the atmosphere. As hot air moves higher in the atmosphere, its temperature starts to decrease—it cools down—and becomes heavier, so it begins to move downward. This process in which hot air moves upward while cold air moves downward is known as *convection*, and it is responsible for the formation of winds.

Winds can push and move objects around. The energy of winds can be transformed into more useful forms of energy; for example, a windmill is a structure that transforms wind's energy into rotational kinetic energy. This rotational kinetic energy can then be used to mill (grind) grain.

In this investigation, you will build a spinning pyramid that uses air convection as the source of kinetic energy. You will propose and test modifications to the initial design to make the spinning pyramid rotate in a continuous and steady manner.

## Experiment Overview

In this investigation, you will build and optimize a spinning pyramid that uses air convection as the source of kinetic energy.

## Materials

- Aluminum pie pan, 2
- Candle lighter, or matches
- Double-sided tape
- Dowel rod
- Modeling clay
- Pen, or fine tip marker
- Pushpin
- Ruler
- Scissors
- Spinning pyramid template
- Tea candles, 6

## Pre-Lab Questions

1. When the air gets heated up it becomes less dense, or lighter. In which direction will hot air move with respect to the ground?

2. Cold air is denser—or heavier—than hotter air. In which direction does colder air move with respect to the ground?

## Safety Precautions

Please follow all laboratory safety guidelines. Wear safety glasses. Tie back long hair. Do not eat or drink anything in the lab. Do not play with fire or flame sources and keep flames away from you and your classmates. Wash hands thoroughly with soap and water before leaving the laboratory.

## Procedure

### Part A. Introductory Activity

Follow these steps to build your own spinning pyramid:

1. Cut the spinning pyramid template along the solid lines. Do not cut along the dotted lines; these are folding lines only.
2. Carefully cut the circular bottom of one of the aluminum pie pans. Keep the aluminum foil flat and free of wrinkles while you do this. Be careful not to cut yourself with the scissors or the aluminum foil edges.
3. Use double sided tape to attach the spinning pyramid template to the aluminum foil circle. Then, cut along the edges of the aluminum foil to make it into a circle that is the same size as the spinning pyramid template.
4. Cut through the template and the aluminum foil circle along the solid lines only.

5. Carefully fold the aluminum foil along the dotted lines. Do this on a flat, hard surface like a lab bench or desktop. You may use a small ruler to help you fold along these dotted lines.

6. Hold the aluminum foil circle horizontally and ensure that the folded part of each blade forms an angle of approximately 30–45° with respect to an imaginary vertical line.

7. Gently remove the paper template and double-sided tape from the aluminum fan. Once the paper template and tape have been removed, make sure the aluminum fan keeps the initial shape and folds made in previous steps.

8. Pierce the center of the aluminum fan using the pushpin. Wiggle the pushpin to widen the hole so that it is slightly wider than the needle of the pushpin.

9. Carefully insert the pushpin needle into one end of the 15 cm-long Dowel rod such that the rod is perpendicular to the aluminum fan. Do not press the pushpin all the way into the Dowel rod; the aluminum fan should be able to spin freely without wobbling up and down too much.

10. Set the second aluminum pie pan on a flat surface (lab bench or desktop) and mark the center of the circular bottom using a pen or marker.

11. Knead some modeling clay and stick it to the center of the aluminum pie pan. Shape the modeling clay into a cone-shaped pile.

12. Then, stick the bottom end of the Dowel rod into the modeling clay and knead the clay around it until it sits straight up and steadily on the pan.

13. Place two candles inside the aluminum pan surrounding the base of the spinning pyramid but not directly in contact with the modeling clay. Use a pen or marker to mark the positions of the candles.

14. Carefully light the candles using a lighter or matches. Observe carefully what happens during the first five minutes after lighting the candles and write any observations in **Table 1**.

**Table 1. Spinning Pyramid Observations**

| Observations |
|---|
| |

**Part B. Experimental Challenge**

Congratulations! You have built your own spinning pyramid.

Now your challenge is to get the spinning pyramid to spin.

15. If your spinning pyramid is not rotating, think about possible reasons why this may be happening. Record one or two possible reasons for this and how you could test if these are real causes for the pyramid's lack of movement.

16. Test the reasons you described in step 15 and record your results.

**Post Lab Questions**

1. Is there any relationship between the number of candles used and the rotation of the spinning pyramid? Explain your answer based on your own observations and results.

2. Draw a sketch of the spinning pyramid and use arrows to indicate the direction in which the hot air moves and the direction in which the blades move.

3. What makes the spinning pyramid rotate? To write your explanation, consider what happens when the air's temperature increases. Also, think about how air causes objects to move, or recall how a windmill works.

**4.** What forms of energy are involved in the rotational movement of the spinning pyramid?

**5.** What energy transformations are involved in the rotational movement of the spinning pyramid? Describe as many energy transformations as you can identify.