Gas Laws and Pressure Discovery Bundle

P1-2070

Contents

Vortex Tube

Pressure Pumper

Vacuum Pumper and Chamber

LCD Strip Thermometer

Cartesian Diver

Bernoulli Bags 4 pack

Drinking Bird

Pascal’s Demonstrator

Elasticity of Gases Demo

Hand Boiler

Atmospheric Pressure Cups

Item	Topic	Instructions
Vortex Tube (P1-1120)	Air pressure Vortices Fluid flow	Instructional Guide Included
Pressure Pumper (P1-2050)	Increasing pressure	Attach to the top of a soda bottle and increase the pressure inside. See also LCD Temperature Strips below.
Vacuum Pumper and Chamber (P1-2140)	Reducing Pressure	Use the valve in the top of a glass bottle, or use the Vacuum Chamber. Place the Vacuum Pumper on top of the valve and decrease the pressure inside the container. Try placing different objects, such as balloons and marshmallows, in the chamber. Squeeze the valve to release the pressure.
LCD Strip Thermometer (2) (P1-2060-02)	For use with Pressure Pumper and Vacuum Pumper	Place a temperature strip in a container. Change the pressure (increase or decrease) and let the temperature equalize for a minute or two. Then watch the temperature when you abruptly release the pressure.
Cartesian Diver (P1-2000)	Compressibility of gases Density and buoyancy	Instructional Guide Included
Bernoulli Bags (P6-7350)	Bernoulli Effect	Instructional Guide Included
Drinking Bird (P3-5001)	Heat and pressure	Instructional Guide Included
Pascal's Demonstrator (P1-2190)	Pascal's Principle (Pressure in all directions)	Instructional Guide Included
Elasticity of Gases Demo (P1-2075)	Boyle's Law Charles' Law	Instructional Guide Included
Hand Boiler (P3-5005)	Heat and pressure	Instructional Guide Included
Atmospheric Pressure Cups (P1-2005)	Atmospheric pressure	Instructional Guide Included

Related Products

Fire Syringe (P1-2020) A smokin' example of an adiabatic process. Using the Fire Syringe to compress air into a smaller volume is a classic example of how rapidly doing work on a gas results in an increase in temperature.

Atmospheric Mat (P1-2010) A simple design that demonstrates a powerful concept: atmospheric pressure! Place this rubber mat on any flat surface and pull on the handle. It's like the mat is glued down!

Pressure Globe (P1-2015) Demonstrate the amazing power of air! This specialized bottle is fitted with a balloon and a stopper. Inflate the balloon with air or water, with the stopper in place and removed, and see what happens.

ARBOR SCIENTIFIC

Vortex Tube

P1-1120

INSTRUCTIONAL GUIDE

Contents

- Vortex Tube
- Instructional Guide

Recommended for activities:

- Two 2-liter plastic soda bottles

Introduction

An initial small rotation causes the water to move in a circle near the tube opening. The water is forced downward and toward the lower bottle by gravity. As water approaches the small opening in the tube, they move in a gradually smaller circle. Each water molecule's angular momentum***** is conserved, so as its rotational radius decreases, its speed increases. (The same thing happens when a spinning ice skater pulls in her arms.)

The hole that develops in the center of the vortex allows air to move from the lower bottle to the upper one, making room for the water.

Directions

1. Remove the labels from two 2-liter soda bottles.
2. Fill one bottle 2/3 full with water and attach the Vortex Tube to the top.
3. Attach another (empty) bottle to the top of the Vortex Tube.
4. Quickly invert the assembly.
5. Rest the bottom bottle securely on a flat surface, and briefly rotate the top bottle in a circular motion.
6. Observe the vortex that forms as the water moves through the Vortex Tube!

Activities

1. Add visual interest by putting food coloring or glitter in the water. The glitter works particularly well because each particle can represent a "unit" of water whose angular momentum is conserved.
2. Relate the bottle vortex to vortices in nature, such as tornadoes, hurricanes and smoke rings.
3. Notice that the vortex can easily rotate either way, and does not start without an initial rotation. The vortex is not influenced by the Coriolis Effect, and neither is the vortex that forms when you empty a sink. These systems are far too small to be affected by the earth's rotation.

4. Introduce the topic by challenging a student to a race. Fill two bottles 2/3 with water and cap each with a Vortex Tube. Ask the student to empty the bottle as fast as possible (without removing the Vortex Tube). Surface tension at the hole will make it quite difficult to do quickly. Students may have to shake or squeeze the bottle to get the water out. Record the student's time. To empty your bottle, invert it, hold the Vortex Tube steady in one hand, and rotate the top of the bottle in the other hand. This will create a vortex at the tube opening, allowing the water to quickly escape. This "trick" has been used to quickly empty large glass bottles that would "glug" and release water slowly. Note: This works best with smaller or more rigid bottles, whose sides are not likely to collapse when a partial vacuum forms in the bottle.

Related Products

Airzooka Air Cannon (P8-5700) A takeoff from the old Trashcan Air Cannon; this amazing new vortex launcher sends a strong blast of air all the way across the room! No batteries or fuel needed. Just point and shoot! Powerful and accurate!

Fountain Connection (P8-6000) Hero of Alexandria described his compressed-air fountain principle in the first century A.D., but it took the invention of the two-liter soda bottle to make it this easy to demonstrate.

Bernoulli Bag 4 pack (P6-7350) How many breathes would it take to inflate an 8-foot long, 10-inch diameter bag? Just ONE using Bernoulli's principle! Commonly called the Wind Tube or Wind Bag.

Single Cartesian Diver

P1-2000

INSTRUCTIONAL GUIDE

Contents

- Cartesian Diver
- Instructional Guide

Required for activities:
- Empty 2-liter bottle

Background

Gas		Density (kg/m^3)
Dry Air	0ºC	1.29
	10ºC	1.25
	20ºC	1.21
	30ºC	1.16
Helium		0.178
Hydrogen		0.090
Oxygen		1.43

* At sea-level atmospheric pressure and at 0ºC (unless otherwise specified)

We are so accustomed to the invisible air surrounding us that we sometimes forget that air has mass and weight, occupies space, and exerts pressure. Each of these properties are directly related to the concept of air *density*. A table with the densities of various gases is on the right. Let your students calculate the number of cubic meters in your classroom and multiply by 1.21 kg/m^3.

Air density simply reflects the relation between its weight and the amount of space it occupies. Decrease the volume and the density goes up because the same amount of mass is being squeezed into a small area. Increase the volume and the density goes down as the mass is spread over a larger area. Air density is also related to air pressure. A scientist named Robert Boyle discovered this relationship. *Boyle's Law* simply states that if the density goes up or down, then the pressure goes up or down with it. Conversely, if you apply pressure to a gas by, say, pushing it into a smaller container, the density goes up. If you release pressure, the density goes down.

Air pressure and density can help explain the barometric property of air. When two air pressures meet, they push on each other (they are forces, after all). The two pressures will push on each other until they balance. For example, your windows don't break because the air pressure on one side is equal to the air pressure on the other.

Introduction

Buoyancy rules are also related to density. The buoyancy law states that an object surrounded by a fluid is buoyed up by a force equal to the weight of the fluid displaced by the object. In the case of a boat, as long as the boat weighs less than the total weight of the water that it displaces, it will float.

Buoyancy laws apply to the cartesian diver as well. As long as the combined density of the pipette, rubber cover, steel mass, and the air/water mixture inside are less than the density of the water it displaces, it will float. These cartesian divers were designed with just enough weight to bring it very close to the point of sinking, but not quite. But as soon as outside pressure is exerted, the air inside compresses, the volume of the air decreases, and more water is pushed into the pipette. The diver now is too dense to remain buoyant - hence, it sinks.

Activities

1. The diver usually requires a bit of water inside the pipette to float. To find out exactly how much is mostly a trial and error game. First, try this: Fill a clear glass with water. Get water inside the diver by squeezing the pipette and releasing so that it sucks up water. Then drop the diver in the glass. Does it float or sink? If it sinks to the bottom, the diver contains too much water. If it falls over and lays on top of the water, it needs more. The water level is just right when it stands upright but is mostly submerged. After a little experience, you will be able to suspend the diver at different depths in the glass by controlling the water level.
2. Fill a 2-liter bottle all the way to the top with water. Place the diver in the bottle with the correct amount of water contained inside of it (the steps in (1) can be done by trial and error now with the 2-liter by adjusting the water level until the diver behaves properly.) Put the cap on the bottle and squeeze the middle of the bottle. The diver should sink. When you release the pressure on the bottle, the diver should rise back up to the top.
3. Try demonstrating the above phenomenon without the squid rubber cover on the pipette (be careful not to tear the rubber when taking it off and putting it back on; see the last hint below.) This way, students can see the water level inside the pipette before, during, and after squeezing the bottle. To make it more visible, try using water with coloring in it. When the bottle is squeezed, the water level in the pipette goes up. Ask your students where all of the air goes? This demonstration requires students to understand the concept of air density.

Helpful Hints

- Make sure to fill the bottle to the very top with water.
- Use room temperature water when filling your bottle. Otherwise, as the water heats up or cools, it will affect the pressure in the bottle and the water level in the diver.
- The diver may sink on its own over time due to temperature and atmospheric pressure changes and gas coming out of solution in the water. To correct, first try opening the 2-liter bottle. If this doesn’t work, remove the diver and readjust the water level as in step 1.
- Try not to leave the rubber squid in the water for a long period of time because it may start to deteriorate.
- If you decide to remove the rubber squid from the pipette, put a few drops of oil on the pipette before replacing. This will allow it to slide on easily and will help make a tight seal so that water doesn’t get underneath.

Related Products

Super Diver Kit (P1-2000-01) The Cartesian Diver demonstrates all three properties using hands-on experiments. Make 30 plain divers with this kit.

Galileo’s Thermometer Fahrenheit (P3-5006) Our Galileo's Thermometer is a great attention getter when discussing topics on pressure and fluids or the gas laws.

Hand Boiler (P3-5005) This energy transformation is sure to capture your students' attention! Hold the glass vessel in your hand, and your body heat causes the liquid inside to boil and shoot into the top bulb! Assorted colors and styles.

Bernoulli Bags 4 Pack

P6-7350

INSTRUCTIONAL GUIDE

Contents

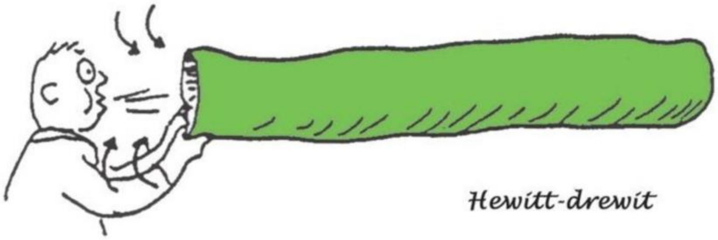
- 4 Bernoulli Bags (8' x 10" diameter)
- Instructional guide

Introduction

The Bernoulli Bag is an eight-foot-long, ten-inch-wide plastic bag that is inflated by blowing air into it. After unrolling the bag, tie off one end. Begin by having a student try to blow up the bag in the normal way through a small opening. Crunching down the open end to make a small opening and placing the mouth against the bag, see how many breaths of air it takes to inflate the tube. This should require many breaths to partially fill the bag. Now, fully open the end of the bag and with your mouth several inches from the opening give one long blow into the bag. This should result in nearly filling the bag. Most of the air that enters the bag comes from the surrounding air that mixes with the air from your mouth.

Theory:

The movement of air results from a difference in air pressure. A law of physics known as the Bernoulli principle explains that pressure within a fast-moving volume of air deceases with the speed of the air. This principle is used to explain many phenomena in nature such as how musical instruments produce sound and how baseball pitchers are able to throw a curve ball. The Bernoulli Bag works on this principle when a fast-moving stream of air is blown into one end of the tube. When blowing into the tube, air from the surrounding room rushes into the fast-moving low-pressure stream increasing the volume of air entering the tube. As a result, one strong blow into the bag picks up enough surrounding air to fill the bag.



Related Products

Eyepops (P4-2300) Blow into the mouthpiece, and the eyes float on a stream of air! A fun Bernoulli demonstration.

Airzooka Air Cannon (P8-5700) This amazing new vortex launcher sends a strong blast of air all the way across the room!

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ARBOR SCIENTIFIC

Drinking Bird

P3-5001

INSTRUCTIONAL GUIDE

Background

The Drinking Bird uses evaporative cooling to move a fluid in its body. When the fluid moves, it changes the center of mass and makes the bird tip.

When the bird tips, the beak should touch water. The water sticks to this fuzzy head and starts to evaporate. This cools the gas inside, lowering its pressure. Some of this gas will also condense, lowering the pressure further. The pressure in the bottom is now higher than the pressure in the top, which pushes the fluid up the body. When enough fluid moves up, the center of mass (center of gravity) is moved above and forward of the pivot point. The bird tips, allowing the pressure to equalize and the fluid to flow back down into the bottom. The beak gets wet and the process repeats itself.

Heat consists of random motion and the vibrations of atoms, molecules, and ions. The higher the temperature, the greater the atomic or molecular motion. Increased temperature means greater average energy of motion, so most substances expand when heated. Describe common physical changes in materials: evaporation, condensation, thermal expansion, and contraction.

Introduction

The Drinking Bird has a fuzzy head with a weighted beak. The body contains a fluid and can pivot forward on its legs. The drinking bird needs a glass or beaker of water positioned so that when he tips his beak will get wet.

The fuzzy head is important. It allows water be drawn up to the head. More water can stick to the fabric than to glass and it increases the surface area for the water to evaporate. The weighted beak makes it possible for the fluid to change the center of mass enough to make it tip.

The working fluid inside the traditional drinking bird is methylene chloride. It is a volatile (easily evaporated) fluid. The fluid will easily evaporate in the bottom and condense in the top, helping to create more of a pressure difference. Non-volatile fluids would work, but would not be as effective.

The key to making the fluid move is a pressure difference between the two sections of the bird. Since the body is sealed, a temperature difference is used to change the pressure. Instead of cooling the head by evaporation, it is possible to heat the bottom and make the bird tip. Anything that will cause the body to be at a higher temperature than the head will make the bird work.

Troubleshooting

- The pivot and legs are not adjusted properly – the bird cannot move freely.
- The head is dry – it is not reaching the water.
- The humidity is too high – the water will not evaporate quickly enough from the head.

SAFETY INFORMATION:

This product is not a toy and is not intended for use by children under age 8. Contains Phthalates. Keep away from heat and flame.

Activities

- Set up the Drinking Bird in front of a glass of water. Adjust the level of the bird and the glass so that the bird will dip his beak into the water when he tips. Hold the head in the water long enough so that it gets thoroughly wet. Let him go!
- Have the students give a complete explanation of why he tips – make sure to include the center of mass, evaporation, and the pressure difference.
- How long will the bird operate if the water is removed? It will still go for a while until most of the water on the head evaporates.
- Try other ways of making the bird operate. Some possibilities: cool the head with something else, such as ice, heat the body with your hand or some other warm object.
- Paint the bottom bulb of the bird black. Place him in sunlight or under a bright light. The body will absorb enough energy to make the bulb warm and the bird will operate without water.
- Have races between groups. Who can make their bird tip the most times in a minute (without touching it)? Try different temperatures of water, using a light, using a fan, and other methods.

Related Products

Hand Boiler (P3-5005) This energy transformation is sure to capture your students' attention! Hold the glass vessel in your hand, and your body heat causes the liquid inside to boil and shoot into the top bulb! Assorted colors and styles.

Ice Melting Blocks (P6-7060) Touch these two black blocks, and one feels cooler. This discrepant event introduces many concepts, including heat transfer, change of state, and thermal conductivity.

Radiation Cans (PX-2084) are perfect for experimenting with the Laws of thermodynamics. Just add water and a thermometer or temperature sensor to each of these three cans, place in near a light source, and watch the temperature rise.

ARBOR SCIENTIFIC

Pascal's Demonstrator

P1-2190

INSTRUCTIONAL GUIDE

Contents

- Pascal's Demonstrator
- Instructional Guide

Background

Pascal's Demonstrator consists of a vertical glass bulb about 3.5cm in diameter with small openings along one circumference and a branch tube containing a tight-fitting piston. It is designed to show that pressure in a fluid is transmitted equally in all directions.

In short, the apparatus is filled with water, and when the piston is pushed in, a stream of water is projected from each of the openings with the same force, showing that the pressure is transmitted in all directions.

Operation

1. Fill a large beaker or other container with water.
2. Immerse the bulb in the water and, starting with the piston at its lowest position, pull the piston upward. Atmospheric pressure will force the water into the openings and fill up the bulb.
3. A few rapid pumps of the piston may be necessary to completely fill the bulb and the cylinder.
4. When the apparatus is filled it may be quickly taken from the water and the piston pressed against the liquid, forcing streams of liquid out in all directions.
5. The apparatus may be held in any position to produce this result, but perhaps the horizontal position is best. In this position, students will observe that the streams of water are projected about the same distance from the bulb and that, therefore, is a rough measure of the amount of force, thus verifying that the liquid pressure is transmitted in all directions.

Alternatively, the apparatus may be filled by removing the piston from the apparatus and filling from a faucet. However, with this method, some water will be lost before you can begin the demonstration. Using a vessel as described will allow you to being the demonstration immediately after filling.

Related Products

Gas Laws and Pressure Discovery Bundle (P1-2070) Don't just teach the gas laws. Let students deduce them with these exploratory activities!

Pressure Globe (P1-2015) Demonstrate the amazing power of air! This specialized bottle is fitted with a balloon and a stopper. Inflate the balloon with air or water, with the stopper in place and removed, and see what happens.

Atmospheric Mat (P1-2010) A simple design that demonstrates a powerful concept: atmospheric pressure! Place this rubber mat on any flat surface and pull on the handle. It's like the mat is glued down!

Elasticity of Gases Demo

P1-2075

INSTRUCTIONAL GUIDE

Contents

Included Materials:

- Wooden base
- Wooden top
- Small plastic cap
- Syringe with piston
- Packet of silicone grease

Recommended but not included:

- Ring stand and clamp(s)
- Beaker (250mL)
- Thermometer
- Several uniform masses (books or weights)
- Ice

Introduction

1. Place the large wooden base on a firm surface with the larger hole down.
2. There should be no small plastic cap on the end of the syringe at this point. Pull the plunger completely out of the syringe. Use the silicone rubber grease to lubricate the entire side wall of the black rubber plunger.
3. Press the syringe body into the hole on the top side of the base.
4. Press the top end of the syringe plunger into the hole in the wooden top. (Thin wooden block.)
5. Reassemble the syringe.
6. Draw a measured volume of air into the syringe and **press the small plastic cap over the nozzle end of the syringe under the large block.**

You are now ready to perform experiments with Boyle's law. To expel air or gas from the syringe, first, remove the small plastic cap from the end of the syringe and push in on the piston. **Be careful not to tear the cap or distort its shape by the careless use of pliers.** Replace the small plastic cap.

Investigation

Boyle's Law

Given any gas in a state of thermal equilibrium we can measure its pressure *p*, temperature *T*, and volume *V*. Experiments show that for a constant temperature, the volume of the gas varies with the pressure of the gas. Robert Boyle, a British physicist, studied this phenomenon in 1662 and found that there was a specific relationship between pressure and volume and that it was the same for all types of gases. To determine what this relationship is, we will look at the compressibility of gas.

With the assembled apparatus, draw approximately 30cc of air into the cylinder and cap the end. Stack several equal weights carefully on the top block of the apparatus. You can use several copies of the *same* textbook for this. **When stacking weights, keep centered and do not exceed 30 lbs.** Record the volume of the gas as indicated on the scale of the syringe. Before reading the scale on the syringe, tap the table or the top of the apparatus a couple of times to help overcome the static friction between the piston and the syringe walls.

Record the weight and corresponding volume for as many values as possible. After all of the weights are stacked on the apparatus, unstack them one at a time and record the volumes again. Use this data as trial #2. Plot each of these and the averaged data on graph paper, plotting the number of weights (which is proportional to the pressure) on the independent axis and the volume on the dependent axis.

How does the volume depend on the pressure? Is the plot linear? Try making a new plot with 1/(weight) plotted on the independent axis. Is this plot linear? It should be close to linear with the exception of the points that correspond to one or two weights. Can you explain why these points do not fit the curve? Any plot of data that is a straight line says that the two parameters are directly proportional.

Therefore, the volume is directly proportional to 1/pressure (since pressure equals force times area and the area of the piston is constant). Mathematically, this can be written:

$$V \propto \frac{1}{p} \text{ where } \propto \text{ means "is proportional to."}$$

This is Boyle's law. Under conditions of constant temperature, volume varies inversely with pressure. Try repeating this experiment using different gases.

Charles' Law:

You have discovered how equal changes in pressure affect equal volumes of gases. Can you predict how equal changes in temperature affect equal volumes of gases?

Heat approximately 200mL of water in a 250mL beaker. A larger beaker may be easier for students to use. Remember it is necessary to have enough water in the beaker to cover the portion of the syringe that holds the trapped volume of air. Bring the water to about 90˚C.

Remove both wooden blocks from the syringe, draw 20cc of air into the syringe then place the cap on the syringe nozzle. Place the thermometer in the beaker of hot water. Hold the syringe by its top and push the portion of the syringe containing the trapped volume of air under the hot water. Wait a few minutes for the air in the cylinder to equilibrate, then measure the volume shown on the syringe scale. When measuring the volume of the trapped air, it is helpful to quickly push the piston down and then release it. The measured volume in this case will be larger. Again, this is due to friction between the piston and cylinder wall. The actual volume will be the average of these two measurements.

Allow the beaker of water to cool by 10˚C and make a new volume measurement. Repeat this procedure of cooling by 10˚C and measuring the volume until you've covered the range from about 60 or 70˚C to 0˚C. From 30˚C and lower it may be necessary to add small pieces of ice to help bring the temperature down, or place the beaker in a container of crushed ice.

Plot your data points on a graph with volume as a function of temperature. Are the results of your experiment consistent with your prediction? Can you summarize the findings of your experiment in a general statement similar to the method used in Boyle's law? Remember, if the plot is linear, it represents a direct proportionality and can be written as:

$$V \propto T$$

Ideal Gas Law:

The concept of “proportional to” can be changed to “equal to” by introducing a constant of proportionality.

First, we must combine the two laws by saying that volume is proportional to both the temperature and 1/pressure:

$$V \propto T \text{ and } V \propto \frac{1}{p} \text{ combine to } V \propto \frac{T}{p}$$

Then, we can replace the proportionality with equality and a constant.

$pV = constant \bullet T$ or $\frac{pV}{T}$ is a constant for any particular gas sample

And

$\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$ when conditions of the sample change, allowing one to solve for any single unknown.

The constant referred to above is related to the mass of gas in the cylinder and is given a value calculated as the number of moles of gas (n) times the universal gas constant (R), found in most physics textbooks. By making this substitution, we have constructed the ideal gas law:

$$pV = nRT$$

Related Products

Pressure Pumper (P1-2050) Attach this pump to the top of a soda bottle and pump up the pressure on the bottle contents. Kit includes temperature strips and lessons.

Vacuum Pumper and Chamber (P1-2140) This hand-powered vacuum pump works on glass bottles or the specially designed wide-mouth chamber. Test the effect of lowered pressure on objects and liquids.

Cartesian Diver (P1-2000) Use the elastic properties of air for this classic diving demonstration.

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ARBOR SCIENTIFIC

Hand Boiler

P3-5005

INSTRUCTIONAL GUIDE

Contents

- Hand Boiler
- Instructional Guide

Background

The liquid inside the Hand Boiler does not actually boil. The "boiling" is caused by the relationship between the temperature and pressure of a gas. The thermal energy given off as body heat raises the temperature of the gas in the chamber. The increased temperature causes gas molecules to move faster, thereby increasing the pressure in the closed system. There must be a temperature (and pressure) difference between the two large chambers for the liquid to move. When held upright (with the smaller bulb on top), the liquid will move from the bulb with the higher pressure to the bulb with lower pressure. As the gas continues to expand, the gas will then bubble through the liquid, making it appear to boil. The fact that the liquid is volatile (easily vaporized) makes the hand boiler more effective. Adding heat to the liquid produces more gas, also increasing pressure in the closed container.

Caution! Contains flammable liquid! The hand boilers contain ethyl alcohol. Keep away from heat or flame. Flush with water if contact with eyes. Do not drink.

Activities

Have the students hold the boiler upright by the larger bulb. How long does it take for the liquid to "boil"? Is there a student in class whose hand does not make it "boil"? Take the temperature of the students' hands. Notice the difference. How do you make the liquid go down again? Hold onto the top bulb only. What happens if you hold both bulbs? Why? Can you make the liquid move by using cooling instead of heating? Try putting ice on the bulbs and see what happens. After several uses, the boiler won't work for a while. Why not? Will the boiler work if upside down? Why not?

Related Products

Advanced Gas Laws Demo (P1-2065) Quantitatively confirm the Combined Gas Law with one complete apparatus! Students can verify this relationship using air and this unique apparatus.

Fire Syringe (P1-2020) A smokin' example of Charles's Law. Using the Fire Syringe to compress air into a smaller volume is a classic example of how rapidly doing work on a gas results in an increase in temperature.

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Atmospheric Pressure Cups

P1-2005

INSTRUCTIONAL GUIDE

Contents

- Two Atmospheric Pressure Cups
- Instructional Guide

Background

The original Magdeburg Hemisphere demonstration was staged in about 1656 by Otto von Guericke (1602 - 1686) in Magdeburg, Germany. He used a modified stirrup pump to remove the air from between two metal hemispheres that had been fitted together with grease. Teams of eight horses hitched to each hemisphere could not separate them.

Instructions:

Push the flat sides of the two halves together, removing as much air as possible from between them. Now try to pull them apart! The cups can be released by using the tabs on the edges.

How it Works

The cups are held together by atmospheric pressure, which is approximately 15 pounds per square inch. A quick calculation leads to a total pressure of over 100 lbs. on each cup (assuming the air was completely evacuated from between the two cups). Try to avoid calling this apparatus "suction cups." Using the word "suction" can cause students to focus on a fictitious force that pulls inward on the cups, when in fact the force is from the atmosphere pushing the cups together.

Related Products

Atmospheric Mat (P1-2010) A simple design that demonstrates a powerful concept: atmospheric pressure! Place this rubber mat on any flat surface and pull on the handle. It's like the mat is glued down!

Gas Laws and Pressure Discovery Bundle (P1-2070) Don't just teach the gas laws. Let students deduce them with these exploratory activities!

Vacuum Pumper and Chamber (P1-2140) With this affordable hand vacuum pump and chamber set students can test the effects of reduced pressure on many different objects, such as marshmallows, balloons, and water.