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.

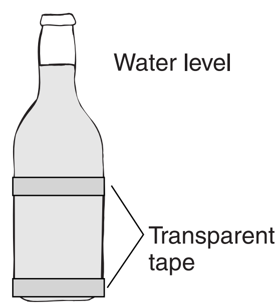

Figure 1.

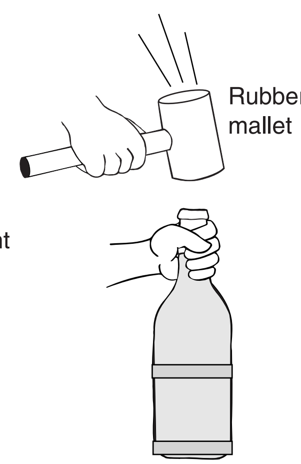

Figure 2.

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.