Hero's Fountain

Introduction

Hero's Fountain has been around for a long time (circa 62 A.D.). Hero of Alexandria described a water fountain that used compressed air to lift water to a point higher than its origin. At first glance it seems the fountain requires no energy to run.

It actually runs on the potential energy in the water in bottle A relative to bottle B. As water flows throughout the system of tubing, the pressure in bottle B, and in turn in bottle A, increases and water is forced out the thin glass tube in bottle A. See Figure 1 on page 3.

Concepts

- Pressure
- Energy

Materials (for each demonstration)

Bunsen burner

File

Glass tubing, OD 6 mm, 100-cm

Plastic tubing, ID ⅜″, 10 ft

Rubber stoppers, two-hole, 3

Soda bottles, two-liter, plastic, 3

Stopcock grease or other lubricant

Water, tap

Safety Precautions

Exercise extreme caution when cutting and fire polishing glass tubes. Wear eye protection, gloves and an apron. To further protect your hands when breaking the glass, wrap a cloth around the glass tubing.

Preparation

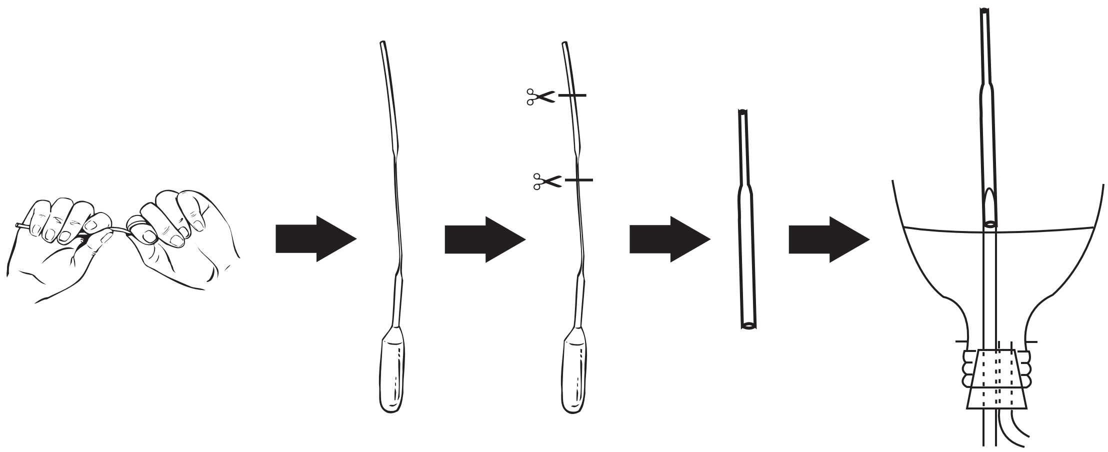
1. Cut the top third off of one of the plastic soda bottles. Leave the other two intact.
2. Cut a 2-cm length off the plastic tubing and then cut the remaining tubing in half to produce two 4- to 5-ft pieces.
3. Score and break the glass tubing into six pieces: approximately 40 cm, 32 cm, 10 cm, 6 cm, 6 cm and 6 cm. Fire polish all ends. Heat the center of the 10-cm length in a Bunsen burner flame and draw it out into a thin tubule, the tip should have a diameter slightly smaller than a Pasteur pipet tip. Let the tube cool, then break it in half and fire polish the tapered tips briefly, being careful not to close them off. The tip of the tubing must be even and straight. This tube will be connected to the 40-cm piece of glass tubing by the 2-cm piece of plastic tubing. See Figure 1 on page 3 for setup.
4. Using adequate lubrication, insert the tubes into the stoppers, and the stoppers into the bottles as shown in Figure 1.

Procedure

1. Fill the top bottle (A) with tap water. Make sure all stoppers are securely inserted.
2. To start the fountain, place Bottle A on a table and B (empty) at a lower level (on the floor or a chair, etc.). Fill the top funnel with water. In a few seconds, the fountain will begin spurting up and it will continue to flow for 20 to 40 minutes. As soon as the water begins spurting, it will be seen if the glass tubing tip is straight. Adjustments may need to be made.
3. To control the flow rate of the fountain, simply adjust the relative heights of the two bottles. The higher A is above B, the greater the force of the fountain. To stop the flow, completely raise B until it is higher than A.

Tips

- Practice making glassware. An even thin tube will be needed for the spout of the fountain.
- To make an adjustable spout for your fountain, simply take a thin stem plastic pipet and stretch the middle of the stem as shown below.
- For added lubrication, soak the end of the plastic tubing in a little acetone before sliding it over the glass tubing.



A.) Firmly grasp the stem and bulb of the pipet and pull.

B.) Cut out specified section of the stem.

C.) Slip this section over the tip of the glass tube spout.

Discussion

Initially the pressure in both bottles A and B is equivalent to atmospheric pressure. As water is poured into the fountain bowl on top, it drains down through hose #1 into the lower bottle (B) and creates additional (hydrostatic) pressure there. If, for example, the water level in the bowl is 100 cm higher than the water level in bottle B, then the air pressure inside B must increase to 1 atm + 100 cm water. Since the air pockets in A and B are connected by hose #2, the pressure in bottle A must also rise to 1 atm + 100 cm. In other words, since the pressure outside the fountain is only 1 atm, the pressure in bottle A should be able to support a column of water 100 cm tall. Since the tapered nozzle is only about 20 cm above the water level in bottle A, the water is easily pushed up through it—with enough pressure left over to spray droplets upward, creating the fountain effect.

If bottle B is lowered even further, then the hydrostatic pressure increases inside B, and consequently inside A as well, causing the fountain to spray even higher. Conversely, if bottle B is raised relative to the bowl, the hydrostatic pressure will decrease, and the fountain spray will diminish. If "X" is used to denote the vertical distance between the water level in the bowl and the water level in bottle B, and "Y" is used to indicate the vertical distance from the water level in A up to the top of the tapered fountain head, then the fountain will always spray upward with a force proportional to X – Y. As soon as Y equals or exceeds X, the fountain will stop.

Note that the water draining down from the bowl into bottle B is being replaced by a more or less equal volume of water spraying up from the fountain into the bowl. Thus, once the fountain is started, it should run continuously without any additional priming. At first glance this may appear to be some kind of perpetual motion machine. But, since water is draining downward through hose #1 and only air is flowing back upward to replace it through hose #2, the fountain will not flow perpetually, but only 20 to 40 minutes—until the water in bottle A has drained out completely or, if the bottles are pretty much on the same level, until Y = X, as discussed above.

After some discussion of barometers and/or manometers, students should have some familiarity with the concept that gas pressure can, by pushing down on a liquid surface, push up and support a column of liquid in a tube, be that liquid mercury or water. This is, after all, how drinking straws and siphons work!

Once this has been established, initiate the Hero's fountain, and invite the students to come up, examine the setup, sketch it and see if they can explain how the fountain is working. The essential question is: Where is the energy coming from to drive the fountain? (*Answer:* It is coming from the potential energy possessed by the water in bottle A relative to bottle B below it.)

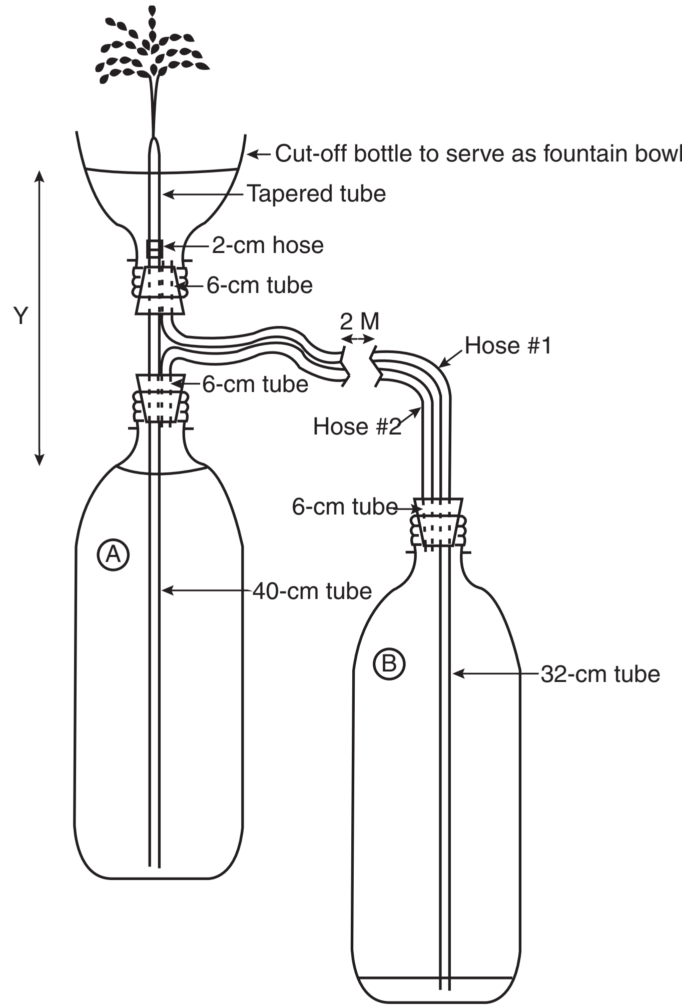


Figure 1. Hero's Fountain Setup

Connecting to the National Standards

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

Unifying Concepts and Processes: Grades K–12
Evidence, models, and explanation
Content Standards: Grades 5–8
Content Standard B: Understanding of motions and forces, transfer of energy
Content Standard G: History and Nature of Science, science as a human endeavor, nature of science, history of science
Content Standards: Grades 9–12
Content Standard B: Physical Science, motions and forces, interactions of energy and matter
Content Standard G: History and Nature of Science, science as a human endeavor, nature of scientific knowledge, historical perspectives

Acknowledgments

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Materials for the *Hero's Fountain Apparatus* are available from Flinn Scientific, Inc.

Catalog No.	Description
CP9025	Glass Tubing, Soft Glass, 240, Pkg.10
AP2313	Rubber Stopper, #3, 2-hole
AP8377	Plastic Tubing, 3⁄80 ID, 10 ft

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