Two Large-Scale Devices for Demonstrating a Bernoulli Effect

Harold Cohen and *David Horvath,* California State University, Los Angeles, CA

An object placed in a moving fluid experiences a net force when the speed of the fluid is greater on one side of the object than on the other. This is due to a difference in pressure on the two sides of the object and is known as the Bernoulli effect. A number of demonstrations of this Bernoulli effect have appeared in the physics teaching literature.[1-4] In this article, we describe two such demonstrations that are quite dramatic and suitable for showing to large classes.[5]

Airstream Past Two Bowling Balls

One of our devices consists of two 9-lb bowling balls suspended from a frame by chains of equal length as shown in Fig. 1(a). An airstream is created using the Electric Power Sweep Blower manufactured by Toro Co. (model #51586). This blower is advertised to produce an airstream with a speed of 140 mph. The blower was purchased at Home Depot for less than \$35.[6] For this apparatus, the optimum space between the balls before directing the airstream between them is approximately the width of an adult's hand.

When the airstream from the blower is directed between the bowling balls, there is a reduction of the air pressure in the region between the balls created by the airflow, and they are drawn together as shown in Fig. 1(b). Our experience has been that students most often anticipate that the balls will be pushed apart by the airstream. With that initial lack of understanding, this apparatus provides a dramatic demonstration of the Bernoulli effect.

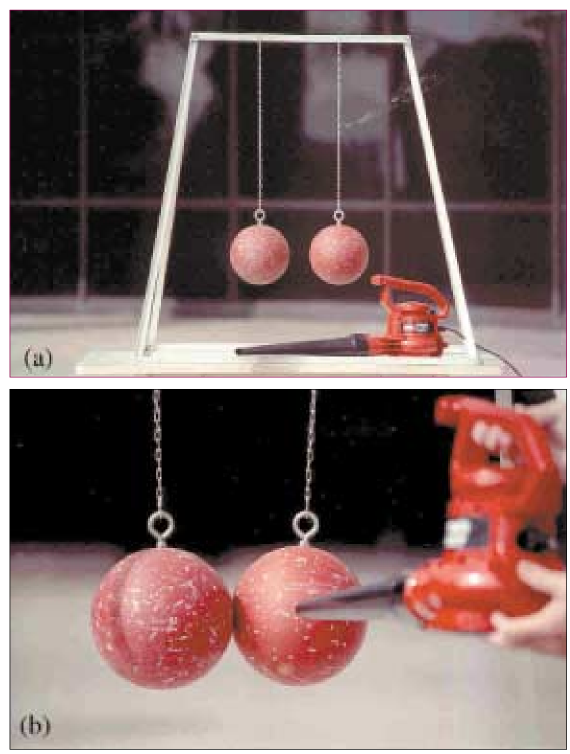

Fig. 1 (a). Bowling ball and blower apparatus. (b) Airstream between the bowling balls causing them to be drawn together.

An Airfoil

The other device we have constructed for demonstrating the Bernoulli effect is an airplane wing (an airfoil) mounted on a base. The airstream across the wing gives it a lift, causing it to rise. The apparatus is shown in Figs. 2(a) and 2(b). We use an airfoil called

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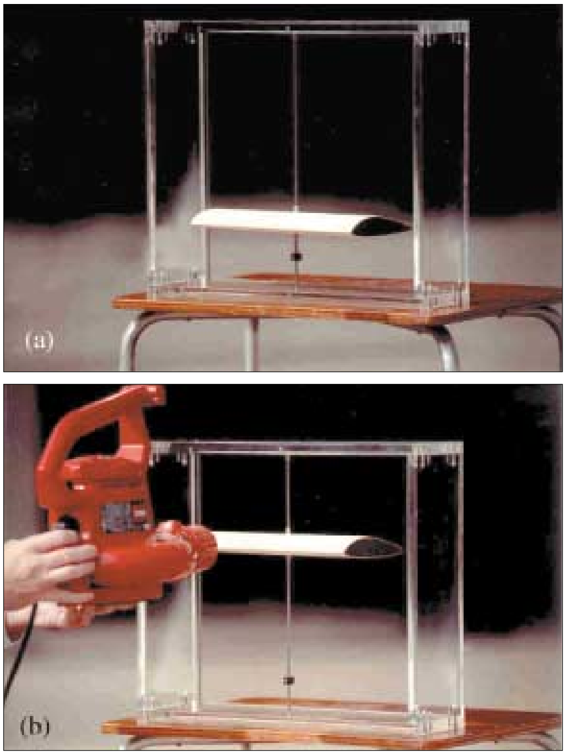

Fig. 2. (a) Airfoil apparatus. (b) Airstream causing the airfoil to rise. Note that the blower nozzle is removed. [See Fig. 1(b) to achieve distribution over wide region of the airfoil.]

a CLARK-Y wing. It is a classic airfoil shape that is familiar to those who are knowledgeable about wing design. This airfoil was chosen based on the experience one of the authors (D.H.) has with model airplanes.[7] Our airfoil was cut from a block of polystyrene at a local hobby shop at a cost of only a few dollars.

The leading and trailing edges of the wing are made of light, smooth balsa wood glued to the polystyrene. Such edges are necessary to eliminate much of the turbulence created by rough polystyrene edges. Our wing is 30.5 cm long with a surface area of 600 cm^2. It has a mass of 45 g.

As can be seen in Fig. 2, the wing is constrained to slide on two thin rods. One rod passes through the center of mass, which is located approximately 30% of the distance from the leading edge of the wing. The other rod passes through a guide attached to one end of the wing. After experimenting with several designs, we have found that this arrangement minimizes the frictional forces between the rods and the wing.

In order to achieve lift, it is essential that the front edge of any wing be tilted upward at some small angle (called the "attack angle") so as to present a small cross section of the underside of the wing to the airstream. We find that the best results are obtained for our wing when the attack angle is approximately 2°, and the blower is held horizontally, approximately 6 in from the front edge of the wing. The wing should rest about 4 in above the base of the frame in order to allow substantial airflow around both surfaces of the wing. If the wing rests on the base of the apparatus, a partial vacuum is formed under the wing and no lift is achieved.

Acknowledgments

The bowling balls for this project were donated by Gary Kowarsch, manager of the CalBowl Lanes in Lakewood, Calif. Damage to the surfaces of the balls was repaired at a very small cost by Greg Candari of Cerritos Lanes in Cerritos, Calif. Ron Johnson of our department built the frames for both pieces of apparatus. As usual, his work exceeded our expectations. Anton Stark of the California Institute of Technology suggested the design for supporting the airfoil by a rod through its center of mass to minimize friction. Larry Crowley and Edgar Zwieback made many helpful suggestions about the design of the wing. Each has acquired expertise with the aerodynamics of wing design through more than 20 years of experience as aeronautical engineers. The photography and image processing of Stan Carstensen, of the Office of Publications and Public Affairs of our institution, produced the pictures that are presented in this paper.

We express our gratitude to these people who contributed to this project.

References

1. A. Sieradzan and W. Chaffee, "Bernoulli revisited: A simple demonstration," *Phys. Teach.* **27**, 306–307 (April 1989); Joe Pizzo, "Bernoulli station," *Phys. Teach.* **27**, 308–310 (April 1989); and Brian Holmes, "My teacher is a blowhard," *Phys. Teach*. **34**, 362 (Sept. 1996).
2. Julius Sumner Miller, *Demonstrations in Physics* (Ure Smith Publishers Ltd., Sydney, 1969), p. 143.

3. *Physics Demonstration Experiments,* edited by Harry F. Meiners (The Ronald Press Co., New York, 1970), Vol. I, p. 405.
4. *Demonstration Experiments in Physics,* edited by R.M. Sutton (McGraw-Hill, New York, 1938), pp. 115–119.
5. Devices similar to those described in this paper can be seen at the Discovery Science Center in Santa Ana, Calif.
6. The costs for these devices were paid from a grant awarded to Donald Paulson, professor of chemistry at our institution, by the National Science Foundation, Grant #DUE-9453608. The authors express their thanks to the NSF and Paulson for funding these costs.
7. See also D. Dommasch, S. Sherby, and T. Connolly, *Airplane Aerodynamics*, 4th ed. (Pitman Publishing Co., New York, 1967).

Harold Cohen *is a professor of physics in Particle Physics Theory and Mathematical Methods within the Department of Physics and Astronomy at California State University, Los Angeles, Los Angeles, CA 90032; twohc@earthlink.net*

David Horvath *is the electronics technician for the Department of Physics and Astronomy, California State University, Los Angeles. He is also an avid model airplane hobbyist.*