More Diamagnetism Demonstrations

Chris Conery, Broomfield High School, Broomfield, CO
L.F. Goodrich and T.C. Stauffer, National Institute of Standards and Technology, Boulder, CO

Inspired by, among others, Charles Sawicki's description of an inexpensive diamagnetic levitation apparatus,[1] we built two such devices for classroom use and for educational outreach at the National Institute of Standards and Technology, Boulder, Colo. With a slightly different setup, the same demonstration can be done horizontally on an overhead projector.

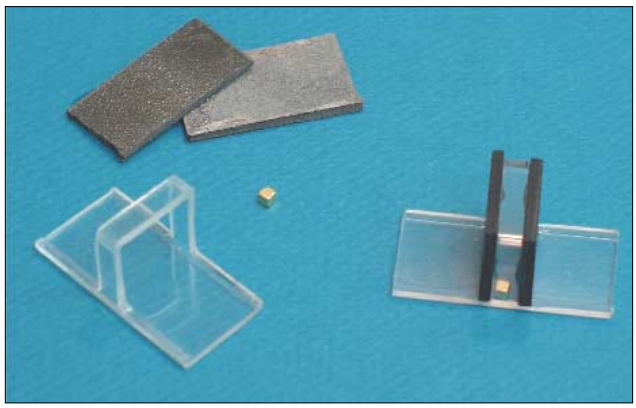

Fig. 1. Pyrolytic graphite pieces are sawed to size and epoxied to the plastic tube.

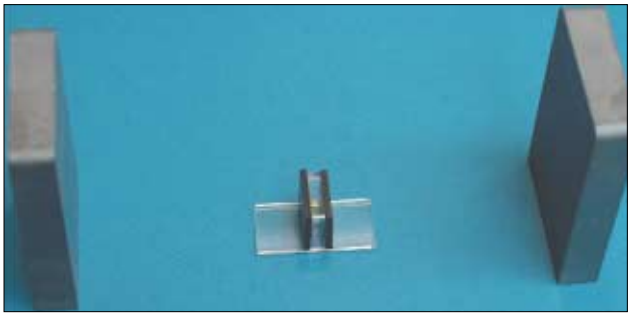

Fig. 2. The large magnets are carefully adjusted to produce levitation.

Diamagnetic Levitation for Overhead Projection

A rigid plastic tube with a square cross section[2] of 19 mm (3/4 in) was cut (a small, fine-toothed hobby saw works well) to leave 5 mm of the tube with a base (Fig. 1). Squares of pyrolytic graphite,[3] 12 mm, were sawed from larger pieces and epoxied to the plastic with a 2-mm cubic NdFeB magnet[4] trapped inside. Two large ceramic magnets[5] placed with opposite poles facing each other were set 15 to 20 cm apart, standing on one of the narrow sides, on an overhead projector with the graphite squares enclosing the magnet at the center. The small magnet orients its poles to face the opposite poles of the large magnets. When it is below the center of the field, there are upward force components that provide lift. Pyrolytic graphite is highly diamagnetic. Since the force is repulsive when the magnet approaches the diamagnetic material, a negative feedback is produced, providing stability. Distances between the large magnets are adjusted so that the small magnet is levitated and near the center of its enclosure (Fig. 2). When the projector is focused on the magnet, its bobbing about the equilibrium position makes the levitation evident to all.

The ceramic magnets can be sealed in plastic boxes (not shown) that are lined with foam rubber to keep the magnet faces at a minimum distance of about 1 cm at all times. This reduces the chance of scratching the projector surface and the chance of injury or magnet chipping when the magnets slap against each other. If the boxes have a flat end, the magnets can still be stood on edge without tipping.

DOI: 10.1119/1.1542039

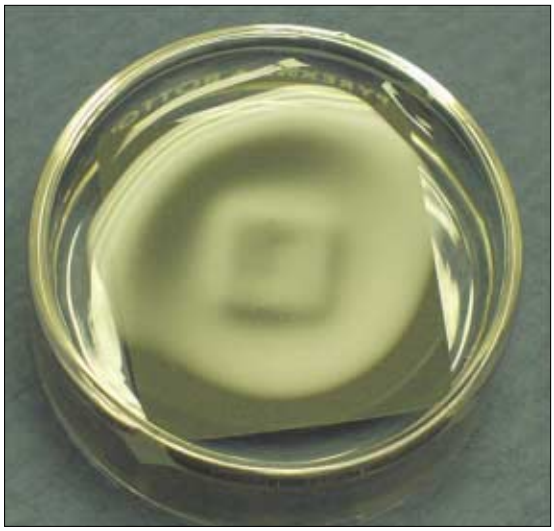

Fig. 3. A square concavity can be seen on the water's surface.

Viewing Water's Diamagnetism

The availability of high-field rare earth magnets allows us to observe the diamagnetism of water. To easily demonstrate this, a 12-mm NdFeB cube magnet,[6] with a pole end facing up, is covered by about 1 mm of water. Since the diamagnetism of water causes it to be repelled by the magnetic field, a square concave dent appears on the surface (Fig. 3). The trick to making this visible is placing some flat black paper (emery paper works well) over the magnet, reducing reflections other than from the water's surface. By focusing on bright reflections, the concavity on the surface above the magnet is quite evident.

Acknowledgment

This project was undertaken through the program for Practical Hands-on Application to Science Education (PHASE).

References

1. C.A. Sawicki, "Small inexpensive diamagnetic levitation apparatus," *Phys. Teach*. **39**, 556–558 (Dec. 2001).
2. Available at large hardware stores; or, look in the telephone directory under "Plastics-Rods, Tubes, Sheets, Etc." The more commonly available round tubing will provide an adequate, but not quite as good, effect.
3. Pieces of pyrolytic graphite are carried by Scitoys at http://scitoys.com, three pieces for $6.
4. Scitoys also carries 2-mm NdFeB magnets, 50 cents each, see Ref. 3.
5. Large ceramic magnets are widely available. We use 3 x 3 x 1/2 in thick (Catalog #CB-802, $6 each) from The Magnet Source, 607 S. Gilbert St., Castle Rock, CO 80104; 888-293-9399, http://www.magnetsource.com.
6. NdFeB magnets are widely available. We obtained ours from Scitoys, $4.50 each (see Ref. 3). Another source is Force Field, 2606 W. Vine Dr., Fort Collins, CO 80521; 877-944-6247, http://www.wondermagnet. com.

PACS codes: 85.70, 85.79Rp, 75.01A, 75.20g

Author's Note: Certain commercial materials are identified in this paper. Such identification does not imply recommendation or endorsement by NIST or by the U.S. government, nor does it imply that the materials identified are necessarily the best available. The paper is not subject to copyright.

Chris Conery *is a physics teacher and Science Department chair at Broomfield High School, Broomfield, CO 80020; conery@bvsd.k12.co.us*

Loren Goodrich *has been a research physicist at NIST for 23 years in the Standards for Superconductor Characterization Project in the Magnetic Technology Division. He conducts research on the electrical transport properties of superconductors, assists U.S. industry, universities, and national laboratories with their measurements, participates in interlaboratory comparisons of measurements, and helps develop international measurement standards for superconductivity.*

Ted Stauffer *has been an Engineering Technician at NIST for 15 years in the Standards for Superconductor Characterization Project in the Magnetic Technology Division. He handles most of the design and construction of specialized equipment needed for superconductor standards research. He has also designed and constructed many magnetic demonstration models for NIST outreach programs. National Institute of Standards and Technology, Boulder, CO 80305.*