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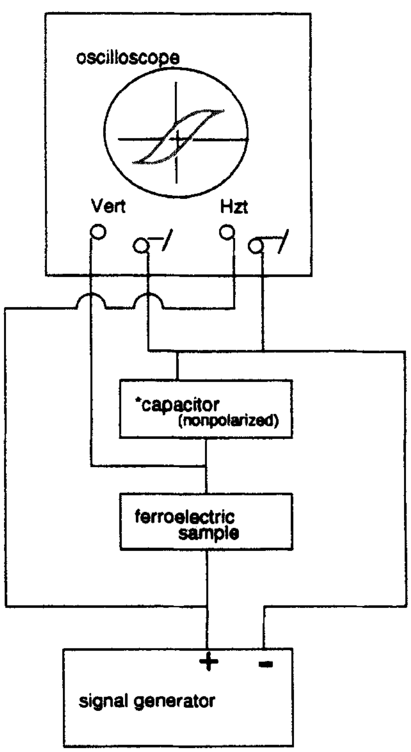
Ferroelectrics are a subset of a larger classification of materials called piezoelectrics. They are similar to ferromagnetic materials in that they exhibit spontaneous dipoles (ferromagnetics have magnetic dipoles and ferroelectrics have electric dipoles), coercive field, and hysteresis loops. To illustrate the polarization reversal mechanism, the tracing of a hysteresis loop can be observed on an oscilloscope. To obtain such a hysteresis tracing, place the ferroelectric sample in a modified Sawyer-Tower circuit (Fig. 1) and connect the material in series with a capacitor where C is made large enough so that almost all of the voltage appears across the crystal. The oscilloscope should be set in the x-y mode.



*Nonpolarized capacitor Radio Shack #272-999 works well.

Fig. 1. Modified Sawyer-Tower circuit.

We found many examples of ferroelectric material with which we could produce dramatic hysteresis loop tracings on the oscilloscope, including piezoelectric items such as transducers, tweeters, sirens, and buzzers. Table I gives a partial list of some easily procurable ferroelectric materials and shows the diversity of applications for ferroelectric materials.

Modifications of the activity include varying the temperature of the ferroelectric sample. We were able to heat the sample, and in most cases alter or destroy the hysteresis loop formation, by using a 1200-W hair dryer or a heat gun. We found that it was helpful to place the ferroelectric sample on a metal surface after removing any surrounding plastic from the sample. We also examined the effect of cooling by using dry ice or liquid nitrogen to achieve the necessary temperatures, which were measured with a thermocouple. This allowed students to monitor at what temperature changes in the hysteresis loop occurred and at what point the polarization reversal mechanism was destroyed. Hysteresis loops for some samples were unaffected by the temperature range we were able to obtain in a high-school classroom.

Table I. Piezoelectric demonstration and supply sources.

Radio Shack:

273-074	pc board mount
273-065A	piezo buzzer
49-490	fire alarm
various	phono needles
273-068	piezo buzzer
273-070	piezo buzzer
273-091	piezo speaker element
273-073	piezo transducer
273-060A	piezo buzzer

Learning Spectrum, General Materials Science, and others:
Piezo Crystal Demonstration (compress the crystal by hand or with a tuning fork to cause a small bulb to light)

Heathkits:
A variety of items such as electric dragon fly, which uses piezoelectric film; phone for catalog: 800-253-0570

Atochem North American Piezo Film, P.O. Box 799, Valley Forge, PA 19482:
Many piezoelectric film kits and materials available, including motion sensors kit and infrared sensor kit

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Further Reading

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A.M. Glass and M.E. Lines, *Principles and Applications of Ferroelectrics and Related Materials* (Oxford University Press, 1977).

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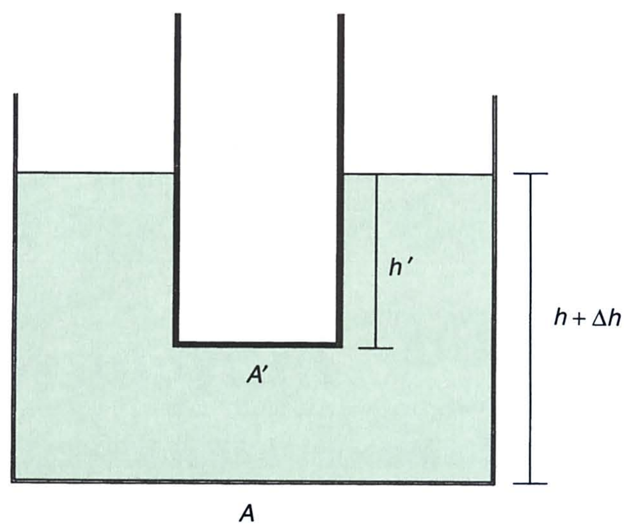
Trick of the Trade

Explanation of a Buoyancy Demonstration

An excellent demonstration of buoyancy and Newton's third law can be done with a balance and a beaker of water. By placing the beaker on a balance, leveling the balance, and asking students to predict what will happen when a finger is placed in the water, these concepts are tested. Students usually predict that nothing will happen since the finger is in contact with the water only and is supported from above. This, of course, is incorrect. But even hearing that the reaction to the upward buoyancy force pushes the water and beaker downward often does not satisfy the students. They have difficulty in understanding how and why the force is communicated to the beaker. An alternative explanation is helpful.

Instead of looking at the buoyant force, consider the increase in pressure on the bottom of the beaker due to the increase in water depth when the finger is submerged. Assume that the initial depth of the water is h and that the beaker and finger have uniform cross-sectional areas of A and A' respectively. Let the submerged finger length be h' and the depth of the water to finally be at $h + \Delta h$ (see figure).



The change in the force, ΔF, of the water due to the increase in water pressure, Δp, is $\Delta F = \Delta p \cdot A$ where $\Delta p = \rho g \Delta h$.

Therefore,

$$\Delta F = \rho g A \Delta h \quad (1)$$

This can be written in terms of the dimensions of the finger by realizing that the volume of the water is conserved. This gives the relationship

$$Ah = A(h + \Delta h) - A'h' \quad (2)$$

that can be solved for Δh,

$$\Delta h = \frac{A'h'}{A}$$

Combining Eqs. (1) and (2) yields $\Delta F = \rho g A'h'$, which is the buoyant force. This explanation can also be used as an alternative derivation of the buoyant force.

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