

# USING DEMONSTRATIONS IN TEACHING PHYSICS

by Ernie McFarland

Using lecture demonstrations can be an important component of an overall teaching strategy. Demonstrations provide a concrete visual way to help explain a topic, and can be very helpful in promoting student learning. They can be used to involve students interactively in lectures, and are an effective means to recapture students' attention partway through a class.

## INTRODUCTION

Demonstrations can make the difference between a dry-as-dust physics lecture in which students can barely keep their eyes open and an active lecture in which students are required to think about the physics and can see physics at work with actual apparatus. Even though a good demonstration requires work to design it, set it up, and think about the best way to use it, the end results can be extremely positive.

## MATHEMATIZERS, VERBALIZERS, AND VISUALIZERS

Several years ago Don Woods (a Chemical Engineering faculty member at McMaster University and a 3M Teaching Fellow), explained at a teaching conference that he considers students to fall into three broad categories: mathematizers, verbalizers, and visualizers. When a new topic is being introduced, it is useful to present it in more than one way so that students in each category can understand it well. Mathematizers enjoy having concepts presented with numbers and mathematics, verbalizers respond well to word descriptions, and visualizers work best with diagrams or actual apparatus. It is the visualizer group that is especially helped with demonstrations, which allow abstract concepts to be illustrated in concrete, visual ways. Generally, the more ways in which a difficult topic can be approached, the deeper the understanding of the students.

As an example, Faraday's law of induction can be written as

$$\varepsilon = - \frac{d\Phi_B}{dt}$$

where  $\varepsilon$ ,  $\Phi_B$ , and  $t$  are the induced electromotive force (emf), magnetic flux, and time, respectively. In words, this law can be stated as "the induced emf in a closed loop equals the negative of the time rate of change of magnetic flux through the loop." However, these mathematical and verbal descriptions are theoretical enough that an understanding of

the ideas involved is helped immensely by a demonstration. Electromagnetic induction can be shown simply by pulling a bar magnet through a coil of wire (Fig. 1) connected to a photographic flashcube. The magnet is pulled twice through the coil -- first slowly, then quickly. The emf generated during the slow pull is insufficient to fire the flashcube,

but the fast pull does create an emf large enough to produce a flash. This straightforward illustration gives the students a much firmer grasp of the concept of induction of an emf by a changing magnetic flux, and has the added advantage of waking up everyone in the lecture room when the flashcube fires.

This Faraday's law demonstration also illustrates the KIS principle of demonstrations: Keep It Simple. The only apparatus required is a magnet, a coil of wire, and a flashcube (although a flashcube is difficult to find nowadays). Demonstrations that have complicated equipment are less

enlightening, especially if all that happens is that a reading on a meter changes if someone turns a dial.

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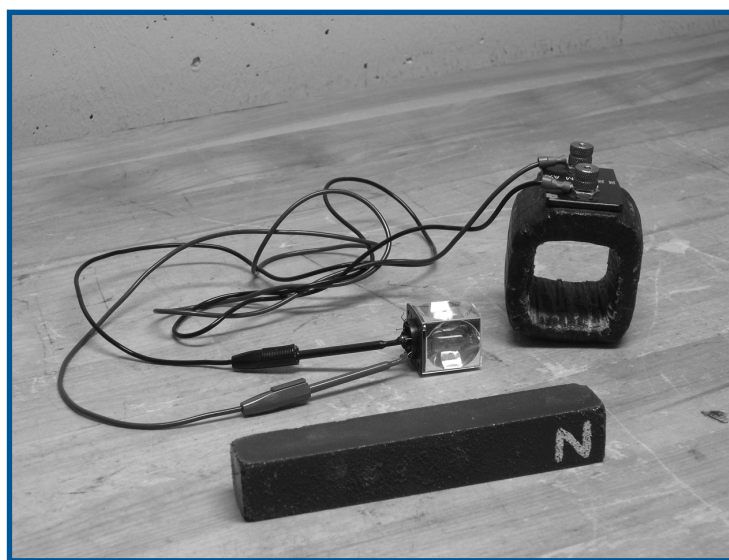


Fig. 1 Simple apparatus to show electromagnetic induction

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## INTERACTIVE LECTURE DEMONSTRATIONS

In recent years the active engagement of students in lectures has become increasingly common, especially with the publication of Eric Mazur's book "Peer Instruction" [1]. A frequently used format of active engagement is to pose a multiple-choice question, and ask the students to discuss the question in small groups and vote on the possible answers by a show of hands or computerized remote-control technology. This basic approach can be used with a question about the possible outcomes of a lecture demonstration. The lecturer shows the demonstration apparatus and states what will be done with it, but does not perform the demonstration nor indicate what the result will be. Students discuss the possible outcomes and vote on them, and then the demonstration is completed to show what actually happens, and the relevant physics is discussed.

Figure 2 shows the apparatus for one demonstration using this technique. A beaker of water is balanced on a triple-beam balance sitting on a table. Beside it is a vertical wooden dowel attached to a retort stand also sitting on the table. The bottom of the dowel is at a vertical level below that of the water surface, as shown. The question is: what will happen to the balance if the dowel and stand are picked up, moved sideways and then downward, so that the bottom end of the dowel is now submerged in the water? The dowel will still be attached to the retort stand, which will again be sitting on the table. Will the apparent mass, as indicated by the balance, of the water + beaker + submerged dowel be greater than, equal to, or less than the mass of just the water and beaker? This particular demonstration almost always produces a roughly equal split between the three possible answers, even if the audience consists of professional physicists! What do you think will happen to the apparent mass? The answer is given at the end of this article [2].

## STUDENT PARTICIPATION

Another reason for using demonstrations is to allow students to take part in what is going on in the lecture. As often as possible, I ask students to perform the demonstra-

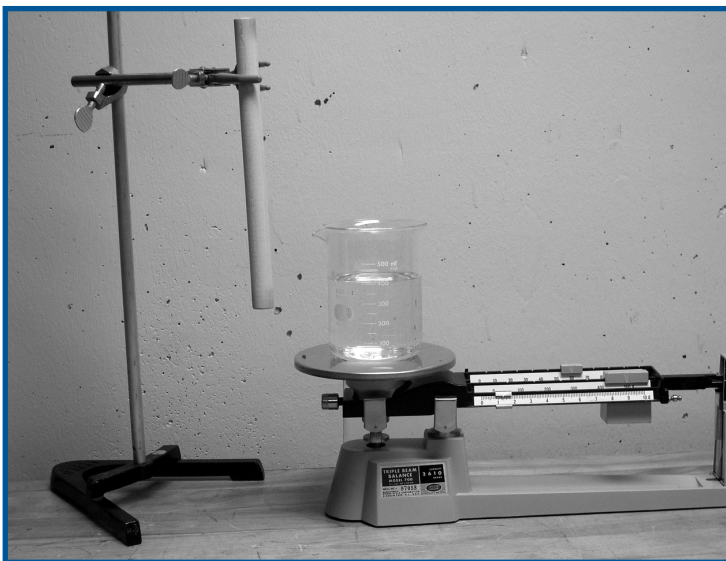


Fig. 2 Apparatus for an interactive demonstration

tions. Through this participation, the lecture becomes more of a situation where the students and the lecturer are working as a team in teaching and learning, instead of the lecturer standing alone doing the teaching and the students sitting doing the learning.

An interesting connection often seems to develop between the lecturer and a student participant. My experience is that a student who has performed a demonstration is much more likely to answer or ask a question in class, or to come to my office to ask questions. Apparently working together with the lecturer during a demonstration reduces some students' inhibitions about participating in class and seeking help.

## 20-MINUTE ATTENTION SPAN

Demonstrations also provide a change of pace. Most people listening to a speaker have an attention span of approximately 20 minutes. You can confirm this yourself: at the next physics talk you attend, observe the listeners -- at about the 20-minute mark, they usually become restless and start looking away from the speaker. Accordingly, it is wise to use a demonstration at about the 20-minute mark in lectures. Especially if students participate, it provides a wonderful change from lecturing.

When a topic is being discussed that does not lend itself well to a demonstration, something else can be done when 20 minutes of the lecture have elapsed. Possibilities include showing a segment of a videotape or DVD, giving the students some questions to answer singly or in groups, using a computer simulation, or providing the students with an opportunity to ask questions about an upcoming test or examination. I think it is very important to provide some sort of break in the lecture material. A colleague of mine often just takes a two-minute "time-out," thus giving students time to make additions to their notes, and giving him time to glance over his notes for the second half of the lecture.

This idea that there is a limited attention span is not new. Michael Faraday wrote [3]: "To all true philosophers, science and nature will have charms innumerable in every dress, yet I am sorry to say that the generality of mankind cannot accompany us one short hour unless the path is strewn with flowers." I like to think of demonstrations as the flowers that are strewn along the path.

## AROUSING CURIOSITY

I often use demonstrations, particularly ones that students cannot explain, to arouse curiosity. Sometimes this is done in the context of a single lecture, in which a demonstration is performed early in the lecture and then explained later in the same lecture, and sometimes I show a demonstration in the first lecture of a course, knowing that we will not get to the explanation until much later in the course. Curiosity keeps students actively involved in the course content. If students are curious about something, they might actually go away after a lecture and read the textbook to find the explanation! Anatole France, the 1921 Nobel Prize Winner in Literature, stated that "the whole art of teaching is only the art of awakening the natural curiosity of young minds."

## STUDENT FEEDBACK

Student comments and feedback about the use of lecture demonstrations are generally extremely positive. In a paper<sup>[4]</sup> in the *American Journal of Physics* (AJP) in 1996, R. Di Stefano reported on field tests of the Introductory University Physics Project (IUPP). As part of these field tests, students wrote comments about the physics course in personal journals. One aspect of the course that generated a lot of feedback was in-class demonstrations. To quote from the AJP paper:

"When demonstrations of physical principles were performed in class, they were consistently mentioned as a positive aspect of the course. There are two especially noteworthy features of student comments about demonstrations. The first of these has to do with the role that students perceive demonstrations to play in their learning. Although it might be supposed that students would be predisposed to like in-class demonstrations for their possible entertainment value, and for the way they 'break-up' potentially dull lecture time, this was not the aspect of in-class demonstrations that was most commented on. More often, students remarked on how demonstrations helped them to visualize, focus on, and think about physics. This result was confirmed in the data collected during the second year of testing, and at every site where in-class demonstrations were consistently used. The second noteworthy feature of student commentary about demonstrations was how ubiquitous it was. It is probably true that no other course feature elicited more spontaneous comments than in-class demonstrations."

The AJP paper includes some journal entries from students, a few of which are repeated here:

"Experiments [demos] are good because they break what most people call the monotony of a lecture, but the best part is that when there are theory questions on tests, you can figure them out if you think back to in-class experiments and their results."

"... the professor's classroom demonstrations helped to keep class interesting and also helped me to remember the material and understand how it relates to real life."

"The demonstrations really helped me a lot of think about the material. It's easy to just take notes and let the lecture go from ear to ear without really absorbing anything. The demonstrations helped to get me thinking."

My own experience is that on the end-of-semester professor evaluation forms many students comment very positively about lecture demonstrations. Remarks such as "good demonstrations help understanding concepts" and "class demos made physics fun" are common. And demonstrations can have a long-lasting impact on students. I have met former students who have clear memories of demonstrations that they saw in lectures many years ago.

## SOURCES OF DEMONSTRATIONS

Information about physics demonstrations can be found in a variety of places. The *American Journal of Physics*, published monthly by the American Association of Physics Teachers (AAPT), has an Apparatus and Demonstration Notes sec-

tion. The AAPT also publishes *The Physics Teacher* ten times per year, and there are often demonstration ideas available there.

There are a number of other demonstration-oriented publications available from the AAPT. Visit the website at [www.aapt.org/store](http://www.aapt.org/store), select "Product Type: Print Products," then select "Category: Demos and Apparatus," and click "submit." These products are also listed in the printed AAPT Physics Products Catalog.

The Physics Instructional Resource Association (PIRA) has an extensive list of demonstrations with brief descriptions on their website at <http://www.physics.ncsu.edu/pira/>. Here are other websites<sup>[5]</sup> that provide useful ideas:

- [http://www.wfu.edu/Academic-departments/Physics/demos/labs/demos/avimov/bychptr/chptr4\\_matter.htm](http://www.wfu.edu/Academic-departments/Physics/demos/labs/demos/avimov/bychptr/chptr4_matter.htm)
- [http://info.phys.uvic.ca/dbr/resman/demo\\_contents.html](http://info.phys.uvic.ca/dbr/resman/demo_contents.html)
- <http://www.physics.umd.edu/lecdem/services/demos/main-index.htm>
- <http://www.ph.unimelb.edu.au/staffresources/lecdem/main-index.htm>
- <http://www.haverford.edu/physics-astro/Demonstrations/index1.htm>
- [http://www.colorado.edu/che/CLASSES/3320f/pages/experiments\\_menu.html](http://www.colorado.edu/che/CLASSES/3320f/pages/experiments_menu.html)
- <http://webs.wichita.edu/facsme/nitro/pong.htm>

Finally, members of the Ontario Association of Physics Teachers (OAPT) receive a quarterly newsletter that includes "The Demonstration Corner" in each issue. OAPT membership is only \$8 annually, and is open to physics educators anywhere. Check out the OAPT website at <http://www.physics.uoguelph.ca/OAPT/index.html> for more information.

## FINAL WORDS

Good teaching involves (in part) addressing different learning styles of students, promoting active student participation in lectures, providing a change of pace to keep student attention, and arousing student curiosity. Demonstrations can make a valuable contribution in achieving these goals.

## REFERENCES

1. E. Mazur, *Peer Instruction*, Prentice Hall, 1997
2. The apparent mass, as indicated by the balance, of the water + beaker + submerged dowel is greater than the mass of just the water and beaker. Archimedes' principle states that the water exerts an upward buoyant force on the dowel, and by Newton's third law of motion, the dowel must therefore exert a downward force on the water. This additional downward force is transmitted to the balance pan. Another way to think about this is that as the dowel is submerged in the water, the water level rises, and hence the pressure exerted by the water on the bottom of the beaker increases.
3. A. Bartlett, "Etcetera," *The Physics Teacher*, **27** (4), 318 (1989), quoting from *Die Leybold-Welle*, October 1963, p. 46
4. R. Di Stefano, "Preliminary IUPP results: Student reactions to in-class demonstrations and to the presentation of coherent themes," *American Journal of Physics*, **64** (1), 58-68 (1996)
5. Thanks to my colleague Khosrow Farahbakhsh in the School of Engineering at the University of Guelph for this list.