continued from page 15

pany physicists are rare individuals. My contacts with other companies lead me to similar conclusions. Physicists have one dominant trait that offers them rich opportunities in industry—their ability to solve problems. This trait makes them highly adaptable. Industry greatly covets individuals who can attack a problem and get answers that can be demonstrated to make sense. With the availability of personal computer technology, I believe that physics can once again enjoy a day in the sun. If academia integrates this technology into the physics curriculum, it can make physics appealing to more students and, at the same time, train them to pursue careers outside of academia (if that is their bent).

Stan Siegel
Grumman Data Systems
1/89 *McLean, Virginia*

The article "Using Computers in Teaching Physics," by Jack M. Wilson and Edward F. Redish (January 1989, page 34) mentions briefly a project known as PLATO, but leaves the possible impression that this project was developed solely by Control Data Corporation in the 1970s and has since faded from use. The PLATO system is actually a development of the University of Illinois at Urbana–Champaign and has been in constant and expanding use since its 1959 inception. Today it is one of the largest university-based computer-aided instruction systems in the world.

The first phase of the PLATO system consisted of one student terminal connected to the ILLIAC I computer. This was followed by three other versions, each supporting more terminals. The system was developed with the intention of providing interactive, self-paced instruction to a large body of students. As the project grew, support was provided by the National Science Foundation, the State of Illinois, Control Data Corporation and many private and public agencies. Control Data Corporation purchased the rights to the name PLATO and the license to market the system in 1976. By that time there were approximately 1000 terminals across the Urbana campus, at other universities and colleges, at several levels of public schools, and in businesses and medical institutions. Almost 3 000 000 student contact hours of system use had already been delivered. An extensive volume of PLATO courseware is now available in physics, mathematics, engineering and other disciplines, some of which has been extended to other CAI systems, and there are dozens of PLATO systems around the world.

Research has continued on this project at Urbana. The original system has grown to about 2000 terminals and has delivered almost 20 million contact hours of instruction. A new PLATO-like network is experiencing rapid growth due to recent developments that have dramatically lowered the cost of the communications network and the central computer, as well as made provision for a wide variety of student terminals.

PLATO terminals were installed in the university's physics department in 1971. These and more recent additions have been in constant use since in a wide range of courses, but primarily those at the introductory level. As one example, students in the first semester of the calculus-level introductory course can elect a lecture–laboratory–PLATO version or a "standard" lecture–laboratory–recitation format. The PLATO version has been taken by about 800 students each year for the past 14 years. A review of the early experience with PLATO in physics was published[1] in 1983.

PLATO components have subsequently been added to other physics courses. This system continues to be an effective way to deliver computer-aided instruction, especially in courses with large enrollments. PLATO has also proven to be a useful tool for handling administrative aspects of large courses, including the assignment of students to class sections and the determination, storage and dissemination to students of grade and rank-in-class information. In past years, before personal computers became available, PLATO permitted the use of numerical techniques to solve problems in advanced courses (such as quantum mechanics).

The experience with PLATO at Urbana in physics and chemistry provides a rich and valuable base for any study of the limitations, advantages and role of computer-aided instruction in university-level science courses. We were therefore surprised to discover that that experience had been both misstated and greatly understated by Wilson and Redish.

Reference

1. L. M. Jones, D. Kane, B. A. Sherwood, R. A. Avner, Am. J. Phys. **51**, 533 (1983).

Ansel C. Anderson
Dennis Kane
University of Illinois
4/89 *at Urbana–Champaign*

In the article "Using Computers in Teaching Physics" by Jack M. Wilson and Edward F. Redish, there was an omission—an oversight, I'm sure—in the section on simulations. There was no mention of the recent two-volume work *An Introduction to Computer Simulation Methods: Applications to Physical Systems*, by Harvey Gould and Jan Tobochnik (Addison–Wesley, Reading, Mass., 1988). These volumes can be considered a major contribution to physics pedagogy. Anyone interested in encouraging students to explore physical concepts with the assistance of a computer should consult these works.

Denis Donnelly
Siena College
2/89 *Loudonville, New York*

Wilson and Redish reply: We were not trying to either misstate or understate the role of the University of Illinois in the PLATO project. We were simply constrained by article length and only planned to mention PLATO in passing.

Similar constraints led to the deletion of our reference to Gould and Tobochnik's excellent two-volume work. The original article as submitted was nearly twice as long and had over twice the number of references. Our apologies to others who may have felt that we slighted their work. The editors' work resulted in an article that was much less complete but (we must admit) much more readable than the original.

Jack M. Wilson
American Association of Physics Teachers and University of Maryland
Edward F. Redish
University of Maryland
10/89 *College Park, Maryland*

Feynman: Wobbles, Bottles and Ripples

Being more adventurous but less careful than B. Fong Chao (February 1989, page 15), I have tried to reconstruct Richard Feynman's explanation for the motion of a wobbling spinning plate. Why, in "simple" terms, does a wobbling plate wobble twice as fast as it spins? One seeks an explanation like Feynman's textbook explanation for the torque on a forced-precession gyroscope in terms of the Coriolis acceleration of its particle masses. The wobbling plate is in free precession and, it turns out, is in some sense easier to understand. So here, for general entertainment, is an explanation with some equations to help with visualization.

Consider a particle in a circular orbit about the origin that is slightly tilted off a reference plane. Consider another particle of equal mass also in circular orbit about the origin, but on a plane tilted just slightly the other way. Looking down at the reference plane, let the particles be one-quarter of a revolution apart. Specifically, say $\mathbf{r}_1 \approx (\cos t,\ \sin t,\ \epsilon \cos t)$ and $\mathbf{r}_2 \approx (\sin t,\ -\cos t,\ -\epsilon \sin t)$. These two particles, with the origin, define a plane. One can see that this plane wobbles around twice as fast as either of the particles by tracing the particles' motion with two fingers (a quarter of an orbit should give the idea). That is, the x and y components of its downward normal are $\epsilon \cos 2t$ and $\epsilon \sin 2t$. Each of the planar circular orbits could be caused, say, by tying each of the particles to the origin with a massless rod. But since the angle between these two particles is always $\pi/2$ (to first order), the two rods might as well be welded to each other, though still hinged at the origin. The two connected particles now constitute a rigid body with an inertia tensor about the origin proportional to that of any planar axisymmetric body about its center of mass—a plate, for example. The particle pair's equations of rotational motion and its actual rotational motion are thus the same as those of a freely moving plate.

So it turns out that the slight wobbling of a free-flying plate is in fact a very simple motion kinematically. All of the particles are traveling in circles (almost) around the center. All particles on a given radial line share an orbital plane, tilted slightly from the planes of other radial lines. This kinematics has other consequences as well. There exists the possibility that a planetary ring of particles in independent circular orbits could appear as a rigid wobbling "hula hoop." Also, a loop of chain floating in space could move in this rigid mode even though the chain has no bending stiffness.

There are other problems for which it is useful to realize that the rotational motion of *any* three-dimensional rigid body is totally equivalent to that of three particles attached to three rigid massless rods that are welded orthogonally to one another and pivoted at the origin (just two particles for flat objects). Or, if one does not like tying things to a fixed origin, one can weld three dumbbells together to construct an object that looks like a child's jack (six masses).

Rigid-body dynamics is hard in general because it is hard to figure the interaction forces and moments that might maintain the rigid-body constraint, even with the few-particle descriptions of a rigid body described above. But Feynman's wobbling plate

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problem just happens to be simple in this regard.

Andy Ruina
Cornell University
3/89 *Ithaca, New York*

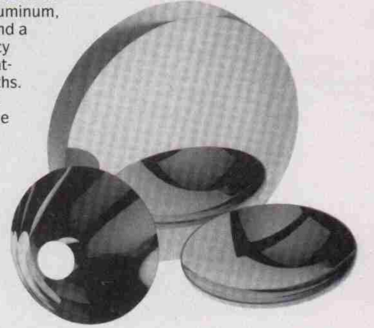
John Wheeler's account (February 1989, page 24) of the "busted bottle" incident that occurred when Richard Feynman was a graduate student at Princeton does not seem to be consistent with Feynman's own account.[1] For the case when water was drawn into the sprinkler, Wheeler's account states: "Ha! A little tremor as the pressure was first applied, as water first began to run backward through the miniature lawn sprinkler. But as the flow continued there was no reaction. . . ." In Feynman's account, the passage reads: "The water was coming out, and the hose was twisting, so I put a little more pressure on it, because with a higher speed, the measurements would be more accurate. I measured the angle very carefully, and measured the distance, and increased the pressure again, and suddenly, the whole thing just blew."

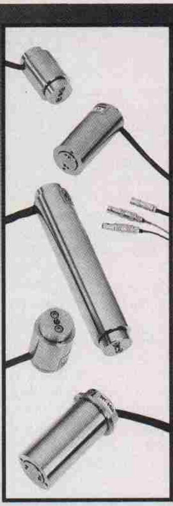
So Feynman's version implies that the sprinkler moved, whereas Wheeler's implies that it didn't move.

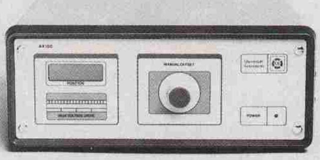
This possible contradiction was pointed out to me one evening in April after some colleagues and I had adjourned from a conference on Quantum Electronics and Laser Science to a rooftop lounge. Having downed a few drinks, we got into a heated argument over which way the sprinkler should move when water is drawn in—if it moves at all. I decided to settle the argument by conducting an experiment.

Instead of using water, I chose a more convenient fluid—the air in my lungs. Collecting two straws from spent margaritas and joining them together (luckily, the straws had corrugated elbows), I formed a single tube with two ends, each of whose three straight sections was set normal to the other two. Using my mouth as an O-ring, I blew into this contraption, causing it to spin like a sprinkler. When I sucked with equal intensity, nothing happened. Even to the point of exertion, every effort to make the straw spin with air drawn in failed.

Our experiment shows that the sprinkler moves when air is blown out but not when air is drawn in. While Feynman's account seems to imply that the sprinkler moved when water was drawn in, he never stated this conclusion, perhaps to arouse his readers to think about the problem and perhaps to tease them into doing the experiment for themselves. If







these were his intentions, he was successful.

Reference

1. R. P. Feynman, as told to R. Leighton, *"Surely You're Joking, Mr. Feynman!"* Norton, New York (1985), p. 52.

Mark Kuzyk
AT&T Bell Laboratories
5/89 *Princeton, New Jersey*

Richard Feynman the teacher was shortchanged in your February 1989 special issue. His encounter with an erstwhile student is fondly remembered in this letter.

Though not the brightest among my class, I eked through Methods of Mathematical Physics as a senior electrical engineering student at Caltech in the early 1950s. Feynman taught it on alternate days with Robert Walker. It was Walker who would methodically write out his lecture material on the wall-to-wall blackboards, proceeding from left to right repeatedly as the hour passed in the old Bridge lecture room. But it was Feynman who electrified the class with his enthusiasm. Everything was clear while he lectured. Unfortunately for me, I was usually too spellbound during his classes to take anything but the most skimpy lecture notes.

Not too many years later, after I had joined the Hughes Research Laboratory, Feynman came to teach the "Feynman Lecture" series there. During one of those sessions I had the delightful experience of sharing with him the results of an ongoing experiment. We had just recorded for the first time the planar acoustic beam cross section of acoustic surface waves on an anisotropic substrate. It showed the nearly textbook beam profile of Fresnel diffraction. This had been the topic of Feynman's lecture that day, during which he led us through the derivation of optical diffraction from a slit. When I told him of my work he asked eagerly to see the results. You cannot imagine how thrilled and happy, almost childlike, he was to see the changing Fresnel ripples demonstrating the near-field diffracted beam cross section at progressively distant points from the radiating aperture. He beamed and said something like "Gee, it really works in the real world too."

This was a high point in my early career. I shall not forget the exhilaration of that encounter. It remains a source of inspiration to this day.

Rolf D. Weglein
4/89 *Los Angeles, California*

High School Science: Why East Beats West

I am writing to clarify some points concerning Asian high school science that appeared in the letter by Francis M. Tam (March 1989, page 156). As a product of the educational system of Hong Kong, I think I am in a position to give an insider's view of what Asian high school science really is. This, I hope, will dispel some of the myths surrounding Asian science education in general.

High school students in Hong Kong usually start "majoring" in science or humanities in form 4 (grade 9). Most of these students will continue their major into forms 6 and 7 (provided they pass the Hong Kong Certificate of Education examination). For example, a major in mathematics will take an intensive curriculum in physics, chemistry, biology, general math and additional math (including calculus) plus other, nonscience subjects during forms 4 and 5. In forms 6 and 7, the student will take physics, chemistry, pure math and applied math. The intensity of this program means that by the time students reach form 7 (pre-university year), they will have taken courses in their major subjects that are equivalent to sophomore courses at US universities, as Tam rightly pointed out. In view of this intense training, the "quantum leap" of Hong Kong science students from last place in ninth grade to first place in the senior year of high school (see PHYSICS TODAY, June 1988, page 50) in a "mere" three years is neither unimaginable nor a misrepresentation.

I wholeheartedly agree with Bassam Z. Shakhashiri when he said, "American children have just as much innate curiosity and intellectual capacity for learning about science as students in any other country" (June 1988, page 52). What puzzles me is the attempt to explain away the differences in achievement between high school science students here and abroad by yanking in philosophical and sociological differences, cultural and family influences, and so on. As far as the present issue is concerned, these factors are simply irrelevant. Knowledge of these differences may be comforting, but it will not alter the fact that, as various studies have suggested, American high school science *is* lagging behind other countries, and the gap is no less than that reported.

American high school students may receive a much broader general education than their Asian counterparts, but as a trade-off, this must also imply a reduced emphasis on science as a specialization. After all, high school students are (still) human beings, and it's unfair to expect them to excel in all subjects. The American philosophy of education advocates the complete education of an individual rather than early specialization. This in itself is a very respectable goal, as long as there's an understanding of the above-mentioned trade-off. I am quite confident that American high school students would score high in a test of general education. As far as science is concerned, however, we already have the facts.

To close this letter, I would like to give a piece of advice to the educators of this country: It's time to decide which way the American intellect should steer itself, toward general encyclopedic knowledge or toward specialization. In view of the keen competition from abroad, it is unrealistic to try to embrace both these aims: Better to keep one than lose both!

Chi Ming Hung
State University of New York
3/89 *at Buffalo*

Balancing the Branches of Physics

The 1988 survey of physics department chairs by the APS Committee on Opportunities, or COP (February 1989, page 101), indicates that there is a need for more experimentalists in condensed matter and in atomic, molecular and optical physics, and that there is an abundance of high-energy theorists. Any COP that tries to separate the good guys from the bad guys probably deserves a medal for courage, but also should expect to be used for target practice.

So let me commend the heroes of this survey who are suggesting that there is a demand for useful physics. If we want to work, maybe we should do something that other people find useful.

On the other hand, I don't believe that a healthy balance in science is determined by job demand alone. There are areas of physics that, for historically sensible reasons, have been bypassed or ignored but that can contribute in a vital way to vigorous science. Atomic physics, for example, offers pictures and concepts used in other areas including not only physics and materials science but also chemistry and a little biology. As an atomic theorist who has worked in other fields, I would like to make note of the beauty of the many problems in atomic physics that have clean and elegant solutions and that, at the same time, are useful. But atomic and molecular