# OPINION

# Lessons from Lily on the Introductory Course

## Paul G. Hewitt

Often something can be terribly wrong about a well-established practice, but identifying that wrong can be very difficult—especially when the practice is ingrained with a tradition we have a stake in continuing. Such occurs in the teaching of the introductory physics courses for science and engineering majors, premeds and biology students. We all know that something isn't right with these courses, but we can't seem to put our finger on it. I suggest the source of what ails us is what we most cherish in these courses: the emphasis on problem solving.

We put a high premium on problem solving for very good and well-known reasons. Maybe the best reason is that, to put it simply, solving problems is quite wonderful. With straightforward rudiments and the application of one or more physics concepts, we can unravel complexities and make predictions about nature that would have amazed science-minded people in previous ages. Every physicist, without exception, rightfully places a high value on problem solving. This activity makes up the core of our courses. One cannot do physics without mathematics, a knowledge of physics concepts and the ability to apply them to physics problems. Without mathematics, physics might well be little different from the science of the dark ages.

Teaching physics concepts via solving problems is perhaps the most expeditious way to teach a physics course. For one thing, lecture notes need be little more than a selection of choice problems whose explanations will fill class time. There is considerable merit to this practice, for information that answers a question is highly valued. How better to make a clear distinction between momentum and kinetic energy, for example, than in a thoughtful explanation of the classic ballistic pendulum problem? How better to introduce Kepler's third law than to equate gravitation between the Sun and a planet to the centripetal force on that planet? Physics concepts are often illuminated in the solutions to problems. The central role of problem solving in the intro courses would seem irrefutable.

As a background to countering this practice, I'll relate the experience of a student friend whom I'll call Lily. Lily's ambition was to become a pharmacist. She wasn't very bright, but she had a keen memory, perseverance and enough patience to finally and barely graduate from pharmacy school. But when it came to taking the state boards for pharmacy certification, she flunked twice. An ad in the newspaper came to her rescue. It promised success in passing the state exam via a three-weekend crash course. She took the course, which bypassed all the rudiments of pharmacy and trained her to answer questions from previous state exams. She passed the state exam on her next try and became a certified pharmacist. But she wasn't able to hold onto her first two positions, and I lost track of her after that.

I tell this story not to demean Lily (whom I admire for her persistence) but to show the parallel to and danger of training students to solve physics problems in crash-course style. Lily's "proof" that she understood pharmacy by passing the exam is not altogether different from our belief that students who can solve problems understand physics. Just as one can learn to recite poetry without understanding it and one can memorize the periodic table with no notion of what chemistry is about, students can learn to solve physics problems—not all of them or even most of them, but enough to pass a course—without the faintest gut feeling for the concepts that underlie them. I know this is true, because up to the time I got my BS in physics, I was one of those students.

When I was an undergraduate, it was problem solving from day one. We never took time to consider the qualitative questions at the end of the chapters. We didn't even *read* the chapters, except to glean information that might apply to the end-all: solving the problem sets. It was push, push, push, problems, problems, problems. What was the conservation of energy? Basically little more than the gimmick for solving $\Delta mgh = \Delta\frac{1}{2}mv^2$-type problems. How great the course would have been if the professor had placed as much emphasis on the qualitative questions as on the problems. How richer my encounter with physics would have been if we had learned to articulate concepts, distinguish them from one another, see their role in everyday experiences and view them for what they are—the foundation of all the sciences. Instead I learned to see physics concepts as useful devices for solving problems. Physics itself was applied mathematics. I didn't see otherwise until after graduation, during a delightful summer spent reading *The Feynman Lectures on Physics*, Ken Ford's *Basic Physics* and Eric Rogers's *Physics for the Inquiring Mind*. A summer of physics without problem sets—utter joy!

It is unfortunate that this elation is not the typical outcome of the introductory courses. I don't mean to imply there isn't joy in solving a problem, for there often is. But the joy has more to do with celebrating one's personal abilities, which is different from the joy of discovering more about the physical world. The joy that comes from learning concepts is rare in a course that tackles problems from day one. This is a serious matter, because very few students who take the intro courses become physics majors. What are the chances that a student who goes on to chemistry, biology or the Earth sciences will later learn physics concepts?

Contrast the way the professor and the students view problems. The professor classifies problems in terms of physics concepts, while the students classify them by situations. There are "pulley problems," "inclined-plane problems," "pulleys-combined-with-inclined-plane problems" and so on. Since most students don't see the experience of solving such problems as building the foundation for their chosen careers (by then, rarely physics), they yearn for the end of the course. In her book *They're Not Dumb, They're Different* Sheila Tobias tells us, quite convincingly, that students avoid physics beyond the intro-

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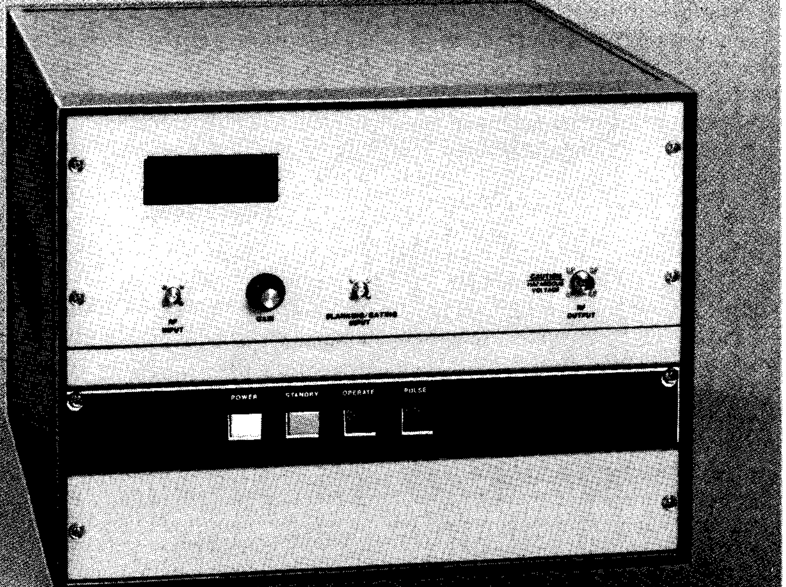

ductory course not because they can't handle it, but mainly because they're simply not interested in more physics—not the way it's taught.

Would this be the case if concepts at the qualitative level were given the same priority as problem solving? Would bright students who don't particularly value solving problems not value instead the challenge of articulating physics concepts qualitatively, distinguishing between closely related ideas and specifying where concepts do and do not apply in everyday examples? Would they not value understanding that all the diverse phenomena that surround us are tied together by a surprisingly few relationships? Would they not value the derivations of those relationships and the formulation of concepts in their own right—devoid of their usefulness for solving, say, problems 23–28 at the end of the chapter?

Qualitative concepts first, problems second was the credo of now-retired high school physics teacher Art Farmer, who year after year had the highest-scoring students in California. Art spent the first half of his advanced physics course going quickly through a college-level book, covering only qualitative questions. Only in the later part of the course did he train his students in problem solving. By that time Art had them ready, willing and able. Can't we do the same in college?

Correcting the overemphasis on problem solving does not call for any revolution in the way we teach, nor does it call for any changes in the textbooks, which are generally quite excellent. Most of all, it does not call for pushing more modern physics into the introductory course, which would be a most regrettable approach if it diminished a first solid encounter with Newtonian physics. What is needed is revamped exams, little else. Exam questions, after all, define what is important for a student in a course. If half the grading weight of physics exams were on qualitative questions akin to the many excellent ones already in the textbooks, the situation would be self-correcting. The outcome would be a richer, more satisfying and more sought-after educational experience.

As physics educators, our first obligation is to see that physics concepts are learned, in order to provide the conceptual framework upon which all the other sciences are based. If spending more time developing concepts means spending less time applying them to problem solving, then the time is wisely invested. Placing concepts before computation is a priority we owe not only to our students but to the health of our profession. ■