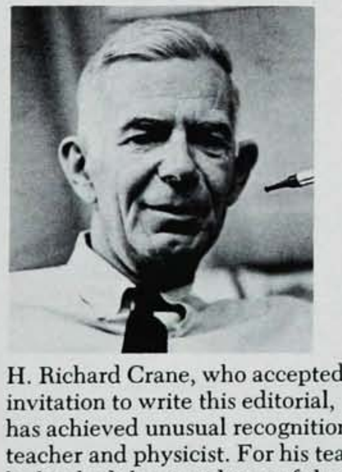
GUEST EDITORIAL

Better Teaching with Better Problems and Exams



H. Richard Crane, who accepted our invitation to write this editorial, has achieved unusual recognition as teacher and physicist. For his teaching he has had the presidency of the American Association of Physics Teachers and, from the University of Michigan for which he has taught since 1935, a distinguished-service award. The American Physical Society honored him with its Davisson–Germer prize for his method of measuring the g factor of the electron. He has also worked in nuclear physics and accelerator design. Currently he is the chairman of the Committee on Physics and Society (COMPAS) of the American Institute of Physics.

I have been searching for ways to raise the students' respect for what we call the "nonscience" or "noncalculus" physics course, the course for students who are not scientists or engineers. I am concerned not only as a teacher, but as a researcher and administrator; for this course is a major channel of communication with the people who are going to become the congressmen, doctors, business executives, bureaucrats.

Nonscience courses come in some variety. But the big bread-and-butter one in each university is for the "captives"[1] – the ones who are in it against their desires, to satisfy requirements for careers in which physics will play a minor part. There would be nothing wrong with their *starting* the course against their desires if only we could make allies out of them by the end. The majority of them go away thinking the course was a poor investment of an inordinately great amount of work, of limited relevance to their aims in life, even though the teaching quality may have been excellent.

There is a particular urgency now for the course for captives. Students everywhere are beginning to scrutinize the requirements and prerequisites in their curricula.

How can we accelerate our progress in relating the course to modern needs? The problem has been pretty resistant to the usual conferences of experts, and I do not think hope lies in that direction. Last summer I started an experiment to see if an appeal to a sizable cross section of physics teachers could turn up some fresh ideas and material and identify some new talent. To begin it I went to the Tempe, Arizona, meeting of the American Association of Physics Teachers and gave a speech,[2] which was intended to stir people up about the problem. Following the meeting I sent to about 170 persons who were registrants a copy of the speech with a request for ideas and pieces of teaching material that would at the least follow up some of the leads I had given but, better yet, strike off in new directions. I agreed to process what I would receive and send it back to all those who had replied. For the happy eventuality that the experiment should prove viable and outgrow my one-man capability, I was backed up by the Commission on College Physics.

The results of the first round are in. I received 44 letters, a lot of ideas and views and a lot of moral support. But when it came to actual software, the yield was small. Nevertheless, remembering that a self-excited generator builds up voltage slowly at first, I declared the first round a success and fed back into the circuit what I had been able to gather.

The interchange of ideas has brought into focus at least one area that can be attacked fruitfully through correspondence: problems and examinations. These two items have resisted change; yet they are the kind of thing that can readily be passed around, tried out in classrooms, and eventually absorbed into textbooks and courses. They appear to make an excellent first target and represent the way the project is going at present. Therefore, let me discuss what I have against present problems and exams and how we can hope to improve them.

Problems and exams, together, from a vicious circle. Students will not put serious effort on problems that are not going to pay off at exam time; in turn the professor makes the exam "cover" the problems that have been worked on. Textbooks perpetuate the style in problems: Questions propagate from one author to the next. Many teachers nowadays put forth wonderful effort and personal style in teaching only to have the course weighed down by the textbook problems, most of which lie on the student like a wet blanket. It does no good to improve the problems without changing the nature of the exams; so improvement is doubly hard.

It will be useful to distinguish problems from exercises, according to a suggestion made to me by Walter Michels. When a new principle or method is shown, exercises must be given, just as in a music lesson where the teacher says, "Here is how to do it; now you do it a few times." In physics we say, "A wheel of moment of inertia 20 kg m^2 is acted upon by a torque of . . . etc." These exercises are necessary, in their places.

We might characterize a *problem* by saying it should invite the student to put something in on his own, have some part in selecting the aim, conditions, options, method of attack. In other words, he should be invited to begin behaving a little bit like a physicist. But we seldom go beyond the exercise; instead everything needed is given concisely in the statement, and he can, and does, carry out the solution in a vacuum without any personal involvement or connection to anything outside the piece of paper on which the problem is given.

I would like to develop a whole new generation of problems, new in this respect: The student would participate in their formulation and would, as a necessary step in their solution, connect them with the real world. That might go far toward answering the accusation that physics is not "relevant." At least we know it is an approach that has not been given a try.

I may be overly pessimistic, but I do not believe students ever do much with a course afterwards except what they are taught to do while they are taking it. These nonscience students are not going to have the chance to apply the physics they learn to typical textbook exercises. Therefore if they are to make any use of physics, it will have to be by transferring the concepts and ways of thinking to problems of their own nonphysics world. We seem to assume that they will begin making this transfer the day they finish the course if only we give them a solid foundation in the basic principles. "The application is left to the student." We sadly delude ourselves. The great majority will not make this transfer unless they are given practice in doing so *right in the course,* day by day.

Countless physics questions can be formulated about things and events in the everyday world, and these can be answered within the limits of the physics that the student gets from the course. He will *never* in his life meet one that is already formulated like a textbook exercise. Nor will he do his own formulating unless he has had practice, day by day, in doing it *in the course*. Hidden behind the scenes as far as the student is concerned are: the nature of the result that would be useful or interesting, selection of parameters, options as to method of attack. He is seldom allowed to play with changes of scale, order-of-magnitude estimates, statistical validity of data or adjustment of conditions for an optimal result. Most important, he is never asked to set conditions that are missing by making reasonable assumptions or supply missing data by using his own estimates. How much more interesting it would be if the students were to make out the problems and have the professors do the solving!

What I have been proposing will remain meaningless until we try it on live students. We are doing some of that at Michigan; I am urging my correspondents to do it. We can already see that there is a potential-barrier or critical-mass effect. Giving a class a few isolated problems of the kind described simply causes dismay. "But, sir, you haven't given us all the data." (That observation in itself is progress!) "But I don't *know* anything to put in."

We have collected about 40 problems that pretty well answer the requirements I have given, and more are coming in all the time; so we have material to try out. There is less progress on exams, and that worries me. Although (as expected) only a small fraction of the original 170 players have stayed in the game, others are now contributing. Some new talent is emerging, which probably is the most important result of all. My guess is that the project is viable.

References

1. H. R. Crane, Am. J. Phys. **34,** 799 (1966).
2. H. R. Crane, Am. J. Phys. **36,** 1137 (1968).

—*H. Richard Crane*