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Physics First

Marcelo Alonso

Letters
to the Editor

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The timely article by K. Sheppard and D.M. Robbins, "Physics was Once First and Was Once for All" [*TPT* **41**, 420 (Oct. 2003)] brings once more into focus one of the most serious anomalies in the high school science curriculum.

To my knowledge the United States is the only country in the world in which the order B-C-P is maintained in high school. To make things more serious, P is only one course and is not required of all students. When that order was firmly established in 1920, B was mainly descriptive, C dealt basically with chemical reactions, and P was mostly applied mechanics. But since 1920 a lot has happened in science. Thus, in my opinion a major problem is not just the order in which those three sciences are taught, but how they are taught.

To begin with, during the 20th century a profound conceptual revolution occurred in our understanding of matter: Both inert and living systems are recognized as being composed of molecules, atoms, electrons, nuclei, etc. These are basically systems of electrically charged units, and most of what happens in those systems is the result of electromagnetic interactions, including radiation (photons). That means that the traditional sciences are not really independent, but rather deal with different related sets of systems and processes involving the same basic components. Therefore, the teaching of those sciences must be integrated in some meaningful way, and that integration requires a more detailed attention to the physical properties of matter.

It is true that now most biology courses begin with the DNA molecule, and many chemistry courses introduce the notion of electronic orbitals in atoms and molecules, topics for which students are not well prepared, since most of them have not taken physics courses. Physics courses in turn relegate to the end some discussion of the structure of matter and electromagnetic interaction, or do not discuss that at all. Thus, students miss the overall picture.

The excuse that mathematics is a limiting factor for not teaching physics earlier is not valid; all that has to be done is revise the high school math curriculum.

I look forward to the day in which those in charge of high school science education will recognize the need and urgency of a conceptual reform.

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More Physics First

A broad, conceptual physics course for all, followed by a more focused "classical" course for scientists, would solve most of the questions raised in your October editorial and in the Sheppard and Robbins paper[1] in the same issue. The editorial poses questions about the "less is more" philosophy: How much less? Newtonian mechanics only in the high school course? Mechanics plus electromagnetism? How to include modern physics, as envisioned in the Introductory University Physics Project of a decade ago? When should such courses be offered? Writing from a historical perspective, Sheppard and Robbins ask how we can make physics accessible to all students, and whether it should be taught first.

The natural answer to all of these questions is to teach a broad and conceptual (little or no algebra) physics course first for all students, scientists and nonscientists alike. Those students who miss such a course in high school should take it in college. A conceptual course can move faster without rushing because no time is spent on math or math-based problems, so that one can move beyond the usual classical topics to modern physics as well as thermodynamics and societal implications. As Brian Greene (*The Elegant Universe*) and others have shown, it is quite possible to teach the subtleties of quantum field theory, general relativity, string theory, and other modern concepts to nonscientists, provided one does it carefully and without mathematical technicalities.

Sheppard and Robbins indicate that many physics teachers resist teaching conceptual physics for all. If we insist on teaching a math-based course first, we will continue turning away both science and nonscience students in droves, and it will be essentially impossible to institute physics first.

For future scientists, the conceptual course will probably be followed in the 12th grade with an AP course that can focus on mechanics and/or electromagnetism. The earlier conceptual course can provide a broad physics orientation for these students and peak their interest in further study. Even more importantly, a broad, conceptual course for all is essential for general science literacy and to improve the attitude of non-scientists toward physics.

1. K. Sheppard and D. Robbins, "Physics was once first and was once for all," *Phys. Teach.* **41,** 420–424 (Oct. 2003).

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Still More Physics First

In a recent article Sheppard and Robbins[1] review the order of science subjects in U.S. high schools over the past century. This article naturally appears in the context of the ongoing "Physics First" movement. These discussions typically discuss the following sequences: B-C-P or B-P-C or P-B-C or P-C-B. They also typically omit discussion of what is being taught in the other year of the typical four-year high school.

Any discussion of Physics First should be informed by knowledge of what is taught in the "physical science," "Earth science," and similar such courses in the ninth grade (or eighth grade). I believe that if one takes into account these courses, the current state of affairs would be more fairly characterized as "physics first and for all" in a much higher percentage (if not majority) of school systems than the impression one gets from the article or from advocates of the current Physics First movement.

One can argue that many high schools have been doing physics first. The sequence would most properly be denoted in the notation of the article as P-B-C-P. This was the situation in my not-atypical public high school located in the Atlanta metropolitan area of the 1970s. It is still a fairly common ordering of the subject matter to this day. I'm reasonably sure that if my high school principal or science department head had been sent a survey asking how they ordered the science subjects, they would have answered, "Physics last," thus being one of those 99% B-C-P schools referred to in the article. The ninth-grade science course just wasn't called "physics." At the time and place of my high school education, it was called "physical science" and was a required course for graduation. To the extent that one can differentiate between science disciplines at this level, the course was predominately physics. This was not atypical for the era.

1. K. Sheppard and D. Robbins, "Physics was once first and was once for all," *Phys. Teach.* **41,** 420–424 (Oct. 2003).

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Benefits of a "Cheat Sheet"

I read with interest Donald E. Rehfuss's article "Formula Sheet Caveat" in the September 2003 *TPT*. He finds much fault with the use of "Formula Sheets," explaining in detail his reasons (although in some cases I think he reaches a little far). His points are insightful and reminded me of a practice I felt was quite successful that I used when teaching my high school physics classes. I think it also responds to many of the concerns he expresses.

On many (but not all) of my tests I allowed my students the option of preparing for themselves what I called a "Cheat Sheet" (CS). I gave the following rules for its preparation and use:

1. "You may write your Cheat Sheet on only one side of a regular sheet of paper."
2. "Everything on the sheet must be in your own handwriting."
3. "You may prepare in groups but everything on your CS must be only your own writing."
4. "You may put down anything you think will be useful: notes, formulas, constants, etc."
5. "You may be asked to turn in your Cheat Sheet with your test."

The students' actual use of these CSs was interesting and varied: Some did not use them at all; a few almost needed a magnifying glass to read all that they had written; and most had anything from a few words to half a page. I found many positive results from this technique:

1. It provided an excellent incentive and method for students to prepare for the test. They could look over the material and decide for themselves those areas where they felt comfortable or where they wanted to further review with perhaps a write-up on their CS.
2. I noticed a much more healthy and useful approach to tests — a lessening of tensions. Students did not panic or worry about remembering or memorizing; they could always put down the infor-

mation or data on the CS. This allowed them to concentrate on their understanding of the physics rather than the details or the formulas.

3. The very practice of personally writing down material on the CS helps in its internalization. I was surprised and delighted at the number of students who, following the test, said to me that they never even looked at their CS. The making of the CS itself often meant that it was no longer needed.
4. This method is much closer to real-life situations where you have to solve a problem but you have reference material available.
5. This method also allows for better and more interesting test construction where you are not concerned with what the student has committed to memory, but rather with the type and depth of problems (both mathematical and conceptual) that the student can work on with some degree of success. When using this format, I generally tried to make up exams with the following mix: easy one-step problems, about 50%; harder two-step problems, about 35%; and tough and insightful problems, the last 15%. I always tried to include one exceptional problem that would rarely be solved but would be of interest when reviewing the test. I did construct these tests so that no one would complete them and told my students not to expect to.

All in all, I found this way a much more satisfactory and constructive alternative to the use of a Formula Sheet.

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Archimedes' Principle and the FCI

The recent article "Reconsidering Archimedes' Principle"[1] has important ramifications that physics teachers should take into account. Change the fluid from a liquid to air and you have essentially Question 12 on the Force Concept Inventory[2] that is commonly used as pre- and post-instruction analysis of student progress and instructional effectiveness. It asks, "A book is at rest on a table top. Which of the following force(s) is (are) acting on the book?"

1. A downward force due to gravity.
2. The upward force by the table.
3. A net downward force due to air pressure.
4. A net upward force due to air pressure.

The choices are

(A) 1 only
(B) 1 and 2
(C) 1, 2, and 3
(D) 1, 2, and 4
(E) none of these, since the book is at rest and there are no forces acting on it.

It is the only question with two "correct" answers given, already compromising its use as a multiple-choice item for optical marking sheets. Which combination is your choice?

When the Inventory was relatively new, participants at the summer Texas Faculty Enhancement Program for two-year college physics faculty members debated over the best answer. The proposed answers are (B) and (D). But compare the question to Fig. 2 in the article, which shows forces corresponding to choices 1, 2, and 3, surprisingly leading to (C) as the appropriate answer. We even tested (and failed to verify) the concept using water and a block in a laboratory drain, but as described in the article it is difficult to keep the bottom dry.

If the bottom of the book is well sealed from air, the choice of an alert student would be (C) based on ideal conditions (the norm for basic physics problems). A superior conceptual student — or one who read the article — would be penalized. In practice, however, a book cover is microscopically rough and (D) would be correct. Choice (B) may be allowance for students not knowing anything about the effect of pressure at the beginning. Since the students' reasoning is not available for analysis in a multiple-choice question like this, I just omit the question as being too ambiguous for a definitive answer.

1. Jeffrey Bierman and Eric Kincanon, *Phys. Teach.* **41**, 340–344 (Sept. 2003)
2. D. Hestenes, M. Wells, and G. Swackhammer, *Phys. Teach.* **30**, 141–158 (March 1992).

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