THE PERTINENCE OF THE PHYSICS TEACHER

Comments based on a presentation at the Tutorial on Physics and the Environment. AAPT Summer Meeting, Beloit, Wisconsin, June 19, 1971.

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Note: About half the time of the tutorial was devoted to the specific experiences of teachers of experimental courses, and these are not reported here. In addition to my account of courses at Princeton and Yale, the audience heard from Charles Creager (Kansas Wesleyan), David Workman (Kent State), Robert Bauman (University of Alabama, Birmingham), Robert Meijer (Parsons College), and John Shonle (University of Colorado, Denver). These reports were enthusiastic. Most of the courses had emphasized local issues, and the teachers were often subject to unprecedented attention from beyond the campus, generally to their pleasure after they learned to cope with it.

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The big idea underlying the increased concern for environmental quality is the realization that the earth is vulnerable. This is a quantitative concept: the disturbances that man is capable of generating on the earth are capable of substantially altering its character. Until recently, man was not sufficiently active to affect the viability of the earth in a substantial way in a period as short as a generation. Man's understanding of the earth's processes was also insufficient to detect and interpret the slower effects that man <u>was</u> responsible for. As man's capacity to harm the earth increases, his capacity to monitor and control also increases-- fortunately. The task ahead is to refine our understanding of the interaction of man with his environment, to disseminate a conscousness of this interaction, and to make adjustments in values and behavior where necessary.

Several specific problem areas are likely to lead to modifications of social and economic behavior: 1) Resource depletion, which will change the relative costs of certain raw materials, give greater gravity to recycling efforts in some areas, and require unfamiliar types of rationing. 2) Land use, where irreversible changes are most serious, including the loss of wilderness. 3) The disappearance of species that had shared the planet; the task of resurrecting vanished species is likely to remain beyond the capabilities of the biologists, and thus the fact that man, through greed and carelessness, has endangered numerous species of birds, whales, and other forms of wildlife, implies an impending irreversible loss of variety in nature. 4) Pollution, threatening the integrity of our climate and water supply.*

There is a natural tendency for physicists, and more particularly physics teachers, to feel that these issues lie outside their domain of competence. It is my purpose in these notes to argue that this attitude is mistaken and even slightly irresponsible. I am concerned in particular to establish the connection between the physics classroom and the environmental challenge.

The study of physics is helpful preparation for environmental problem-solving in several ways. The most direct connection is through the subject matter: The gas laws and the earth's atmosphere, nuclear physics and radiation standards, Carnot cycles and thermal pollution, etc. But there are even more important connections, at a deeper level, that the physics teacher ought to bear in mind.

Physics is noteworthy for its scepticism and irreverence, qualities of mind of great value in dealing with the environmental agenda. We are faced, in the next few decades, with constraints on human activity that are unprecedented and for which our

* These problem areas are best comprehended, I believe, in terms of real-life case studies, and to that end last year I assembled a set of case studies (with my colleague, John Harte) in a textbook, Patient Earth, published by Holt, Rinehart and Winston in June 1971. See for example "The Helium Conservation Program of the Department of Interior" (Chap. 6), "Law-Sulfur Fuel for New York City" (Chap. 4), and "The Everglades: Wilderness versus Ramplant Land Development in South Florida" (Chap 12).

psyches and methods of social organization have left us unprepared. Perhaps the most significant message that the physics teacher can impart, even to a casual student, is that the central scientific dogmas of one generation have often been overhauled by a later one. Where jurisprudence, by contrast, is founded on the idea of <u>gradual</u> change, physics is a story of continual upheaval and reorientation.

The physics teacher might also consider the utility of communicating the internationalism of physics to his students. The fact that physicists are comfortable with a global perspective is in a large part the result of working with subject matter that retains its validity from one country to another. Moreover, experiments designed to study the earth from space, world-wide programs to coordinate ground-based measurements in geophysics, measurements in astronomy using two telescopes on opposite sides of the earth, all reinforce the global point of view. A very serious deficiency of most current discussions of environmental issues in this country is the absence of a global perspective, and thus whatever the physics teacher can do to communicate the internationalism that is deeply imbedded in his field ought to have a salutory effect on his students' capacity to grasp an essential feature of many of the most serious environmental problems.

Third, the physics teacher might consider confronting the significance of "time-frames" with his students. The students will probably agree that the time frame of a legislator worried about reelection is too short to grapple with the environmental agenda. I would argue that there is also a time frame that is too long, and that we physicists can be as encumbered as politicans because it is the longest time frames that often most appeal to us. I would suggest that a time-frame of 10 to 40 years is the time frame of most environmental discourse: the time frame during which population, productivity, and pollution are likely to deviate substantially from current trends, whether for planned or unplanned reasons. By contrast, the physicist's *forté* may be a more far-ranging speculation: Freeman Dyson contemplates taking Jupiter apart and harnessing all 4π steradians of solar energy, for example.

Along with an instinctual preference for the very distant future (and past), physicists have a preference for the very large and very small. This is not going to be helpful for dealing with most of the pressing environmental problems, unless some unexpected discovery in one of these domains makes contact with the ordinary macroscopic realm, a possibility that can never be excluded. The study of extremes of time and space can be justified best, I feel, in terms of its contribution to man's deepest understanding of his universe--a justification at a religious level, if you will. The physics tradition, however, contains large amounts of macroscopic physics, and the imminent return of subjects like hydrodynamics to the physics curriculum seems overdue. Those of us who were schooled while macroscopic physics was on a back burner have some dietary deficiencies that we will have to struggle to correct.

The student emerging from a physics course more sceptical of conventional wisdom, more internationalist, and with a time-frame stretched just the right amount would have had a worthwhile experience, but there is another level of communication between teacher and student in physics courses that is even more critical to the student's capacity to deal with the problems of our planet. In physics courses the teacher has an opportunity to communicate a respect for and a love of <u>nature</u>. Respect and love are not the same thing, and both are crucial. The physicist's respect is intrinsic to his knowledge that nature has not been designed for man's convenience; this is built not only into the fundamental laws of physics but also into Murphy's law: in the laboratory, if something can go wrong, it will. That law is not a bad place to start from in contemplating a pipeline across the arctic tundra or a scheme to divert the flow of Siberian rivers. The love of nature is even more essential; above all, environmental problems need the attention of those who <u>care</u> about the outcome.

The physicist, of course, is also the custodian of certain very central ideas that underlie environmental issues, and I would in no way want to belittle the job of getting these ideas across in the classroom. I would single out the idea of entropy (especially the connection of entropy with the mixing of two previously separated substances) and the conservation

The tension within physics and within physicists between the great generalizations (the laws) and the special cases (the phenomenology) is a central fact of the field. The teacher of physics must accept that tension and must communicate it. He must do justice both to the unifying ideas and to the details of important systems.

It is probable that in recent years we have not done justice to the details, in our attempt to communicate the unifying ideas. We took a whole raft of poorly explained technology out of the curriculum, and we didn't put very much technology back. Most unfortunately, we forgot to tap geophysics for examples. (Consider a beautiful exception to this: Feynman's treatment of thunderstorms in his second red volume.)

The role of the physics teacher is not just to communicate the great syntheses. Especially in a liberal arts college, the physics teacher is the interpreter of technology as well as science. It is his job to sensitize the students to the technology in their surroundings, just as it is the job of the art teacher to sensitize them to the interplay of shapes in their surroundings. Otherwise, colleges will graduate men and women who are partially blind. There is no one else to do this job. We are in for a period of adjustment to the constraints imposed by a finite and vulnerable planet. An understanding of how these constraints arise will require a consciousness of the earth as a physical system and of man's technology that in some instances threatens to overwhelm that system. The physics teacher, as soon as he recognizes that he is responsible for imparting that consciousness, ought to have yet another reason to feel confident that his task is a pertinent one.