PHYSICS AS A CULTURAL SUBJECT.*

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The traditional attitude of the physicist toward cultural courses in general and a cultural course in physics in particular has been one of relative indifference. Not that he has disclaimed any desire for culture, but he has regarded culture as a by-product to be obtained while seeking something more worth while. He has associated "cultural" with courses that are decidedly weak in content—for example, in physics non-mathematical descriptive courses. Among his other objections to a course for which nothing better could be said than that it is "cultural" has been that the word "cultural" does not admit of the rigorous definition that he has been accustomed to apply to his concepts. It is subjective, while he has regarded his interests as essentially objective. However recent developments in physics have obliterated what was formerly considered to be the sharp boundary between the objective and the subjective. Other developments have made him a little less certain of the absolute character of his knowledge. With these realizations—though perhaps independently—has come a more human point of view. A physics department head in a prominent university recently deplored the fact that physics made so small a contribution to the cultural development of the average undergraduate. Such concern would have been rare a few years ago. An undergraduate national physics fraternity has lately been sponsored by eastern physicists, one of the aims of which is to promote a greater appreciation of physics. Witness too the number of books that leading physicists have written for the layman since 1928. Evidently physicists are having increased interest in cultural considerations.

What then should be the proper criterion of the cultural course? It must be the degree to which it provokes thought and develops permanent interests rather than the degree of difficulty with which it is assimilated; the extent to which the

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student may be induced to work beyond the definitely assigned and formal tasks; and when he has finished the course and received his credit and grade does he forget it as he would a bad dream, or does it color the whole of his thinking; has the seeking of new knowledge on the subject become one of the avocations of his life; does it fortify leisure hours against dissipation. What study can compare with physics in these tests, yet how many students have left the subject of physics without being in the least impressed!

Of what does the cultural course in physics consist? It is not a compendium of facts. Facts attain cultural value only as they become materials for thought. The student in the cultural course must be given ample exercise in the manipulation of the facts he has learned. Now the ideas in physics are essentially mathematical, and before the student can do any constructive thinking in the subject, he must have at least some working knowledge of mathematics. A purely descriptive course is then ruled out. In such a course he can only give back parrot-fashion the facts he has heard or read, lacking even the ability to evaluate them. For a similar reason a popular demonstration course must be rejected, as well as for the additional reason that no physicist can compete with a magician in making a spectacular exhibition. Is the cultural course then rigorously mathematical? In no case would general physics taught on an exclusively mathematical basis have the highest cultural value. The function of the mathematics is that of a skeleton in holding vital elements together. The application of the mathematical developments to the physical ideas must be brought out in innumerable ways. Many instructors omit numerous simple applications as being altogether obvious, but they are not obvious to the average student, and the cultural course must not lack appeal to the average student. Class demonstrations are of the utmost value in illustrating the physical significance of the mathematical formulae. The illustrations and demonstrations not only add to the student's interest, but they justify in his mind the introduction of the mathematics. But how deeply into mathematical methods the instructor should go probably has no objective answer. A course is not cultural for any student if a considerable portion of his study is in memorizing formulae which he does not comprehend. But for that matter neither would it be of great value to him as a technical student.

A physics professor in a state university said some years ago, "If college physics (by which he undoubtedly meant cultural physics) is to persist, it must divest itself of its mathematical formulation." We can see in this statement little if any foundation in fact. No one has ever questioned the permanence of mathematics as a cultural subject, and if the mathematical student can not be interested in physics and if the physics course does not create a desire to know mathematics even where none existed before, there is something wrong with the course and it ought to perish. The most common trouble in our opinion is that there is far too little mathematics in the physics course. Perhaps the department does not have sufficient mathematical prerequisites for its courses, and as a result the instructor is more or less apologetic in introducing the mathematics. Even with prerequisites in college mathematics, there are many necessary mathematical ideas which the student seldom learns in the mathematics department. One of these concepts is functionality. Few students entering college physics even after two years of college mathematics know how to build up an expression for the dependent variable in terms of the independent variables though they are told the laws governing the independent variables. A rigorous presentation of mechanics in the general course furnishes opportunity for a vast amount of drill in fundamental mathematical concepts, and for a great deal more in associating the abstract mathematics with the physical ideas. In the derivation of the formulae every assumption and every approximation must be clearly pointed out, and a sharp distinction made between the experimental and the theoretical bases. Considerable use of dimensional equations is highly profitable. Admitting that this portion of the work rates low culturally for many students—(cultural is subjective), the students must be made to learn this technique by any methods found to be effective. The ability to use has high cultural value though the *process* of learning it may be almost as lacking in cultural value as the *process* of learning the alphabet or of learning to read.

In many physics departments the inferior student receives small consideration, irrespective of whether the reason for his inferiority is inability, laziness, or deficient back-ground due to early lack of opportunity. Many of the latter group are highly deserving. A little investigation shows a rather large percentage of these students with deficient back-ground to be

science teachers in the public schools or even high schools. If we do nothing for them, we have ourselves to blame for the unsatisfactory teaching in the secondary schools of which we all complain, and the vicious circle will persist. Often it is impossible to give them a great deal of individual attention, but the introducing of each new subject by simple qualitative ideas is of the greatest value to these students. Furthermore this practice is not without value to the superior student in aiding him to connect up the familiar with the unfamiliar, and in no case, if the qualitative ideas are presented in a concise interesting way, is the attention of the superior student lost. There is on the other hand no place for sluggards and drones in the cultural physics course.

When the class has learned sufficient mathematical technique to use in a constructive way, the instructor may discard his driving methods, substituting therefor inspirational methods. Nor do these preclude giving in the general course such derivations as the equation of the adiabatic and Carnot's cycle. However the student must previously be given some comprehension of isothermal, adiabatic, and graphical representation of work, or he will have a mass of material that he can only memorize.

We have made the average student the determining factor in the presentation of the cultural course. But when his needs are given proper consideration, the whole class may be carried to greater heights, and hence this course is best for the superior student as well.

Something should be said concerning the qualifications of the teacher of the cultural course. In addition to the qualifications commonly emphasized, he should be interested in people and in the way in which their minds work. Fully realizing the mental deficiencies of his students, he needs endless patience in dealing with them, and he can use the zeal of a reformer.

Finally, the qualifications of the teacher of the cultural physics course and those of the course itself are the very ones that make it the most valuable for the technical student as well.