course is separation of text and laboratory guide and the fact that the text contains full descriptions of all the basic experiments performed by students (although they are not done with the same equipment, and techniques are usually quite different). Contrary to what was feared, students do not read ahead of their assignments to know what results they "should" get; students enjoy experiments in which they do not know the answers in advance. Existence of a self-sufficient text gave many PSSC teachers, in particular those with poor preparation, an excuse to reduce the laboratory work, demonstrating a few of these things themselves.

To discourage such misuse of the IPS course, the laboratory guide appears as regular sections of the textbook, and experimental results are not described in the text. Thus the text plus the students' notebooks, which contain the results of the entire class, comprises the complete set of reference materials—not the printed words alone. The effectiveness of this approach has been clearly proved in the pilot classes.

Reading sections of the text require concentration by the students, but these are short enough to be read aloud in class if necessary. We feel that ability to read a logical development of a topic is an important part of the student's education in general and his science education in particular.

Simplicity and durability requirements in the laboratory equipment are even more stringent in the IPS course than in the PSSC. Furthermore, many junior high schools do not have adequate laboratory facilities. Therefore, all experiments are designed to be performed in a regular classroom with flat tables and one sink.

Course content is rather restricted to provide sufficient time for a study in depth. Essentially the IPS course deals with the basic properties of matter and leads to the development of the atomic model of matter. It thus develops the basic language that students must have to make any progress in the modern study of natural sciences. □

Harvard Project Physics

by Gerald Holton

HARVARD PROJECT PHYSICS is developing a new one-year physics course to meet the contemporary needs of high schools and junior colleges. Physicists and science educators for some time have wanted a coherent, tested course for national use alongside other previously developed courses. Moreover there is a desire among physics educators to halt and reverse the decline in physics enrollment. New course materials and organization are necessary to exploit effectively recent developments in educational philosophy and techniques. In particular the trend toward recognition and response to individual differences as well as availability of films, transparencies, film strips, film loops, programed student guides and new laboratory equipment and experiments require changes in course structure for best utilization.

The Project Physics course has been developed by a large number of distinguished people from all parts of the US, participating full time while on leave at Harvard University or as consultants. Directorship of the project has been divided three ways among James Rutherford, a former high-school teacher and a fine administrator, Fletcher Watson of the Harvard graduate school of education and a former astronomer, and myself, a physicist and historian of science. This triumviral arrangement has allowed the project to keep working contact with a whole range of professions from the very beginning.

The group is now slightly more than half through its work. Materials are presently being tried out in 54 schools with 2600 students under carefully controlled conditions. Next year the material will be tried at about 100 schools, half of them drawn at random and induced to use Project Physics. Completion and final evaluation of the project is expected by late 1968 or early 1969.

Aims and objectives

It has been widely held that there is a need for variety in available physics curricula, partly because in a society as rich and diverse as ours there is no reason to be limited to one nationally recognized curriculum, and also because there are course aspects that need to be emphasized but have been neglected. Harvard Project Physics is a response to this need for diversity.

The whole problem of physics-course enrollments is nothing short of a national emergency. Out of two and one-half million high school seniors, more than two million take no physics; that is, more than 80% take none. As far as PSSC is concerned, though it is excellent for the kind of student it was meant for, still only about 4% of seniors took this course in 1964–65, according to recently released US Office of Education figures. As Susanne Ellis shows in her article on page 75 of this issue the decline in physics enrollments is extending into the colleges. Clearly if physicists are not to lose contact with their society, some way must be found to overcome this trend. This job is far from done!

Trying to reverse the trend of decreasing enrollments in physics may not, by itself, justify the labor that goes into such an effort. But there are also social and individual reasons for seeking such a goal. High-school seniors are making crucial career decisions and if they have the talent and inclination for careers in science, it is important that they be given a chance to find this out by exposure to a broad-based physics course.

Beyond the purely professional considerations, some acquaintance with science and scientific thinking is becoming increasingly essential in our more and more technological society. Without this acquaintance, young people will find it increasingly difficult to profit from in-plant training, technical home-study and all the other

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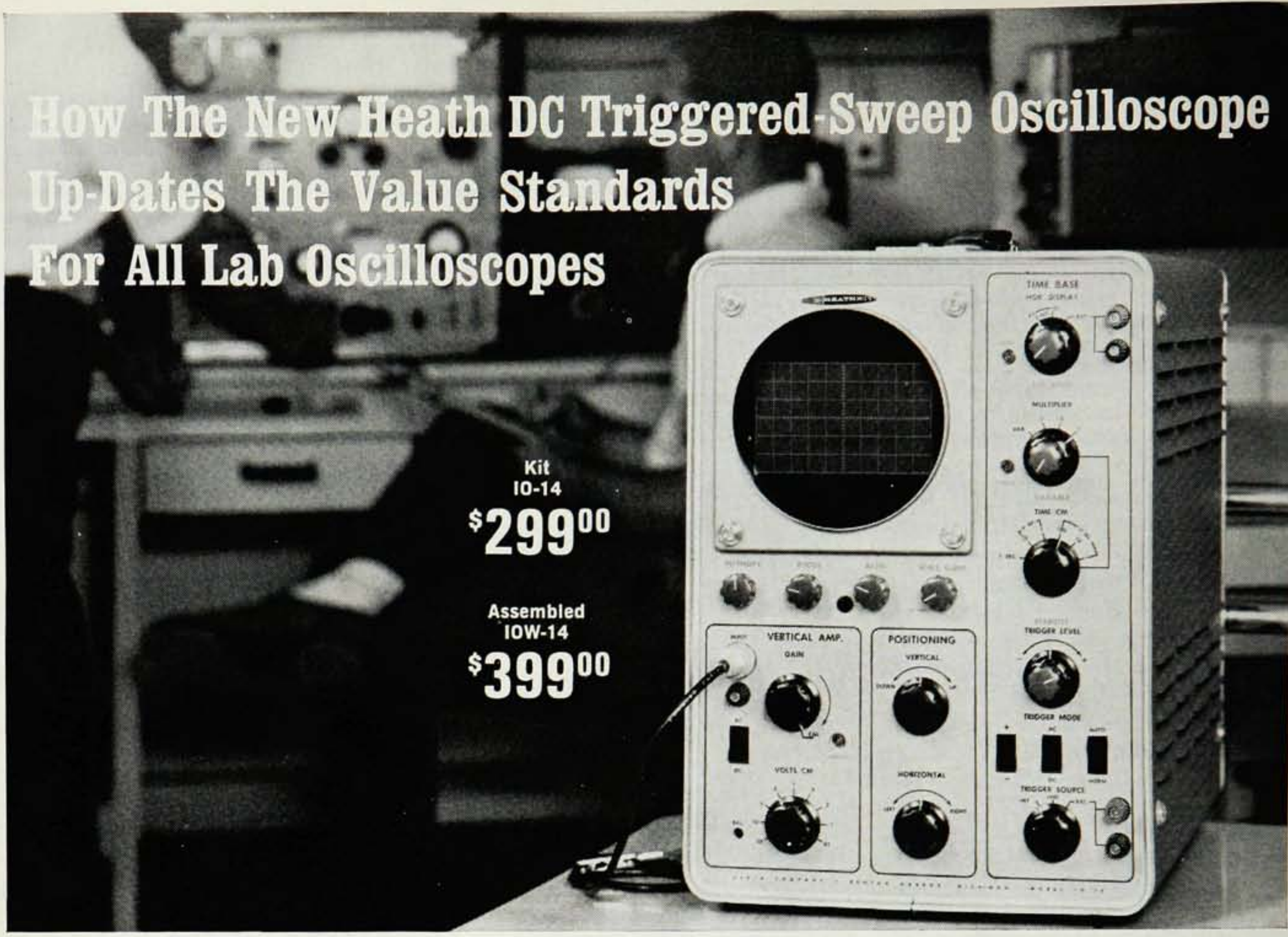

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There is also a group of students who go on to college and study the humanities or social sciences while avoiding the physical sciences. It is important and possible to reach more of them in high school, and to show them that physics is neither an isolated bloodless body of facts and theories with mere vocational usefulness nor a glorious entertainment restricted to an elite of specialists. We can and must show them that physics now lies, in the words of I. I. Rabi, "at the core of the humanistic education of our time."

Course outline

Harvard Project Physics is developed around six basic units. First the student is introduced to the concepts of motion. With this grounding in the elements of kinematics, he then studies motion in the heavens. This material forms the basis for a development of the scientific consequences of the triumph of mechanics—the conservation laws of momentum and mechanical energy, the first law of thermodynamics and some discussion of the second law.

The fourth unit presents electricity and magnetism in the context of fields at rest and in motion, and traces the subsequent failure of the mechanistic view. The origins of the new physics are shown and the atomic and nuclear models of matter are introduced in the last two units. The chemical basis for the atomic model is examined and electrons and quanta are discussed. The Rutherford-Bohr model of the atom provides a bridge to a treatment of the nucleus, from radioactivity to nuclear energy and elementary particles.

From time to time the connection of physics and other sciences and science to other endeavors is emphasized. This is a realistic procedure; after all one cannot survive a single day in a real physics laboratory on physics alone. One may well need mathematics and chemistry and metallurgy and technology, as well as the commitment of society as a whole.

In this course physics is related to the broader scope of human affairs principally through reading materials outside the text. This is part of our attempt to reduce the usual reliance upon the text. For example, after a discussion of the Newtonian synthesis and celestial mechanics, the student has available materials that point out how Newton's work helped to bring a wholly new sense of intellectual possibilities into the age that he shaped. Again, in discussing the laws of thermodynamics, we take the opportunity to make the point, in not many pages of the student guide and more extensively in the book of associated readings, that the heat engine, like many other technical by-products of scientific work, is not a device operating in a vacuum of social consequences. Rather it helped to alter the structure of Western society during the Industrial Revolution and affected the imagination of poets and theologians no less than of mathematicians.

We can and must show them that physics now lies . . . "at the core of the humanistic education of our time."

New course materials and organization are necessary to exploit effectively recent developments in educational philosophy and techniques.

Course materials

We have attempted to reduce traditional dependence upon the student text by adapting modern communication media to modern educational needs. The result has been an extensive array of materials and guides for teachers on their coherent use. For the teachers we are planning 16-mm sound films that help in the necessary teacher training. For the actual teaching itself there is a teachers' guide for each unit which discusses the use of the other components such as the laboratory experiments and demonstrations and films, as well as the physics and history of science background. Each unit has about 10 transparencies for use by the teacher in his lectures or discussions. Also there are more than 80 film loops in various stages of completion, which can be used by the teacher or the students together or individually. These 2-4-min, 8-mm loops have been so successful in classroom tests that production of an additional 100 is planned.

For each unit the students will have available a guide or text usually consisting of four chapters. The student guides are supplemented with approximately 12 programed instruction booklets and six books of selected readings. Fifty laboratory experiments and demonstrations have been prepared with newly developed equipment. Film strips of the same material as in the teachers' transparencies are available to the student so that he will be able to study this material by himself.

It is an essential point for this project that it is planned to produce a course that can be finished in one year in any school. An experienced teacher or one with an above-average class should be able to finish the material of the six basic units in six to eight months leaving one to three months for enrichment by means of units chosen by the teacher himself. To provide a choice of topics for enrichment, supplemental units are being prepared in addition to the six basic units. Incidentally, the production of a basic course that leaves the choice of up to one-third of additional material in full control of the teacher provides a course in which decisions are far more teacher-centered than has sometimes been true.

Innovations of HPP

What are the changes introduced by Harvard Project Physics? Most apparent, perhaps, is the extensive use of the systems approach to the production of a new curriculum. We have brought to bear on the problem of curriculum formation, talents from a wide variety of professions—physicists, high-school teachers, chemists, historians of science, philosophers of science, astronomers, experts in publishing, scientific-manpower experts. We have organized these talents into a group to deal with scheduling the use of the various media, a group working on research and evaluation, and one that is concerned with teacher training.

The progressive move away from the idea that a text should carry so much of the load as far as a student is concerned, reflects our use of a systems approach. The burden of teaching does not remain with the printed word of the text when this turns out not to be the best channel for learning.

As pointed out already we have attempted to show the cultural and humanistic roots of physics when this can be done on this level. By avoiding over specialized topics and making use of history of science as a pedagogic aid where appropriate, we are seeking to make the student aware of the humanistic aspects of physics.

And last but not least, we are seeking to refine and accentuate the teacher's role and to build into the course enough flexibility so that it can be a model for dealing with diversity. In this way we hope to respond positively to the major new developing interest in educational philosophy today: the preservation and exploitation of individual differences both in teachers and in students. The end result, one may begin to hope on the basis of encouraging feedback from trial classes during the past two years, will be a modern course that helps to bring more physics to more students. □

Engineering Concepts

by Edward E. David Jr and John G. Truxal

In the fall of 1963, the National Science Foundation held a meeting in Washington, D. C. to explore the question: "Are there desirable approaches to the study of physics and physical science in high schools other than those presently available?" Discussion was spirited, but most of the conferees left convinced that a "pluralistic" approach to high-school physics could go far in bolstering lagging student enrollments in physics. It seemed reasonable that the enormous range of student interests, inclinations and aptitudes could be well served by several alternative approaches. Some of us who attended that exploratory conference shared a strong interest in engineering. We thought that the engineering viewpoint offered an opportunity for a radically different approach.

This viewpoint, oversimplified to be sure, is merely that engineering is synthesis oriented. It is inspired by Bacon's view that knowledge can often be used to better man's lot. It is from this notion of *knowledge and relevance* that the Engineering Concepts Curriculum Project was begun. A group of seven met several times during fall, 1963 under the sponsorship of the Commission on Engineering Education (a nonprofit organization dedicated to the development of new educational resources) to examine the idea further.

Development of ECCP

First and foremost, what should be taught? The multitude of man's artifacts, which so influence his life today, is indeed impressive. However, to teach about some particular artifact or artifacts without a unifying framework would be of little lasting value to many students. Rather, we managed to identify certain generalities common to many artifacts.

Some of these generalities were new to the list of concepts usually taught in high-school physics. The additions were largely oriented toward systems and included concepts such as stability, feedback and optimization. Also, there was the idea of modeling as a technique for aiding human thought, for predicting, and for fashioning and tailoring devices, processes, structures and systems. One culmination of modeling comes in the creative design of today's grand artifacts which, though immensely complex, are understood deeply since they are created by man himself. This kind of understanding of complexity is rare, but it is extremely powerful. These ideas form the framework on which the course is based. As a descriptive title, "The Man-Made World," was suggested and is still in use.

Our ideas were not entirely original, to say the least. Many educators and scientists have been urging approaches of this general kind. Prominent among these people is Alvin Weinberg, director of the Oak Ridge National Laboratory, who stated in the 6 Aug. 1965 issue of *Science:* "But education at the elementary level of a field is too important to be left entirely to the professionals in that field, especially if the professionals are themselves too narrowly specialized in outlook. Instead, curriculum reform should be strongly influenced by disciplines bordering the discipline being