The COMPLEMENTARY ROLE of PHYSICS and MECHANICS in ENGINEERING EDUCATION

By Glenn Murphy

A report of a conference held between teachers of engineering mechanics and those teaching physics to engineering students. The meeting took place at New York University's Gould House, January 23–26, 1955.

AMONG the many ideas being explored in the continual attempt to improve engineering education is that of eliminating unnecessary duplication of effort in allied departments. At the outset, it is evident that some duplication of subject matter, particularly as it relates to principles, is essential. However, undue duplication robs the student of the opportunity to receive instruction in additional areas which may be vital to his continued growth and development throughout his professional career.

One possible area of duplication is that of mechanics as it is usually taught in the department of physics and later in one or more departments in engineering. To explore the teaching of mechanics, the National Science Foundation sponsored a conference of about twenty of the leading educators in the field. The conference was organized by the Physics Division and the Mechanics Division of the American Society for Engineering Education under the guidance of F. L. Singer of the Engineering Mechanics Department of New York University, who is also current chairman of the Mechanics Division of ASEE. The conference was held at the Gould House of NYU 23–26 January 1955.

In evaluating the instruction in mechanics as it has been and is given by physics departments, the group found that in the majority of schools the courses in physics are considered prerequisite to engineering mechanics. As a result the student is exposed to a barrage of ideas, concepts, principles, formulas, and solutions to problems at a rate well above that at which he can be expected to absorb them simply because so much material must be covered in so little time. The students quickly learn that grades are assigned on the basis of problems solved in examinations and problems are solved by formulas. Consequently, they place the emphasis on formulas and seldom attain the depth of understanding of principles that is desirable and increasingly essential. This is particularly true when the instruction is in the hands of graduate assistants.

As the conference progressed it became clear that the function of the first course in physics in an engineering curriculum should not be that of serving as a prerequisite to mechanics and other engineering courses. Instead, the course should be directed toward giving the student an understanding of the concepts and principles that are basic in our physical world. Applications of the principles in the physics department should be directed in such a way that the student will develop confidence in his reasoning ability, and his ability to arrive at correct conclusions when working with phenomena the details of which are not directly apparent.

In the physics course the emphasis should be on synthesis, or the building up of an understanding of laws and principles governing physical phenomena. On the other hand, the primary objective of the courses in mechanics in engineering is that of predicting the behavior of real engineering systems. Consequently, the emphasis in engineering mechanics will necessarily be on analysis and problem solving rather than synthesis and principle development.

With these objectives the initial course in physics for engineers will not be subordinated to engineering mechanics in functioning as a prerequisite. The training in mechanics in physics departments and in engineering was visualized by the members of the conference as proceeding most advantageously in parallel, rather than in sequence, with numerous cross ties to lend mutual support, strengthening, and balance. In this way the first course in physics may be better designed to serve as a base for later courses in atomic physics or nuclear physics for which increasing demand is expected to develop. With the broader scope of engineering physics as visualized by the conference, it is clearly evident that the instruction in the first course in physics for engineers must be in the hands of the most capable teachers who will give it sympathetic and dynamic treatment, and that it not be relegated as a chore for graduate assistants.

In considering solid-state physics as a part of the physics program, it was brought out that the engineers are interested in a course at the junior or senior level that will give the students some insight of the behavior of materials so that the development of courses

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in engineering materials can proceed along other than strictly empirical lines. It was conceded that classical solid-state physics is at the graduate level for physics majors.

Instruction in mathematics as it related to the problem was considered and led to the conclusion that the student should be introduced to the concepts and a working knowledge of calculus as early as practicable in his college curriculum. It is equally important that the mathematics then be used in the engineering courses.

The discussions culminated in the following statement which was adopted unanimously by the members of the conference.

"The conference found, after a careful analysis of the statements of the objectives of undergraduate instruction in both physics and engineering, that the objectives are not competitive in scope but actually complementary when the courses are properly planned and taught. It cannot be overemphasized that the instruction by physicists will provide the engineering student with an understanding of physical phenomena basic to much of his later studies. On the other hand, the objective of instruction in mechanics by engineers is to achieve professional competence in the practical solution of problems encountered in engineering.

"We conclude, therefore, that there is an essential difference in the approaches to mechanics by the physicist and the engineer. There is a place and, indeed, a need for both of these approaches to the teaching of mechanics. The different objectives should continually be recognized and used as guides in planning courses.

"Objectives of Physics Instruction in Mechanics. The primary objective of physics instruction in an engineering or scientific curriculum is to provide the student with an understanding of the physical principles that describe nature, of how these principles have evolved, and of their scope and limitations. Such an undertaking must begin with the study of Newtonian mechanics. Great emphasis should be placed on the conservation principles. The generalization of these principles along with associated concepts has formed the basis for modern physics, including such special branches as atomic and nuclear physics and the physics of the solid state. With this approach, it is neither practical nor desirable in the physics course to devote attention to the development of facility in detailed application of physical laws to practical problems encountered in engineering practice. Stimulating problems should be selected with a view to illustrating physical principles, and it is essential that they be accompanied by a challenging laboratory experience. These courses, approached in this manner, should provide an adequate base for the student's continued scientific growth.

"In order that the study of Newtonian mechanics be effective in setting the stage for a proper understanding of the concepts and methods of modern physics, it must be recognized that a significant difference exists between the older physics and most of modern physics. In modern physics a large amount of theory is often interposed between observations and the conclusions based on them. Nevertheless, the pedagogical approach in which macroscopic observations are used directly as a guide in building theory must first be employed, as it can in mechanics; the student must later be led to the present day methods of inferring conclusions regarding phenomena not directly observable. These methods are in fact used in kinetic theory, optics, and electricity, as well as in many topics of modern physics.

"To achieve this goal, the role of conservation laws in mechanics and electricity can hardly be over-emphasized. The study of mechanics should also include the dynamics of systems of particles, wave propagation, standing wave systems, etc. Valuable for later work in modern physics will be the study of resonant systems, such as the mechanical harmonic oscillator, accompanied by demonstrations or discussions of similar resonant systems in electricity, nuclear-magnetic resonance, and examples from acoustics and optics. It is in this spirit that instruction in mechanics makes a significant contribution toward the understanding of phenomena in atomic, nuclear, and solid-state physics.

"Objectives of Instruction in Mechanics by the Engineer. The prime objective of instruction in engineering mechanics is to provide the student with a useful understanding of the methods and principles needed to design and predict the performance of real engineering systems and structures. The preparation of engineers for creative design should be kept always in mind. Creative design requires as much ingenuity, imagination, and resourcefulness in the application of physical laws and principles and in making them useful to man as is required in the original formulation of them.

"In order to solve real problems of the great variety and number that are presented to the engineer, it is necessary that he become proficient in a systematic method of problem solution. Consequently, instruction in methodology is an essential part of engineering mechanics. Instruction must include ample emphasis on the following operations which are basic to engineering analysis.

"The student must learn to identify the essential elements and characteristics of each specific engineering problem. Is it, for example, on involving statics or dynamics, rigid or deformable bodies, a conservative or a dissipative system? He must be able to select relevant information and data and recognize those which are not pertinent. In doing this an ideal model must be created and the problem made amenable to solution. The results based on the idealized model must next be interpreted in the light of the original real situation. The engineer must form a judgment of the extent to which he can rely on the results obtained on the ideal model, and finally he must be able to communicate this to others in suitable and usable form.

"The engineer must devote major emphasis to the formulation and evaluation of his problem quite apart from the necessary analysis. Instruction given the engineering student should reflect this fact.

"It is in this spirit that the instruction in engineering mechanics assumes a significant role as a springboard to a truly professional attitude and approach to all engineering situations.

"*Objectives of Instruction in Solid-State Physics.* Before considering the place, if any, of solid-state and nuclear physics in engineering curricula, it is desirable to consider the activities of physicists in these respective fields. In nuclear physics, the physicist is concerned with the quantitative behavior and structure of nuclei, the nature of forces involved between nuclear particles, and the interaction between nuclei and radiation. In solid-state physics the physicist is seeking to develop an understanding of the properties of solids on the basis of their atomic constitution.

"To take part in the current activities in either of these fields requires a background and a working knowledge of quantum mechanics as well as of the general principles and conservation laws of classical mechanics and electrodynamics. Such knowledge can be obtained only through several years of study, generally including graduate work. This conference is convinced that there is no short-cut by which this knowledge can be given to undergraduate engineering students by means of a one- or two-semester course in modern physics.

"On the other hand, an introductory course of one or two semesters' duration covering some of the topics mentioned above could be given following the general physics course. Such a course should broaden the training of the undergraduate engineer.

"It is the conviction of this conference that the time should not be taken from that now devoted to an understanding of the fundamental principles of mechanics, which should be required of all engineers. Instead, the conference recommends that the basic physics course be strengthened by greater emphasis on fundamental classical principles and conservation laws, and by an introduction to wave and quantum concepts. Inclusion of these topics is an essential introduction to the later study of solid-state or nuclear physics. It is also recommended that, as far as possible, such particles as electrons, protons, and neutrons be used in the elementary physics course to illustrate general dynamical principles. In the case of existing two-year physics courses, it is the belief of the conference that some concepts of modern physics can be introduced without requiring additional time. In the use of one-year physics courses, an extension of time of at least a semester is recommended.

"*Mathematics Instruction as Related to Mechanics.* It is urged that the concepts of calculus be introduced in engineering curricula as soon as possible, preferably in the freshman year, and used in physics and engineering as soon as feasible.

"*Conclusion.* In comparing the different objectives and points of view of instruction in mechanics by physicists and engineers, it should be emphasized that the physicist uses problems and examples from experimental physics essentially for the purpose of developing by the inductive method those concepts and principles which it is his objective to have the student understand. The engineer, on the other hand, uses certain concepts and principles for the purpose of achieving the solution of practical engineering problems. This distinction should determine in a major way the essentially different character of illustrative material used in each area.

"If instruction in physics and engineering mechanics follows the objectives outlined, it appears that, although some duplication of content is inevitable and even desirable, the real duplication in terms of influence on the engineering student will be negligible. On the other hand, if instruction in physics follows in any major way the direction of application to engineering situations, or if instruction in engineering mechanics fails to emphasize the professional engineering approach, then this duplication will result in a serious waste of time.

"Consequently, it is evident that the preservation of the two different but mutually supporting points of view of the physicist and the engineer is a necessary condition for maintaining the progressive program of engineering education, which in these critical days is of vital interest to the entire nation.

"Finally, the conference recognizes that progress occurs through continuing experimentation, and therefore recommends that such an attitude be encouraged in the teaching and the curricular arrangements of physics and engineering mechanics."

Throughout the conference there was the recurrent theme that the improvement of engineering education, which is of vital concern to all, can be achieved through the enthusiastic participation of individual staff members in coordinated local programs of evaluation and improvement of teaching of engineers. While a conference of the type held at the Gould House can indicate general patterns of improvement, the details which constitute the real benefits must be worked out at each school in harmony with the particular local situation. It is only through continual experimentation toward improvement at the individual institutions that over-all progress will be made.

A detailed report on the conference was the subject of one session at the annual ASEE meeting at Pennsylvania State University in June. The participants in the conference were:

Dean J. W. Buchta, University of Minnesota
Prof. J. W. Cell, North Carolina State College
Prof. P. F. Chenea, Purdue University
Prof. W. L. Collins, University of Illinois
Prof. J. P. Den Hartog, Massachusetts Institute of Technology
Dean H. Fletcher, Brigham Young University
Prof. N. Frank, Massachusetts Institute of Technology
Dean L. E. Grinter, University of Florida
Dr. G. H. Hickox, National Science Foundation
Dean E. Hutchisson, Case Institute of Technology
Dean R. B. Lindsay, Brown University
Prof. J. L. Meriam, University of California
Prof. Glenn Murphy, Iowa State College
Prof. M. S. Plesset, California Institute of Technology
Prof. J. J. Potter, Texas A and M
Prof. J. A. Sauer, Pennsylvania State University
Dr. Raymond Seeger, National Science Foundation
Prof. F. L. Singer, New York University
Prof. I. S. Sokolnikoff, University of Calif. at Los Angeles
Prof. W. B. Stiles, University of Alabama
Prof. D. Williams, Ohio State University