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THEORETICAL MECHANICS IN ENGINEERING SCHOOLS

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As indicated by the title, it is proposed to deal with theoretical mechanics chiefly from the engineer's point of view, but in modern engineering colleges it is impossible to draw a sharply defined line between the education of engineers and physicists. The modern engineers of advanced scientific standing, notably research engineers of all professions, are required to be physicists as well as engineers. Moreover, a high-grade technical school seems to afford the best environment for the education of physicists, while physics forms one of the most important disciplines in the education of engineers. We shall therefore on several occasions refer to the requirements of the physicists.

Mechanics is commonly subdivided into two parts, theoretical and applied, but it is proposed here to deal in particular with the former, which bears a close relationship to mathematics and, in its widest sense, forms the main body of what is usually called applied mathematics. Often the two parts of mechanics, the theoretical and the applied, are dealt with and taught together, but it will be here attempted to distinguish rather sharply between them, although it is not always easy to do so.

The name applied mechanics is misleading and confusing. As commonly understood this science deals only with the application of theoretical mechanics to structural and mechanical engineering, but it might with equal right be said to deal with other branches of engineering where theoretical mechanics in the modern and wider sense is applied to the same extent. We shall not, however, try to widen the meaning of the term applied mechanics beyond common usage, but rather extract that which does not belong to it, for as taught at present it comprises much of an abstract nature which properly belongs under theoretical mechanics. The name technical mechanics (technische Mechanik) would seem better than applied mechanics, being more readily distinguished from theoretical mechanics.

We divide the science of theoretical mechanics into four sections in accordance with the nature of the bodies with which it deals: (1) Mechanics of a particle and of rigid bodies; (2) mechanics of elastic bodies; (3) mechanics of fluids, and (4) mechanics of gases. In the following we shall refer to these sections by their numbers.

Under each heading we consider separately equilibrium and motion, and the latter falls into two parts according as we consider motion with or without regard to the forces which produce it. We have thus a further subdivision into three parts: (a) Statics; (b) kinematics, and (c) kinetics or dynamics.

In accordance with this definition we include under theoretical mechanics the following subjects:

Statics, kinematics and kinetics of a particle and of rigid bodies; theory of elasticity; elastostatics and elastokinetics; plasticity; hydrostatics, hydrodynamics and aerodynamics.

Vector analysis and calculus of variation in their application to mechanics may properly be added to this list, but the abstract theory of these sciences should be taught under pure mathematics.

The list is necessarily somewhat arbitrary, but it gives an idea of the range of subjects, some of which are indeed difficult to distinguish from the applied sciences to which they form the stepping-stones.

For the sake of clearness we shall mention some of the subjects which are here considered to be outside of the province of theoretical mechanics: theory of structures, hydraulics, dynamics of gases, thermodynamics, acoustics, ballistics, capillarity, etc.

Theoretical mechanics is the foundation of all physical sciences and forms the intermediate link between pure mathematics and the various engineering sciences as well as physics. It is like pure mathematics a fundamental subject in engineering schools; it should be treated as such, and the instruction should proceed along the same lines. First a foundation of the elementary parts of the subject should be given to all students as soon as they have the necessary mathematical preparation, preferably in the freshman year. In the later years the more advanced parts should be taught, each profession being allotted what is necessary for its special purpose, without, however, disrupting the continuity and harmony in the instruction of the science as a whole.

In American engineering or scientific schools theoretical mechanics is rarely taught separately as such, at least, not in a complete manner; in fact, in many cases it does not appear on the schedule at all except in the form of special courses adjusted to the various engineering professions.

Under the heading of physics there is given in many schools a course called mechanics with the specific aim of preparing students for the study of physics. It comprises the most elementary parts of theoretical mechanics, but is not always well suited as a foundation for other subjects, for which purpose it is not directly intended. It is often repeated in a somewhat different and more extended form in the lectures on applied mechanics, being here designed to cover the elementary parts of sections (1) and (2).

In theory of structures, which is in fact a branch of applied mechanics, parts of section (1) are apt to be given. The same is true of certain subjects under electrical engineering. Under hydraulics is given a course in hydrostatics and flow of water.

Advanced parts of theoretical mechanics are often taught not only under the heading of mechanical engineering and of mathematics, but also and perhaps chiefly in physics (higher dynamics, hydrodynamics and elasticity) and in electrical engineering (mechanical forces due to magnetic fields, theory of vibrations, sound waves). Fragments of this science are also taught in the departments of civil engineering (the fundamentals of statically indeterminate structures, plasticity in connection with soil mechanics), in aeronautical engineering (hydrodynamics and aerodynamics) and in naval architecture (wave motion).

This description may not fit all engineering schools in this country but is believed to be fairly representative. On the whole it appears that in the United States theoretical mechanics is too often taught in a scattered way and as a subsidiary science, of which each department gives only what is required for its specific needs without much regard to unification of the science.

The subject is rarely given under its own name and then only in parts. In many cases no special teachers are assigned to it in such a way that they can devote all their energy to it. No one is responsible for imparting to the students a well-rounded course in theoretical mechanics giving a complete presentation of the subject within the limits set by the requirements of the various technological courses.

It is clearly impossible to do justice to a science under these circumstances. Overlappings and gaps in the instruction unavoidably occur, insufficient emphasis is placed on fundamental concepts, and what perhaps is worse, the science suffers in standing and prestige. This must react unfavorably upon the attitude of the students, who can not be expected to realize the importance of a subject the name of which they have perhaps never heard and which is presented to them as an incidental, a handmaid to other sciences.

Turning now to European schools, it appears that ordinarily theoretical mechanics is ranked as equivalent to mathematics in importance and is regarded as one of the corner-stones of engineering education, although certain parts of (1) and (2) may be given under applied mechanics or under mathematics in some schools. Also parts of (3) and (4) are in many cases taught as belonging to the applied sciences. Yet greater portions of this science and especially sections (1) and (2) are quite commonly listed as separate and independent subjects, certainly more so than is ordinarily the case in this country. This is indicated by the names commonly given to the subject. In England it is taught under the names of applied mathematics, theoretical mechanics, analytical mechanics or simply mechanics; in France under the names of mathématique appliquée, mécanique analytique or mécanique rationelle. In Germany it is called angewandte Mathematik, rationelle Mechanik or Mechanik. In the "Handbuch der Physik,"[1] which is a monumental work of twenty-four volumes, theoretical mechanics is shown in its true perspective. The entire subject, as defined above, is here given in volumes V, VI and VII, preceded by a résumé of pure mathematics in Volume III and followed by the works on physics proper.

The remark is often heard that graduates from European technical colleges who continue their studies in this country are better equipped to attack technical problems mathematically than are American students of equal standing. Since many of those European students come over on scholarships, they are probably picked men so that it is difficult to judge whether that statement is true in general, but if it is, it is believed to be due not to superior mental capacity of the European students or to inferior ability of our teachers, but chiefly to the more complete and systematic training which European students get in theoretical mechanics.

The reason why theoretical mechanics has been given such a subordinate position in American engineering schools is not clear, but probably it is due largely to the rapid development of these schools, which have been working under a great pressure from the industry and often under economic difficulties. The demand for results, for turning out young engineers as quickly as possible, has forced the pace.

But conditions are changing, technical colleges do not have to fight so hard for their existence, and moreover, in recent years a great development has taken place in theoretical mechanics, which has acquired greater importance than ever before. We need only refer to the advances made in theory of elasticity and plasticity, in hydrodynamics and aerodynamics and the application of theoretical mechanics to electrical engineering, thermodynamics, acoustics and all branches of theoretical physics. In this connection we may mention some of the names of the many eminent workers in this field: Love, Lamb, Appell, Schrödinger, Heisenberg, Prandtl, von Mises, von Kármán, Levi Civita, Nádaj and Timoshenko.

It is time that theoretical mechanics be given its appropriate place in the curriculum of American engineering schools. As a means of training in scientific methods of thinking and as a mental discipline introductory to research work, the subject is probably unequaled.

One of the foremost German mathematicians, Dr. von Mises, in an introductory article to the *Zeitschrift für angewandte Mathematik und Mechanik* on the occasion of its first issue, made the following statement concerning theoretical mechanics:

> More than any other science it forms an indispensable foundation for creative engineering. Mechanics, which by Leonardo da Vinci was called the paradise of the mathematician, has become for the modern engineer the most comprehensive field of work, the laborious exploitation of which is left almost entirely in his hands, and from which he will reap ample rewards, even although only through hard work.

If properly taught, a course in theoretical mechanics will have great cultural value. A brief historical review of the development of this science should be given, its function as an indispensable tool for progress in all physical sciences and its profound influence on our fundamental scientific concepts should be explained.

Theoretical mechanics should be unified, harmonized and treated, not as a subsidiary, but as a science in its own right and as a fundamental in engineering education, ranking with pure mathematics and physics. It should be listed under its own name, have its own staff of teachers, preferably organized in a special independent department, and should be taught as a separate subject. Laboratories should be available for the department and the teachers should be allowed time for research.

Great as are the achievements of American engineers, it is believed that they will be still greater with such an important improvement in their training. Modern technical development calls for more refined methods of construction and hence more advanced analytical knowledge and more research. Engineers now, more than ever before, are confronted with entirely new problems. They are required to do things that have never been done before, whether in

[1] H. Geiger and Karl Scheel, 1926–29.

magnitude or in kind, and in such cases, when previous experience fails, they are thrown back on experiments and theoretical analysis, where a thorough knowledge of theoretical mechanics is indispensable.

A reform in the engineering schools as here suggested will undoubtedly meet with many obstacles. Administrative arrangements may be somewhat dislocated, text-books may have to be revised, new teachers may have to be engaged and instruction may suffer somewhat in the period of transition, but the course in theoretical mechanics may not need to be longer or more difficult than at present. What is proposed is chiefly a rearrangement of courses, with an addition of such matter as will make the resulting courses, each of them, more self-contained and complete. By avoiding repetitions time will be saved, and by a more complete and logical presentation of the subject, including a full explanation of fundamental concepts, it is believed that it will be easier for the students to grasp. The reform may perhaps be best carried out by an evolutionary process beginning with the establishment of a small department in theoretical mechanics. This department might gradually take over the scattered courses now given under various departments and strengthen them by a process of unification and completion. Thus the department would gradually grow in magnitude and importance. This method may be preferred in particular where the services of a teacher eminent in this science are available, to whom the task of building up the new department can be entrusted.

When fully developed, such a department should have charge of the entire range of subjects specified under sections (1) to (4) above, but besides the classical mechanics it might also properly include wave mechanics and mechanics of relativity. It should work in close cooperation with the department of mathematics on one side and with the various professional courses including physics on the other side.

With the adoption of such a program in the American technical colleges, it should be possible not only to equal but to surpass the achievements of corresponding European institutions.

PLANT QUARANTINE

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THE idea of quarantine[1] had its inception in connection with the attempts on the part of early Europeans to exclude and prevent the spread of dreaded plague or black death. Venice inaugurated such a restrictive measure as early as 1348, which was followed by other European countries. In spite of the long experience of human health quarantine, England did not establish her first health quarantine until 1710, and delayed in passing the Public Health Act until 1896. Thus we see that many years have been required to perfect the present highly efficient and valuable public health measures now maintained by all the progressive nations of the world, and accepted by all their citizens. It is my firm belief that plant quarantine will, in a much shorter space of time, attain a similar place in the affairs of civilized peoples. Fundamentally it is as sound to protect the plant life of a country from the constant encroachments of insect depredators and plant diseases as it is to protect human health. An abundant and available food supply is as essential to human beings as is health and almost as personal, because it affects the livelihood of every individual, since the prices and availability of food are largely regulated by supply.

In view of the fact that there is so much general misunderstanding regarding plant quarantine, this article is written with the aim of presenting the claims of this young member of the administrative family.

In the first place, quarantine is a police power. This makes it very objectionable to certain minds. Anything that questions the free rights of individuals to act as they please is ever open to criticism. Law enforcement is always a difficult task, and even the most thoroughly qualified, tactful and resourceful official has great difficulty in handling the public as agreeably as is expected. Nearly all the complaints that arise from quarantine originate in regulatory and law-enforcement proceedings. This fact must be recognized at the outset. In this respect quarantine is no different from other measures enforced by due processes of law.

Plant quarantine, like health quarantine, was born of necessity—it was not the child of speculative philosophy, nor was it an ethical experiment. The early introduction into this country of such serious pests as the codling moth, San José scale, citrus scale insects, cotton boll weevil, pear psylla, cabbage worm, gipsy and brown-tail moths and many stored-product

[1] The term *quarantine*, literally meaning a period of forty days, was originally designated as the time during which a ship, suspected of being infected with a serious contagious disease, was obliged to refrain from all intercourse with the shore. It has always come under the powers of the police.