ENGINEERING APPLICATIONS OF HIGHER MATHEMATICS; PART I. PROBLEMS ON MACHINE DESIGN

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OF

HIGHER MATHEMATICS

BY

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PART I.

PROBLEMS ON MACHINE DESIGN

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FIRST THOUSAND

NEW YORK
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1912

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BOSTON, U.S.A.

PREFACE.

THIS is not a book on calculus or analytic geometry (the market is flooded with them); nor is this a book on engineering or any branch of it. *The book is intended to enable an engineer to make a better and more extended use of higher mathematics in his work.* The purpose of the book may be best amplified by a parable.

In a manual-training school (on the moon) machinist apprentices were taught their trade in the following manner: During the first year they had a highly theoretical course on the subject of various tools used on lathes, planers, boring mills, milling machines, etc. The shapes of the tools were derived and explained in detail on complicated drawings; most general theorems were proved concerning these tools; it was shown how to design these tools, not only for a few simple practical cases, but principally for many hypothetical cases which were supposed to be of some importance on Mars. This latter part of the course was justified on the plea of mental gymnastics. No actual machine-tools were provided in this department and no practice was afforded the student in the use of the tools.

During the next two years the students were required to finish, fit, and assemble the parts of various engines and other pieces of mechanical apparatus. Had they been previously trained in the use of machine-tools, their shop-work would have been much simplified. But their highly theoretical information about tools was of no use to them, even if they had not forgotten it during the summer vacation. At any rate, they did not possess enough manual skill to put even an iron rod in a lathe and turn it down by a millimeter or two. So they preferred to use the old-fashioned chisel and file, and finished most of their parts in a vise. And their teachers acquiesced in this way of doing things, partly because they did not consider it to be their duty to teach the use of tools, since that was a part of the freshman-year instruction and was taught by another department, and partly because, having gone themselves through a similar school, they considered such a lack of correlation in teaching to be inevitable. Some teachers even considered this state of affairs to be a fundamental law of nature, second only to the law of gravitation.

But a heretic, an anarchist, an iconoclast, is sure to appear on the stage sooner or later. Such a one made his appearance one day and began undermining the pillars of the time-honored system. He claimed that it was wrong to instruct freshmen in the theory of the tools, without having applications and practical shop work going hand in hand. His idea was to show the student one or two simple tools and to apply them immediately to finishing a few pieces of work in a suitable machine-tool. In other words, according to this man, *knowledge and skill, or science and art, ought to be acquired simultaneously*. The reformer insisted that with this method of instruction the knowledge gained would become organic with the student, instead of being on the surface only. Besides, said he, modern psychology shows that interest is a paramount factor in education, and applications are always more interesting to an average student than a general theory. He was perfectly willing to grant that with his method, considerably less ground could be covered in pure theory during the first year; but then he claimed that machinist apprentices needed only a few simple tools during the next year's work, and that enough time could be spared later on to give an advanced course in the theory of special and fancy tools to those who desired it. This time could be spared, because the practical knowledge and skill in the use of tools, acquired during the first year, would enable the students to accomplish their shop-work in less time.

While it may seem incredible that mechanic arts should be taught anywhere in the ridiculous way described above, yet it is a fact that mathematics is most universally taught to engineering students in a similar fashion, without any correlation whatever with their profession. The student is first filled with analytics and calculus, as if he expected to become a pure mathematician. Then, very little of this mathematics is used in the engineering courses, partly because the students find it very difficult to follow, and partly because many professors of engineering themselves have not enough grounding in mathematics to feel at ease in it and to make it interesting and attractive to their students. The case is somewhat similar to that of modern languages. The engineering faculties insist that students shall acquire proficiency in French and German, while the students know perfectly well that most of their teachers never read foreign books or magazines. The old saying about the mote and the beam in the eye involuntarily suggests itself.

The heretic who first raised his voice against the unsatisfactory teaching of mathematics to engineering students, and who showed the way out of it, was the noted British engineer and educator, John Perry. In his "Calculus for Engineers" (1897), he limits the theory to a minimum, and gives a large number of examples taken from various branches of engineering. After the student has mastered the differentiation and the integration of a few principal functions and has solved a large number of practical engineering problems, involving these functions, he is led into a more general theory of differentiation and integration, somewhat as it is done in the ordinary courses in calculus.*

Perry's pioneer work, and the so-called "Perry Movement" for teaching mathematics in a practical way, will forever remain important monuments in the history of engineering education. Like any other pioneer work, Perry's Calculus proved to possess some defects when used as a regular textbook, and several similar works by other writers followed it (see Appendix).

This book differs from that of Perry and his followers in two respects:

(1) An elementary knowledge of analytics and calculus is presupposed;

(2) The arrangement of the chapters is according to the engineering topics and not according to the mathematical functions or operations.

It is not necessary to burden a book of this character with the theory of analytic geometry and calculus, because it is treated in numerous excellent works, large and small. The names of some of these books are given in the list at the end of this book. This book

* For a detailed development of this idea in application to all engineering subjects, see V. Karapetoff, "On the Concentric Method of Teaching Electrical Engineering," in *Trans. Amer. Inst. Electr. Engrs.*, Vol. 26 (1907), p. 1441; also his paper "On the Concentric Method of Education in Engineering," *Proc. Soc. Promotion Eng. Educ.*, Vol. 16 (1908), p. 258.

is intended to supply the engineering applications and reasoning not found in the other books. The arrangement by engineering topics permits the giving of more interesting examples than if they were arranged according to the mathematical functions or operations; namely, having explained to the student the purpose of a simple engineering appliance, such as a belt or a flywheel, the teacher can give a number of mathematical examples on these appliances, from the most elementary to the most difficult, without going into engineering practice. In other words, the aim is to enable a teacher of mathematics to give a large number of practical problems, with very little engineering information. All the necessary explanation in regard to the construction and use of each device is given at the beginning of each chapter, so that it is not necessary to look up any books on machine design. However, a list of such engineering works will be found at the end of this book.

In accordance with the above-described purpose and plan of the book, the following possible uses of it are suggested:

(*a*) As a problem book in connection with a regular course in analytics and calculus.

(*b*) As a textbook in a supplementary course (after the completion of a brief course in calculus) taught in the department of mathematics for the purpose of fixing the mathematical operations in the mind of the student and preparing him for the engineering subjects.

(*c*) As a textbook in a course in Engineering Mathematics, taught in the junior or in the senior year by an engineer, to illustrate the methods of engineering research and analysis.

(*d*) As a text- or reference-book in a seminar for graduate students in engineering. Most of these men come