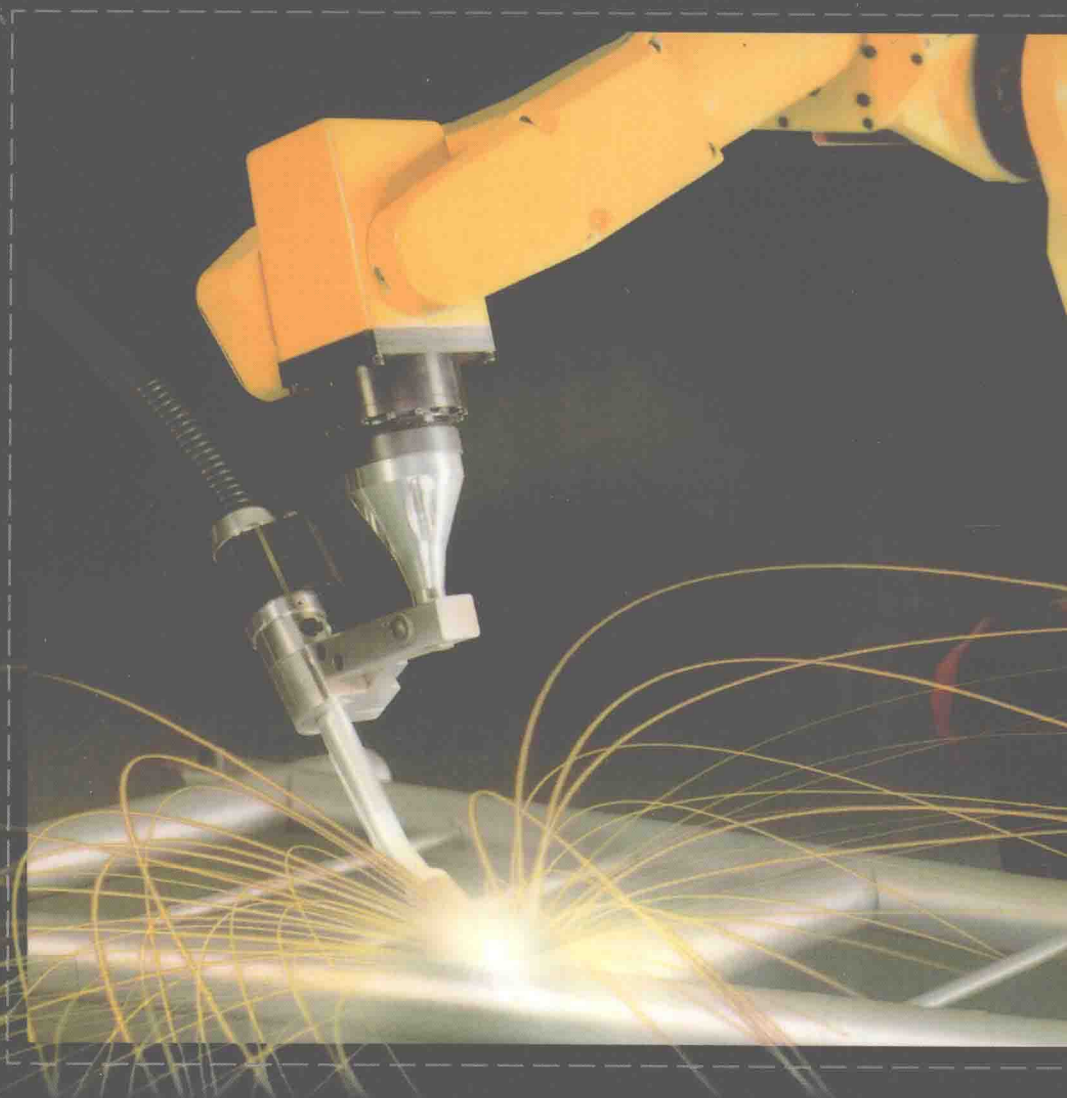


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机械工程导论 (影印版)

An Introduction to Mechanical Engineering

〔美〕Jonathan Wickert 著



西安交通大学出版社
XI'AN JIAOTONG UNIVERSITY PRESS

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Carnegie Mellon University

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内 容 简 介

本书入门性地介绍了机械工程领域所涉及的一些基本知识和分析问题、解决问题的方法。全书共 8 章, 主要内容有: 解决问题能力的训练; 机械零件与机床; 结构与流体力学; 材料和应力; 热和能量系统; 机械的运动和机械设计。各章后有多种类型习题供学生思考、练习, 篇幅适当, 适合我国高等学校机械、能源、动力工程等相关专业的本科一、二年级学生使用。

Jonathan Wickert

An Introduction to Mechanical Engineering, 1st Edition

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序

对刚刚进入大学校门的机械工程类专业学生来讲,“什么是机械工程”、“机械工程包含哪些内容”、“机械工程专业学生要学习哪些课程”等问题常使他们感到困惑,而国内传统的教学体系并没有安排相应的课程来解决这些问题。面向机械工程类专业一年级学生开设“机械程
程导论”课程,将使学生对机械工程有较为完整、系统的认识,明确今后的学习目标和努力方向。

《机械程
程导论》(An Introduction to Mechanical Engineering)是美国卡内基·梅隆大学机械程
程类专业本科一、二年级学生用教材。该书结合大量实例系统地介绍了机械程
程领域所涉及的一些基本知识和分析问题、处理问题的基本方法,内容新颖,与国内机械程
程的教学内容相吻合。全书共8章,第1章为机械程
程专业介绍;第2章为解决问题的能力训练;第3章为机械零件与机床;第4章为结构与流体力学;第5章为材料和应力;第6章为热和能量系统;第7章为机械的运动;第8章为机械设计。通过对本书强调的机械程
程六要素的学习,可以帮助学生对机械程
程领域的发展有一个前瞻性的了解,使他们既见“森林”,又见“树木”,从而激发学生对后续专业课程的兴趣和向往。

本书作者乔纳森·威克特是美国卡内基·梅隆大学机械程
程系教授,多年来一直致力于应用力学、动力学和机械振动等方面的教学和研究。乔纳森·威克特在美国加州大学伯克利分校获机械程
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程系任教,并任美国机械程
程协会(ASME)分会主席。《机械程
程导论》是乔纳森·威克特教授教学和研究的力作。

直接采用国外名校原版教材进行英语授课或双语教学,不仅可以使学生完成本课程的学习,而且对促进教学、教材的改革,提高教与学的英文水平也大有裨益。我们希望通过此种尝试,能够对培养高质量、有国际竞争力的人才打下良好的基础。欢迎读者将使用中的体会和问题反馈给我们。

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西安交通大学机械程
程学院

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2003-09-01

Student Preface

PURPOSE

This textbook will introduce you to the field of mechanical engineering and help you appreciate how engineers design the hardware that builds and improves our society. As the title implies, this textbook is neither an encyclopedia nor a comprehensive treatment of the discipline. Such a task is impossible for a single textbook, and, regardless, my perspective is that the traditional four-year engineering curriculum is just one of many steps taken during a lifelong education. By reading this textbook, you will discover the “forest” of mechanical engineering by examining a few of its big “trees,” and along the way you will be exposed to interesting and practical elements of the profession called mechanical engineering.

APPROACH AND CONTENT

This textbook is intended for students who are in the first or second years of a typical college or university program in mechanical engineering or a closely related field. Throughout the following chapters, I have attempted to balance the treatments of problem-solving skills, design, engineering analysis, and practical technology. The presentation begins with a narrative description of mechanical engineers and what they do (Chapter 1), and an outline of good problem-solving skills, particularly with respect to numerical values and unit systems (Chapter 2). Six elements of mechanical engineering are emphasized subsequently in Chapter 3 (Machine Components and Tools), Chapter 4 (Forces in Structures and Fluids), Chapter 5 (Materials and Stresses), Chapter 6 (Thermal and Energy Systems), Chapter 7 (Motion of Machinery), and Chapter 8 (Mechanical Design). Some of the applications that you will encounter along the way include internal combustion engines, rapid prototyping, computer-aided engineering, robotics, magnetic resonance imaging, jet engines, automatic transmissions, and solar power.

What should you be able to learn from this textbook? First and foremost, you will discover who mechanical engineers are, what they do, and what technologies they create. Section 1.3 details a “top ten” list of the profession’s achievements. Take a look at it now for a glimpse of mechanical engineering technologies, and recognize how the profession has improved your day-to-day life and society in general. Second, you will learn some of the order-of-magnitude approximations and back-of-the-envelope calculations that mechanical engineers can perform. To accomplish their jobs better and faster, mechanical engineers combine mathematics, science, computer-aided engineering tools, experience, and hands-on skills. Third, you will find that engineering is a practical endeavor with the objective of designing things that work, that are cost-effective to manufacture and sell, that are safe to use, and that are responsible in terms of their environmental impact.

You will not be an expert in mechanical engineering after having read this textbook, but that is not my intention, and it should not be yours. If my objective has been met, however, you will set in place a solid foundation of problem-solving, design, and analysis skills, and those just might form the basis for your own future contributions to the mechanical engineering profession.

Instructor Preface

APPROACH

This textbook is intended for a course that provides an introduction to mechanical engineering during either the freshman or sophomore years. Over the past decade or so, many colleges and universities have taken a fresh look at their engineering curricula with the objective of positioning engineering skills and applications earlier in their programs. Particularly for the freshman year, the formats vary widely, and content includes descriptions of “who are mechanical engineers” and “what do they do,” seminars, design experience, problem-solving skills, basic analyses, and case studies. Courses at the sophomore level often emphasize design projects, exposure to computer-aided engineering, principles of engineering science, and a healthy dose of mechanical engineering hardware.

Core engineering science courses (for example, fluid mechanics, strength of materials, and dynamics) have evolved since the post-World War II era into their present relatively steady states. On the other hand, little standardization exists among introductory mechanical engineering courses at the freshman and sophomore levels. With limited discipline-specific instructional materials available for such courses, I believe that an important opportunity remains for attracting students, exciting them with a view of what to expect later in their program of study, and providing them with a foundation of good design, analysis, and problem-solving skills.

OBJECTIVES

While developing this textbook, my objective has been to provide a resource that others can draw upon when teaching introductory mechanical engineering to first- and second-year students. I expect that most such courses would encompass the bulk of material presented in Chapter 1 (The Mechanical Engineering Profession), Chapter 2 (Problem-Solving Skills), Chapter 3 (Machine Components and Tools), and Chapter 8

(Mechanical Design). The descriptions in Sections 6.6 through 6.8 of internal combustion engines, electrical power generation, and jet engines are largely expository in nature, and that material can be incorporated in case studies to demonstrate the operation of important mechanical engineering hardware. Based on the level and contact hours of their particular courses, instructors can select additional topics from Chapter 4 (Forces in Structures and Fluids), Chapter 5 (Materials and Stresses), Chapter 6 (Thermal and Energy Systems), and Chapter 7 (Motion of Machinery). For instance, Section 4.5 on buoyancy, drag, and lift forces is largely self-contained, and it provides an introductory-level student with an overview of some issues in fluid mechanics.

This textbook reflects my experiences and philosophy for introducing students to the vocabulary, skills, applications, and excitement of the mechanical engineering profession. My writing over the past six years has been motivated in part by teaching Fundamentals of Mechanical Engineering, a large course at Carnegie Mellon University that is open to both majors and nonmajors. This course includes lectures, a computer-aided design and manufacturing project, and a team design project (a portion of which is outlined in Section 8.3 in the context of design conceptualization). A number of vignettes and case studies are also discussed to demonstrate for students the realism of what they are learning: the Space Shuttle Challenger, the Kansas City Hyatt hotel, the “top ten” list of achievements developed by the American Society of Mechanical Engineers (Section 1.3), Air Canada Flight 143 (Section 2.2), the Mars Climate Orbiter spacecraft (Section 2.5), the twin towers of the World Trade Center (Examples 6.3, 6.7, and 6.9), integrated computer-aided engineering (Section 8.4), the first automobile automatic transmission (Section 8.5), and patents in engineering (Section 8.6).

CONTENT

I have not intended this textbook to be an exhaustive treatment of mechanical engineering, and I trust that it will not be read in that light. Quite the contrary: in teaching first- and second-year students, I am ever conscious of the mantra that “less really is more.” To the extent possible, I have resisted the urge to add just one more section on a particular subject, and I have tried to keep the material manageable and engaging from the reader’s perspective. Indeed, many topics that are important for mechanical engineers to know are simply not included here; this is done intentionally (or, admittedly, by my own oversight). I do have confidence, however, that students will be exposed to those otherwise omitted subjects in due course throughout the remainder of their engineering curricula.

I have not relied on any mathematics beyond algebra, geometry, and trigonometry, and there are no integrals or cross-products in this textbook. As with many general-purpose rules, I do admit one exception: Section 7.6 includes differentiation within the context of mechanisms and cams in internal combustion engines. That material is intended to motivate students during their concurrent study of mathematics through several concrete and easily visualized applications. Overall, this textbook’s content

should be readily accessible to any student having a conventional secondary school background in mathematics and physics.

In Chapters 3 through 8, I have selected a subset of mechanical engineering elements that can be sufficiently covered for early students to develop useful design, analysis, and problem-solving skills. The coverage has been chosen to facilitate the textbook's use within the constraints of courses having various formats. In particular, I have selected content that I have found to

- Match the background, maturity, and interests of students early in their study of engineering
- Help students think critically and learn good study and problem-solving skills, particularly with respect to order-of-magnitude approximation, double-checks, and the book-keeping of units
- Convey aspects of mechanical engineering science and empiricism that can be applied at the freshman and sophomore levels
- Expose students to a wide range of hardware and the hands-on nature of engineering
- Generate excitement through applications encompassing computer-aided design, medical imaging, aircraft, space flight, engines, automobile transmissions, ocean thermal energy conversion, nuclear power generation, and more

To the extent possible at the freshman and sophomore levels, the exposition, examples, and homework problems have been drawn from realistic applications. Because I find engineering to be a visual and graphical activity, I have placed particular emphasis on the quality and breadth of the nearly three hundred photographs and illustrations, many of which were provided by colleagues in industry, federal agencies, and academe. My view has been to leverage that realism and motivate students through interesting examples that offer a glimpse of what they will be able to study in later courses, and subsequently practice in their own careers.

Acknowledgments

It would have been impossible to develop this textbook without the assistance and contributions of many people and organizations, and, at the outset, I would like to express my appreciation to them. Foremost, generous support was provided by the Marsha and Philip Dowd Faculty Fellowship, which encourages educational initiatives in engineering. Adriana Moscatelli, Jared Schneider, Katie Minardo, and Stacy Mitchell, who are now alumni of Carnegie Mellon University, helped to get this project off the ground by drafting many of the illustrations that appear in the following chapters. The expert assistance provided by Ms. Jean Stiles in preparing and proofreading the textbook and the instructor's manual was indispensable, and I very much appreciate the many contributions she made.

My faculty colleagues and teaching assistants at Carnegie Mellon have provided many valuable comments and suggestions over the past six years. I am likewise indebted to my students in Fundamentals of Mechanical Engineering. Their collective interest and enthusiasm provided the forward momentum that was needed to bring this work to closure. Joe Elliot and John Wiss kindly offered engine dynamometer and cylinder pressure data to better frame the discussion of internal combustion engines in Chapter 6. Solutions to the homework problems were meticulously prepared by Brad Lisien and Al Costa, who are the lead authors of the companion instructor's manual. In addition, I gratefully acknowledge the feedback of the following reviewers: John R. Biddle, California State Polytechnic University at Pomona; Robert Hocken, University of North Carolina at Charlotte; Damir Juric, Georgia Institute of Technology; Pierre M. Laroche, Florida Institute of Technology; Anthony Renshaw, Columbia University; and Gloria Starns, Iowa State University.

On all counts, I have enjoyed interacting with the editorial staff at Brooks/Cole—Thomson Learning. As the textbook's publisher, Bill Stenquist was committed to developing a high quality product, and it was a pleasure to collaborate with him. Martha Emry managed the textbook's production with skill and professionalism, and with a keen eye for detail. Other members of the team included production project manager Mary Vezilich, senior art director Vernon Boes, executive marketing manager Tom

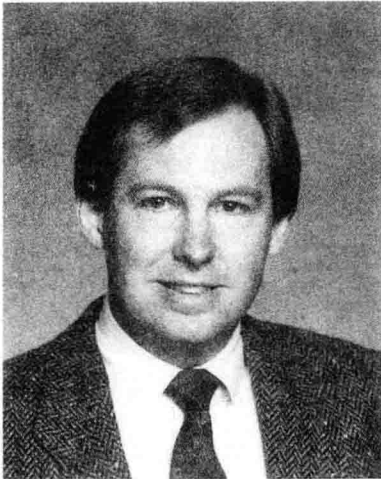
Ziolkowski, editorial assistants Valerie Boyajian and Julie Ruggiero, and permissions editor Kiely Sexton. To each of them, I express my thanks for a job well done.

In conjunction with this textbook's design and analysis content, I have attempted to introduce readers to the hardware and applications of mechanical engineering. In that vein, colleagues at the following academic, industrial, and governmental organizations were remarkably helpful and patient in providing photographs, illustrations, and technical information: General Motors, Intel, Fluent, General Electric, Enron Wind, Boston Gear, Mechanical Dynamics, Caterpillar, NASA, NASA's Glenn Research Center, W. M. Berg, FANUC Robotics, Bureau of Reclamation, Niagara Gear, Velocity11, Stratasys, Carnegie Mellon, National Robotics Engineering Consortium, Lockheed-Martin, Algor, MTS Systems, Westinghouse Electric, and Timken. In particular, Sam Dedola and John Haury of Medrad, Incorporated, went the extra mile and developed numerous illustrations for the discussion of computer-aided design in Section 8.4. I've surely not listed everyone who has helped me with this endeavor, and I apologize for any inadvertent omissions that I may have made.

Last, but in no means least, let me express heartfelt gratitude to Karen and Becky for their patience and encouragement throughout this project.

Jonathan Wickert

About the Author



A Professor of Mechanical Engineering at Carnegie Mellon University, Jonathan Wickert teaches and conducts research in the areas of applied mechanics, dynamics, and mechanical vibration. As a researcher and consultant, he has worked with companies and federal agencies on a diverse range of engineering problems including computer disk and tape drives; the manufacture of sheet metal, fiberglass, polymers, and industrial chemicals; automotive brakes; radial flow gas turbines; and various consumer products. Dr. Wickert received his B.S., M.S., and Ph.D. degrees in mechanical engineering from the University of California, Berkeley, and he was a postdoctoral fellow at the University of Cambridge. He has served as associate editor of engineering journals, as a division chair in the American Society of Mechanical Engineers, and as chair of the undergraduate mechanical engineering program at Carnegie Mellon. Dr. Wickert has received awards in recognition

of his teaching and research from the Society of Automotive Engineers, and the American Society for Engineering Education, and he was elected a fellow of the American Society of Mechanical Engineers.

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