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# Mechanics of Materials

# 材料力学

Anthony Bedford & Kenneth M. Liechti



清华大学出版社

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# Mechanics of Materials

## Anthony Bedford & Kenneth M. Liechti

# 影 印 版 序

本书是2000年新编写的材料力学教材，反映了美国材料力学课程改革的一些动向。随着计算机和数值解法的迅速发展、有限元分析软件的广泛应用，以及固体力学和材料科学间越来越紧密的联合趋势，对基础力学课程的教学要求发生了重要变化。老的材料力学教材把重点放在讲透一维问题，更一般的概念由弹性力学来讲，而许多工程专业并没有把弹性力学列入其后续课程，因而导致学生毕业后处理复杂结构部件的强度设计问题时往往觉得力学基础知识不够。为此国内外都在研究如何在材料力学课程中压缩一维问题的讲述内容，以便留出学时讲述一般问题的基本概念。

本书在这方面进行了有益的探讨。书中突出材料力学的重点，对原教学内容进行了删简，而用相当的篇幅来讲述应力和应变的一般概念、三维应力-应变关系，以及失效与断裂准则。内容简练、重点突出，是按一学期教学计划编写的教材。

全书共分12章，7个附录。第1章“引论”，介绍材料力学和静力学的基本概念；第2章“应力与应变的度量”，讲述正应力、切应力和正应变、切应变等概念；第3章“受轴向载荷的杆”和第4章“扭转”的内容比常用的材料力学教材更丰富、更结合实际应用，包括机械载荷和热载荷、静定和静不定问题、柱形杆和截面缓慢变化的非柱形杆，介绍了材料的弹性模量和剪切模量；第5章“应力状态”和第6章“应变状态”，从三维一般情况来阐明应力和应变状态、坐标转换关系和莫尔圆、主应力和主应变，以及线性弹性材料的应力－应变关系，即广义虎克定律，系统地提升了老材料力学教材的教学内容；第7章“梁的内力和内力矩”、第8章“梁的应力”、第9章“梁的挠度”和第10章“柱的屈曲”是材料力学的经典内容，叙述简明、重点突出。作者把第11章“能量法”和第12章“失效和断裂准则”定为选讲内容，包括功和能的概念、卡氏第二定律、失效、应力集中和断裂。附录A是常用数学公式；附录B是材料性质；附录C是形心与惯性矩；附录D是面积的性质；附录E是梁的挠度与斜率；附录F是各向同性应力－应变关系；附录G是偶数号习题的答案。

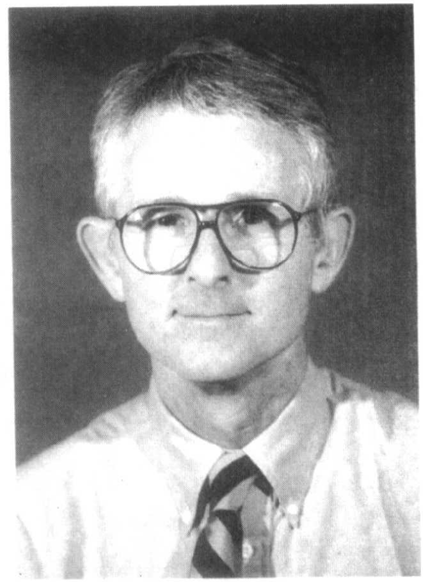
书中包括大量例题和习题，并附有偶数号习题的答案。

本书是一本以精简材料力学原有教学内容为基础，吸收固体力学中应力、应变一般概念、广义虎

克定律、失效与断裂准则等重要内容，并加强与工程设计应用相结合的新型材料力学教材，反映了材料力学教学改革的一种动向，可以作为我国高等院校材料力学或工程力学课程的英文教材或教学参考书。

清华大学工程力学系
陆明万

# ABOUT THE AUTHORS



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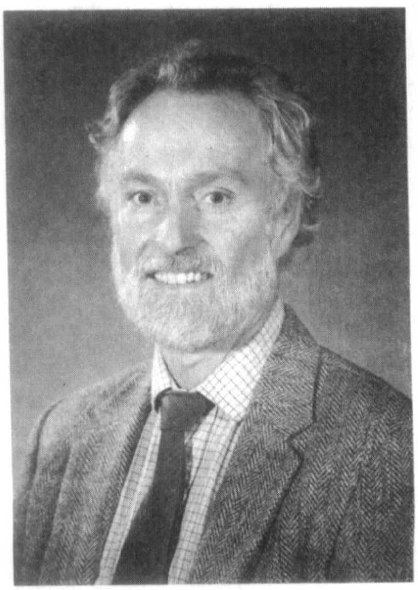
Dr. Bedford's main professional activity has been education and research in engineering mechanics. He is author or coauthor of papers on the mechanics of composite materials and mixtures and four books, including *Engineering Mechanics: Statics* and *Engineering Mechanics: Dynamics* published by Addison Wesley Longman. From 1973 until 1983 he was a consultant to Sandia National Laboratories, Albuquerque, New Mexico.

He is a licensed professional engineer and a member of the American Society for Engineering Education, the Society for Engineering Science, the American Academy of Mechanics, and the Society for Natural Philosophy.



KENNETH LIECHTI is Professor of Aerospace Engineering and Engineering Mechanics at the University of Texas at Austin and holds the E. P. Schoch Professorship in Engineering. He received his B.Sc. in Aeronautical Engineering at Glasgow University and M.S. and Ph.D. degrees in Aeronautics at the California Institute of Technology. He gained industrial experience at General Dynamics Fort Worth Division prior to joining the faculty of the University of Texas at Austin in 1982.

Dr. Liechti's main areas of teaching and research are in the mechanics of materials and fracture mechanics. He is the author or coauthor of papers on interfacial fracture, fracture in adhesively bonded joints, and the nonlinear behavior of polymers. He has consulted on fracture problems with several companies.

He is a fellow of the American Society of Mechanical Engineers and a member of the Society for Experimental Mechanics, the American Academy of Mechanics, and the Adhesion Society. He is an associate editor of the journal Experimental Mechanics.

# PREFACE

Mechanics of materials is concerned with the internal forces and deformations of objects that result from the external forces acting on them. This book appears in a time of transition for education in the mechanics of materials. The traditional course in "strength of materials" that long formed an important part of the engineering curriculum had as one of its primary goals acquainting students with the details of many analytical and empirical solutions that could be applied to structural design. This reliance on a catalog of results has lessened as the finite element method has become commonly available for stress analysis. Another important development is that current research in mechanics of materials is beginning to bring to reality the long-held dream of the merger of continuum solid mechanics and materials science into a unified field. For these reasons, the principle emphasis in the first course in mechanics of materials is becoming oriented toward helping students understand the theoretical foundations, especially the concepts of stress and strain, the stress-strain relations including the meaning of isotropy, and criteria for failure and fracture.

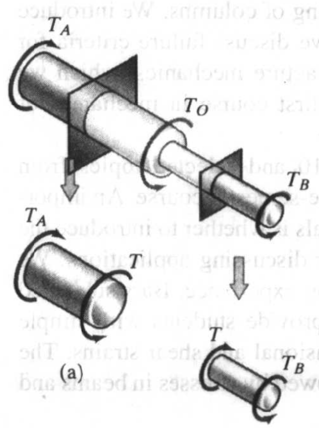
In Chapter 1 we provide an extensive review of statics, including problems, that the instructor may choose to cover or simply have students read. In reviewing distributed loads, we lay the groundwork for our definitions in Chapter 2 of the traction vector and the normal and shear stresses. In Chapter 2 we also introduce the longitudinal and shear strains in terms of changes in infinitesimal material elements. In Chapters 3 and 4 we cover bars subjected to axial and torsional loads and introduce the definitions of the elastic and shear moduli. With these examples as motivation, in Chapters 5 and 6 we introduce the general states of stress and strain and their transformations and the stress-strain relations for linearly elastic materials. In Chapters 7–10 we discuss stresses in beams, deformations of beams, and the buckling of columns. We introduce energy methods in Chapter 11. In Chapter 12 we discuss failure criteria for general states of stress and introduce modern fracture mechanics, which we believe should become an integral part of the first course in mechanics of materials.

Most of the topics in Chapters 1 through 10 and selected topics from Chapters 11 and 12 can be covered in a typical one-semester course. An important decision in teaching the mechanics of materials is whether to introduce the general states of stress and strain before or after discussing applications. We have chosen a compromise based on our teaching experience. Bars subjected to axial load and torsion are first discussed to provide students with simple examples of normal and shear stresses and extensional and shear strains. The states of stress and strain are then discussed, followed by stresses in beams and beam deflections. Instructors preferring to introduce the general states of stress and strain in the beginning should cover Chapters 1, 2, 5, and 6 before covering Chapters 3 and 4.

The first course in mechanics of materials prepares students for subsequent courses in structural analysis, structural dynamics, and advanced mechanics of deformable media. In comparison to courses in statics and dynamics, it is an interesting challenge for instructors and students. Engineering students begin the study of statics and dynamics having had some prior experience with the basic concepts in high school and college physics courses. In contrast, the core concepts in mechanics of materials are new to most students. It is therefore essential that the textbook used introduce and explain these concepts with great care and reinforce them with many examples. This has been our objective in writing this book. Our approach is to present the material as we do in the classroom: emphasizing understanding of the basic principles of mechanics of materials and demonstrating them with examples drawn from contemporary engineering applications and design.

## Features

- **Examples That Teach** We continue reinforcing the problem-solving skills students have learned in their introductory mechanics courses. Separate *Strategy* sections preceding most examples and selected problems teach students how to approach and solve problems in engineering. What principles apply? What must be determined, and in what order? Many examples conclude with *Discussion* sections that indicate ways of checking and interpreting answers, point out interesting features of the solution, or suggest alternative methods of solution.
- **Free-Body Diagrams** Correct and consistent use of free-body diagrams is the most essential skill that students of mechanics must acquire. We review the steps involved in drawing free-body diagrams in Chapter 1 and emphasize their use throughout the book. Many of our figures are designed to teach how free-body diagrams are chosen and drawn:

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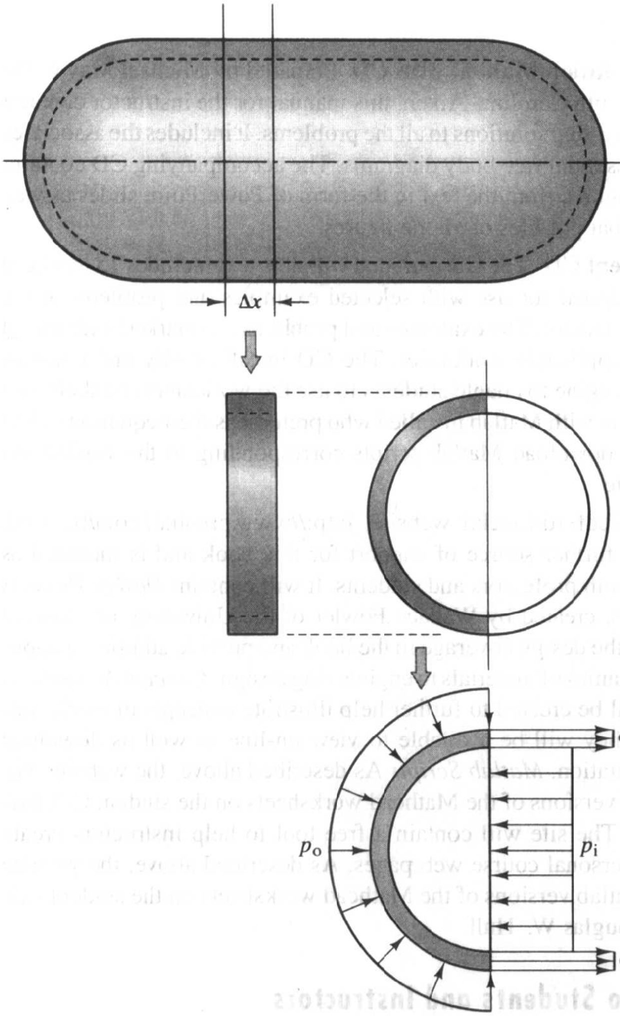


- **Design** The Accrediting Board for Engineering and Technology (ABET), as well as many practicing engineers, strongly encourage the introduction of design throughout the engineering curriculum. By expressing many of our examples and problems in terms of engineering design, we demonstrate the use of mechanics of materials within the larger context of engineering practice. Design problems are designated by blue problem numbers. Chapters 3, 4, 5, and 8 contain sections explicitly addressing the design of particular structural elements, and in Chapter 12 we discuss failure and fracture criteria used in structural design.

## Supplements

We have developed and are developing supplements to the book that will contribute to students' understanding as well as enable instructors to enrich their presentations:

- **Instructor's Solution Manual with CD** Prepared by Michael May of the University of South Carolina–Aiken, this manual for the instructor contains complete step-by-step solutions to all the problems. It includes the associated art as well as essential free body diagrams. The accompanying CD contains a selection of figures from the text in the form of PowerPoint slides as well as Adobe Acrobat pdf files of all the figures.
- **Mathcad Student CD** The CD included with this text includes 15 Mathcad worksheets designed for use with selected examples and problems at the option of the instructor. The examples and problems are marked with an indicating the applicable worksheet. The CD installs easily and contains the Mathcad 8 engine to enable students to use the worksheets on their own computers. Users with Matlab installed who prefer it as their equation solver will be able to download Matlab scripts corresponding to the worksheets from the website.
- **Website** The Bedford/Liechti website, http://www.prenhall.com/bedford, will serve as a further source of support for this book and is intended as a resource for both professors and students. It will contain: *Design Projects* These problems, created by Wallace Fowler of the University of Texas at Austin, extend the design coverage in the book and provide additional applications of mechanics of materials to engineering design. *Concept Animations* Animations will be created to further help illustrate concepts in mechanics of materials. They will be available to view on-line as well as download for class presentation. *Matlab Scripts* As described above, the website will contain Matlab versions of the Mathcad worksheets on the student CD. *Syllabus Builder* The site will contain a free tool to help instructors create and maintain personal course web pages. As described above, the website will contain Matlab versions of the Mathcad worksheets on the student CD, prepared by Douglas W. Hull.

## Commitment to Students and Instructors

We have ensured the accuracy of this book to the best of our ability. We have solved every example and problem in an effort to confirm that their answers are correct and that they are of an appropriate level of difficulty. Suzanne Mescan of Progressive Publishing Alternatives carefully checked the entire manuscript. Any errors that remain are our responsibility. We welcome communication from students and instructors concerning needed corrections or improvements. Our address is Department of Aerospace Engineering and Engineering Mechanics, University of Texas at Austin, Austin, Texas 78712 or abedford@mail.utexas.edu.

## Acknowledgements

A book of this kind results from a collaboration by many people. We have learned mechanics from our own teachers, colleagues, and students. The following faculty at other institutions critically reviewed the manuscript and gave us many insightful suggestions based on their knowledge of mechanics of materials and how it can best be taught:

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