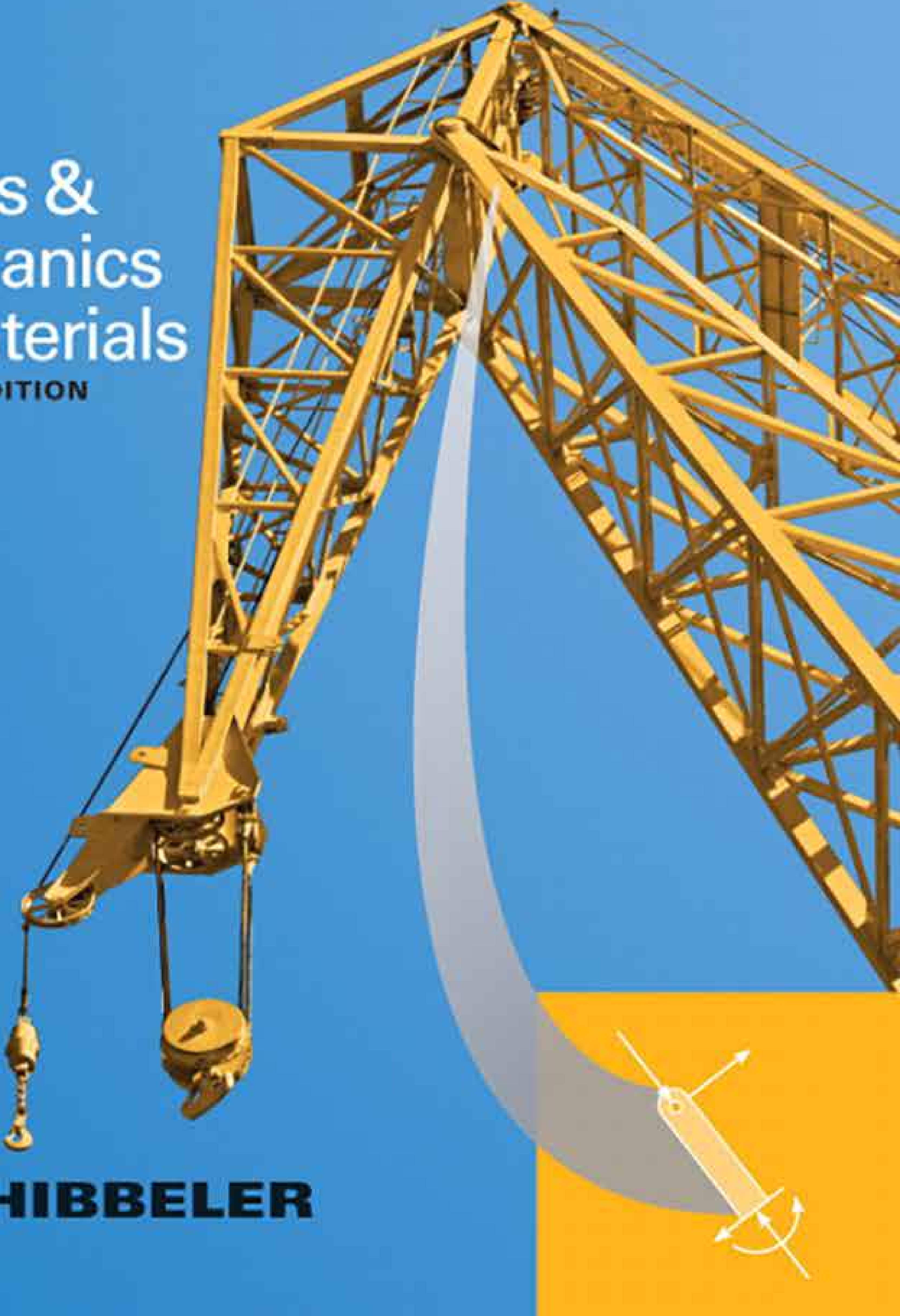
Statics & Mechanics of Materials

FOURTH EDITION



R. C. HIBBELER

Fundamental Equations of Statics and Mechanics of Materials

Cartesian Vector

$$\mathbf{A} = A_x\mathbf{i} + A_y\mathbf{j} + A_z\mathbf{k}$$

Magnitude

$$A = \sqrt{A_x^2 + A_y^2 + A_z^2}$$

Directions

$$\mathbf{u}_A = \frac{\mathbf{A}}{A} = \frac{A_x}{A}\mathbf{i} + \frac{A_y}{A}\mathbf{j} + \frac{A_z}{A}\mathbf{k}$$

$$= \cos\alpha\,\mathbf{i} + \cos\beta\,\mathbf{j} + \cos\gamma\,\mathbf{k}$$

$$\cos^2\alpha + \cos^2\beta + \cos^2\gamma = 1$$

Dot Product

$$\mathbf{A}\cdot\mathbf{B} = AB\cos\theta$$

$$= A_xB_x + A_yB_y + A_zB_z$$

Cross Product

$$\mathbf{C} = \mathbf{A}\times\mathbf{B} = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ A_x & A_y & A_z \\ B_x & B_y & B_z \end{vmatrix}$$

Cartesian Position Vector

$$\mathbf{r} = (x_2 - x_1)\mathbf{i} + (y_2 - y_1)\mathbf{j} + (z_2 - z_1)\mathbf{k}$$

Cartesian Force Vector

$$\mathbf{F} = F\mathbf{u} = F\left(\frac{\mathbf{r}}{r}\right)$$

Moment of a Force

$$M_O = Fd$$

$$\mathbf{M}_O = \mathbf{r}\times\mathbf{F} = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ r_x & r_y & r_z \\ F_x & F_y & F_z \end{vmatrix}$$

Moment of a Force About a Specified Axis

$$M_a = \mathbf{u}\cdot\mathbf{r}\times\mathbf{F} = \begin{vmatrix} u_x & u_y & u_y \\ r_x & r_y & r_z \\ F_x & F_y & F_z \end{vmatrix}$$

Simplification of a Force and Couple System

$$\mathbf{F}_R = \Sigma\mathbf{F}$$

$$(\mathbf{M}_R)_O = \Sigma\mathbf{M}_c + \Sigma\mathbf{M}_O$$

Equilibrium

Particle

$$\Sigma F_x = 0,\ \Sigma F_y = 0,\ \Sigma F_z = 0$$

Rigid Body—Two Dimensions

$$\Sigma F_x = 0,\ \Sigma F_y = 0,\ \Sigma M_O = 0$$

Rigid Body—Three Dimensions

$$\Sigma F_x = 0,\ \Sigma F_y = 0,\ \Sigma F_z = 0$$

$$\Sigma M_{x'} = 0,\ \Sigma M_{y'} = 0,\ \Sigma M_{z'} = 0$$

Friction

Static (maximum) $F_s = \mu_s N$

Kinetic $F_k = \mu_k N$

Center of Gravity

Particles or Discrete Parts

$$\bar{r} = \frac{\Sigma\tilde{r}W}{\Sigma W}$$

Body

$$\bar{r} = \frac{\int \tilde{r}\,dW}{\int dW}$$

Area Moment of Inertia

$$I = \int r^2 dA$$

Parallel-Axis Theorem

$$I = \bar{I} + Ad^2$$

Radius of Gyration

$$k = \sqrt{\frac{I}{A}}$$

Axial Load

Normal Stress

$$\sigma = \frac{P}{A}$$

Displacement

$$\delta = \int_0^L \frac{P(x)dx}{A(x)E},\ \delta = \Sigma\frac{PL}{AE},\ \delta_T = \alpha\,\Delta TL$$

Torsion

Shear Stress in Circular Shaft

$$\tau = \frac{T\rho}{J}$$

where

$$J = \frac{\pi}{2}c^4 \text{ solid cross section}$$

$$J = \frac{\pi}{2}(c_o^4 - c_i^4) \text{ tubular cross section}$$

Power

$$P = T\omega = 2\pi fT$$

Angle of Twist

$$\phi = \int_0^L \frac{T(x)dx}{J(x)G} \qquad \phi = \Sigma\frac{TL}{JG}$$

Average Shear Stress in a Thin-Walled Tube

$$\tau_{avg} = \frac{T}{2tA_m}$$

Shear Flow

$$q = \tau_{avg}t = \frac{T}{2A_m}$$

Bending

Normal Stress

$$\sigma = \frac{My}{I}$$

Unsymmetric Bending

$$\sigma = -\frac{M_z y}{I_z} + \frac{M_y z}{I_y}, \qquad \tan\alpha = \frac{I_z}{I_y}\tan\theta$$

Shear

Average Direct Shear Stress

$$\tau_{\text{avg}} = \frac{V}{A}$$

Transverse Shear Stress

$$\tau = \frac{VQ}{It}$$

Shear Flow

$$q = \tau t = \frac{VQ}{I}$$

Stress in Thin-Walled Pressure Vessel

Cylinder

$$\sigma_1 = \frac{pr}{t}, \qquad \sigma_2 = \frac{pr}{2t}$$

Sphere

$$\sigma_1 = \sigma_2 = \frac{pr}{2t}$$

Stress Transformation Equations

$$\sigma_{x'} = \frac{\sigma_x + \sigma_y}{2} + \frac{\sigma_x - \sigma_y}{2}\cos 2\theta + \tau_{xy}\sin 2\theta$$

$$\tau_{x'y'} = -\frac{\sigma_x - \sigma_y}{2}\sin 2\theta + \tau_{xy}\cos 2\theta$$

Principal Stress

$$\tan 2\theta_p = \frac{\tau_{xy}}{(\sigma_x - \sigma_y)/2}$$

$$\sigma_{1,2} = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

Maximum In-Plane Shear Stress

$$\tan 2\theta_s = -\frac{(\sigma_x - \sigma_y)/2}{\tau_{xy}}$$

$$\tau_{\max} = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$\sigma_{\text{avg}} = \frac{\sigma_x + \sigma_y}{2}$$

Absolute Maximum Shear Stress

$$\tau_{\substack{\text{abs}\\ \max}} = \frac{\sigma_{\max} - \sigma_{\min}}{2}$$

$$\sigma_{\text{avg}} = \frac{\sigma_{\max} + \sigma_{\min}}{2}$$

Material Property Relations

Poisson's Ratio

$$\nu = -\frac{\epsilon_{\text{lat}}}{\epsilon_{\text{long}}}$$

Generalized Hooke's Law

$$\epsilon_x = \frac{1}{E}[\sigma_x - \nu(\sigma_y + \sigma_z)]$$

$$\epsilon_y = \frac{1}{E}[\sigma_y - \nu(\sigma_x + \sigma_z)]$$

$$\epsilon_z = \frac{1}{E}[\sigma_z - \nu(\sigma_x + \sigma_y)]$$

$$\gamma_{xy} = \frac{1}{G}\tau_{xy}, \quad \gamma_{yz} = \frac{1}{G}\tau_{yz}, \quad \gamma_{zx} = \frac{1}{G}\tau_{zx}$$

where

$$G = \frac{E}{2(1 + \nu)}$$

Relations Between *w*, *V*, *M*

$$\frac{dV}{dx} = w(x), \qquad \frac{dM}{dx} = V$$

Elastic Curve

$$\frac{1}{\rho} = \frac{M}{EI}$$

$$EI\frac{d^4 v}{dx^4} = w(x)$$

$$EI\frac{d^3 v}{dx^3} = V(x)$$

$$EI\frac{d^2 v}{dx^2} = M(x)$$

Buckling

Critical Axial Load

$$P_{\text{cr}} = \frac{\pi^2 EI}{(KL)^2}$$

Critical Stress

$$\sigma_{\text{cr}} = \frac{\pi^2 E}{(KL/r)^2}, \quad r = \sqrt{I/A}$$

Secant Formula

$$\sigma_{\max} = \frac{P}{A}\left[1 + \frac{ec}{r^2}\sec\left(\frac{L}{2r}\sqrt{\frac{P}{EA}}\right)\right]$$

STATICS AND MECHANICS OF MATERIALS

FOURTH EDITION

R. C. HIBBELER

PEARSON

Upper Saddle River Boston Columbus San Francisco New York
Indianapolis London Toronto Sydney Singapore Tokyo Montréal Dubai
Madrid Hong Kong Mexico City Munich Paris Amsterdam Cape Town

Vice President and Editorial Director, ECS: Marcia Horton
Senior Acquisitions Editor: Norrin Dias
Editorial Assistant: Sandra Rodriguez
Executive Marketing Manager: Tim Galligan
Marketing Assistant: Jon Bryant
Senior Managing Editor: Scott Disanno
Art Director: Kenny Beck
Text and Cover Designer: Kenny Beck
Manager, Cover Visual Research & Permissions: Karen Sanatar
Photo Researcher: Marta Samsel
Cover Image: © Construction Photography/Corbis

Credits and acknowledgments borrowed from other sources and reproduced, with permission, in this textbook appear on the appropriate page within text or on page xxiv.

---

10 9 8 7 6 5 4 3 2 1

Library of Congress Cataloging-in-Publication Data on File.

PEARSON

www.pearsonhighered.com

ISBN-10: 0-13-345160-7
ISBN-13: 978-0-13-345160-3

To the Student

With the hope that this work will stimulate
an interest in Engineering Mechanics and
Mechanics of Materials and provide
an acceptable guide to its understanding.

This page intentionally left blank

PREFACE

This book represents a combined abridged version of two of the author's books, namely *Engineering Mechanics: Statics, Thirteenth Edition* and *Mechanics of Materials, Ninth Edition*. It provides a clear and thorough presentation of both the theory and application of the important fundamental topics of these subjects, that are often used in many engineering disciplines. The development emphasizes the importance of satisfying equilibrium, compatibility of deformation, and material behavior requirements. The hallmark of the book, however, remains the same as the author's unabridged versions, and that is, strong emphasis is placed on drawing a free-body diagram, and the importance of selecting an appropriate coordinate system and an associated sign convention whenever the equations of mechanics are applied. Throughout the book, many analysis and design applications are presented, which involve mechanical elements and structural members often encountered in engineering practice.

New to This Edition

- **New Problems.** There are approximately 65% new problems in this edition. These problems relate to applications in many different fields of engineering. Also, an increase in algebraic type problems has been added, so that a generalized solution can be obtained.
- **Content Revisions.** Each section of the text was carefully reviewed and, in some areas, the material has been redeveloped to better explain the concepts.
- **New & Revised Example Problems.** Throughout the book examples have been altered or enhanced in an attempt to help clarify concepts for students. Where appropriate a new example has been added in order to emphasize important concepts that were needed.
- **Additional Fundamental Problems.** These problem sets serve as extended example problems since their solutions are given in the back of the book. Additional problems have been added, in some areas of the book where they are needed.
- **Expanded Solutions.** Some of the fundamental problems now have more detailed solutions, including some artwork, for better clarification. Also, some of the more difficult problems have additional hints along with its answer when given in the back of the book.
- **New Photos.** The relevance of knowing the subject matter is reflected by the real-world applications depicted in any new or updated photos placed throughout the book. These photos generally are used to explain how the relevant principles apply to real-world situations and how materials behave under load.

Hallmark Features

Besides the new features mentioned above, other outstanding features that define the contents of the text include the following.

Organization and Approach. Each chapter is organized into well-defined sections that contain an explanation of specific topics, illustrative example problems, and a set of homework problems. The topics within each section are placed into subgroups defined by boldface titles. The purpose of this is to present a structured method for introducing each new definition or concept and to make the book convenient for later reference and review.

Chapter Contents. Each chapter begins with a photo demonstrating a broad-range application of the material within the chapter. A bulleted list of the chapter contents is provided to give a general overview of the material that will be covered.

Emphasis on Free-Body Diagrams. Drawing a free-body diagram is particularly important when solving problems, and for this reason this step is strongly emphasized throughout the book. In particular, within the statics coverage some sections are devoted to show how to draw free-body diagrams. Specific homework problems have also been added to develop this practice.

Procedures for Analysis. A general procedure for analyzing any mechanics problem is presented at the end of the first chapter. Then this procedure is customized to relate to specific types of problems that are covered throughout the book. This unique feature provides the student with a logical and orderly method to follow when applying the theory. The example problems are solved using this outlined method in order to clarify its numerical application. Realize, however, that once the relevant principles have been mastered and enough confidence and judgment have been obtained, the student can then develop his or her own procedures for solving problems.

Important Points. This feature provides a review or summary of the most important concepts in a section and highlights the most significant points that should be realized when applying the theory to solve problems.

Conceptual Understanding. Through the use of photographs placed throughout the book, the theory is applied in a simplified way in order to illustrate some of its more important conceptual features and instill the physical meaning of many of the terms used in the equations. These simplified applications increase interest in the subject matter and better prepare the student to understand the examples and solve problems.

Fundamental Problems. These problem sets are located just after each group of example problems. They offer students simple applications of the concepts covered in each section and, therefore, provide them with the chance to develop their problem-solving skills before attempting to solve any of the standard problems that follow. The fundamental problems may be considered as extended examples, since the key equations and answers are all listed in the back of the book. Additionally, when assigned, these problems offer students an excellent means of preparing for exams, and they can be used at a later time as a review when studying for the Fundamentals of Engineering Exam.

Conceptual Problems. Throughout the text, usually at the end of each chapter, there is a set of problems that involve conceptual situations related to the application of the principles contained in the chapter. These analysis and design problems are intended to engage students in thinking through a real-life situation as depicted in a photo. They can be assigned after the students have developed some expertise in the subject matter and they work well either for individual or team projects.

Homework Problems. Apart from the Fundamental and Conceptual type problems mentioned previously, other types of problems contained in the book include the following:

- **General Analysis and Design Problems.** The majority of problems in the book depict realistic situations encountered in engineering practice. Some of these problems come from actual products used in industry. It is hoped that this realism will both stimulate the student's interest in engineering mechanics and provide a means for developing the skill to reduce any such problem from its physical description to a model or symbolic representation to which the principles of mechanics may be applied.

  Throughout the book, there is an approximate balance of problems using either SI of FPS units. Furthermore, in any set, an attempt has been made to arrange the problems in order of increasing difficulty, except for the end of chapter review problems, which are presented in random order. Problems that are simply indicated by a problem number have an answer given in the back of the book. However, an asterisk (*) before every fourth problem number indicates a problem without an answer.

- **Computer Problems.** An effort has been made to include some problems that may be solved using a numerical procedure executed on either a desktop computer or a programmable pocket calculator. The intent here is to broaden the student's capacity for using other forms of mathematical analysis without sacrificing the time needed to focus on the application of the principles of mechanics.

Accuracy. In addition to the author, the text and problem solutions have been thoroughly checked for accuracy by four other parties: Scott Hendricks, Virginia Polytechnic Institute and State University; Karim Nohra, University of South Florida; Kurt Norlin, Laurel Tech Integrated Publishing Services; and finally Kai Beng Yap, a practicing engineer.

Contents

The book is divided into two parts, and the material is covered in the traditional manner.

Statics. The subject of statics is presented in 6 chapters. The text begins in Chapter 1 with an introduction to mechanics and a discussion of units. The notion of a vector and the properties of a concurrent force system are introduced in Chapter 2. Chapter 3 contains a general discussion of concentrated force systems and the methods used to simplify them. The principles of rigid-body equilibrium are developed in Chapter 4 and then applied to specific problems involving the equilibrium of trusses, frames, and machines in Chapter 5. Finally, topics related to the center of gravity, centroid, and moment of inertia are treated in Chapter 6.

Mechanics of Materials. This portion of the text is covered in 10 chapters. Chapter 7 begins with a formal definition of both normal and shear stress, and a discussion of normal stress in axially loaded members and average shear stress caused by direct shear; finally, normal and shear strain are defined. In Chapter 8 a discussion of some of the important mechanical properties of materials is given. Separate treatments of axial load, torsion, bending, and transverse shear are presented in Chapters 9, 10, 11, and 12, respectively. Chapter 13 provides a partial review of the material covered in the previous chapters, in which the state of stress resulting from combined loadings is discussed. In Chapter 14 the concepts for transforming stress and strain are presented. Chapter 15 provides a means for a further summary and review of previous material by covering design of beams based on allowable stress. In Chapter 16 various methods for computing deflections of beams are presented, including the method for finding the reactions on these members if they are statically indeterminate. Lastly, Chapter 17 provides a discussion of column buckling.

Sections of the book that contain more advanced material are indicated by a star (*). Time permitting, some of these topics may be included in the course. Furthermore, this material provides a suitable reference for basic principles when it is covered in other courses, and it can be used as a basis for assigning special projects.

Alternative Method for Coverage of Mechanics of Materials. It is possible to cover many of the topics in the text in several different sequences. For example, some instructors prefer to cover stress and strain transformations *first,* before discussing specific applications of axial load, torsion, bending, and shear. One possible method for doing this would be to first to cover stress and strain and its transformations, Chapter 7 and Chapter 14 then Chapters 8 through 13 can be covered with no loss in continuity.

Problems. Numerous problems in the book depict realistic situations encountered in engineering practice. It is hoped that this realism will both stimulate the student's interest in the subject and provide a means for developing the skill to reduce any such problem from its physical description to a model or symbolic representation to which the principles may be applied.

Throughout the text there is an approximate balance of problems using either SI of FPS units. Furthermore, in any set, an attempt has been made to arrange the problems in order of increasing difficulty. The answers to all but every fourth problem are listed in the back of the book. To alert the user to a problem without a reported answer, an asterisk (*) is placed before the problem number. Answers are reported to three significant figures, even though the data for material properties may be known with less accuracy. Although this might appear to be poor practice, it is done simply to be consistent and to allow the student a better chance to validate his or her solution. All the problems and their solutions have been independently checked four times for accuracy.

Acknowledgments

Over the years, this text has been shaped by the suggestions and comments of many of my colleagues in the teaching profession. Their encouragement and willingness to provide constructive criticism are very much appreciated and it is hoped that they will accept this anonymous recognition. A note of thanks is also given to the reviewers of both my *Statics* and *Mechanics of Materials* texts. Their comments have guided the improvement of this book as well.

During the production process I am thankful for the assistance of Rose Kernan, my production editor for many years, and to my wife, Conny, and daughter, Mary Ann, for their help in proofreading and typing, that was needed to prepare the manuscript for publication.

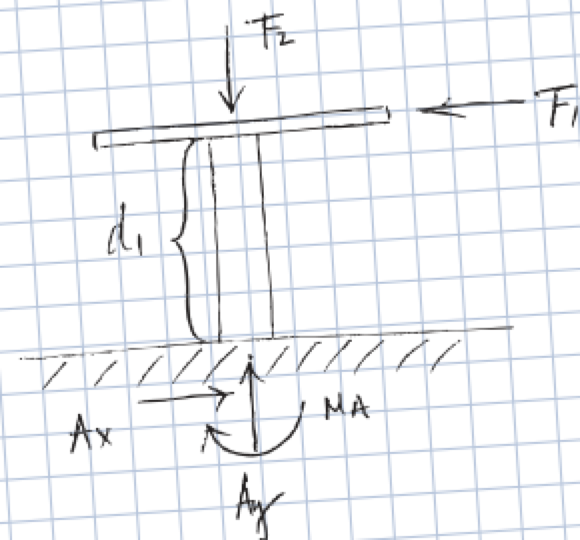
I would also like to thank all my students who have used the previous edition and have made comments to improve its contents; including those in the teaching profession who have taken the time to e-mail me their comments.

I would greatly appreciate hearing from you if at any time you have any comments or suggestions regarding the contents of this edition.

Russell Charles Hibbeler
hibbeler@bellsouth.net

your work...

PART A



Given: $F_1 = 55.0\,lb$, $F_2 = 170\,lb$, $M_A = 160\ lb \cdot ft$

$$\sum M_A = 0 \Rightarrow \quad (F_1 + F_2) \times d_1 - M_A = 0$$

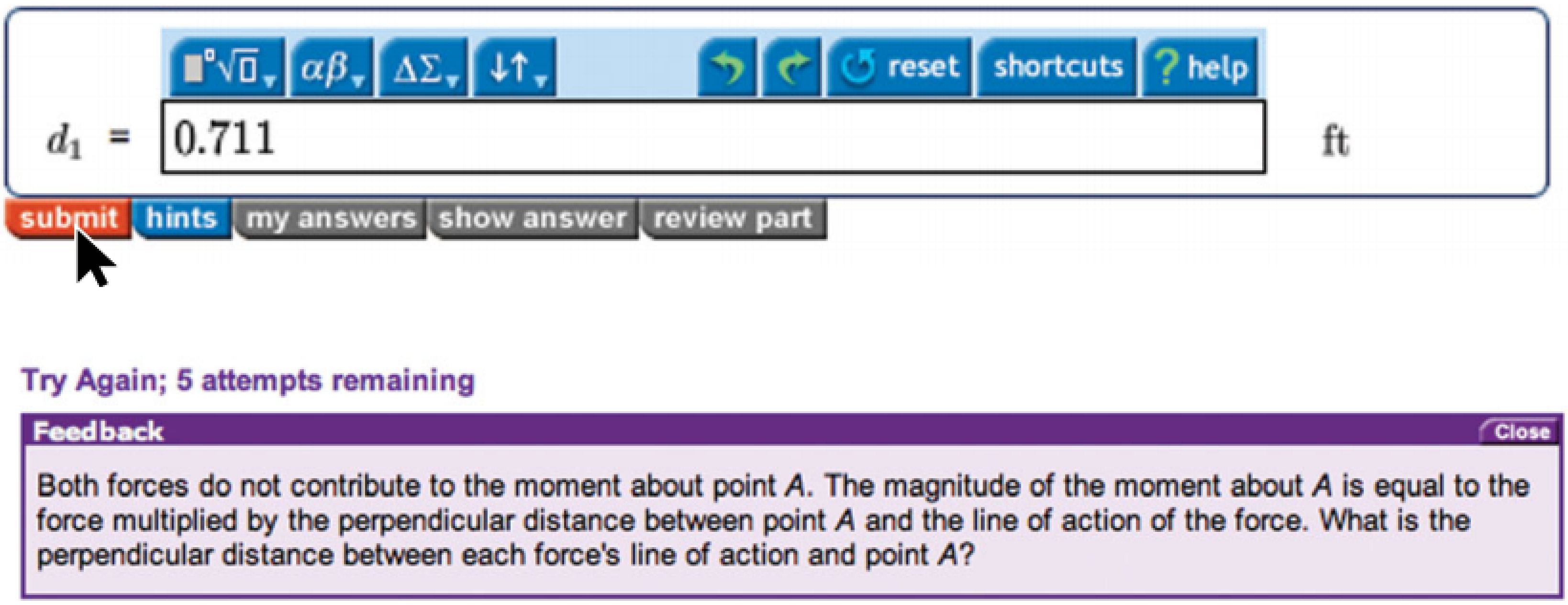
$$(F_1 + F_2) \times d_1 = M_A$$

$$d_1 = \frac{M_A}{F_1 + F_2}$$

$$= \frac{160\ lb \cdot ft}{55.0\,lb + 170\,lb}$$

$$\boxed{d_1 = 0.711\ ft}$$

your answer specific feedback



Resources for Instructors

- **MasteringEngineering.** This online Tutorial Homework program allows you to integrate dynamic homework with automatic grading and adaptive tutoring. MasteringEngineering allows you to easily track the performance of your entire class on an assignment-by-assignment basis, or the detailed work of an individual student.

- **Instructor's Solutions Manual.** This supplement provides complete solutions supported by problem statements and problem figures. The thirteenth edition manual was revised to improve readability and was triple accuracy checked. The Instructor's Solutions Manual is available on Pearson Higher Education website: www.pearsonhighered.com.

- **Instructor's Resource.** Visual resources to accompany the text are located on the Pearson Higher Education website: www.pearsonhighered.com. If you are in need of a login and password for this site, please contact your local Pearson representative. Visual resources include all art from the text, available in PowerPoint slide and JPEG format.

- **Video Solutions.** Developed by Professor Edward Berger, University of Virginia, video solutions are located on the Companion Website for the text and offer step-by-step solution walkthroughs of representative homework problems from each section of the text. Make efficient use of class time and office hours by showing students the complete and concise problem-solving approaches that they can access any time and view at their own pace. The videos are designed to be a flexible resource to be used however each instructor and student prefers. A valuable tutorial resource, the videos are also helpful for student self-evaluation as students can pause the videos to check their understanding and work alongside the video. Access the videos at www.pearsonhighered.com/hibbeler/ and follow the links for the *Engineering Mechanics: Statics*, Thirteenth Edition text.

Resources for Students

- **MasteringEngineering.** Tutorial homework problems emulate the instructor's office-hour environment, guiding students through engineering concepts with self-paced individualized coaching. These in-depth tutorial homework problems are designed to coach students with feedback specific to their errors and optional hints that break problems down into simpler steps.

- **Statics Study Pack.** This supplement contains chapter-by-chapter study materials, a Free-Body Diagram Workbook and access to the Companion Website where additional tutorial resources are located.

- **Companion Website.** The Companion Website, located at www.pearsonhighered.com/hibbeler/, includes opportunities for practice and review including:
  - **Video Solutions**—Complete, step-by-step solution walkthroughs of representative homework problems from each section. Videos offer fully worked solutions that show every step of representative homework problems—this helps students make vital connections between concepts.
- **Statics Practice Problems Workbook.** This workbook contains additional worked problems. The problems are partially solved and are designed to help guide students through difficult topics.

This page intentionally left blank

CONTENTS

1 General Principles 3

2 Force Vectors 17

5
Structural Analysis 215

6
Center of Gravity, Centroid, and Moment of Inertia 261

9 Axial Load 405

10 Torsion 451

11
Bending 501

12
Transverse Shear 559

13
Combined Loadings 591

14
Stress and Strain Transformation 619

17
Buckling of Columns 769

Appendix

CREDITS

Chapter 1, © Roel Meijer/Alamy.
Chapter 2, © Atli Mar/Getty Images USA, Inc.
Chapter 3, © Huntstock/Getty Images USA, Inc.
Chapter 4, © Corbis Images.
Chapter 5, © Martin Jenkinson /Alamy.
Chapter 6, © RubberBall /Alamy.
Chapter 7, © Jack Sullivan/Alamy.
Chapter 8, © Ragnar Th Sigurdsson/Alamy.
Chapter 9, © George Hammerstein /Corbis Images.
Chapter 10, © HAWKEYE/Alamy.
Chapter 11, © Corbis RF.
Chapter 12, © Design Pics / LJM Photo/Newscom.
Chapter 13, © Erik Isakson/Alamy.
Chapter 14, © Yurchyks/Shutterstock.
Chapter 15, © Jarous/Shutterstock.
Chapter 16, © Flirt/Superstock
Chapter 17, © John Dorado/Shutterstock.

Other images provided by the author.

STATICS AND MECHANICS OF MATERIALS

Chapter 1

Large cranes such as this one are required to lift extremely large loads. Their design is based on the basic principles of statics and dynamics, which form the subject matter of engineering mechanics.

General Principles

CHAPTER OBJECTIVES

- To provide an introduction to the basic quantities and idealizations of mechanics.
- To give a statement of Newton's Laws of Motion and Gravitation.
- To review the principles for applying the SI system of units.
- To examine the standard procedures for performing numerical calculations.
- To present a general guide for solving problems.

1.1 Mechanics

Mechanics can be defined as that branch of the physical sciences concerned with the state of rest or motion of bodies that are subjected to the action of forces. In this book we will study two very important branches of mechanics, namely, statics and mechanics of materials. These subjects form a suitable basis for the design and analysis of many types of structural, mechanical, or electrical devices encountered in engineering.

Statics deals with the equilibrium of bodies, that is, it is used to determine the forces acting either external to the body or within it necessary to keep the body either at rest or moving with a constant velocity. *Mechanics of materials* studies the relationships between the external loads and the intensity of internal forces acting within the body. This subject is also concerned with computing the deformations of the body, and it provides a study of the body's stability when the body is subjected to external forces. In this book we will first study the principles of statics since for the design and analysis of any structural or mechanical element, it is *first* necessary to determine the forces acting both on and within its various members. Once these internal forces are determined, the size of the members, their deflection, and their stability can then be determined using the fundamentals of mechanics of materials, which will be covered later.