

ENGINEERING MECHANICS

PRINCIPLES OF  
**STATICS**



**R. C. Hibbeler**

Uses On-Line Homework  
through OneKey!



# ENGINEERING MECHANICS

## P R I N C I P L E S O F S T A T I C S

R. C. Hibbeler



Upper Saddle River, NJ 07458

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

Vice President and Editorial Director, ECS: *Marcia Horton*

Associate Editor: *Dee Bernhard*

Executive Managing Editor: *Vince O'Brien*

Managing Editor: *David A. George*

Production Editor: *Daniel Sandin*

Director of Creative Services: *Paul Belfanti*

Manager of Electronic Composition and Digital Content: *Allyson Graesser*

Assistant Manager of Electronic Composition and Digital Content: *William Johnson*

Art Director: *Jonathan Boylan*

Electronic Composition: *Lawrence La Raia*

Art Editor: *Xiaohong Zhu*

Manufacturing Buyer: *Lisa McDowell*

Senior Marketing Manager: *Holly Stark*

*About the Cover:* The forces within this truss bridge must be determined if they are to be properly designed.

Photo by R.C. Hibbeler



© 2006 by R.C. Hibbeler

Published by Pearson Prentice Hall

Pearson Education, Inc.

Upper Saddle River, New Jersey 07458

All rights reserved. No part of this book may be reproduced or transmitted in any form or by any means, without permission in writing from the publisher.

Pearson Prentice Hall™ is a trademark of Pearson Education, Inc.

The author and publisher of this book have used their best efforts in preparing this book. These efforts include the development, research, and testing of the theories and programs to determine their effectiveness. The author and publisher shall not be liable in any event for incidental or consequential damages with, or arising out of, the furnishing, performance, or use of these programs.

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

ISBN 0-13-186674-5

Pearson Education Ltd., *London*

Pearson Education Australia Pty. Ltd., *Sydney*

Pearson Education Singapore, Pte. Ltd.

Pearson Education North Asia Ltd., *Hong Kong*

Pearson Education Canada, Inc., *Toronto*

Pearson Educación de México, S.A. de C.V.

Pearson Education—Japan, *Tokyo*

Pearson Education Malaysia, Pte. Ltd.

Pearson Education, Inc., *Upper Saddle River, New Jersey*

## **TO THE STUDENT**

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

# ABOUT THIS PACKAGE

Hibbeler's *Principles of Statics* and *Principles of Dynamics* series is a unique text/web system designed with two goals in mind: 1) to provide students with a lower priced, paperback mechanics textbook and 2) to provide instructors with a better, more secure way to assign homework.

## Paperback Text with On-Line Homework Assignments

These paperback texts contain all the topics, explanations, and examples of the best-selling Hibbeler hardcover texts; no mechanics content has been deleted. Students who use these texts will have every equation, example, description, etc., available for study during the course and to keep as long-term reference material. However, almost all problem material has been deleted from the printed text; only a section of end of chapter review problems remain.

Instead of accessing homework problems printed in the text, students simply access their homework assignments on-line through Hibbeler's OneKey Course. Hibbeler's OneKey course contains a bank of approximately 3000 editable *Statics* and *Dynamics* problems that instructors can use to create their assignments. Instructors simply choose the homework problems they want, customize them if they choose, and then post these problems to the secure assignment area for their class. Instructors are provided with Mathcad versions of problem solutions so they can quickly generate custom solutions for their custom problems. Or, instructors can use PHGradeAssist—Prentice Hall's on-line, algorithmic homework generator—to create assignments. PHGradeAssist automatically generates a unique version of each problem for students and grades their answer.

---

## OneKey: Custom Homework, Secure Solutions, and Much More



Hibbeler's OneKey course—available at [www.prenhall.com/onekey](http://www.prenhall.com/onekey)—offers over 3000 *Statics* and *Dynamics* problems that you can personalize and post for your student assignments. Editing the values in a problem guarantees a fresh problem for your students. Then, use solutions powered by Mathcad to generate your own personal solution, and if you choose, post the solutions for your students on-line. OneKey also contains PHGradeAssist—an on-line assessment tool with approximately 600 algorithmic test bank problems. PHGA generates unique problems for students, grades the answer, and tracks student results automatically.

You'll find Hibbeler's OneKey course contains much more to help you and your students, including

- Student Hints: Each problem contains a student hint that you may choose to provide to your students. This hint is also fully editable should you wish to change it.

④

Announcements

Course Information

Course Tools

Course Documents

eBook

Current Events

Communication

Course Map

Control Panel

Course Documents

OneKey 2.0

Start Here!

Log in to your premium course resources!

Engineering Mechanics: Statics and Dynamics

Russell C. Hibbeler

Course Documents

What's Key?

Your OneKey course for Engineering contains many valuable learning resources. These include:

- Supplemental practice problems and solutions
- MATLAB/Mathcad Tutorials
- E-book
- PH GradeAssist
- Additional material from your instructor

Browser Tuneup

Set up for premium resources? Click here to check.

Protect Your Work!

Always remember to quit your browser when you're done.

Student Learning Resources

Non chapter-specific resources you may find useful at any time during the semester.

Table of Contents

A sample OneKey homepage.

- Active Book: A complete, online HTML version of the textbook students can use and refer to while completing homework and assignments.
- An extra bank of practice problems with solutions.
- Complete bank of .jpg images.
- Complete set of PowerPoint Slides.
- Active Learning slides—Perfect for classroom response systems.
- Mathcad and MATLAB tutorials.
- Animations and Simulations
- Math review tutorials.
- Mechanics visualization software—Ideal for in-class demonstrations

Instructors should visit [www.prenhall.com/onekey](http://www.prenhall.com/onekey) and/or contact their local sales rep to register and receive more information. You may also send an email requesting information to [engineering@prenhall.com](mailto:engineering@prenhall.com).

**Hibbeler's OneKey course is available free with any new Hibbeler text: Contact your local Prentice Hall sales rep or email [engineering@prenhall.com](mailto:engineering@prenhall.com) for ordering isbns and course management system options.** It is also available as a standalone item for student purchase at either your bookstore or on-line at [www.prenhall.com/onekey](http://www.prenhall.com/onekey).

## How to Get Started

### For Instructors

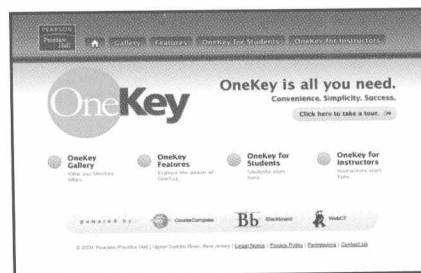
To use this text, you need to create your own unique OneKey course, where students will retrieve their homework problems and any other course materials you provide. To do so, you will need a OneKey access code. This will have either come bundled with the text or is available through either your local Prentice Hall Sales Rep, by request at [www.prenhall.com/onekey](http://www.prenhall.com/onekey), or by emailing [engineering@prenhall.com](mailto:engineering@prenhall.com).

Once you have your access code, go to [www.prenhall.com/onekey](http://www.prenhall.com/onekey) and follow instructions for instructors to register and establish your course. Complete on-line help is available through OneKey. You'll also find a "How To" FAQ in the Hibbeler OneKey Instructor Resource Center, which quickly explains how to create/save/post problem sets, solutions, and student hints. For general help, you can also contact the support staff at 1-800-677-6337.

Distribute your course information to your students in class. Students use this identifier to find your assignments at the site. Complete help is available on-line for students as well as through our support staff at 1-800-677-6337.

### For Students

You should keep the Access card that comes with new copies of the text since it contains complete instructions for registering for your course. Once you register, you simply log in to access these course materials as you need them. If you have difficulty registering, or logging in, either report the problem on-line as described on your access card, or call our support staff at 1-800-677-6337. If you need to purchase an access code, you'll find instructions for ordering one at [www.prenhall.com/onekey](http://www.prenhall.com/onekey). Before ordering, you should verify with your instructor which course management system you use.



You can always visit [www.prenhall.com/onekey](http://www.prenhall.com/onekey) for information and help getting started.

The main purpose of this book is to provide the student with a clear and thorough presentation of the theory and applications of engineering mechanics. To achieve this objective, the author has by no means worked alone; to a large extent, this series, through 10 editions, has been shaped by the comments and suggestions of hundreds of reviewers in the teaching profession as well as many of the author's students.

---

## New Features

Some unique features used throughout this tenth edition include the following:

- **Illustrations.** Throughout the book, new photorealistic illustrations have been added that provide a strong connection to the 3-D nature of engineering. In addition, particular attention has been placed on providing a view of any physical object, its dimensions, and the vectors applied to it in a manner that can be easily understood.
- **Problems.** The problems sets have been revised so that instructors can select both design and analysis problems having a wide range of difficulty. Apart from the author, two other professionals have checked all the problems for clarity and accuracy of the solutions. At the end of some chapters, design projects are included.
- **Review Material.** New end-of-chapter review sections have been added to help students recall and study key chapter points.

Of course, the hallmarks of the book remain the same: Where necessary, a strong emphasis is placed on drawing a free-body diagram, and the importance of selecting an appropriate coordinate system, and associated sign convention for vector components is stressed when the equations of mechanics are applied.

---

## Contents

The book is divided into 11 chapters, in which the principles are applied first to simple, then to more complicated situations. Most often, each principle is applied first to a particle, then to a rigid body subjected to a coplanar system of forces, and finally to a general case of three-dimensional force systems acting on a rigid body.



Chapter 1 begins with an introduction to mechanics and a discussion of units. The notation of a vector and the properties of a concurrent force system are introduced in Chapter 2. This theory is then applied to the equilibrium of a particle in Chapter 3. Chapter 4 contains a general discussion of both concentrated and distributed force systems and the methods used to simplify them. The principles of rigid-body equilibrium are developed in Chapter 5 and then applied to specific problems involving the equilibrium of trusses, frames, and machines in Chapter 6, and to the analysis of internal forces in beams and cables in Chapter 7. Applications to problems involving frictional forces are discussed in Chapter 8, and topics related to the center of gravity and centroid are treated in Chapter 9. If time permits, sections concerning more advanced topics, indicated by stars (★) may be covered. Most of these topics are included in Chapter 10 (area and mass moments of inertia) and Chapter 11 (virtual work and potential energy). Note that this material also provides a suitable reference for basic principles when it is discussed in more advanced courses.

**Alternative Coverage.** At the discretion of the instructor, some of the material may be presented in a different sequence with no loss of continuity. For example, it is possible to introduce the concept of a force and all the necessary methods of vector analysis by first covering Chapter 2 and Section 4.2. Then after covering the rest of Chapter 4 (force and moment systems), the equilibrium methods of Chapters 3 and 5 can be discussed.

---

## Special Features

**Organization and Approach.** The contents of each chapter are organized into well-defined sections that contain an explanation of specific topics and illustrative example 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 an illustration 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.

**Free-Body Diagrams.** The first step to solving most mechanics problems requires drawing a diagram. By doing so, the student forms the habit of tabulating the necessary data while focusing on the physical aspects of the problem and its associated geometry. If this step is performed correctly, applying the relevant equations of mechanics becomes somewhat methodical since the data can be taken directly from the diagram. This step is particularly important when solving equilibrium problems, and for this reason drawing free-body diagrams is strongly emphasized throughout the book. In particular, special sections and examples are devoted to show how to draw free-body diagrams.

**Procedures for Analysis.** Found after many of the sections of 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. It is to be understood, 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.

**Photographs.** Many photographs are used throughout the book to explain how the principles of mechanics apply to real-world situations. In some sections, photographs have been used to show how engineers must first make an idealized model for analysis and then proceed to draw a free-body diagram of this model in order to apply the theory.

**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, 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.

**Example Problems.** All the example problems are presented in a concise manner and in a style that is easy to understand.

**Homework Problems** Instead of accessing homework problems printed in the text, students simply access their homework assignments on-line through Hibbeler's OneKey Course. Hibbeler's OneKey course contains a bank of approximately 3000 editable *Statics* and *Dynamics* problems that instructors can use to create their assignments. Instructors simply choose the homework problems they want, customize them if they choose, and then post these problems to the secure assignment area for their class. Instructors are provided with Mathcad versions of problem solutions so they can quickly generate custom solutions for their custom problems. Or, instructors can use PHGradeAssist—Prentice Hall's on-line, algorithmic homework generator—to create assignments. PHGradeAssist automatically generates a unique version of each problem for students and grades their answer.

Types of problems in OneKey include:

- **Free-Body Diagram Problems.** These assignments will impress upon the student the importance of mastering this skill as a requirement for a complete solution of any equilibrium problem.
- **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 and are stated

as such. 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.

- **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. Suitable numerical techniques along with associated computer programs are given in Appendix B. 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.
- **Design Projects.** At the end of some of the chapters, design projects have been included. It is felt that this type of assignment should be given only after the student has developed a basic understanding of the subject matter. These projects focus on solving a problem by specifying the geometry of a structure or mechanical object needed for a specific purpose. A force analysis is required and, in many cases, safety and cost issues must be addressed.

**Chapter Reviews.** New chapter review sections summarize key points of the chapter, often in bulleted lists.

**Appendices.** The appendices provide a source of mathematical formula and numerical analysis needed to solve the problems in the book. Appendix C provides a set of problems typically found on the Fundamentals of Engineering Examination. By providing a partial solution to all the problems, the student is given a chance to further practice his or her skills.

---

## Supplements

Hibbeler's robust supplements package supports students and instructors.



### OneKey: Custom Homework, Secure Solutions, and Much More

Hibbeler's OneKey course—available at [www.prenhall.com/onekey](http://www.prenhall.com/onekey)—offers over 3000 *Statics* and *Dynamics* problems that you can personalize and post for your student assignments. Editing the values in a problem guarantees a fresh problem for your students. Then, use solutions powered by Mathcad to generate your own personal solution, and if you choose, post the solutions for your students on-line. OneKey also contains PHGradeAssist—an on-line assessment tool with approximately 600 algorithmic test bank problems. PHGA generates unique problems for students, grades the answer, and tracks student results automatically.

You'll find Hibbeler's OneKey course contains much more to help you and your students, including

- Student Hints: Each problem contains a student hint that you may choose to provide to your students. This hint is also fully editable should you wish to change it.
- Active Book: A complete, online HTML version of the textbook students can use and refer to while completing homework and assignments.
- An extra bank of practice problems with solutions.
- Complete bank of .jpg images.
- Complete set of PowerPoint Slides.
- Active Learning slides—Perfect for classroom response systems.
- Mathcad and MATLAB tutorials.
- Animations and Simulations
- Math review tutorials.
- Mechanics visualization software—Ideal for in-class demonstrations

Instructors should visit [www.prenhall.com/onekey](http://www.prenhall.com/onekey) and/or contact their local sales rep to register and receive more information. You may also send an email requesting information to [engineering@prenhall.com](mailto:engineering@prenhall.com).

**Hibbeler's OneKey course is available free with any new Hibbeler text:** Contact your local Prentice Hall sales rep or email [engineering@prenhall.com](mailto:engineering@prenhall.com) for ordering isbns and course management system options. It is also available as a standalone item for student purchase at either your bookstore or on-line at [www.prenhall.com/onekey](http://www.prenhall.com/onekey).

**Instructor's Resource CD-ROM and Instructor Access Code** This supplement offers visual resources in CD-ROM format. These resources are also found on the Hibbeler OneKey Course.

**Statics Study Pack** (0-13-141209-4) Improved for the tenth edition, this supplement now contains chapter-by-chapter study materials, a Free-Body Diagram Workbook and access to a separate Practice Problems Website.

**Student Study Guide** *Statics* (0-13-141211-6)

Students may purchase a Study Guide containing more worked problems. Problems are partially solved and designed to help guide students through difficult topics.

---

## Acknowledgments

This text was derived from the tenth edition of Hibbeler's *Engineering Mechanics* series.

The author endeavored to write this book so that it will appeal to both the student and instructor. Through the years, many people have helped in its development, and I will always be grateful for their valued suggestions and comments. Specifically, I wish to personally thank the following individuals who have contributed their comments to this edition of *Statics* and *Dynamics*:

Paul Heyliger, *Colorado State University*  
Kenneth Sawyers, *Lehigh University*  
John Oyler, *University of Pittsburgh*  
Glenn Beltz, *University of California—Santa Barbara*  
Johannes Gessler, *Colorado State University*  
Wilfred Nixon, *University of Iowa*  
Jonathan Russell, *U.S. Coast Guard Academy*  
Robert Hinks, *Arizona State University*  
Cap. Mark Orwat, *U.S. Military Academy, West Point*  
Cetin Cetinyaka, *Clarkson University*  
Jack Xin, *Kansas State University*  
Pierre Julien, *Colorado State University*  
Stephen Bechtel, *Ohio State University*  
W. A. Curtain, *Brown University*  
Robert Oakberg, *Montana State University*  
Richard Bennett, *University of Tennessee*

A particular note of thanks is also given to Professors Will Liddell, Jr. and Henry Kuhlman for their specific help. A special note of thanks is given to the accuracy checkers, Scott Hendricks of VPI and Karim Nohra of the University of South Florida, who diligently checked all of the text and problems. I should also like to acknowledge the proofreading assistance of my wife, Conny (Cornelie), during the time it has taken to prepare this manuscript for publication.

Lastly, many thanks are extended to all my students and to members of the teaching profession who have freely taken the time to send me their suggestions and comments. Since this list is too long to mention, it is hoped that those who have given help in this manner will accept this anonymous recognition.

I would greatly appreciate hearing from you if at any time you have any comments, suggestions, or problems related to any matters regarding this edition.

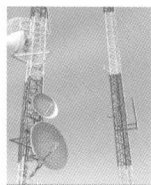
*Russell Charles Hibbeler*  
hibbeler@bellsouth.net



## 1

### General Principles 3

- Chapter Objectives 3
- 1.1 Mechanics 3
- 1.2 Fundamental Concepts 4
- 1.3 Units of Measurement 6
- 1.4 The International System of Units 8
- 1.5 Numerical Calculations 10
- 1.6 General Procedure for Analysis 14



## 2

### Force Vectors 17

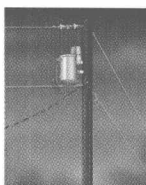
- Chapter Objectives 17
- 2.1 Scalars and Vectors 17
- 2.2 Vector Operations 18
- 2.3 Vector Addition of Forces 20
- 2.4 Addition of a System of Coplanar Forces 27
- 2.5 Cartesian Vectors 34
- 2.6 Addition and Subtraction of Cartesian Vectors 38
- 2.7 Position Vectors 43
- 2.8 Force Vector Directed Along a Line 46
- 2.9 Dot Product 50



## 3

### Equilibrium of a Particle 59

- Chapter Objectives 59
- 3.1 Condition for the Equilibrium of a Particle 59
- 3.2 The Free-Body Diagram 60
- 3.3 Coplanar Force Systems 63
- 3.4 Three-Dimensional Force Systems 68



## 4

### Force System Resultants 79

- Chapter Objectives 79
- 4.1 Moment of a Force—Scalar Formulation 79
- 4.2 Cross Product 84
- 4.3 Moment of a Force—Vector Formulation 87
- 4.4 Principle of Moments 92
- 4.5 Moment of a Force about a Specified Axis 96
- 4.6 Moment of a Couple 102
- 4.7 Equivalent System 108
- 4.8 Resultants of a Force and Couple System 110
- 4.9 Further Reduction of a Force and Couple System 114
- 4.10 Reduction of a Simple Distributed Loading 122



## 5

## Equilibrium of a Rigid Body 131

- 
- Chapter Objectives 131
  - 5.1 Conditions for Rigid-Body Equilibrium 131
  - 5.1 Equilibrium in Two Dimensions 133
  - 5.2 Free-Body Diagrams 133
  - 5.3 Equations of Equilibrium 145
  - 5.4 Two- and Three-Force Members 154
  - 5.4 Equilibrium in Three Dimensions 157
  - 5.5 Free-Body Diagrams 157
  - 5.6 Equations of Equilibrium 163
  - 5.7 Constraints for a Rigid Body 164



## 6

## Structural Analysis 177

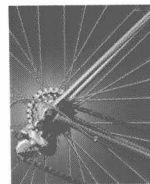
- 
- Chapter Objectives 177
  - 6.1 Simple Trusses 177
  - 6.2 The Method of Joints 180
  - 6.3 Zero-Force Members 186
  - 6.4 The Method of Sections 189
  - ★6.5 Space Trusses 195
  - 6.6 Frames and Machines 197



## 7

## Internal Forces 221

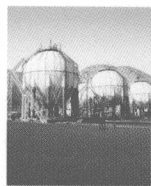
- 
- Chapter Objectives 221
  - 7.1 Internal Forces Developed in Structural Members 221
  - ★7.2 Shear and Moment Equations and Diagrams 232
  - ★7.3 Relations between Distributed Load, Shear, and Moment 236
  - ★7.4 Cables 244



## 8

## Friction 259

- 
- Chapter Objectives 259
  - 8.1 Characteristics of Dry Friction 259
  - 8.2 Problems Involving Dry Friction 263
  - 8.3 Wedges 274
  - ★8.4 Frictional Forces on Screws 276
  - ★8.5 Frictional Forces on Flat Belts 280
  - ★8.6 Frictional Forces on Collar Bearings, Pivot Bearings, and Disks 283
  - ★8.7 Frictional Forces on Journal Bearings 286
  - ★8.8 Rolling Resistance 288



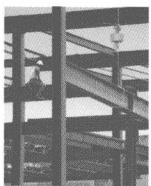
## 9

---

**Center of Gravity and Centroid 295**


---

- Chapter Objectives 295
- 9.1 Center of Gravity and Center of Mass for a System of Particles 295
- 9.2 Center of Gravity, Center of Mass and Centroid for a Body 297
- 9.3 Composite Bodies 311
- ★9.4 Theorems of Pappus and Guldinus 317
- ★9.5 Resultant of a General Distributed Loading 321
- ★9.6 Fluid Pressure 322



## 10

---

**Moments of Inertia 333**


---

- Chapter Objectives 333
- 10.1 Definition of Moments of Inertia for Areas 333
- 10.2 Parallel-Axis Theorem for an Area 335
- 10.3 Radius of Gyration of an Area 335
- 10.4 Moments of Inertia for an Area by Integration 336
- 10.5 Moments of Inertia for Composite Areas 342
- ★10.6 Product of Inertia for an Area 346
- ★10.7 Moments of Inertia for an Area about Inclined Axes 350
- ★10.8 Mohr's Circle for Moments of Inertia 353
- 10.9 Mass Moment of Inertia 357



## 11

---

**Virtual Work 369**


---

- Chapter Objectives 369
- 11.1 Definition of Work and Virtual Work 369
- 11.2 Principle of Virtual Work for a Particle and a Rigid Body 372
- 11.3 Principle of Virtual Work for a System of Connected Rigid Bodies 373
- ★11.4 Conservative Forces 380
- ★11.5 Potential Energy 381
- ★11.6 Potential-Energy Criterion for Equilibrium 382
- ★11.7 Stability of Equilibrium 384

---

**Appendices**


---

- A. Mathematical Expressions 392
- B. Numerical and Computer Analysis 394
- C. Review for the Fundamentals of Engineering Examination 400
- Answers to Selected Problems 419
- Index 421



# P R I N C I P L E S O F S T A T I C S