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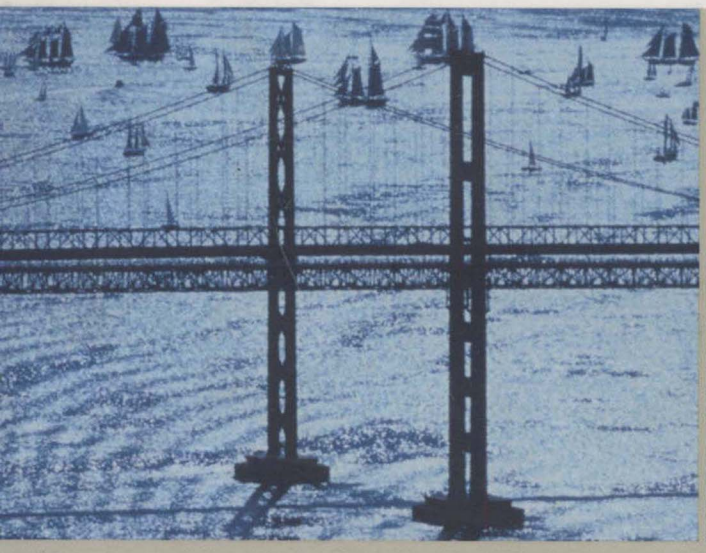
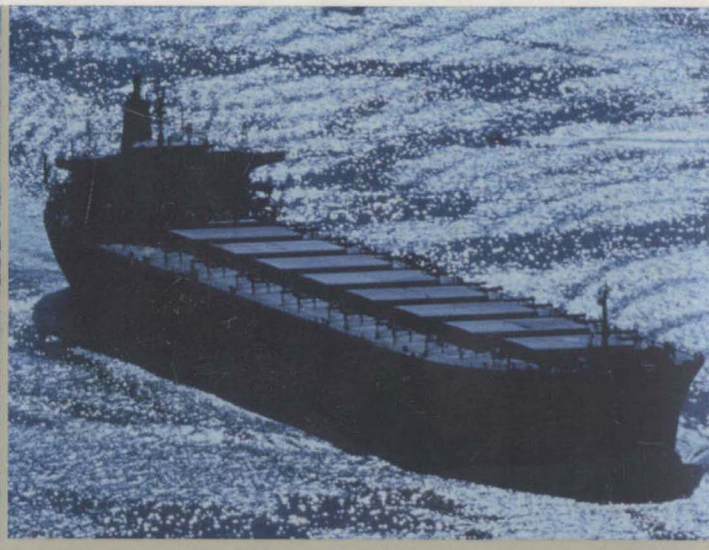
STATICS & DYNAMICS





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R. C. HIBBELER

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Engineering Mechanics

Statics & Dynamics

Ninth Edition

R. C. Hibbeler

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To the Student

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

Preface

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 book, through its eight 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

Significant improvements have been made to this the ninth edition. The following is a list of some of the more important ones:

- **Photographs.** Many photographs are used throughout the book to explain how the principles of mechanics apply to real-world situations. For example, in some sections of Statics, 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.
- **Artwork.** Throughout the book, the artwork has been further enhanced in a multicolor presentation in order to provide the reader with a more realistic and understandable sense of the material. In Dynamics, for example, motion of both particles and rigid bodies is depicted, along with time-lapsed positions of mechanisms, so that students have a full understanding of their kinematic behavior. Particular attention has been given to rendering each body such that its view, its dimensions, and the vectors applied to it can be easily understood.
- **Improved Pedagogy**. The "procedure for analysis" sections, along with a new feature, "important points," are presented using a bulleted list format in order to aid in problem solving and review. Also, clarity throughout the text has been improved, new examples have been provided, and many new problems have been added, including some that provide practice in drawing free-body diagrams.
- **Problems.** The problem sets have been revised so that instructors can select both design and analysis problems having a wide range of difficulty. Apart from the author, three other professionals have checked all the problems for clarity and accuracy of the solutions. At the end of some chapters, design projects have now been included.
- **Review Material.** In both Statics and Dynamics new appendices have been added that provide practice for solving problems for the Fundamentals in Engineering Examination. Partial solutions and the answers are given to all these problems, providing students with further applications of the theory.

In addition to the many improvements, 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.

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Contents

STATICS. The subject of Statics is covered in the first 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 a star (⋆), 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 Sec. 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.

DYNAMICS. The subject of Dynamics is presented in the last 11 Chapters. The kinematics of a particle is discussed in Chapter 12, followed by a discussion of particle kinetics in Chapter 13 (equation of motion), Chapter 14 (work and energy), and Chapter 15 (impulse and momentum). The concepts of particle dynamics contained in these four chapters are then summarized in a "review" section, and the student is given the chance to identify and solve a variety of problems. A similar sequence of presentation is given for the planar motion of a rigid body: Chapter 16 (planar kinematics), Chapter 17 (equations of motion), Chapter 18 (work and energy), and Chapter 19 (impulse and momentum), followed by a summary and review set of problems for these chapters.

If time permits, some of the material involving three-dimensional rigid-body motion may be included in the course. The kinematics and kinetics of this motion are discussed in Chapters 20 and 21, respectively.

Chapter 22 (vibrations) may be included if the student has the necessary mathematical background. As in Statics, sections of the book which are considered to be beyond the scope of the basic dynamics course are indicated by a star (★) and may be omitted.

Alternative Coverage. At the discretion of the instructor, it is possible to cover Chapters 12 through 19 in the following order with no loss in continuity: Chapters 12 and 16 (kinematics), Chapters 13 and 17 (equations of motion), Chapters 14 and 18 (work and energy), and Chapters 15 and 19 (impulse and momentum).

Special Features

Organization and Approach. The contents of each chapter are organized into well-defined sections which 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 to illustrate 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 peformed 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 or applying the equations of motion, and for this reason drawing free-body diagrams is strongly emphasized throughout the book. In Statics, special sections and examples are devoted to showing how to draw free-body diagrams, and specific homework problems in many sections of the book have been added to develop this practice.

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 gained, 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.

Example Problems. All the example problems are presented in a concise manner and in a style that is easy to understand. New examples have been added throughout the text, and some now include photographs to enhance the reality of the problem.

Homework Problems

- ***Free-Body Diagram Problems.*** Many sections in Statics now contain introductory problems that only require drawing the free-body diagram for specific problems within a problem set. 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 involve 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.

  Throughout the book, there is an approximate balance of problems using either SI or FPS units. Furthermore, in any set, an attempt has been made to arrange the problems in order of increasing difficulty. (Review problems are presented in random order.) 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.
- ***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. Problems of this type, which either can or must be solved using numerical procedures, are identified by a "square" symbol (■) preceding the problem number.
- ***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 often required, and in many cases safety and cost issues must be addressed.

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

Student Supplements

Statics/Dynamics Study Packs. The *Statics & Dynamics Study Packs* were designed to give students the tools to improve their study skills. **The Statics & Dynamics Study Packs come bundled for free with every Ninth Edition of the combined text** sold in bookstores. It consists of three study components — free-body diagram workbooks, Visualization CDs based on Working Model Software, and an access code to a website with over 1000 sample Statics and Dynamics problems and solutions.

- ***Free-Body Diagram Workbooks*** Prepared by Peter Schiavone of the University of Alberta. These workbooks begin with a tutorial on free-body diagrams and then each includes 50 practice problems of progressing difficulty with complete solutions. Further "strategies and tips" help students understand how to use the diagrams in solving the accompanying problems.
- ***Working Model CDs*** Prepared with the help of Gilbert Emmert of the University of Wisconsin, Madison and Joe Guarino of Boise St. University. These two CDs contain pre-set simulations of Statics and Dynamics examples in the text that include questions for further exploration. Simulations are powered by the Working Model Engine and were created with actual artwork from the text to enhance their correlation with the text.
- ***Password Protected Website*** This website contains 1000 sample Statics and Dynamics problems for students to study. Problems are keyed to each chapter of the text and contain complete solutions. All problems are supplemental and do not appear in the Ninth Edition. Student passwords are printed on the inside cover of the Free-Body Diagram Workbook. To access this site, students should go to *http://www.prenhall.com/hibbeler* and follow the online directions to register.

The *Dynamics Study Pack* is available as a stand-alone item. Order stand-alone study packs with the ISBN 0-13-090757-X.

The *Statics Study Pack* is also available and may be ordered using ISBN 0-13-029435-7.

Study Guide. Students may also purchase a further-study guide containing more worked out problems. Problems are partially solved and designed to help guide students through difficult topics. Order this supplement with ISBN 0-13-091019-8 for Dynamics, and ISBN 0-13-91015-5 for Statics.

Website—http://www.prenhall.com/hibbeler. This website contains on-line multiple-choice quizzes keyed to each chapter in the book. The *Study Pack* part of this website is password protected. Passwords for the protected portion are printed in the *Free-Body Diagram Workbook* portion of the *Statics and Dynamics Study Packs*.

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Instructor Supplements

Instructor's Solutions Manual with Presentation CD. This supplement available to instructors contains completely worked out solutions. Each solution comes with full problem statements as well as associated artwork. The accompanying CD contains PowerPoint slides of art from examples and text passages, as well as pdf files of all art from the book.

Course Management. Prentice Hall will be supporting Hibbeler with several course management options. Contact your sales rep or *engineering@prenhall.com* for complete information including prices and availability dates.

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The author has 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 related to this edition:

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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
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Contents

Statics

▸ 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

▸ 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 31
2.5 Cartesian Vectors 42
2.6 Addition and Subtraction of Cartesian Vectors 46
2.7 Position Vectors 55
2.8 Force Vector Directed Along a Line 58
2.9 Dot Product 68

▸ 3

Equilibrium of a Particle **81**

Chapter Objectives 81
3.1 Condition for the Equilibrium of a Particle 81
3.2 The Free-Body Diagram 82
3.3 Coplanar Force Systems 85
3.4 Three-Dimensional Force Systems 98

▸ 4

Force System Resultants **113**

Chapter Objectives 113
4.1 Moment of a Force—Scalar Formulation 113
4.2 Cross Product 118
4.3 Moment of a Force—Vector Formulation 121
4.4 Principle of Moments 126
4.5 Moment of a Force About a Specified Axis 138
4.6 Moment of a Couple 148
4.7 Equivalent System 160
4.8 Resultants of a Force and Couple System 162
4.9 Further Reduction of a Force and Couple System 166
4.10 Reduction of a Simple Distributed Loading 180

▸ 5

Equilibrium of a Rigid Body **193**

Chapter Objectives 193
5.1 Conditions for Rigid-Body Equilibrium 193
Equilibrium in Two Dimensions 195
5.2 Free-Body Diagrams 195
5.3 Equations of Equilibrium 209
5.4 Two- and Three-Force Members 218
Equilibrium in Three Dimensions 231
5.5 Free-Body Diagrams 231
5.6 Equations of Equilibrium 237
5.7 Constraints for a Rigid Body 238

▸ 6

Structural Analysis **257**

Chapter Objectives 257

6.1 Simple Trusses 257
6.2 The Method of Joints 260
6.3 Zero-Force Members 266
6.4 The Method of Sections 273
★6.5 Space Trusses 283
6.6 Frames and Machines 287

▸ 7

Internal Forces 323

Chapter Objectives 323
7.1 Internal Forces Developed in Structural Members 323
★7.2 Shear and Moment Equations and Diagrams 340
★7.3 Relations Between Distributed Load, Shear, and Moment 348
★7.4 Cables 358

▸ 8

Friction 377

Chapter Objectives 377
8.1 Characteristics of Dry Friction 377
8.2 Problems Involving Dry Friction 381
8.3 Wedges 402
★8.4 Frictional Forces on Screws 404
★8.5 Frictional Forces on Flat Belts 412
★8.6 Frictional Forces on Collar Bearings, Pivot Bearings, and Disks 419
★8.7 Frictional Forces on Journal Bearings 422
★8.8 Rolling Resistance 424

▸ 9

Center of Gravity and Centroid 435

Chapter Objectives 435
9.1 Center of Gravity and Center of Mass for a System of Particles 435
9.2 Center of Gravity, Center of Mass, and Centroid for a Body 437
9.3 Composite Bodies 459
★9.4 Theorems of Pappus and Guldinus 473
★9.5 Resultant of a General Distributed Loading 481
★9.6 Fluid Pressure 482

▸ 10

Moments of Inertia 497

Chapter Objectives 497
10.1 Definition of Moments of Inertia for Areas 497
10.2 Parallel-Axis Theorem for an Area 499
10.3 Radius of Gyration of an Area 499
10.4 Moments of Inertia for an Area by Integration 500
10.5 Moments of Inertia for Composite Areas 508
★10.6 Product of Inertia for an Area 516
★10.7 Moments of Inertia for an Area About Inclined Axes 520
★10.8 Mohr's Circle for Moments of Inertia 523
10.9 Mass Moment of Inertia 533

▸ 11

Virtual Work 549

Chapter Objectives 549
11.1 Definition of Work and Virtual Work 549
11.2 Principle of Virtual Work for a Particle and a Rigid Body 552
11.3 Principle of Virtual Work for a System of Connected Rigid Bodies 553
★11.4 Conservative Forces 566
★11.5 Potential Energy 567
★11.6 Potential-Energy Criterion for Equilibrium 568
★11.7 Stability of Equilibrium 570

▸ Appendixes

A. Mathematical Expressions 582

B. Numerical and Computer Analysis 584

C. Review for the Fundamentals of Engineering Examination 590

Answers 609

Index 622

Dynamics

▸ 12

Kinematics of a Particle 3

Chapter Objectives 3
12.1 Introduction 3
12.2 Rectilinear Kinematics: Continuous Motion 5
12.3 Rectilinear Kinematics: Erratic Motion 17
12.4 General Curvilinear Motion 30
12.5 Curvilinear Motion: Rectangular Components 32
12.6 Motion of a Projectile 37
12.7 Curvilinear Motion: Normal and Tangential Components 48
12.8 Curvilinear Motion: Cylindrical Components 61
12.9 Absolute Dependent Motion Analysis of Two Particles 76
12.10 Relative-Motion Analysis of Two Particles Using Translating Axes 82

▸ 13

Kinetics of a Particle: Force and Acceleration 97

Chapter Objectives 97
13.1 Newton's Laws of Motion 97
13.2 The Equation of Motion 101
13.3 Equation of Motion for a System of Particles 104
13.4 Equations of Motion: Rectangular Coordinates 106
13.5 Equations of Motion: Normal and Tangential Coordinates 123
13.6 Equations of Motion: Cylindrical Coordinates 135
★13.7 Central-Force Motion and Space Mechanics 146

▸ 14

Kinetics of a Particle: Work and Energy 159

Chapter Objectives 159
14.1 The Work of a Force 159
14.2 Principle of Work and Energy 164
14.3 Principle of Work and Energy for a System of Particles 166
14.4 Power and Efficiency 182
14.5 Conservative Forces and Potential Energy 190
14.6 Conservation of Energy 194

▸ 15

Kinetics of a Particle: Impulse and Momentum 207

Chapter Objectives 207
15.1 Principle of Linear Impulse and Momentum 207
15.2 Principle of Linear Impulse and Momentum for a System of Particles 214
15.3 Conservation of Linear Momentum for a System of Particles 222
15.4 Impact 233
15.5 Angular Momentum 246
15.6 Relation Between Moment of a Force and Angular Momentum 247
15.7 Angular Impulse and Momentum Principles 250
★15.8 Steady Fluid Streams 260
★15.9 Propulsion with Variable Mass 265

▸ Review 1

Kinematics and Kinetics of a Particle 277

▸ 16

Planar Kinematics of a Rigid Body 289

Chapter Objectives 289
16.1 Rigid-Body Motion 289
16.2 Translation 291
16.3 Rotation About a Fixed Axis 292
★16.4 Absolute General Plane Motion Analysis 307
16.5 Relative-Motion Analysis: Velocity 315
16.6 Instantaneous Center of Zero Velocity 329
16.7 Relative-Motion Analysis: Acceleration 339

16.8 Relative-Motion Analysis Using Rotating Axes 354

▸ 17

Planar Kinetics of a Rigid Body: Force and Acceleration 371

Chapter Objectives 371
17.1 Moment of Inertia 371
17.2 Planar Kinetic Equations of Motion 385
17.3 Equations of Motion: Translation 388
17.4 Equations of Motion: Rotation About a Fixes Axis 400
17.5 Equations of Motion: General Plane Motion 416

▸ 18

Planar Kinetics of a Rigid Body: Work and Energy 431

Chapter Objectives 431
18.1 Kinetic Energy 431
18.2 The Work of a Force 435
18.3 The Work of a Couple 437
18.4 Principle of Work and Energy 439
18.5 Conservation of Energy 453

▸ 19

Planar Kinetics of a Rigid Body: Impulse and Momentum 465

Chapter Objectives 465
19.1 Linear and Angular Momentum 465
19.2 Principle of Impulse and Momentum 471
19.3 Conservation of Momentum 486
19.4 Eccentric Impact 490

▸ Review 2

Planar Kinematics and Kinetics of a Rigid Body 500

▸ 20

Three-Dimensional Kinematics of a Rigid Body 515

Chapter Objectives 515
★20.1 Rotation About a Fixed Point 515
★20.2 The Time Derivative of a Vector Measured from a Fixed and Translating-Rotating System 518
★20.3 General Motion 523
★20.4 Relative-Motion Analysis Using Translating and Rotating Axes 532

▸ 21

Three-Dimensional Kinetics of a Rigid Body 545

Chapter Objectives 545
★21.1 Moments and Products of Inertia 545
★21.2 Angular Momentum 555
★21.3 Kinetic Energy 558
★21.4 Equations of Motion 566
★21.5 Gyroscopic Motion 580
★21.6 Torque-Free Motion 586

▸ 22

Vibrations 595

Chapter Objectives 595
★22.1 Undamped Free Vibration 595
★22.2 Energy Methods 608
★22.3 Undamped Forced Vibration 614
★22.4 Viscous Damped Free Vibration 618
★22.5 Viscous Damped Forced Vibration 621
★22.6 Electrical Circuit Analogs 624

▸ Appendixes

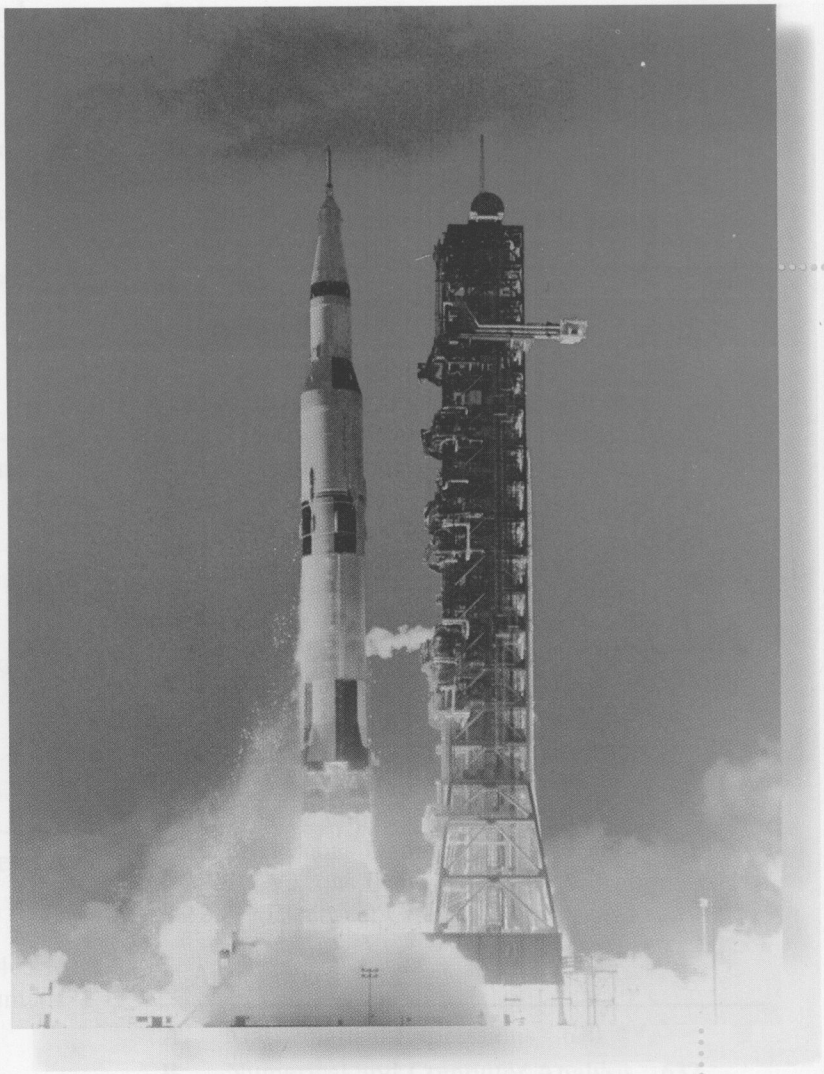
A. Mathematical Expressions 630
B. Numerical and Computer Analysis 632
C. Vector Analysis 641
D. Review for the Fundamentals of Engineering Examination 645

Answers to Selected Problems 661

Index 670

Statics

The design of this rocket and gantry structure requires a basic knowledge of both statics and dynamics, which forms the subject matter of engineering mechanics.



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