



STATICS AND MECHANICS OF MATERIALS

FIFTH 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 Mechanics of Materials and provide an acceptable guide to its understanding.

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PREFACE

This book represents a combined abridged version of two of the author's books, namely *Engineering Mechanics: Statics, Fourteenth Edition* and *Mechanics of Materials, Tenth 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

- **Preliminary Problems.** This new feature can be found throughout the text, and is given just before the Fundamental Problems. The intent here is to test the student's conceptual understanding of the theory. Normally the solutions require little or no calculation, and as such, these problems provide a basic understanding of the concepts before they are applied numerically. All the solutions are given in the back of the text.
- **Improved Fundamental Problems.** These problem sets are located just after the Preliminary Problems. They offer students basic applications of the concepts covered in each section, and they help provide the chance to develop their problem-solving skills before attempting to solve any of the standard problems that follow.
- **New Problems.** There are approximately 80% new problems that have been added to this edition, which involve applications to many different fields of engineering.
- **Updated Material.** Many topics in the book have been re-written in order to further enhance clarity and to be more succinct. Also, some of the artwork has been enlarged and improved throughout the book to support these changes.

- **New Layout Design.** Additional design features have been added to this edition to provide a better display of the material. Almost all the topics are presented on a one or two page spread so that page turning is minimized.
- **New Photos.** The relevance of knowing the subject matter is reflected by the real-world application of new or updated photos placed throughout the book. These photos generally are used to explain how the principles apply to real-world situations and how materials behave under load.

HALLMARK FEATURES

Besides the new features just mentioned, 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.

Preliminary and Fundamental Problems. These 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 Preliminary, 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 or 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.

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, Bittner Development Group; 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 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.

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 *Engineering Mechanics: Statics* and *Mechanics of Materials* texts. Their comments have guided the improvement of this book as well.

In particular, I would like to thank:

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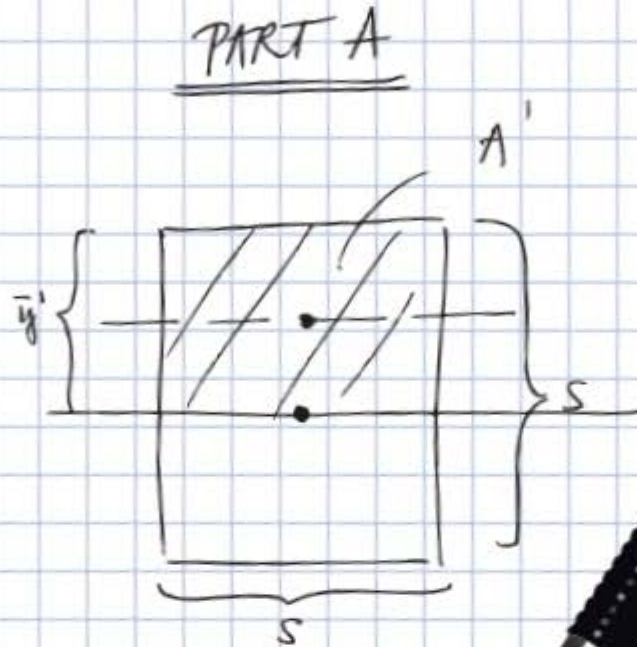
During the production process I am thankful for the assistance of Rose Kernan, my production editor for many years, and to my wife, Conny, for her help in proofreading and typing, that was needed to prepare the manuscript for publication.

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...



$$S = 6.75 \text{ in}$$

$$\bar{y}' = \frac{S}{2} = \frac{6.75 \text{ in}}{2} = 3.375 \text{ in}$$

$$A' = S \times 0.5 \times S = 6.75 \text{ in} \times 0.5 \times 6.75 \text{ in} = 22.8 \text{ in}^2$$

$$Q = \bar{y}' A' = 3.375 \text{ in} \times 22.8 \text{ in}^2 = 76.9 \text{ in}^3$$

$$Q = 76.9 \text{ in}^3$$

your answer **specific feedback**

Express your answer to three significant figures and include appropriate units.

$Q =$

Submit

[Hints](#) [My Answers](#) [Give Up](#) [Review Part](#)

Incorrect; Try Again; 5 attempts remaining

The distance between the horizontal centroidal axis of area A' and the neutral axis of the beam's cross section is half the distance between the top of the shaft and the neutral axis.

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.** An instructor's solutions manual was prepared by the author. The manual was also checked as part of the accuracy checking program. The Instructor Solutions Manual is available at www.pearsonhighered.com.
- **Presentation Resources.** All art from the text is available in PowerPoint slide and JPEG format. These files are available for download from the Instructor Resource Center at www.pearsonhighered.com. If you are in need of a login and password for this site, please contact your local Pearson representative.
- **Video Solutions.** Developed by Professor Edward Berger, Purdue University, video solutions located on the Pearson Engineering Portal 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 anytime 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 pearsonhighered.com/engineering-resources/ and follow the links for the *Statics and Mechanics of Materials* text.

RESOURCES FOR STUDENTS

- **Mastering Engineering.** Tutorial homework problems emulate the instructor's office-hour environment.
- **Engineering Portal**—The Pearson Engineering Portal, located at pearsonhighered.com/engineering-resources/ includes opportunities for practice and review including:
- **Video Solutions**—Complete, step-by-step solution walkthroughs of representative homework problems from each section of the text. Videos offer fully worked solutions that show every step of the representative homework problems—this helps students make vital connections between concepts.

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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 state Newton's Laws of Motion.
 - 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 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 that are necessary to keep the body in equilibrium. *Mechanics of materials* studies the relationships between the external loads and the distribution of internal forces acting within the body. This subject is also concerned with finding the deformations of the body, and it provides a study of the body's stability.

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.

Historical Development. The subject of statics developed very early in history because its principles can be formulated simply from measurements of geometry and force. For example, the writings of Archimedes (287–212 B.C.) deal with the principle of the lever. Studies of the pulley and inclined plane are also recorded in ancient writings—at times when the requirements for engineering were limited primarily to building construction.

The origin of mechanics of materials dates back to the beginning of the seventeenth century, when Galileo performed experiments to study the effects of loads on rods and beams made of various materials. However, at the beginning of the eighteenth century, experimental methods for testing materials were vastly improved, and at that time many experimental and theoretical studies in this subject were undertaken primarily in France, by such notables as Saint-Venant, Poisson, Lamé, and Navier.

Over the years, after many of the fundamental problems of mechanics of materials had been solved, it became necessary to use advanced mathematical and computer techniques to solve more complex problems. As a result, this subject has expanded into other areas of mechanics, such as the *theory of elasticity* and the *theory of plasticity*. Research in these fields is ongoing, in order to meet the demands for solving more advanced problems in engineering.

1.2 FUNDAMENTAL CONCEPTS

Before we begin our study, it is important to understand the definitions of certain fundamental concepts and principles.

Mass. *Mass* is a measure of a *quantity of matter* that is used to compare the action of one body with that of another. This property provides a measure of the resistance of matter to a change in velocity.

Force. In general, *force* is considered as a “push” or “pull” exerted by one body on another. This interaction can occur when there is direct contact between the bodies, such as a person pushing on a wall, or it can occur through a distance when the bodies are physically separated. Examples of the latter type include gravitational, electrical, and magnetic forces. In any case, a force is completely characterized by its magnitude, direction, and point of application.

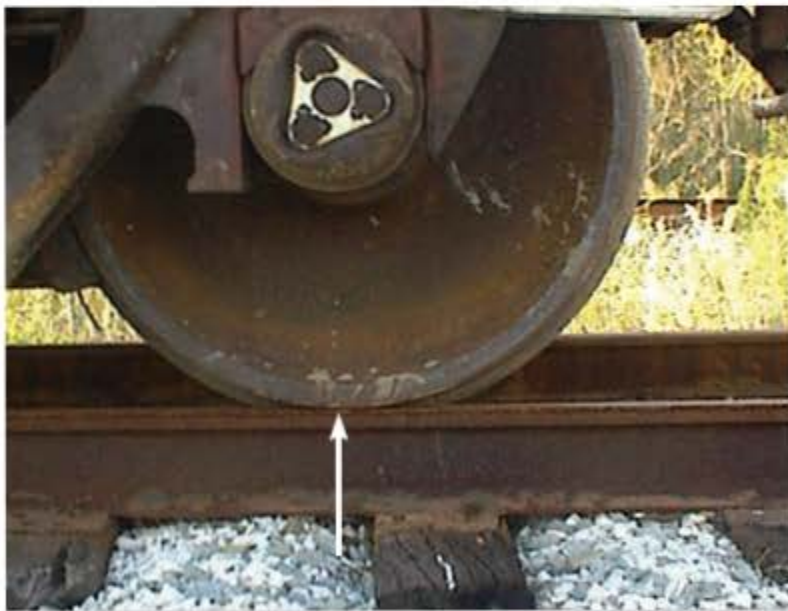
Particle. A *particle* has a mass, but a size that can be neglected. For example, the size of the earth is insignificant compared to the size of its orbit, and therefore the earth can be modeled as a particle when studying its orbital motion. When a body is idealized as a particle, the principles of mechanics reduce to a rather simplified form since the geometry of the body *will not be involved* in the analysis of the problem.

Rigid Body. A *rigid body* can be considered as a combination of a large number of particles in which all the particles remain at a fixed distance from one another, both before and after applying a load. This model is important because the material properties of any body that is assumed to be rigid will not have to be considered when studying the effects of forces acting on the body. In most cases the actual deformations occurring in structures, machines, mechanisms, and the like are relatively small, and the rigid-body assumption is suitable for analysis.

Concentrated Force. A *concentrated force* represents the effect of a loading which is assumed to act at a point on a body. We can represent a load by a concentrated force, provided the area over which the load is applied is very small compared to the overall size of the body. An example would be the contact force between a wheel and the ground.



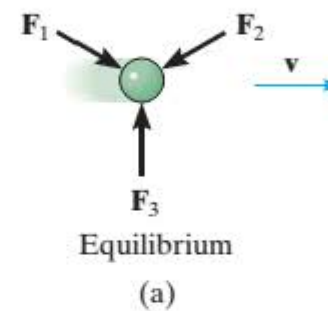
Three forces act on the ring. Since these forces all meet at a point, then for any force analysis, we can assume the ring to be represented as a particle.



Steel is a common engineering material that does not deform very much under load. Therefore, we can consider this railroad wheel to be a rigid body acted upon by the concentrated force of the rail.

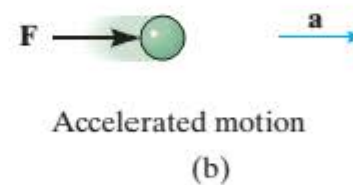
Newton's Three Laws of Motion. Engineering mechanics is formulated on the basis of Newton's three laws of motion, the validity of which is based on experimental observation. These laws apply to the motion of a particle as measured from a *nonaccelerating* reference frame. They may be briefly stated as follows.

First Law. A particle originally at rest, or moving in a straight line with constant velocity, tends to remain in this equilibrium state provided the particle is *not* subjected to an unbalanced force, Fig. 1-1*a*.



Second Law. A particle acted upon by an *unbalanced force* \mathbf{F} experiences an acceleration \mathbf{a} that has the same direction as the force and a magnitude that is directly proportional to the force, Fig. 1-1*b*. If the particle has a mass m , this law may be expressed mathematically as

$$\mathbf{F} = m\mathbf{a} \quad (1-1)$$



Third Law. The mutual forces of action and reaction between two particles are equal, opposite, and collinear, Fig. 1-1*c*.

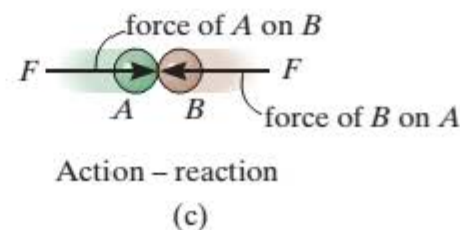


Fig. 1-1

Newton's Law of Gravitational Attraction. Shortly after formulating his three laws of motion, Newton postulated a law governing the gravitational attraction between any two particles. Stated mathematically,

$$F = G \frac{m_1 m_2}{r^2} \quad (1-2)$$

where

F = force of gravitation between the two particles

G = universal constant of gravitation; according to experimental evidence, $G = 66.73(10^{-12}) \text{ m}^3/(\text{kg} \cdot \text{s}^2)$

m_1, m_2 = mass of each of the two particles

r = distance between the two particles

Weight. According to Eq. 1-2, any two particles or bodies have a mutual attractive (gravitational) force acting between them. In the case of a particle located at or near the surface of the earth, however, the only gravitational force having any sizable magnitude is that between the earth and the particle. Consequently, this force, called the **weight**, will be the only gravitational force considered in our study of mechanics.

From Eq. 1-2, we can develop an approximate expression for finding the weight W of a particle having a mass $m_1 = m$. If we assume the earth to be a nonrotating sphere of constant density and having a mass $m_2 = M_e$, then if r is the distance between the earth's center and the particle, we have

$$W = G \frac{mM_e}{r^2}$$

Letting $g = GM_e/r^2$ yields

$$W = mg \quad (1-3)$$

By comparison with $\mathbf{F} = m\mathbf{a}$, we can see that g is the acceleration due to gravity. Since it depends on r , the weight of a particle or body is *not* an absolute quantity. Instead, its magnitude is determined from where the measurement was made. For most engineering calculations, however, g is determined at sea level and at a latitude of 45° , which is considered the "standard location."



This astronaut's weight is diminished since she is far removed from the gravitational field of the earth. (© NikoNomad/Shutterstock)

TABLE 1-1 SI System of Units

Name	Length	Time	Mass	Force
International System of Units	meter	second	kilogram	newton*
SI	m	s	kg	$\frac{\text{N}}{\left(\frac{\text{kg} \cdot \text{m}}{\text{s}^2}\right)}$

*Derived unit.

1.3 THE INTERNATIONAL SYSTEM OF UNITS

The four basic quantities—length, time, mass, and force—are not all independent from one another; in fact, they are *related* by Newton’s second law of motion, $\mathbf{F} = m\mathbf{a}$. Because of this, the *units* used to measure these quantities cannot *all* be selected arbitrarily. The equality $\mathbf{F} = m\mathbf{a}$ is maintained only if three of the four units, called **base units**, are *defined* and the fourth unit is then *derived* from the equation.

For the International System of Units, abbreviated SI after the French “Système International d’Unités,” length is in meters (m), time is in seconds (s), and mass is in kilograms (kg), Table 1-1. The unit of force, called a **newton** (N), is *derived* from $\mathbf{F} = m\mathbf{a}$. Thus, 1 newton is equal to a force required to give 1 kilogram of mass an acceleration of 1 m/s^2 ($\text{N} = \text{kg} \cdot \text{m/s}^2$).

If the weight of a body located at the “standard location” is to be determined in newtons, then Eq. 1-3 must be applied. Here measurements give $g = 9.80665 \text{ m/s}^2$; however, for calculations the value $g = 9.81 \text{ m/s}^2$ will be used. Thus,

$$W = mg \quad (g = 9.81 \text{ m/s}^2) \quad (1-4)$$

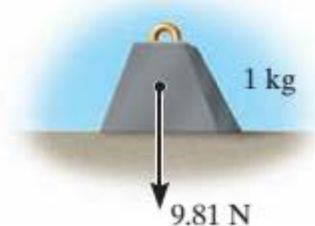


Fig. 1-2

Therefore, a body of mass 1 kg has a weight of 9.81 N, a 2-kg body weighs 19.62 N, and so on, Fig. 1-2. Perhaps it is easier to remember that a small apple weighs one newton. Also, by comparison with the U.S. Customary system of units (FPS),

$$1 \text{ pound (lb)} = 4.448 \text{ N}$$

$$1 \text{ foot (ft)} = 0.3048 \text{ m}$$

Prefixes. When a numerical quantity is either very large or very small, the units used to define its size may be modified by using a prefix. Some of the prefixes used in the SI system are shown in Table 1-2. Each represents a multiple or submultiple of a unit which, if applied successively, moves the decimal point of a numerical quantity to every

third place.* For example, 4 000 000 N = 4 000 kN (kilo-newton) = 4 MN (mega-newton), or 0.005 m = 5 mm (milli-meter). Notice that the SI system does not include the multiple deca (10) or the submultiple centi (0.01), which form part of the metric system. Except for some volume and area measurements, the use of these prefixes is generally avoided in science and engineering.

TABLE 1-2 Prefixes

	Exponential Form	Prefix	SI Symbol
<i>Multiple</i>			
1 000 000 000	10^9	giga	G
1 000 000	10^6	mega	M
1 000	10^3	kilo	k
<i>Submultiple</i>			
0.001	10^{-3}	milli	m
0.000 001	10^{-6}	micro	μ
0.000 000 001	10^{-9}	nano	n

Rules for Use. Here are a few of the important rules that describe the proper use of the various SI symbols:

- Quantities defined by several units which are multiples of one another are separated by a *dot* to avoid confusion with prefix notation, as indicated by $N = \text{kg} \cdot \text{m}/\text{s}^2 = \text{kg} \cdot \text{m} \cdot \text{s}^{-2}$. Also, $\text{m} \cdot \text{s}$ (meter-second), whereas ms (milli-second).
- The exponential power on a unit having a prefix refers to both the unit *and* its prefix. For example, $\mu\text{N}^2 = (\mu\text{N})^2 = \mu\text{N} \cdot \mu\text{N}$. Likewise, mm^2 represents $(\text{mm})^2 = \text{mm} \cdot \text{mm}$.
- With the exception of the base unit the kilogram, in general avoid the use of a prefix in the denominator of composite units. For example, do not write N/mm , but rather kN/m ; also, m/mg should be written as Mm/kg .
- When performing calculations, represent the numbers in terms of their *base or derived units* by converting all prefixes to powers of 10. The final result should then be expressed using a *single prefix*. Also, after calculation, it is best to keep numerical values between 0.1 and 1000; otherwise, a suitable prefix should be chosen. For example,

$$\begin{aligned} (50 \text{ kN})(60 \text{ nm}) &= [50(10^3) \text{ N}][60(10^{-9}) \text{ m}] \\ &= 3000(10^{-6}) \text{ N} \cdot \text{m} = 3(10^{-3}) \text{ N} \cdot \text{m} = 3 \text{ mN} \cdot \text{m} \end{aligned}$$

*The kilogram is the only base unit that is defined with a prefix.



Computers are often used in engineering for advanced design and analysis. (© Blaize Pascall/Alamy)

1.4 NUMERICAL CALCULATIONS

Numerical work in engineering practice is most often performed by using handheld calculators and computers. It is important, however, that the answers to any problem be reported with justifiable accuracy using appropriate significant figures. In this section we will discuss these topics together with some other important aspects involved in all engineering calculations.

Dimensional Homogeneity. The terms of any equation used to describe a physical process must be *dimensionally homogeneous*; that is, each term must be expressed in the same units. Provided this is the case, all the terms of an equation can then be combined if numerical values are substituted for the variables. Consider, for example, the equation $s = vt + \frac{1}{2} at^2$, where, in SI units, s is the position in meters, m , t is time in seconds, s , v is velocity in m/s , and a is acceleration in m/s^2 . Regardless of how this equation is evaluated, it maintains its dimensional homogeneity. In the form stated, each of the three terms is expressed in meters $[m, (m/s)s, (m/s^2)s^2]$ or solving for a , $a = 2s/t^2 - 2v/t$, the terms are each expressed in units of m/s^2 $[m/s^2, m/s^2, (m/s)/s]$.

Keep in mind that problems in mechanics always involve the solution of dimensionally homogeneous equations, and so this fact can then be used as a partial check for algebraic manipulations of an equation.

Significant Figures. The number of significant figures contained in any number determines the accuracy of the number. For instance, the number 4981 contains four significant figures. However, if zeros occur at the end of a whole number, it may be unclear as to how many significant figures the number represents. For example, 23 400 might have three (234), four (2340), or five (23 400) significant figures. To avoid these ambiguities, we will use *engineering notation* to report a result. This requires that numbers be rounded off to the appropriate number of significant digits and then expressed in multiples of (10^3) , such as (10^3) , (10^6) , or (10^{-9}) . For instance, if 23 400 has five significant figures, it is written as $23.400(10^3)$, but if it has only three significant figures, it is written as $23.4(10^3)$.

If zeros occur at the beginning of a number that is less than one, then the zeros are not significant. For example, 0.008 21 has three significant figures. Using engineering notation, this number is expressed as $8.21(10^{-3})$. Likewise, 0.000 582 can be expressed as $0.582(10^{-3})$ or $582(10^{-6})$.

Rounding Off Numbers. Rounding off a number is necessary so that the accuracy of the result will be the same as that of the problem data. As a general rule, any numerical figure ending in a number greater than five is rounded up and a number less than five is not rounded up. The rules for rounding off numbers are best illustrated by example. Suppose the number 3.5587 is to be rounded off to *three* significant figures. Because the fourth digit (8) is *greater than 5*, the third number is rounded up to 3.56. Likewise 0.5896 becomes 0.590 and 9.3866 becomes 9.39. If we round off 1.341 to three significant figures, because the fourth digit (1) is *less than 5*, then we get 1.34. Likewise 0.3762 becomes 0.376 and 9.871 becomes 9.87. There is a special case for any number that ends in a 5. As a general rule, if the digit preceding the 5 is an *even number*, then this digit is *not* rounded up. If the digit preceding the 5 is an *odd number*, then it is rounded up. For example, 75.25 rounded off to three significant digits becomes 75.2, 0.1275 becomes 0.128, and 0.2555 becomes 0.256.

Calculations. When a sequence of calculations is performed, it is best to store the intermediate results in the calculator. In other words, do not round off calculations until expressing the final result. This procedure maintains precision throughout the series of steps to the final solution. In this book we will generally round off the answers to *three significant figures* since most of the data in engineering mechanics, such as geometry and loads, may be reliably measured to this accuracy.

1.5 GENERAL PROCEDURE FOR ANALYSIS

Attending a lecture, reading this book, and studying the example problems helps, but **the most effective way of learning the principles of engineering mechanics is to solve problems.** To be successful at this, it is important to always present the work in a *logical and orderly manner*, as suggested by the following sequence of steps:

- Read the problem carefully and try to correlate the actual physical situation with the theory studied.
- Tabulate the problem data and *draw to a large scale* any necessary diagrams.
- Apply the relevant principles, generally in mathematical form. When writing any equations, be sure they are dimensionally homogeneous.
- Solve the necessary equations, and report the answer with no more than three significant figures.
- Study the answer with technical judgment and common sense to determine whether or not it seems reasonable.



When solving problems, do the work as neatly as possible. Being neat will stimulate clear and orderly thinking, and vice versa.