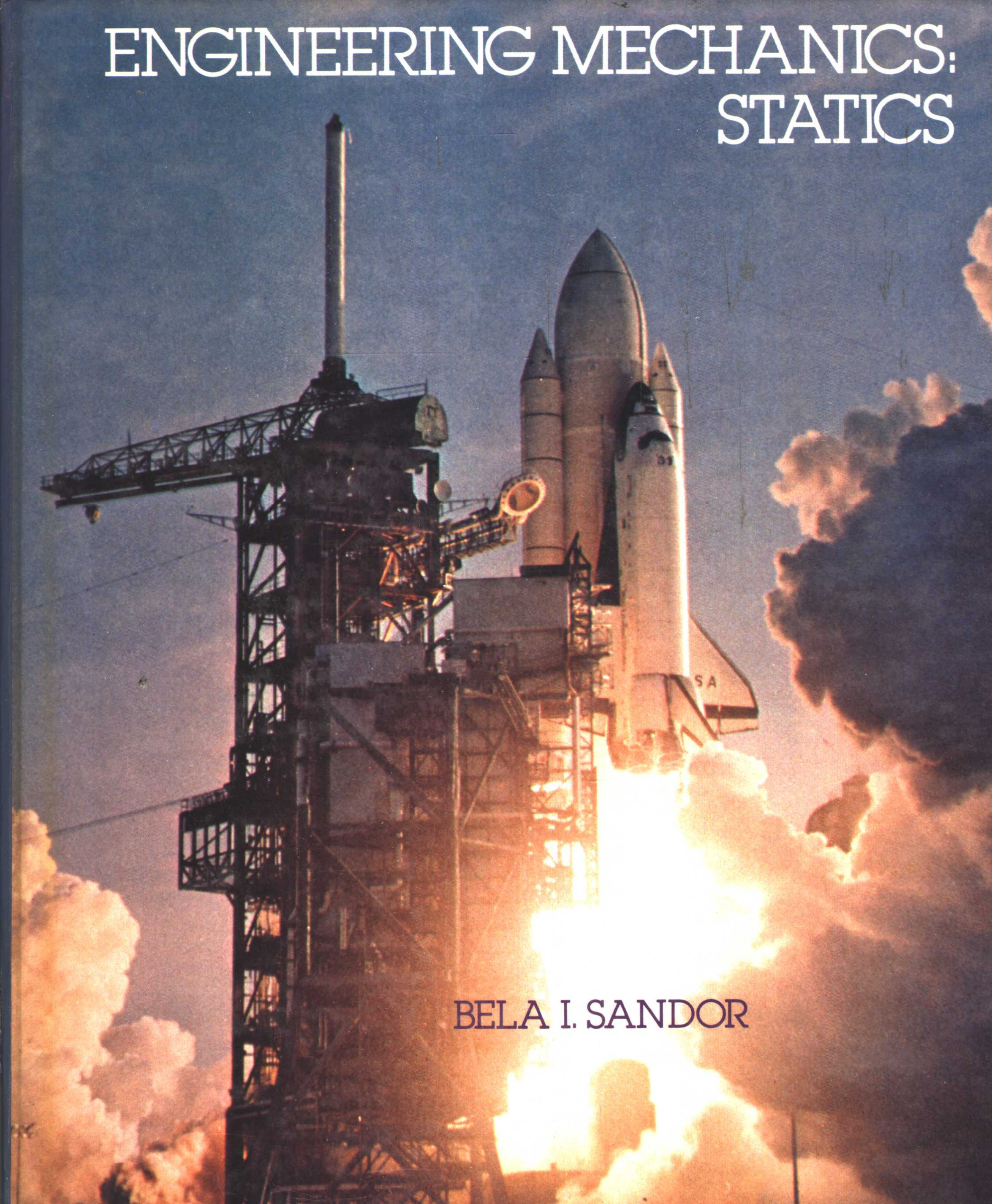
ENGINEERING MECHANICS: STATICS



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PREFACE

PREFACE TO THE STUDENT

Statics is a fundamental engineering subject; its concepts and methods are used in subsequent courses and in engineering practice. It is essential for the student to develop a working knowledge in this area. The material in this text facilitates the learning of statics in the following ways:

Perspectives. Concise statements at the beginning of each chapter describe the need for learning the material in that chapter. A few sections that may be omitted in statics courses are included to serve ambitious students and to provide for special assignments by the instructor if time permits.

Examples. The text is interspersed with groups of worked-out examples to show the applications of the equations and methods developed in the preceding sections. Realistic examples show the relevance of the subject to engineering practice. Additional examples are presented in *Learning and Review Aid for Statics* by Sandor and Schlack, published by Prentice-Hall.

Judgment of the results. Many example problems are concluded by a brief section showing judgment of the results. The student should exercise similar evaluation in all problems because the numerical answer to a problem may or may not be reasonable. Quick and correct assessment of an answer for acceptability requires thought and experience. Whenever possible, the judgment should be based on calculations, preferably using a different method of solution. Even apparently simplistic judgments (for example, knowing that the answer makes sense for the given problem) are important for the student and in engineering practice.

Homework problems. Problem sets of a wide range and of increasing difficulty follow each group of examples. A few of the problems require plotting the results as a function of a given parameter. Although this is time consuming, it is important for two reasons. First, a graphic display of the results enhances the learning process. The patterns of the data may quickly reinforce one's knowledge or provoke thought. Second, engineers often work and communicate in graphic ways. The practice of plotting results and sketching reasonable diagrams is useful preparation for the student. Answers are given to approximately two-thirds of the problems.

Mathematics. A working knowledge of elementary calculus is necessary. Vector methods are introduced in the text and are used in many problems.

Units. The SI and U.S. customary units are used approximately to the same extent throughout. There are enough examples and homework problems to allow a total concentration on either system of units if desired. Engineers in the United States will need to know both systems of units in the foreseeable future.

Summary sections. Each chapter is concluded with a graphically illustrated summary of the essential methods and equations. These summaries are very useful at all stages in the process of learning and preparation for examinations. It is recommended that the student look at the summaries prior to studying new topics. For a final review of the whole course, it may be convenient to remove the summary sheets from the book and use them separately.

PREFACE TO THE INSTRUCTOR

The main purpose in writing this text was to offer a useful learning aid to students of a wide range of abilities and ambitions. Instructors who read the book will notice the educational value of its large-scale structure and the attention given to details. Nevertheless, it is also useful to summarize the book's main features in this space.

Large-scale structure

1. ***Organization of chapters.*** Many topics in elementary mechanics can be studied in various orders, each with some advantages

and disadvantages for the student. The compromises in this text were made with an effort to ease the student's overall progress through the course. For example, bending moments in beams are first discussed in Ch. 5, but bending moments in beams under distributed loadings are presented in Ch. 7, because the latter topic is rather difficult for many students. Therefore, they benefit from the early presentation of the basic concept (which is simple) and from the considerable additional practice with free-body diagrams in Ch. 6 (trusses and frames) before studying distributed loadings. However, such an order of topics is by no means sacred. Those instructors who strongly wish to rearrange some of the presentations can do so without great difficulty for themselves or harm for the students.

2. *Organization within chapters.* Each chapter has three distinct parts:

a. The introductory part (always one section) describes the need for learning the material in that chapter. Concise statements give perspectives to each section in the central, major part of the chapter. The comments about emphasizing, or, in the other extreme, possibly omitting some sections are based on my experiences and observations. Some instructors may have different views for serving their own students, and I would most likely accept their reasons and opinions.

b. The central part of each chapter presents new material to the student. Generally, in this part, every few sections are followed by several worked-out example problems and a set of homework problems.

c. The summary section at the end of each chapter presents the essential methods and equations, graphically illustrated wherever appropriate. The instructor should encourage the students to use these summaries at all stages in the process of learning and in preparation for examinations.

Details

1. *Photographs.* The text is interspersed with photographs to enhance the realistic aspects of the material. In many instances the photographs also arouse the curiosity of the student toward the subject, an important part of educational motivation.

2. *Examples.* Each set of homework problems is preceded by one or more worked-out example problems. The total number of these examples in Statics is 116. It is not reasonable to put many more of them in the text, although some students could benefit from seeing more examples. Such students should be encouraged to obtain *Learning and Review Aid for Statics* by Sandor and Schlack, published by Prentice-Hall. This work book is devoted to worked-out examples of the most important topics.

3. ***Judgment of the results.*** Many example problems are concluded by a brief section showing judgment of the results. The instructor should encourage students to exercise similar evaluation in solving all problems because judgment is an important part of problem-solving in engineering practice.

4. ***Homework problems.*** Problem sets of a wide range and of increasing difficulty follow each group of examples. The instructor occasionally may encourage the students to use a vector method of solution for practice even when a scalar method is simpler. Answers are given to approximately two-thirds of the 860 problems.

5. ***Mathematics.*** The student should have a working knowledge of elementary calculus. Vector methods are introduced in the text where they can be used immediately.

6. ***Units.*** The SI and U.S. customary units are used approximately to the same extent throughout. There are enough examples and homework problems to allow a total concentration on either system of units if desired.

It is hoped that the instructor will encourage some independent effort (other than homework) on the part of the students for enhancing their learning experience and to better prepare them for the realities of engineering work. This book will aid both the teacher and the student in such endeavors. For example, students should study independently some topics of special interest; the instructor may play a role as a counselor in that work. Another useful way for the students to acquire independence is to develop the judgments of the results of problem solutions. This may involve different methods of solution to a given problem, different qualitative judgments, or relevant thought experiments. I believe that instructors would give recognition and credit to students both for effort and ability in this kind of work. Good luck to everyone!

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LIST OF SYMBOLS

SYMBOL	QUANTITY REPRESENTED
a	Constant; distance
$A, B, C, \ldots$	Points in space or on structure
A	Planar area
b	Width; distance
c	Distance
C	Centroid; constant
d	Distance
e	Natural logarithm base
$\mathbf{F}$	Force (vector form)
F	Magnitude of force
$\mathscr{F}$	Friction force
g	Gravitational acceleration
G	Center of gravity; constant of gravitation
h	Height
$\mathbf{i}, \mathbf{j}, \mathbf{k}$	Unit vectors along the x, y, z coordinate axes, respectively
I	Moment of inertia
J	Polar moment of inertia
k	Spring constant
l	Length
m	Mass
$\mathbf{M}$	Moment (vector form)
M	Magnitude of moment; mass
M_O	Moment about point O
M_{AB}	Moment about axis AB
$\mathbf{n}$	Unit vector
$\mathbf{N}$	Force normal to a surface

QUANTITY REPRESENTED	SYMBOL
Origin of coordinate system	O
Force	$\mathbf{P}$
Pressure	p
Position vector	$\mathbf{r}$
Radius; distance	r
Resultant vector; reaction	$\mathbf{R}$
Length of curve	s
Thickness	t
Tension force	T
Work	U
Shearing force	V
Load per unit length	w
Weight	W
Distance dimensions in rectangular coordinates	x, y, z
Coordinate location of centroid	x', y', z'
Angle	α (alpha)
Angle	β (beta)
Specific weight; angle	γ (gamma)
Change in length; angle	δ (delta)
Virtual displacement	$\delta\mathbf{r}$
Virtual work	δU
Efficiency	η (eta)
Angular coordinate; angle	θ (theta)
Coefficient of friction	μ (mu)
Density; distance	ρ (rho)
Angle of friction; angle	ϕ (phi)

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VOLUME 1

STATICS

CHAPTER 1

INTRODUCTION TO ENGINEERING MECHANICS

OVERVIEW

Students of several engineering specialties begin their engineering studies in the sophomore year by taking a course in statics, one of the fundamental subjects in engineering mechanics. These courses are based on the mechanics concepts of physics and provide the foundation for many other courses and engineering practice. Statics is the prerequisite for two common courses, dynamics and mechanics of materials (also called strength of materials). These in turn open the door to many other courses, as illustrated in the following flow diagram.

Statics

Dynamics | Mechanics of materials

Dynamics	Mechanics of materials
Courses in	Courses in
Advanced dynamics	Advanced mechanics of materials
Mechanics of fluids	Machine design
Machine design	Structural mechanics
Vibrations	Experimental stress analysis
etc.	etc.

Both dynamics and mechanics of materials are more difficult than statics for the average student. Therefore, a firm foundation in statics is important to assure satisfactory progress in subsequent courses.

STUDY GOALS

The remaining sections of this introductory chapter present definitions, basic concepts, systems of measurement, and some practical suggestions that are important for all fundamental or advanced courses in engineering mechanics. An overview of these sections is given here.

SECTION 1-1 defines the major branches of engineering mechanics. Most engineers know the fundamentals of all of these subjects, but at the advanced level people tend to specialize in the dynamics, the materials, or the fluids area.

SECTIONS 1-2 and 1-3 present the terminology and basic definitions of Newtonian mechanics, which is the foundation of engineering mechanics. The student should try to remember these sections because a concise review of the basic concepts is desirable from time to time throughout statics and dynamics.

SECTION 1-4 defines the two kinds of quantities used in mechanics, scalars, and vectors. Various aspects and details of manipulations of vectors are presented throughout statics and dynamics. At all levels, these should be studied with intensity to facilitate the solution of complex problems.

SECTION 1-5 describes the SI system of units for the specific measure of the quantities used in engineering mechanics. The student should read this section to understand the scheme of basic and derived units and to note the statements concerning proper practices. For solving problems, the student will find the table inside the front cover the most useful to check the formulas of units and conversion factors between SI and the U.S. customary units.

SECTION 1-6 introduces the method of analytical modeling, which is used throughout statics and dynamics to facilitate the solving of problems. In many cases the modeling will appear very simple. However, sufficiently accurate and yet practical analytical models may require careful thought and should always have high priority in setting up solutions and checking the results.

SECTION 1-7 introduces recurring practical examples which show that the fundamental concepts of engineering mechanics and the necessary simplifications in modeling are indispensable in working on small or large projects. These examples will give the student a perspective view of engineering analysis in general.

1-1 ENGINEERING MECHANICS

Mechanics is a branch of physics, and it has the longest history among the physical sciences. Archimedes (287–212 B.C.) is considered the first systematic investigator of this subject, mainly for