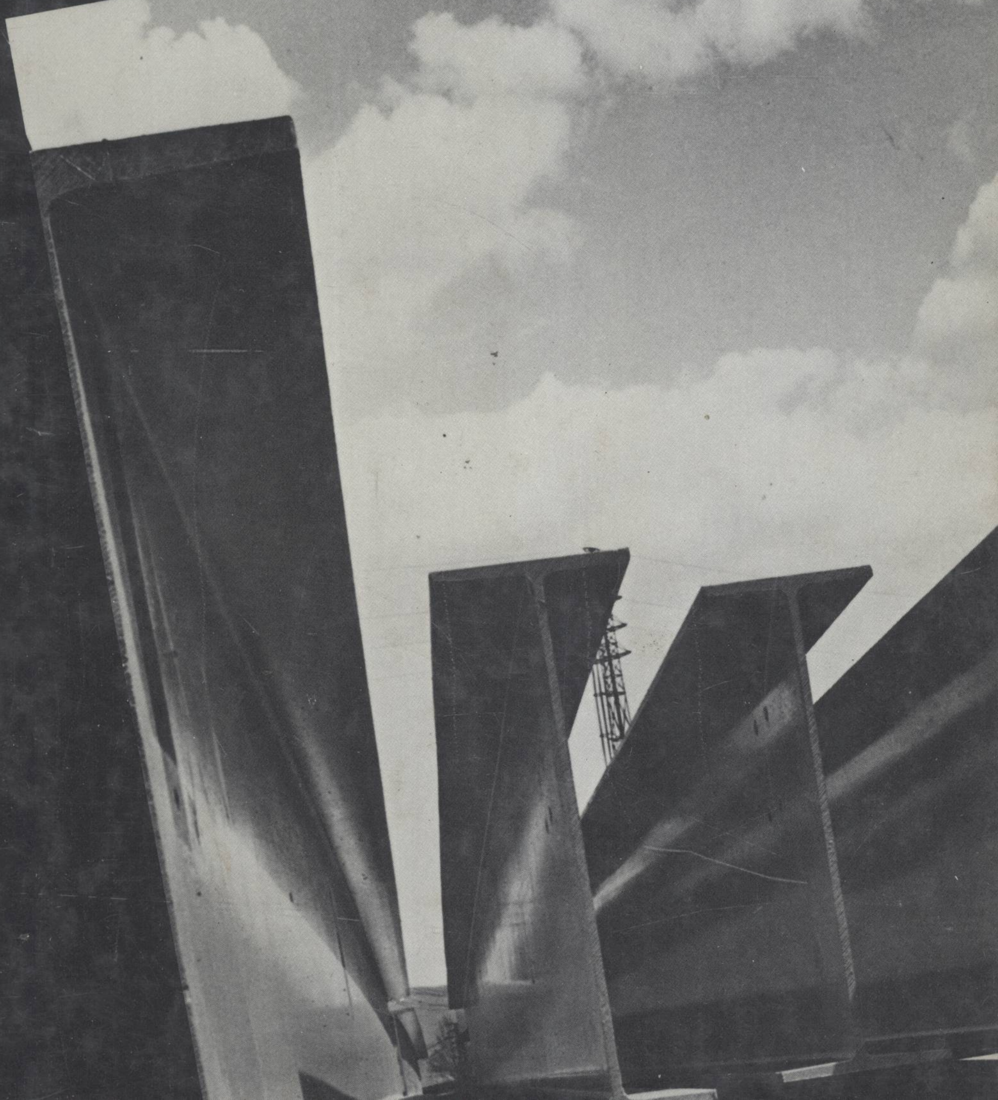
APPLIED ENGINEERING MECHANICS

FOURTH EDITION

JENSEN/CHENOWETH



Applied Engineering Mechanics

Fourth Edition

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Applied Engineering Mechanics

By Alfred Jensen and Harry H. Chenoweth:

Applied Engineering Mechanics, Fourth Edition
Applied Strength of Materials, Fourth Edition
Statics and Strength of Materials, Fourth Edition

Preface

The object of this fourth edition of *Applied Engineering Mechanics* is to provide students who intend to enter the engineering profession with the basic engineering mechanics knowledge that is so essential to their education, regardless of the branch of engineering they eventually may follow.

As in the previous editions, the text material is based on easily and commonly understood physical concepts and principles, rather than on the more abstract mathematical relationships that often are not as well understood. For greater clarity, the text refers in a few places (especially in the appendixes) to the principles of calculus. However, all the text material is so simply stated and the mathematical formulas so carefully developed that nothing more than an understanding of high school mathematics is required. In this respect, this new edition is similar to its companion volume, *Applied Strength of Materials,* also written by us.

Our primary aim has been to develop and to present the material in an easily understood manner in order to make the text suitable in content and approach both for college students in engineering and architecture and for those in junior colleges, technical institutes, and in many industrial training and Armed Services programs. Furthermore, we believe the text will be a continuing aid to the many practicing engineers and engineering aides who, in the past, have found the previous editions useful as a reference text.

The book is divided into two parts: statics and dynamics. In statics, the problems most often occurring in practice are given more than usual emphasis. Analytical and graphical solutions are presented side by side in order to show their close relationship and to encourage students to use them concurrently, one as a check on the other. Experience has shown that graphical solutions enable a student to *visualize* force analysis; such solutions definitely better the students' understanding of corresponding processes in analytical solutions.

In arranging and developing the subject matter in both sections, we have proceeded very gradually from the elementary problems to those more difficult, in the belief that, by such gradation, students learn more quickly and easily. Our experience has been that students learn more efficiently by thoroughly mastering one step at a time and later integrating the various steps and concepts into a completed whole.

About one-fourth of the problems in this fourth edition are in SI units (Système International d'Unités). This change reflects the worldwide movement toward a single international standard for units. Our use of SI units extends to illustrative examples as well as to problems to be solved by students. Problem solutions are available to teachers who have adopted this book for classroom use.

Practical problems are used in the text wherever possible because they stimulate students' interest and often lie within their personal experience or observation. However, many practical problems, especially in dynamics, appear confusing and complex: when stripped of its complexities, the actual object may be reduced to a mere block, or simply "a body," and the problem is then of the so-called academic type. Such a problem, however, has definite teaching value because it enables students to concentrate entirely on the theory involved and to apply this in the solution, leaving any minor complexities for later study.

In the solution of analytical problems, great emphasis is placed on the *complete* free-body diagram. Students are encouraged to develop this diagram gradually as the solution progresses until, on completion of the problem, it shows all forces or their components. Simple arithmetical summations then prove the correctness of the solution without further computation.

The text is divided into 21 chapters, each composed of several sections. Each section presents additional theory, a new concept, or a different aspect, and contains one or more completely solved problems illustrating the application of some theory or concept. A number of problems follow, carefully arranged in order of difficulty. Each chapter closes with a summary of the important points and formulas covered in the chapter; this summary affords students a quick review of the essential parts. The summary, too, is followed by a series of review problems and by a number of review questions carefully arranged to test students' grasp of the subject matter.

Alfred Jensen
Harry Chenoweth

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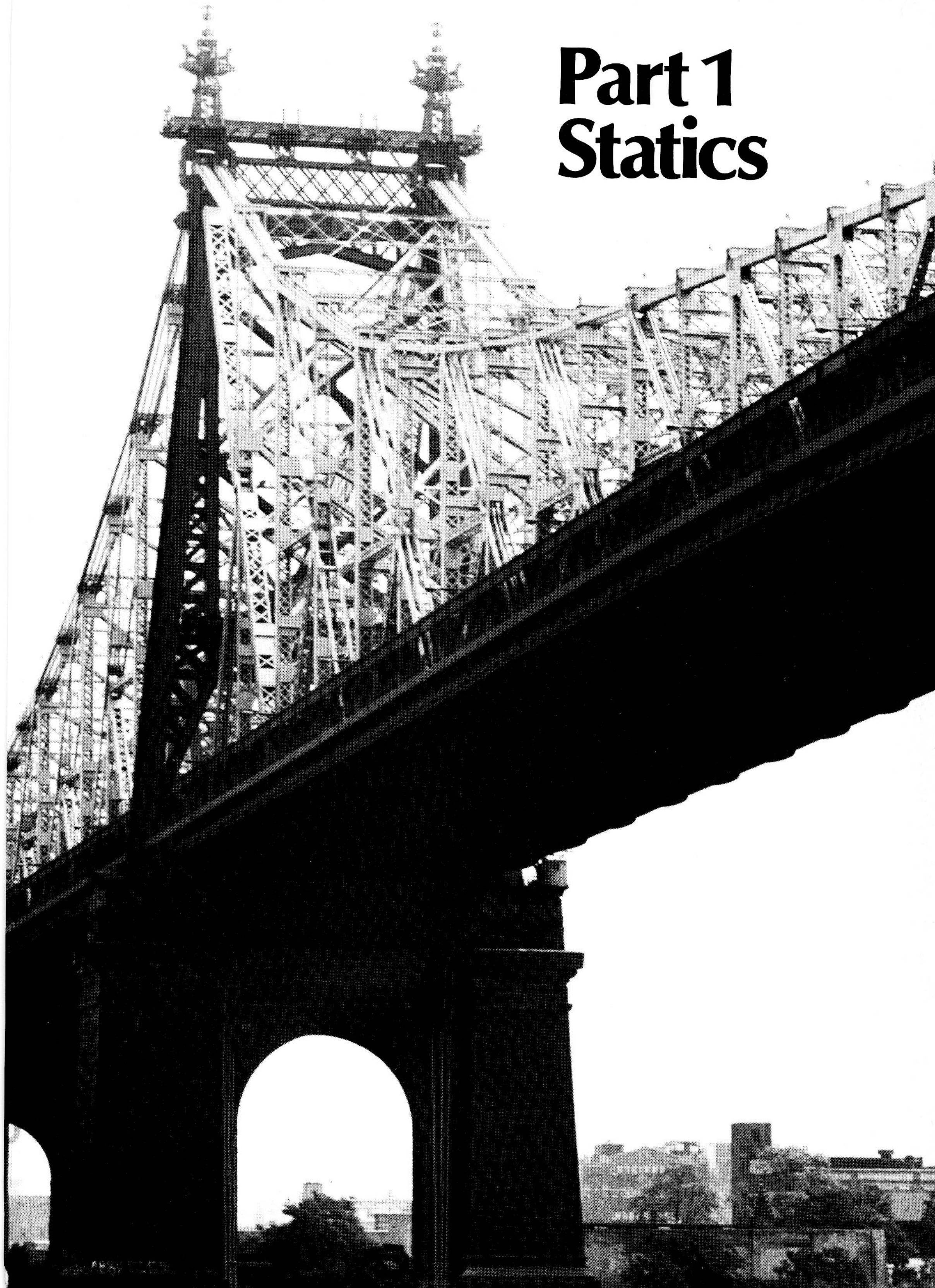
Part 1
Statics



Chapter 1 Introduction

1-1 DEFINITION OF MECHANICS

The science of **mechanics** treats of motion, forces, and the effects of forces on the bodies on which they act.

Applied engineering mechanics concerns itself mainly with applications of the principles of mechanics to the solution of problems commonly met within the field of engineering practice.

Mechanics is generally divided into two main branches of study: (1) statics and (2) dynamics. **Statics** is that branch which deals with forces and with the effects of forces acting on rigid bodies at rest. The subject of statics, therefore, is essentially one of *force analysis,* that is, a study of force systems and of their solutions. **Dynamics** deals with motion and with the effects of forces acting on rigid bodies in motion. Dynamics is divided into two branches: (1) **kinematics,** the study of motion without consideration of the forces causing the motion, and (2) **kinetics,** the study of forces acting on rigid bodies in motion and of their effect in changing such motion.

1-2 PROBLEMS IN APPLIED MECHANICS

Engineers conceive, plan, design, and construct buildings, machines, airplanes, and countless other objects for the comfort and use of the human race. Each of these objects serves a definite and useful purpose; behind each lies an absorbingly interesting story of engineering skill and achievement.

Having in mind a definite purpose for the object to be constructed, the engineer then conceives its appropriate form, either entirely new, or an improvement on one already in existence. The next step is to analyze and determine the forces, known and unknown, acting on the object, and the motions, if any, of its various related parts. To do this successfully, *the engineer must* *have a thorough knowledge and understanding of the principles of mechanics and of their applications to the particular problem.*

Having thus determined the forces and the motions involved, the engineer may proceed with the design of the object, using available materials of suitable strength and other requisite properties. The final size and shape of the object, and of each of its separate parts, may then be expressed in blueprints, after which the object is ready for production.

From this brief analysis of the work of the engineer, we see clearly that *a knowledge of mechanics is as fundamental to success in the field of engineering as is an understanding of the alphabet to those who would learn to read and write their own language.* The extent of this knowledge of mechanics may have an important bearing on the opportunities that will open to the student in this great field of work. Certainly, without some knowledge and training in mechanics, the student would have little or no chance of entering the engineering profession.

1-3 PROCEDURES IN THE SOLUTION OF MECHANICS PROBLEMS

Successful and efficient solution of any engineering problem calls for a well-organized and logical method of attack, involving a number of steps, each of which must first be well understood and then carefully executed. Among these steps, the following five include in a general way the entire process of solving any problem:

1. Analyze carefully the given data and ascertain the known quantities and the unknown quantities to be determined.
2. Recognize all the acting forces, known and unknown.
3. Decide on a suitable type of solution to use to determine the unknown quantities.
4. Formulate the steps to be taken to complete this solution.
5. Execute these steps, using available methods of checking the results.

The necessity for checking intermediate as well as final results as the solution progresses cannot be overemphasized, and yet it is most difficult to impress this fact on students, especially during the early part of their training; too many insist on dashing on to some answer, often finding it to be wrong and then, on a recheck, discovering some foolish or careless mistake which a second glance at the proper time would have quickly revealed.

1-4 STANDARDS OF QUALITY IN PROBLEM SOLUTION

Because of the great responsibility that attaches to the practice of engineering, high standards of work are demanded by the profession. These standards call for clear and neat figures and letters, and for uncrowded and logical arrangement of all computations and diagrams. Squared paper, 8½ by 11 inches (in.), and a straightedge for drawing diagrams are recommended. All diagrams must be complete; that is, they must show all forces, dimensions, and other items that are parts of the problem.

In order that computations may readily be checked, as they must be, all work except the simplest additions, subtractions, multiplications, and divisions must be shown. Of course, if the slide rule is used, no multiplications or divisions need be shown, but the processes must be indicated. One of the best ways of checking data and computations is to glance over them *as soon as they are completed,* to see that no mistake has been made and that the result obtained so far is *reasonable.* Often an absurd answer or a misplaced decimal point is thus quickly detected. The use of scratch paper encourages sloppy work and should, therefore, not be allowed.

In most engineering computations, a *degree of accuracy* to three significant figures is considered satisfactory. (The numbers 64,800 and 0.0648 both contain three significant figures, 6, 4, and 8.) The process of learning the subject matter and of attaining the required standards of quality is progressive. Students are encouraged, therefore, to file completed problems in a loose-leaf notebook which should always be available for ready reference.

Chapter 2
Basic Principles of Statics

2-1 FORCE

In his *first law of motion,* Sir Isaac Newton states that a body will continue in its state of rest or of uniform motion unless acted on by a force that changes or tends to change its state. Therefore, we may state that **force is an action that changes or tends to change the state of motion of the body on which it acts.** In statics we are interested only in bodies at rest. When applied to bodies at rest, as in statics, this definition more appropriately is that **force is an action that changes the shape of the body on which it acts.**

In his *third law of motion,* Newton states that **to every action there is an equal and opposed reaction.** A force, then, being an action, is always opposed by an equal reaction. Therefore, *forces exist not singly, but always in pairs, equal and opposite.* In analyzing forces and their effects, however, we may consider a force singly in order to study and evaluate its effect.

A body is any object, or any part of an object, which may be considered separately. When two objects are in contact, equal and opposite forces are produced at the contacting surfaces. A ball resting on a person's hand presents an example of two equal and opposite forces: the weight of the ball pressing down on the hand, and the hand pushing upward with a force equal to this weight, with force exerted on the two surfaces of contact.

When acted on by forces, a body is necessarily somewhat deformed; thus the relative positions of the points at which the forces are applied are changed slightly. In solid bodies, such as are normally encountered in engineering practice, these changes are so insignificant that, for the purpose of force analysis, the bodies may be considered to be "rigid" and are therefore referred to as *rigid bodies.*