STATICS & STRENGTH OF MATERIALS

SECOND EDITION

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STATICS AND STRENGTH OF MATERIALS

Second Edition

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PREFACE

Like the first edition of *Statics and Strength of Materials* and its predecessor, *Practical Mechanics and Strength of Materials,* by the late Charles W. Leigh and John F. Mangold, this second edition focuses on courses in statics and strength of materials which do not require the use of calculus. Thus, although the text is directed toward programs in community colleges, technical institutes, and junior colleges, it is equally suited for university extension courses, industrial training programs, and area vocational-technical schools, and for use by technically trained individuals interested in a basic refresher or self-study course. The practical orientation of the text has been retained and emphasized to ensure comprehension of the underlying principles and their application. The text can therefore serve as a foundation for courses in materials testing, materials selection, structural design, and machine design.

In this comprehensive revision, new material has been added and the text has been adapted to the latest requirements and specifications

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of the American Institute of Steel Construction. Many comments and suggestions of those who used the previous edition have also been incorporated.

A new section, Review of Statics, has been incorporated as Appendix A for use by students who have previously taken a course in statics and by instructors who wish to use Chapters 7 through 16 for a separate course in strength of materials.

Throughout the text, new diagrams, sample problems, and supplementary problems have been added. All the problems are graded for difficulty. Chapter 1, Fundamental Terms, has been revised and expanded to include the important general topics of numerical accuracy, rounding off of numerical results, and dimensional analysis. The concept of average stress as a useful approximation of real systems has been emphasized in Chapter 7, Simple Stresses. Chapter 8, Properties of Materials, has been almost entirely rewritten, and the section on multimaterial members has been expanded to include a greater variety of systems and associated problems. Chapter 9 has been substantially rewritten and expanded to include bolted joints based on the current AISC code, a more comprehensive treatment of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code for rivets, and the AISC code provisions for rivets and welds. In Chapter 12, the section on beam deflection has been rearranged so that the reader will be able to relate the text discussion directly to the appropriate diagram. In this chapter allowable stresses for various steels are given individually and are related to yield points in conformity with the revised AISC specifications. In Chapter 15, the AISC design equations for steel columns reflect the latest code revision.

The most frequently used tables have been kept, in Appendix B, and a list of important formulas is again placed at the end of the appendix for convenient reference. Answers to more than half the supplementary problems are given at the back of the book.

The symbols used throughout the book conform to the latest recommendations of the American Standards Association.

The authors invite suggestions, comments, and corrections by persons using the text.

We wish to acknowledge the many useful suggestions we received, with special thanks to the members of the Mechanical Technology and Construction Technology Departments of the New York City Community College.

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Harold Wolkoff

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1.

FUNDAMENTAL TERMS

1·1 INTRODUCTION TO MECHANICS

The importance of a thorough knowledge of fundamentals in any field cannot be overemphasized. Fundamentals have always been stressed in the learning of new skills whether it be football or physics.

Similarly, the science of mechanics is founded on basic concepts and forms the groundwork for further study in the design and analysis of machines and structures.

Mechanics can be divided into two parts: (*a*) statics, which relates to bodies at rest, and (*b*) dynamics, which deals with bodies in motion. This text is concerned with statics.

In mechanics, the term *strength of materials* refers to the ability of the individual parts of a machine or structure to resist loads. It also permits the determination of dimensions to ensure sufficient strength of the various parts.

1·2 BASIC TERMS

It is essential that the following 12 basic terms be understood, since they continually recur in all phases of this technical study:

Term	Symbol	Unit
Length	L, l	in.; ft
Area	A, a	in.^{2}; ft^2
Volume	V	in.^{3}; ft^3
Force	F, P	lb; tons; kips
Pressure	p	psi; psf
Mass	m	mass units
Weight	W, w	lb; tons; kips
Density	ρ (rho)	lb per in.^{3}; lb per ft^3
Moment	M	ft-lb; in.-lb
Work	Wk	ft-lb; in.-lb
Power		ft-lb per min; ft-lb per sec; hp
Torque	T	ft-lb; in.-lb

1·3 DEFINITIONS OF BASIC TERMS

Length. This term is applied to the linear dimension of a straight or curved line. For example, the diameter of a circle is the length of a straight line which divides the circle into two equal parts; the circumference is the length of its curved perimeter.

Area. The two-dimensional size of a shape or a surface is its area. The shape may be flat (lie in a plane) or curved, for example, the size of a plot of land, the surface of a fluorescent bulb, or the cross-sectional size of a shaft.

Volume. The three-dimensional or cubic measure of the space occupied by a substance is known as its volume.

Force. This term is applied to any action on a body which tends to make it move, change its motion, or change its size and shape. A force is usually thought of as a push or a pull, such as a hand pushing against a wall or the pull of a rope fastened to a body.

Pressure. The external force per unit area, or the total force divided by the total area on which it acts, is known as pressure. Water pressure against the face of a dam, steam pressure in a boiler, or earth pressure against a retaining wall are some examples.

Mass. The amount of matter in a body is called its mass, and for most problems in mechanics, mass may be considered constant.

Weight. The force with which a body is attracted toward the center of the earth by the gravitational pull is called its weight.

Density. The weight of a unit volume of a body or substance is the density. This term is sometimes called *weight density*, to distinguish it from a similar definition (mass density) made in terms of mass.

Moment. The *tendency* of a force to cause rotation about some point is known as a moment.

Torque. The action of a force which *causes* rotation to take place is known as torque. The action of a belt on a pulley causes the pulley to rotate because of torque. Also, if you grasp a piece of chalk near each end and twist your hands in opposite directions, it is the developed torque that causes the chalk to twist and, perhaps, snap.

Work. The energy developed by a force acting through a distance against a resistance is known as work. The distance may be along a straight line or along a curved path. When the distance is *linear*, the work can be found from *work = force × distance*. When the distance is along a *circular path*, the work can be found from *work = torque × angle*. Common forms of work include a weight lifted through a height, a pressure pushing a volume of a substance, and torque causing a shaft to rotate.

Power. The rate of doing work, or the work done per unit time, is called power. For example, a certain amount of work is required to raise an elevator to the top of its shaft. A 5-hp motor can raise the elevator, but a 20-hp motor can do the same job *four times faster.*

1·4 VECTORS AND SCALARS

Any quantity that is specified by a *magnitude only* is a *scalar* term. That is, a scalar is not related to any definite direction in space. Examples of scalars are $10, 5 ft, 82°F, 16 hp, 6 volts, etc.

A *vector* quantity has *magnitude* and is *related to a definite direction in space.* Force is such a quantity. To properly specify a force, its magnitude and direction must be known.

A vector quantity is represented by a line carrying an arrowhead at one end. The length of the line (to a convenient scale) equals the magnitude of the vector. The line, together with its arrowhead, defines the direction of the vector. Suppose a force of 5 lb is applied to point *A* in Fig. 1·1 at an angle of 30° to the horizontal. The vector **AB** represents this force since its length equals

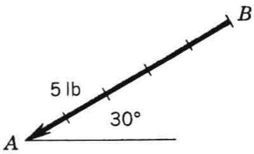

Figure 1·1 Force vector.

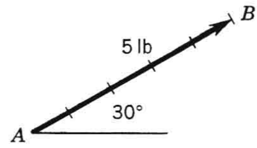

Figure 1·2 Force vector.

5 lb (to scale) and its direction is proper. If the vector **BA** is drawn to the same scale (Fig. 1·2), it represents a 5-lb force having a *direction exactly opposite* to vector **AB.**

1·5 NUMERICAL ACCURACY

Because the data used in engineering calculations vary in accuracy, it is important that we develop some means of indicating the accuracy of the data. This is necessary so that after performing a series of calculations, we arrive at an answer no more accurate than the original data.

We can establish the accuracy of a number by the use of *significant figures.* The larger the number of significant figures, the more accurate the data. For example, the number 2,300.65 has six significant figures and is more accurate than the number 2,301 which has four significant figures.

To establish the significant figures, we must keep in mind that the decimal point has nothing to do with the number of significant figures. Thus, each of the following has four significant figures: 27.61; 276.1; 0.2761; 0.002761; 2,761; 276,100; and 2.761×10^6.

1·6 ROUNDING OFF NUMBERS

If a number is given to the nearest hundredth and we wish to express it to the nearest tenth, what procedure do we follow? The following will apply to the rounding off of all numbers:

1. If the digit to be dropped is 5 or greater, increase the digit to the left by 1. Example: 36.48 becomes 36.5.
2. If the digit to be dropped is less than 5, simply drop it without changing the value of the digit to the left. Example: 36.42 becomes 36.4.

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