APPLIED MATHEMATICS FOR ENGINEERING AND SCIENCE

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PRENTICE-HALL SERIES IN TECHNICAL MATHEMATICS

Frank L. Juszli, *Editor*

Our aim in writing this book is to present mathematics as a useful tool. In this regard we have endeavored to present the fundamental principles of such work as algebra, trigonometry, linear equations and determinants, complex numbers, elementary statistics, basic calculus, etc., in as simple a form as possible consistent with applications to engineering and scientific problems. In addition, we have included numerous examples from all fields of technology and most chapters contain a section specifically devoted to applied problems. Over three thousand problems have been interspersed throughout the book to provide the student with sufficient experience in solving problems. This should give the student confidence in handling mathematics and should enable him to discover its usefulness for himself.

Although this text is intended primarily for students at technical institutes and junior colleges, it will prove useful to students of engineering, physics, and other applied sciences.

We have assumed that the student has had the normal secondary school background in mathematics. However, many of the topics are reviewed in the early chapters. The book begins with a study of operation with numbers and algebraic operations, and then continues with a study of logarithms and trigonometry. There is a thorough coverage of linear equations and determinants. More advanced topics such as vectors, analytical geometry, complex numbers, and solution of higher-order equations are treated in the latter part of the text. In line with the modern trend in education towards teaching computer applications, we have included an introductory treatment of probability and statistics. The book concludes with a thorough introduction to differential and integral calculus.

We have purposely relegated a description of the operations of slide rules to the appendix, in order that it may be presented at any convenient point in a mathematics program without breaking the continuity of the book. In addition, the appendix contains logarithmic and trigonometric tables, as well as many useful mathematical functions. The answers to odd-numbered exercises are provided following the appendices on page 642. Many of these answers were computerized utilizing both the Programma 101 and the PDP-8 computers.

We have endeavored to present the foregoing material in a logical sequence so as to lead the reader from simple and elementary techniques to those that are more complex and advanced. The presentation of the material in this book is based upon the authors' experience in both the industrial and teaching fields.

PREFACE

We are deeply indepted to the staff of Prentice-Hall for their assistance throughout the writing of the manuscript. The authors are also grateful to the reviewers for their important suggestions and objective critique. Finally, we wish to acknowledge the assistance extended to us by various members of the staff at the Manitoba Institute of Technology, too numerous to mention individually.

WARIS SHERE / GORDON LOVE

APPLIED
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"I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it: but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of Science, whatever the matter may be."

LORD KELVIN

CONTENTS

From early historic time, man's civilization has always in some way been measured by his knowledge of mathematics as well as his ability to manipulate numbers. Numbers were used by primitive man before the development of a spoken language; therefore, it is not inconceivable that he was able to appreciate the number ***three*** *without having had a name for numbers beyond* ***two.*** *Similarly, a herdsman was probably able to recognize that one of his sheep was missing without being able to count his flock. There is ample evidence that the nations which did the most trading, the most commerce, and had the highest forms of civilization were also the most conversant in number manipulation and mathematics.*

OPERATIONS WITH NUMBERS 1

Even today, numbers and their operations are fundamental to our advanced civilization just as they are to our way of life. There are numerous instances to be found in science and engineering. As an example, the doctor does not decide that his patient has a fever until the thermometer shows a temperature in excess of 98.6°F. Nor does the engineer design or build anything until he has made exact calculations and measurements.

Because a complete understanding of numbers is paramount to all science and engineering, we begin this book with the study of numbers and their operations.

There are two principal classes of numbers, *real* and *imaginary*, which together form the system of *complex numbers*. Complex numbers will be treated in Chapter 11.

1-1 The Real Number System

The number system in common use today is the *decimal system*, so named because it employs the 10 basic symbols 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, which are called *digits*. Other number systems which are employed for special purposes, such as the *binary system* and *octal system*, will be discussed in Sec. 1-6.

Any combination of the 10 basic digits shown above, other than as fractions (e.g., $\frac{2}{4}$, $1/\sqrt{2}$, $\frac{5}{2}$, . . .) or decimal numbers (e.g., 1.85, 3.176, 14.2, . . .), produces a *whole number*, also called a *natural number*. The technical name for a whole number is *integer;* integers represent numbers like 4, 18, 3, 1, 2, 0, −11, 1064, . . . The integers 1, 3, 5, 7, . . . are called *odd numbers;* while the integers 2, 4, 6, 8, . . . are called *even numbers*.

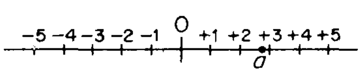

FIGURE 1-1

We can give geometrical meaning to the integers by referring to something known as the *number scale*, shown in Fig. 1-1. In this diagram we have drawn a section of an infinite straight line upon which a point is arbitrarily chosen as the origin and assigned the integer 0. Next we choose an arbitrary line length to correspond to unity and mark this unit distance on either side of the origin. We continue to mark off these unit lengths, assigning integer values as illustrated in Fig. 1-1. By convention, all integers to the right of 0 are positive, while those to the left are negative.

Figure 1-1 shows that for each integer there is a fixed point on the scale; or, conversely, for every unit length there is a unique integer. In more concise language we describe this as *one-to-one correspondence between the real numbers and the points on the line*. For instance, due to this correspondence, the letter ***a*** can mean either the *number* ***a*** or *the point* ***a*** *on the number scale*. Another result of this correspondence is that *equal* *distances between numbers correspond to equal distances between points.*

EXAMPLE 1-1. As shown in Fig. 1-2, 20°C can either be represented by the number or the distance from 0 on the thermometer scale to the point +20 units away.

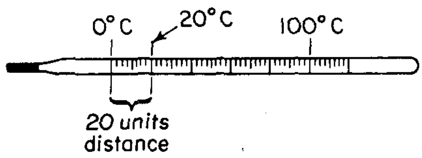

FIGURE 1-2

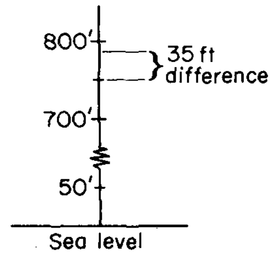

FIGURE 1-3

EXAMPLE 1-2. In driving from an elevation of 750 ft above sea level to 785 ft above sea level, a car would have moved through an elevation of 35 ft. On an elevation scale this would correspond to 35 units, as illustrated in Fig. 1-3.

At this point it is quite conceivable that the student may be confused between the two terminologies—integer and number. They are not necessarily the same because numbers may be fractions or decimals as well as whole numbers. But, *a number is only an integer when it is a whole number (positive or negative).* This fact is illustrated on the number scale shown in Fig. 1-4.

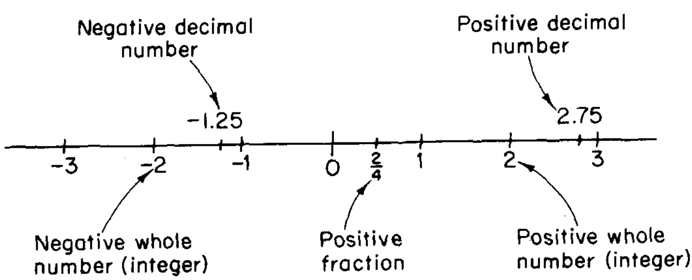

FIGURE 1-4

There is a fundamental property which can be observed by inspecting Fig. 1-4. If we let n represent *any* integer (including 0), then between n and $n + 1$ there *cannot* be an integer. In view of this property, all numbers lying between any two integers must be decimal or fraction numbers. Actually,