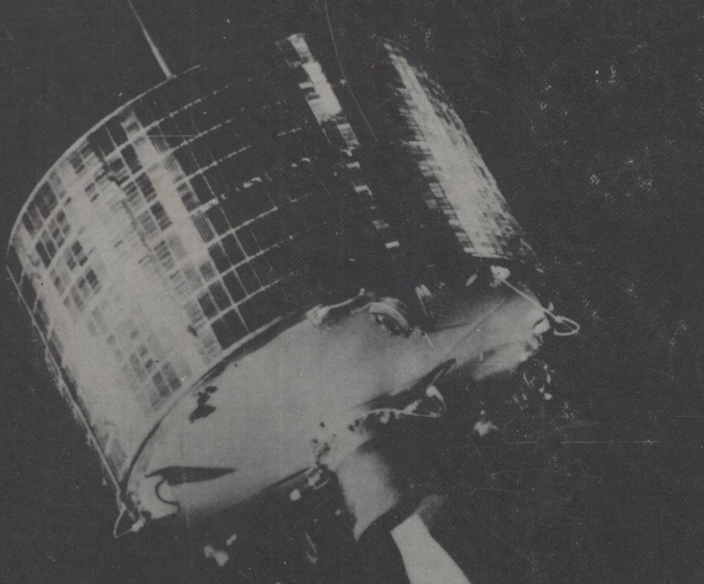

SECOND EDITION

Physics for Engineering Technology

Alexander Joseph · Kalman Pomeranz
Jack Prince · David Sacher

Physics for Engineering Technology

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Alexander Joseph
Professor Emeritus of Physics
Division of Science and Mathematics
John Jay College of Criminal Justice
The City University of New York

Kalman Pomeranz
Professor
Department of Physics
Bronx Community College
The City University of New York

Jack Prince
Professor
Chairman, Department of Physics
Bronx Community College
The City University of New York

David Sacher
Associate Professor
Department of Physics
Bronx Community College
The City University of New York

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Dedications

To my wife, Janet, whose astute criticism is responsible for most of the merit in my work.

K. B. P.

To Marilyn, whose inner strength, courage and unrestrained love are my source of inspiration and creativity.

J. P.

To my sons, Michael and Barry, for their encouragement and criticisms from the students' point of view.

D. S.

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Physics for Engineering Technology

Preface

We have written this textbook for students of the various engineering technologies that are offered in technical institutes, and community and junior colleges. It is intended for students whose mathematical preparation includes at least one year of elementary algebra and some basic elements of plane geometry. The necessary operational formulas in trigonometry are provided in the text.

Our aim, in a world of rapidly evolving new technological developments, is to provide an understanding of the basic principles of physics and the ways in which these principles are directly utilized in the engineering technologies. During the preparation of the first edition and since its publication, this book has been used by the students of engineering technology at the Bronx Community College. It has also been used as the textbook for a noncredit introductory course for engineering science students who have not had any previous exposure to physics.

The second edition has been prepared with both student and professor in mind. To help the student read the text with greater facility, each chapter begins with a brief overview and a listing of the major learning objectives. The student, therefore, is directed to those parts of the chapter that require his most diligent attention. At the close of each chapter, we have introduced a brief summary of the key terms and equations that have been studied. This is followed immediately by a series of questions aimed at testing the student's recollection of the material he has read. The answers to these questions can generally be found in the body of the chapter material. These questions can be used profitably by the students as a self-testing program.

Following the questions, we have provided the instructor with an increased selection of exercises from which to assign homework or recitation practice. For most chapters, these exercises have been grouped in two sections, A and B. The A group generally represents the basic problems that require minimum mathematical manipulation. The student can successfully solve these problems by recalling an appropriate principle or formula and substituting the given information. The B problems are often more challenging, requiring a sequence of thought processes or mathematical steps to arrive at the correct answer.

In revising much of the original text material, we have concentrated on simplifying the reading and mathematical levels while retaining the rigorously accurate physics that characterized the first edition. To help the student master the problem-solving techniques, we have added many solved examples to the body of the text. In streamlining the coverage, we have reduced the number of chapters from 41 to 39. We have increased and revised the material on modern physics while deleting much of the technical material on hydraulics and motion through fluids. We have also combined the chapters on thermometry and expansion into a single chapter. Much of the material previously discussed in the chapter on electrical conduction in solids, liquids, and gases has been deleted or rewritten into other parts of the book. In anticipation of the probable increase in demand by industry and hospitals for nuclear technicians, the revised chapter on atomic and nuclear physics (Chapter 39) emphasizes the subjects of radioactivity, the nuclear reactor and the laser. To our original treatment of applications in optics we have added sections on the camera, polarization and spectroscopy.

We believe this book can be adapted to serve the needs of students within a wide spectrum of ability levels. The more complex derivations have been set apart typographically. This arrangement enables the instructor to use those portions of the text that are best suited to his students. Answers to selected problems are included in the text, and a set of solutions for all problems is available to the instructor from the publisher.

Although the trend among many authors is to use the metric systems of units exclusively, we have chosen to retain the British system of engineering units wherever present practice in engineering technology still calls for it. Thus we use this latter system extensively in the sections on mechanics and to a lesser degree in the sections on heat. In most other areas the metric systems are used exclusively.

The following are suggested possible sequences of chapters for particular technologies using this book for two semesters. They apply, of course, only to situations in which the students take different physics courses in the various technologies:

1. Mechanical engineering technology: Chapters 1 to 3, 7 to 20, 22, 25 to 27, 29 to 32, 34 to 36, 38, 39.
2. Electrical engineering technology: Chapters 1 to 3, 7 to 13, 15 to 19, 22 to 33, and 39.
3. Construction engineering technology: Chapters 1 to 9, 11 to 13, 15 to 24, 29, and 34 to 38.
4. Chemical engineering technology: Chapters 1, 2, 7 to 9, 11 to 13, 16 to 22, 24, 25, and 28 to 38.
5. Medical laboratory technology: Chapters 1 to 3, 5 to 7, 9 to 12, 14 to 18, 22, and 24 to 39.
6. Nuclear technology: Chapters 1 to 3, 7 to 13, 17 to 22, 25 to 39.

When all technologies must take the same physics sequence, we recommend covering the chapters in order, with the possible exclusion of part or all of Chapters 11, 13, 16, 24, 32, 33, 37, 38, and 39.

The production of a textbook requires the dedication and skill of many competent professionals with expertise in the technical aspects of publishing. We are indebted to the staff at Wiley who orchestrated the myriad of details leading from the manuscript to the published book.

We also wish to acknowledge with gratitude the comments received from those who used the first edition during the past 10 years and to those who reviewed parts of the present book and offered us many helpful suggestions. A special thanks, also, to Rhoda Mark, Leonie Meiselman, Marilyn Prince, and Elsie DeCesare for typing the manuscript.

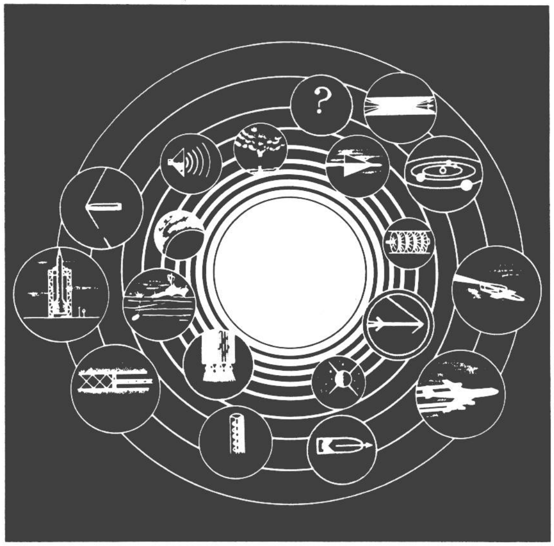
We hope that the students find in this book much of the excitement that the physicist and technologist experience in their work.

ALEXANDER JOSEPH
KALMAN POMERANZ
JACK PRINCE
DAVID SACHER

We mourn the recent passing of our friend, colleague and co-author, Dr. Alexander Joseph. His devotion to physics education for more than four decades was recognized by all who worked *with him. We especially recall his encouragement and important contributions toward the publication of the first edition of this text. We take this opportunity, also, to express our sorrow over the passing of Dr. Morris Meister, first president of Bronx Community College, to whom the first edition was dedicated.*

K. B. P.
J. P.
D. S.

Contents



1. Physics and Engineering Technology

Modern technology leans heavily on physics. Technical progress follows advances in physics and the other basic sciences. It was the increased understanding of electricity and magnetism that led to the electrical power industry, radio, television, radar, and other means of electrical and electronic communication. This applies to electric lighting and heating, too. In medicine today, many of the instruments of diagnosis and therapy are applications of physics, such as X-rays, radioisotopes, electrocardiographs, and electroencephalographs.

Engineering technology is responsible for space flight, rocketry, satellites, and satellite communication systems, which are all applications of physics. The development of modern supersonic aircraft is an obvious application of the principles of physics.

Let us take a look at what physics is. It is often defined as the study of matter, energy, and their transformations. Although we often use "matter" and "energy" as everyday words, the everyday meanings do not provide us with the exact scientific definitions. The physicist in dealing with matter is concerned with the properties of the fundamental particles that make up the atom and with the combinations of these particles that make up the universe.

The concept of energy must be used to understand the combination of these fundamental particles into atoms. Energy is involved in all the engineering technological applications of physics. It is impossible to say exactly when we are dealing only with matter or only with energy, and we shall discover that these two ideas are always closely associated.

This book is divided into six basic areas:

1. Mechanics.
2. Heat.
3. Wave motion.
4. Electricity and magnetism.
5. Light and other electromagnetic radiation.
6. Electronic and nuclear applications.

Mechanics is the foundation for all the other areas of physics. To understand sound, light, and electromagnetic radiation, the physics of wave motion must be studied. The basic laws of the conservation of energy developed in mechanics are needed for the study of heat, sound, wave motion, magnetism and electricity, electromagnetic radiation, and the physics of the nucleus. In other words there is a unity to physics; it is not merely a collection of unrelated topics.

Although this book is concerned with the physics of today, physics is not static; the frontiers of physics change every day. It must be understood, however, that these new developments will probably not change the fundamentals that are studied in this book.

Physics functions to combine our understanding of the world about us into an orderly form that can be intellectually digested. A physicist creates theories based on experimentation in order to understand the nature of the world about him. The role of the engineering technologist is to further the implementation of these ideas into the development of new products and industrial processes.

Although physics goes back in time to ancient history (see Fig. 1-1, showing the development of electricity) the greatest growth has taken place in the past few centuries. The chief growth in engineering technology has occurred during the present century and is an extension of the basic discoveries in physics made in the centuries be-

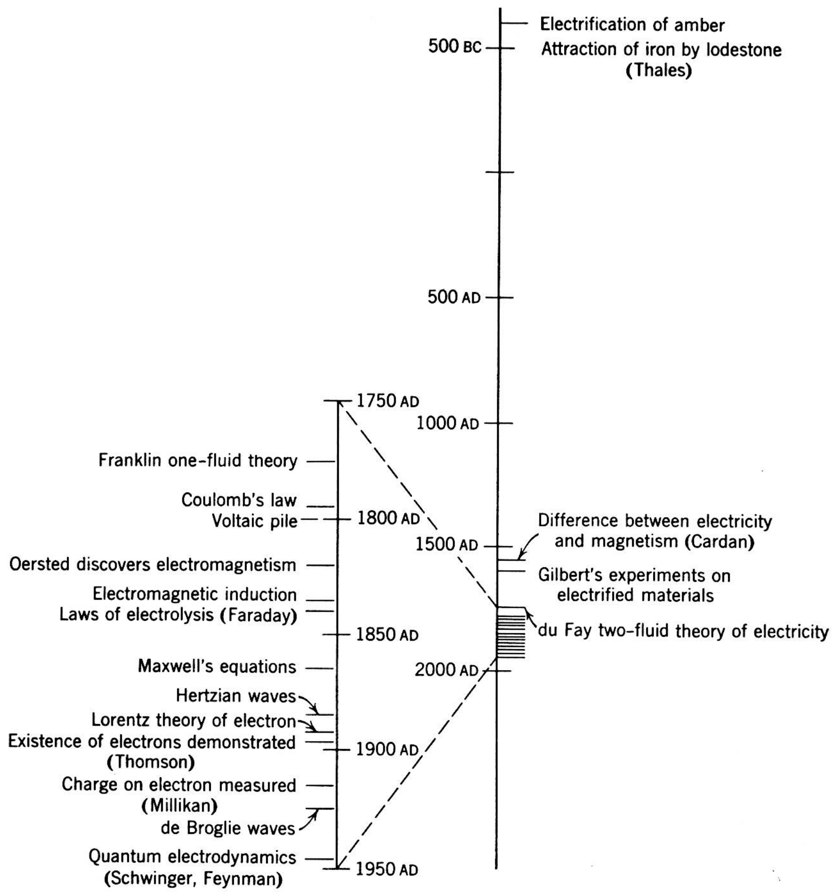


Figure 1-1 "Timetable" showing the development of electricity. (From O. H. Blackwood, W. C. Kelly, and R. M. Bell, *General Physics*, 4th ed., John Wiley & Sons, Inc., New York, 1973.

fore. However, the rate of physical discovery basic to engineering technology is so rapid that it is essential for a solid foundation in physics to be a part of the background of every student of engineering technology.

Since the engineering technologist serves society, it may be useful to understand how basic science, research and development, applications, and the needs of society lead to new products and processes. This complex interaction is illustrated in Fig. 1-2.

Perhaps a good example of the connections between physics and engineering technology is the study of a problem like "sonic boom," a problem still not completely solved. This is related to the physics of shock waves, a field that permeates many new technological applications, as shown in Fig. 1-3.

Physics and engineering technology both deal almost exclusively with quantities that must be measured. We may, for example, measure a room with a foot rule or a yardstick and learn that it is 12 × 15 ft. The unit of length used in measuring the room is the foot; this is an old unit that is still commonly used today.

The measurement of distances was developed by the Egyptians to measure land for tax purposes. In ancient business transactions the mea-

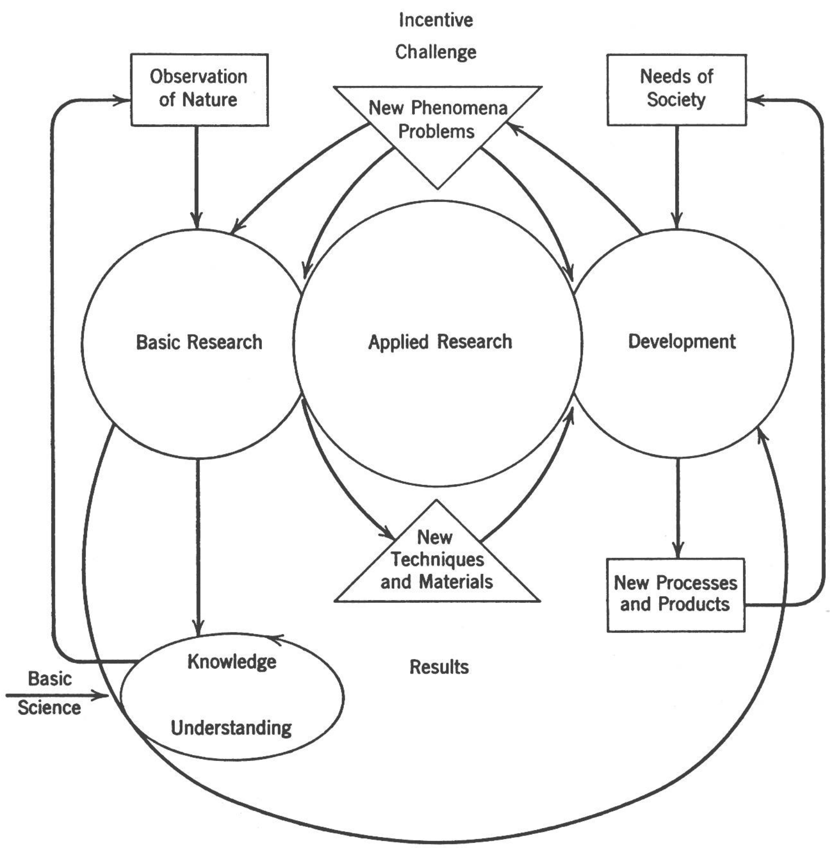


Figure 1-2 Interrelationships in the development of products and processes for society from basic science.

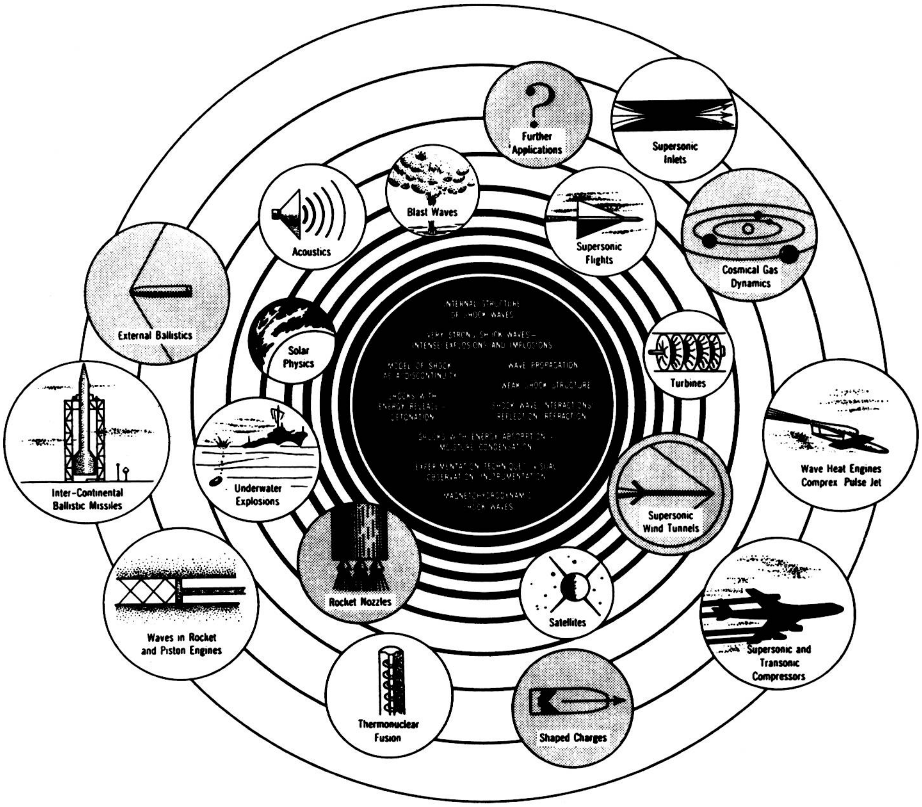


Figure 1-3 Basic research in the nature of shock waves led to a variety of technological applications. (Courtesy Naval Research Advisory Committee.)

surement of weight and volume eventually led to units such as the ounce, the pound, the gill, the pint, the quart, and the gallon.

Physics and engineering technology now need units as small as the diameter of a nucleus and as large as the dimensions of the Milky Way. Transistors, vacuum tubes in TV sets, gyroscopes for controlling the flight of aircraft and rockets, atomic piles (nuclear reactors), and automobile parts must be precisely made if they are to work at all. The manufacturers of these devices require precise measurements based on definite units of measure.

Physicists use the metric system, which was designed in France during the late eighteenth century. It is convenient because it is based on multiples of ten and can be divided into tenths, hundredths, or thousandths. The kilowatt is 1000 watts; a meter is 100 centimeters; a centimeter is 10 millimeters. Thus, 1.46 meters is 146 centimeters or 1460 millimeters. In the metric system, the kilogram is 1000 grams so that 4.25 kilograms is 4250 grams. The American dollar with its 100 cents is a familiar application of the metric system.

At one time the meter was defined as a one-ten-millionth part of the distance from the equator to the North Pole measured along a line passing through Paris. A platinum iridium bar measured at the temperature of melting ice, 0°C, (or 32°F) and marked appropriately served as the standard meter.

Table 1-1 Metric units of length and approximate British equivalents

1 kilometer (km)	=	1000 meters or about $\frac{5}{8}$ mile, or 0.62 mile
1 meter (m)	=	about 1.1 yards or 3.3 feet
1 centimeter (cm)	=	1/100 meter = 1/2.54 inch
1 millimeter (mm)	=	1/1000 meter = 10^{-3} meter
1 micron (μ)	=	1/1,000,000 meter = $1/10^6$ meter or 10^{-6} meter

Later, more accurate measurements of the size of the earth led to the discovery that the original meter was slightly too short. In 1872 the new, correct standard meter (a platinum bar) was made. Exact copies are kept in the Bureau of Weights and Measures in Sèvres near Paris, and other exact copies can be found in the Bureau of Standards in Washington, D.C., London, and the capitals of other nations.

Today the wavelength of the orange-red line in the spectrum emitted by krypton 86 is used to measure the distance between the marks on the standard meter. The wavelengths of light emitted by atoms are not affected by external physical changes, and the wavelength of light is used to provide the most precise standards for the measurement of length.

The yard that you use in everyday life is 3600/3937 of the standard meter. This makes 39.37 inches equal to one meter, and 2.54 centimeters equal to one inch, while one foot equals 30.5 centimeters. Table 1-1 gives the relationships between the metric system and the British system of lengths.

In everyday experiences we do not encounter the quantity *mass*. The scientific meaning of the word differs from the everyday meaning of mass, which makes little distinction between this quantity and weight. Some of the British and metric units for volume and weight are compared in Table 1-2. Weight is the force that gravity exerts on the atoms that make up a substance. An object on the earth weighing 600 lb would weigh only about 100 lb on the moon, where the gravitational attraction is one-sixth that on the earth. However, the mass does not change no matter whether you are on earth or anywhere in space. Mass and the units used for mass will be studied in detail in Chapter 9.

The British system uses the units of foot, pound weight, and second, and is called the fps system or British Engineering System. The oldest metric system, or cgs system, uses the centimeter, gram, and second. In 1904 Giorgi proposed the mks system which uses the meter, kilogram, and second.

In the work in this book, it is assumed that the reader has studied at least two years of high school mathematics (algebra, geometry, and trigonometry). The trigonometric functions needed in this book are presented in Table 1-3. The tables of the values of these trigonometric functions are found in the appendix; it may be wise to review these functions.

Table 1-2 Metric units of weight and volume and British equivalents

1 metric ton = weight of 1000 kilograms	=	1.10 short tons
weight of 1 gram (g)	=	$\frac{1}{454}$ pound
	=	$\frac{1}{28.4}$ avoirdupois ounce
weight of 1 kilogram (kg) (1000 grams)	=	2.20 pounds
1 liter (l) (1000 cubic centimeters)	=	1.06 liquid quarts

Table 1-3 Trigonometry of the right and obtuse triangles

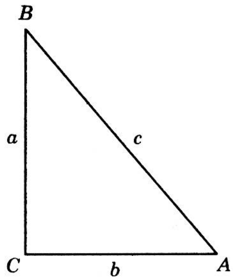
Right Triangle

Base is side b; altitude is side a; hypotenuse is side c; angle A is opposite to side a; angle B is opposite side b; angle C is opposite side c.

For the acute angles of a right triangle:

sine = side opposite the angle/hypotenuse
cosine = side adjacent to the angle/hypotenuse
tangent = side opposite the angle/side adjacent to the angle
cotangent = side adjacent to the angle/side opposite the angle
secant = hypotenuse/side adjacent to the angle
cosecant = hypotenuse/side opposite the angle

$$\sin A = a/c$$
$$\cos A = b/c$$
$$\tan A = a/b$$
$$\cot A = b/a$$
$$\sec A = c/b$$
$$\csc A = c/a$$



The same equations can be written for angle B using the appropriate sides.

The Pythagorean theorem gives the relationship between the sides a, b, and the hypotenuse c.

$$a^2 + b^2 = c^2$$

Oblique Triangles

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}, \text{ or the law of sines.}$$

$$a^2 = b^2 + c^2 - 2bc \cos A, \qquad \text{or} \qquad \cos A = \frac{b^2 + c^2 - a^2}{2bc},$$

which is the law of cosines.

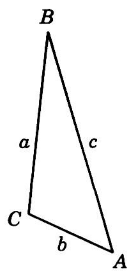


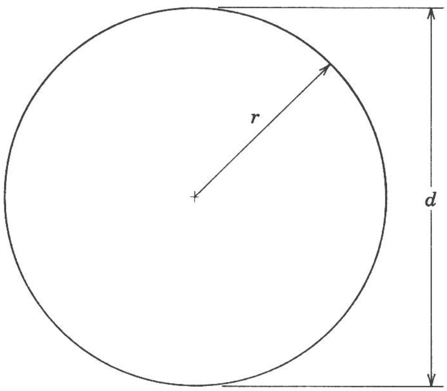
Table 1-3 (*continued*)

Elementary Geometry

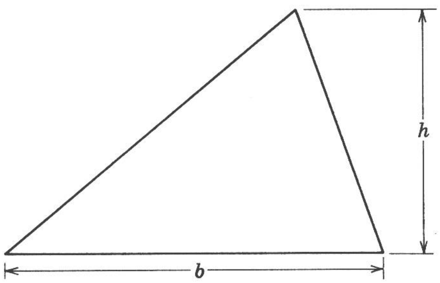
The area of a circle

$$A = \pi r^2 = \frac{\pi}{4} d^2$$

where r = the radius and d = the diameter. The circumference of a circle $C = 2\pi r = \pi d$.



The area of a triangle $A = \frac{1}{2}bh$, where b = the base and h = the altitude.



The area of a trapezoid $A = \frac{1}{2}(b_1 + b_2)h$, where b_1 and b_2 are the bases and h = the altitude.

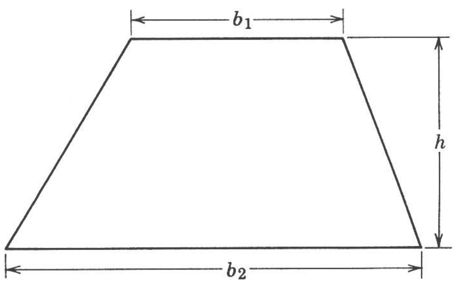
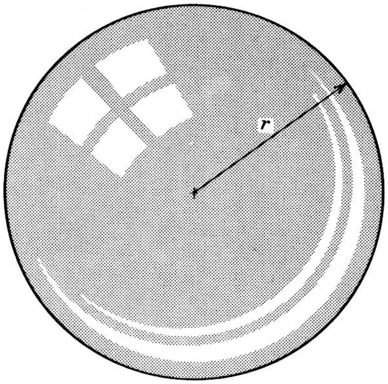
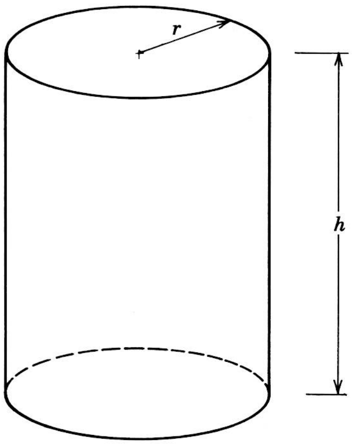


Table 1-3 (*continued*)

The volume of a sphere $V = \frac{4}{3}\pi r^3$, where $r =$ the radius. The surface area of the sphere $A = 4\pi r^2$.



The volume of a cylinder $V = \pi r^2 h$, where $r =$ radius of the base and $h =$ the height.



Elementary Algebra

The quadratic equation $ax^2 + bx + c = 0$ where a, b, and c are constants.

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$