PHYSICS

FIFTH EDITION

PAUL E. TIPPENS

PHYSICS

FIFTH EDITION

PAUL E. TIPPENS
Department of Physics
Southern Technical Institute

GLENCOE
McGraw-Hill
New York, New York Columbus, Ohio Woodland Hills, California Peoria, Illinois

Dedicated to Sarah, Travis, and Ryan

Cover: Pete Saloutos/The Stock Market

Photo Credits for Unit Openers

Unit 1: p. 1, Richard Megna/Fundamental Photographs
Unit 2: p. 347, Fundamental Photographs
Unit 3: p. 627, Richard Megna/Fundamental Photographs
Unit 4: p. 857, Michael Gilbert/Science Photo Library/Photo Researchers

Library of Congress Cataloging-in-Publication Data

Tippens, Paul E.
Physics / Paul E. Tippens. -- 5th ed.
p. cm.
Includes index.
ISBN 0-02-806502-6
1. Physics. I. Title
QC21.2.T55 1995
530--dc20 94-17806
CIP

Physics, Fifth Edition

Imprint 1998

Send all inquiries to:
Glencoe/McGraw-Hill
936 Eastwind Drive
Westerville, Ohio 43081

ISBN 0-02-806502-6

Printed in the United States of America.

4 5 6 7 8 9 10 11 12 13 071/043 05 04 03 02 01 00 99 98

PREFACE

Physics, 5th edition is written for the noncalculus physics course designed for students who are pursuing careers in science or engineering technology. It can also be used as the text for many other disciplines where a clear introduction to applications of physical principles is desired. Although a basic understanding of simple algebra and right-triangle trigonometry is assumed, both the text and the appendices provide adequate review. As with the previous editions, it has been a major goal to produce a readable, friendly text that gives a solid foundation in physics without discouraging students who have traditionally been intimidated by the subject. Ideally, the student will consider the text as a study companion, and the instructor will know that important concepts are not compromised.

Regardless of the abilities and charisma of various physics instructors, no one can doubt that each student is ultimately responsible for his or her own learning. The primary goal of any text, therefore, should be to provide the organization, examples, and exercises that lead to understanding and applications. In addition to the popular instructional enhancements offered in previous editions, this edition of *Physics* offers Problem-Solving Strategies throughout the text. These sections are designed to help the student identify the steps in the problem-solving process for many of the examples and problems given in the text. Other improvements include the addition of color, more examples, additional problems, and greater emphasis on the problem-solving process. Entirely new sections have been prepared on gravitation, satellites, Kepler's laws, fiber optics, lasers, and superconductivity. The following features are available in this edition:

1. Clearly stated objectives begin each chapter.
2. Color has been used to highlight certain features and to enhance the appearance of the text.
3. Introductory paragraphs present a rationale and applications.
4. There is extensive use of examples with detailed solutions designed to develop problem-solving skills.
5. Highlighted sections develop general problem-solving strategies for many of the problems at the end of each chapter.
6. Careful selection and use of more than 800 drawings illustrate concepts in a way that complements the boardwork of the instructor.
7. The nonthreatening, informative writing style should enhance learning objectives.
8. Detailed summaries of important concepts and formulas are given at the end of every chapter.
9. More than 500 questions are designed to stimulate thought and to test understanding of basic concepts.
10. More than 1100 carefully selected problems are organized by subject and level of difficulty.

The organization of the text is convenient for both semester or quarter schedules. The treatment of optics is such that it can either precede or follow electromagnetic theory. Typically, those on a semester schedule would cover mechanics, heat, and thermodynamics during the first semester and electricity, magnetism, sound, light, and modern physics during the second semester. On a quarterly basis, the division might be mechanics for the first quarter; heat, light, and sound for the second quarter; and electricity, magnetism, and modern physics for the last quarter. Wherever possible, each chapter has been organized to stand as a complete unit so that the instructor has maximum flexibility to select and organize topics.

The development of the text maximizes the learning process. For example, the treatment of statics precedes the treatment of kinematics. Newton's first and third laws are covered early to provide a qualitative understanding of force, but the second law is delayed until the concepts of free-body diagrams and static equilibrium are understood. This treatment allows each student to develop his or her understanding in a logical and continuous way. Often, when statics is presented in later chapters, a review of the treatment of forces and vectors is needed. Students' familiarity with free-body diagrams, gained with an early treatment of statics, permits more detailed examples with Newton's second law. Those who disagree with this approach will have no difficulty in rearranging topics to present kinematics before statics. The choice of examples and problems allows considerable flexibility. One or two asterisks are placed before problems indicating their difficulty.

Physics, 5th edition is supported by a number of ancillary products that were not available in previous editions. For example, a comprehensive test bank of questions, problems, and multiple-choice items is available for those with personal computers, and transparencies are available to supplement classroom instruction. Instructors may obtain a solutions manual in which every problem has been worked in detail to assist in the assignment of appropriate practice problems. All answers have been independently verified. A comprehensive study guide, and a practical laboratory manual are also available for students.

As with any work, there have been many who contributed significantly to the process. The author is indebted to Dr. Russell Patrick, Professor of Physics at Southern College of Technology, for his assistance in preparing the added material on superconductivity and in the development of items to be included in a computer test bank. Scott J. Tippens, Professor of Electrical Engineering Technology at Southern College of Technology, contributed the added material on fiber optics, and Dr. Sam Nalley of Chattanooga State Technical Community College helped verify many of the answers to problems in the fifth edition. The author is grateful to Byron L. Combs, ITT Technical Institute, Portland, Oregon; David E. Craven, Guilford Technical Community College, North Carolina; Jody K. Jorgensen, ITT Technical Institute, Utah; and Catherine A. Johnson, Fox Valley Technical College, Wisconsin who were reviewers.

The author thanks the many people who helped in the preparation of this book including Freida O'Neil-Robinson, the editor, Linda D. Jefferson, the production editor, and Lois Porter, the proofreader. As always, the author thanks the many users of previous editions for their critical reviews and comments. Comments, suggestions, and criticisms are always welcome from readers.

CONTENTS

Preface

PART ONE MECHANICS 1

Chapter 1 Introduction 2

What Is Physics? 2
What Part Is Played by Mathematics? 3
How Should I Study Physics? 4

Chapter 2 Technical Measurement and Vectors 5

2-1 Physical Quantities 6
2-2 The International System 7
2-3 Measurement of Length and Time 8
2-4 Significant Figures 12
2-5 Measuring Instruments 13
2-6 Unit Conversions 15
2-7 Vector and Scalar Quantities 18
2-8 Addition of Vectors by Graphical Methods 21
2-9 Force and Vectors 23
2-10 The Resultant Force 26
2-11 Trigonometry and Vectors 27
2-12 The Component Method of Vector Addition 30
2-13 Vector Difference 33

Chapter 3 Translational Equilibrium and Friction 43

3-1 Newton's First Law 44
3-2 Newton's Third Law 44
3-3 Equilibrium 45
3-4 Free-Body Diagrams 47
3-5 Solution of Equilibrium Problems 50
3-6 Friction 55

Chapter 4 Torque and Rotational Equilibrium 74

4-1 Conditions for Equilibrium 75
4-2 The Moment Arm 76
4-3 Torque 77
4-4 Resultant Torque 80
4-5 Equilibrium 81
4-6 Center of Gravity 85

Chapter 5 Uniformly Accelerated Motion 95

5-1 Speed and Velocity 95
5-2 Accelerated Motion 98
5-3 Uniformly Accelerated Motion 98
5-4 Other Useful Relations 101
5-5 Solution of Acceleration Problems 102
5-6 Sign Convention in Acceleration Problems 104
5-7 Gravity and Freely Falling Bodies 105

Chapter 6 Projectile Motion 118

6-1 Horizontal Projection 119
6-2 The More General Problem of Trajectories 122

Chapter 7 Newton's Second Law 129

7-1 Newton's Second Law of Motion 130
7-2 The Relationship Between Weight and Mass 133

7-3 Application of Newton's Second Law to Single-Body Problems 134
7-4 Problem-Solving Techniques 137

Chapter 8 Work, Energy, and Power 150

8-1 Work 151
8-2 Resultant Work 153
8-3 Energy 155
8-4 Work and Kinetic Energy 156
8-5 Potential Energy 158
8-6 Conservation of Energy 160
8-7 Energy and Friction Forces 162
8-8 Power 165

Chapter 9 Impulse and Momentum 175

9-1 Impulse and Momentum 176
9-2 The Law of Conservation of Momentum 178
9-3 Elastic and Inelastic Impacts 180

Chapter 10 Uniform Circular Motion 192

10-1 Motion in a Circular Path 192
10-2 Centripetal Acceleration 193
10-3 Centripetal Force 196
10-4 Banking Curves 198
10-5 The Conical Pendulum 201
10-6 Motion in a Vertical Circle 203
10-7 Gravitation 205
10-8 The Gravitational Field and Weight 206
10-9 Satellites in Circular Orbits 208
10-10 Kepler's Laws 212

Chapter 11 Rotation of Rigid Bodies 221

11-1 Angular Displacement 222
11-2 Angular Velocity 224
11-3 Angular Acceleration 225
11-4 Relationship Between Rotational and Linear Motion 227
11-5 Rotational Kinetic Energy; Moment of Inertia 230
11-6 The Second Law of Motion in Rotation 233
11-7 Rotational Work and Power 235
11-8 Angular Momentum 237
11-9 Conservation of Angular Momentum 239

Chapter 12 Simple Machines 248

12-1 Simple Machines and Efficiency 249
12-2 Mechanical Advantage 250
12-3 The Lever 252
12-4 Applications of the Lever Principle 253
12-5 The Transmission of Torque 257
12-6 The Inclined Plane 260
12-7 Applications of the Inclined Plane 263

Chapter 13 Elasticity 273

13-1 Elastic Properties of Matter 273
13-2 Young's Modulus 276
13-3 Shear Modulus 279
13-4 Volume Elasticity; Bulk Modulus 281
13-5 Other Physical Properties of Metals 282

Chapter 14 Simple Harmonic Motion 289

14-1 Periodic Motion 290
14-2 The Reference Circle 291
14-3 Velocity in Simple Harmonic Motion 293
14-4 Acceleration in Simple Harmonic Motion 296
14-5 The Period and Frequency 297
14-6 The Simple Pendulum 299
14-7 The Torsion Pendulum 301

Chapter 15 Fluids at Rest 309

15-1 Density 309
15-2 Pressure 312
15-3 Fluid Pressure 313
15-4 Measuring Pressure 317
15-5 The Hydraulic Press 320
15-6 Archimedes' Principle 321

Chapter 16 Fluids at Motion 332

16-1 Fluid Flow 332
16-2 Pressure and Velocity 335

16-3 Bernoulli's Equation 337
16-4 Applications of Bernoulli's Equation 338

PART TWO HEAT, LIGHT, AND SOUND 347

Chapter 17 Temperature and Expansion 348

17-1 Temperature and Thermal Energy 349
17-2 The Measurement of Temperature 350
17-3 The Gas Thermometer 355
17-4 The Absolute Temperature Scale 357
17-5 Linear Expansion 360
17-6 Area Expansion 362
17-7 Volume Expansion 364
17-8 The Unusual Expansion of Water 367

Chapter 18 Quantity of Heat 374

18-1 The Meaning of Heat 375
18-2 The Quantity of Heat 375
18-3 Specific Heat Capacity 378
18-4 The Measurement of Heat 381
18-5 Change of Phase 384
18-6 Heat of Combustion 390

Chapter 19 Transfer of Heat 396

19-1 Methods of Heat Transfer 396
19-2 Conduction 398
19-3 Insulation: The *R*-Value 402
19-4 Convection 402
19-5 Radiation 406

Chapter 20 Thermal Properties of Matter 416

20-1 Ideal Gases and Boyle's Law 416
20-2 Gay-Lussac's Law 420
20-3 General Gas Laws 421
20-4 Molecular Mass and the Mole 423
20-5 The Ideal Gas Law 425
20-6 Liquefaction of a Gas 426
20-7 Vaporization 428
20-8 Vapor Pressure 429
20-9 Triple Point 431
20-10 Humidity 432

Chapter 21 Thermodynamics 440

21-1 Heat and Work 440
21-2 The Internal Energy Function 441
21-3 The First Law of Thermodynamics 443
21-4 The *P-V* Diagram 444
21-5 The General Case For the First Law 445
21-6 Adiabatic Processes 446
21-7 Isochoric Processes 448
21-8 Isothermal Processes 449
21-9 The Second Law of Thermodynamics 449
21-10 The Carnot Cycle 451
21-11 The Efficiency of an Ideal Engine 453
21-12 Internal Combustion Engines 454
21-13 Refrigeration 457

Chapter 22 Wave Motion 467

22-1 Mechanical Waves 467
22-2 Types of Waves 468
22-3 Calculating Wave Speed 470
22-4 Periodic Wave Motion 471
22-5 Energy of a Periodic Wave 473
22-6 The Superposition Principle 475
22-7 Standing Waves 476
22-8 Characteristic Frequencies 478

Chapter 23 Sound 485

23-1 Production of a Sound Wave 486
23-2 The Speed of Sound 487
23-3 Vibrating Air Columns 490
23-4 Forced Vibration and Resonance 493
23-5 Audible Sound Waves 494
23-6 Pitch and Quality 497
23-7 Interference and Beats 498
23-8 The Doppler Effect 498

Chapter 24 Light and Illumination 510

24-1 What Is Light? 511
24-2 The Propagation of Light 514
24-3 The Electromagnetic Spectrum 516
24-4 The Quantum Theory 518

24-5 The Speed of Light 520
24-6 Light Rays and Shadows 522
24-7 Luminous Flux 524
24-8 Luminous Intensity 527
24-9 Illumination 528

Chapter 25 Reflection and Mirrors 539

25-1 The Laws of Reflection 540
25-2 Plane Mirrors 541
25-3 Spherical Mirrors 544
25-4 Images Formed by Spherical Mirrors 546
25-5 The Mirror Equation 548
25-6 Magnification 552
25-7 Spherical Aberration 554

Chapter 26 Refraction 562

26-1 Index of Refraction 563
26-2 The Laws of Refraction 564
26-3 Wavelength and Refraction 568
26-4 Dispersion 570
26-5 Total Internal Reflection 570
26-6 Fiber Optics and Applications 572
26-7 Is Seeing the Same as Believing? 575
26-8 Apparent Depth 576

Chapter 27 Lenses and Optical Instruments 584

27-1 Simple Lenses 584
27-2 Focal Length and the Lensmaker's Equation 587
27-3 Image Formation by Thin Lenses 589
27-4 The Lens Equation and Magnification 592
27-5 Combinations of Lenses 595
27-6 The Compound Microscope 595
27-7 Telescope 597
27-8 Lens Aberrations 598

Chapter 28 Interference, Diffraction, and Polarization 606

28-1 Diffraction 606
28-2 Young's Experiment: Interference 607
28-3 The Diffraction Grating 612
28-4 Resolving Power of Instruments 614
28-5 Polarization 618

PART THREE ELECTRICITY AND MAGNETISM 627

Chapter 29 The Electric Force 628

29-1 The Electric Charge 628
29-2 The Electron 631
29-3 Insulators and Conductors 632
29-4 The Gold-Leaf Electroscope 634
29-5 Redistribution of Charge 636
29-6 Charging by Induction 636
29-7 Coulomb's Law 638

Chapter 30 The Electric Field 648

30-1 The Concept of a Field 649
30-2 Computing the Electric Intensity 653
30-3 Electric Field Lines 657
30-4 Gauss's Law 658
30-5 Applications of Gauss's Law 660

Chapter 31 Electric Potential 671

31-1 Electric Potential Energy 672
31-2 Calculating Potential Energy 674
31-3 Potential 676
31-4 Potential Difference 680
31-5 Millikan's Oil-Drop Experiment 683
31-6 The Electronvolt 685

Chapter 32 Capacitance 692

32-1 Limitations on Charging a Conductor 693
32-2 The Capacitor 696
32-3 Computing the Capacitance 698
32-4 Dielectric Constant; Permittivity 700
32-5 Capacitors in Parallel and in Series 705
32-6 Energy of a Charged Capacitor 708

Chapter 33 Current and Resistance 717

33-1 The Motion of Electric Charge 718
33-2 The Direction of Electric Current 720
33-3 Electromotive Force 721
33-4 Ohm's Law; Resistance 722
33-5 Electric Power and Heat Loss 725
33-6 Resistivity 727
33-7 Temperature Coefficient of Resistance 729

33-8 Superconductivity 730

Chapter 34 Direct-Current Circuits 737

34-1 Simple Circuits; Resistors in Series 737
34-2 Resistors in Parallel 740
34-3 EMF and Terminal Potential Difference 743
34-4 Measuring Internal Resistance 744
34-5 Reversing the Current Through a Source of EMF 745
34-6 Kirchhoff's Laws 747
34-7 The Wheatstone Bridge 752

Chapter 35 Magnetism and the Magnetic Field 763

35-1 Magnetism 764
35-2 Magnetic Fields 766
35-3 The Modern Theory of Magnetism 766
35-4 Flux Density and Permeability 768
35-5 Magnetic Field and Electric Current 771
35-6 The Force on a Moving Charge 772
35-7 Force on a Current-Carrying Wire 775
35-8 Magnetic Field of a Long, Straight Wire 777
35-9 Other Magnetic Fields 778
35-10 Hysteresis 780

Chapter 36 Forces and Torques in a Magnetic Field 791

36-1 Force and Torque on a Loop 792
36-2 Magnetic Torque on a Solenoid 794
36-3 The Galvanometer 795
36-4 The DC Voltmeter 796
36-5 The DC Ammeter 798
36-6 The DC Motor 800

Chapter 37 Electromagnetic Induction 807

37-1 Faraday's Law 808
37-2 EMF Induced by a Moving Wire 811
37-3 Lenz's Law 813
37-4 The AC Generator 814
37-5 The DC Generator 818
37-6 Back EMF in a Motor 819
37-7 Types of Motors 820
37-8 The Transformer 822

Chapter 38 Alternating-Current Circuits 832

38-1 The Capacitor 833
38-2 The Inductor 836
38-3 Alternating Currents 839
38-4 Phase Relation in AC Circuits 840
38-5 Reactance 842
38-6 The Series AC Circuit 843
38-7 Resonance 846
38-8 The Power Factor 847

PART FOUR MODERN PHYSICS 857

Chapter 39 Modern Physics and the Atom 858

39-1 Relativity 859
39-2 Simultaneous Events: The Relativity of Time 860
39-3 Relativistic Length, Mass, and Time 862
39-4 Mass and Energy 865
39-5 Quantum Theory and the Photoelectric Effect 867
39-6 Waves and Particles 869
39-7 The Rutherford Atom 870
39-8 Electron Orbits 872
39-9 Atomic Spectra 873
39-10 The Bohr Atom 875
39-11 Energy Levels 878
39-12 Lasers and Laser Light 880
39-13 Modern Atomic Theory 883

Chapter 40 Nuclear Physics and the Nucleus 891

40-1 The Atomic Nucleus 892
40-2 The Elements 893
40-3 The Atomic Mass Unit 897
40-4 Isotopes 898
40-5 The Mass Defect and Binding Energy 901
40-6 Radioactivity 904
40-7 Radioactive Decay 906

40-8 Half-Life 907
40-9 Nuclear Reactions 910
40-10 Nuclear Fission 911
40-11 Nuclear Reactors 913
40-12 Nuclear Fusion 914

Chapter 41 Electronics 922

41-1 Thermionic Emission 922
41-2 Vacuum Tubes 923
41-3 The Cathode-Ray Tube 924
41-4 The X-Ray Tube 926
41-5 Semiconductors 926
41-6 N-Type and P-Type Semiconductors 928
41-7 PN Junction 930
41-8 Diode Applications 932
41-9 The Zener Diode 934
41-10 The Transistor 935
41-11 Transistor Amplification 938
41-12 Other Semiconductor Devices 942
41-13 Integrated Circuits 946

Appendix A Mathematics Review 954

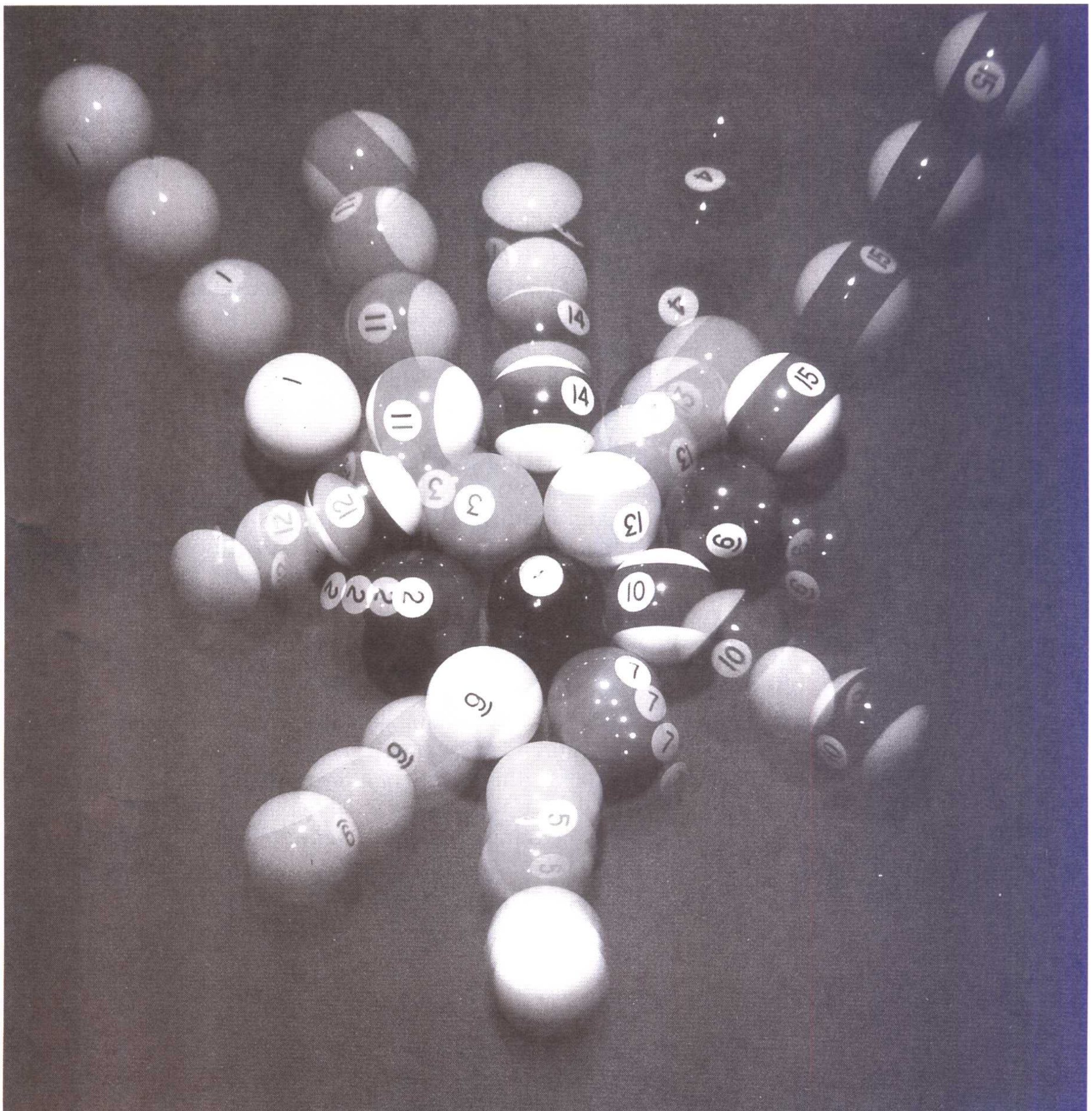
A-1 Exponents and Radicals 954
A-2 Scientific Notation 955
A-3 Literal Equations and Formulas 957
A-4 Trigonometry 958

Appendix B Conversion Equivalents 964

Index 967

PART ONE

MECHANICS



CHAPTER 1

INTRODUCTION

A knowledge of physics is essential to an understanding of our world. No other science has been as active in revealing the causes and effects of natural events. A casual glance at our past demonstrates a continuum of experiment and discovery ranging from early measurements of gravity to later conquests of space. By studying objects at rest and in motion, scientists have been able to derive fundamental laws for many applications in mechanical engineering. The investigation of electricity and magnetism produced new sources of energy and new methods of distributing power for the use of mankind. An understanding of the physical principles that govern the production of heat, light, and sound has added countless applications that have served to make us more comfortable and more able to cope with our environment.

It is difficult to imagine a single product available today that does not represent an application of some physical principle. This means that regardless of your career choice, you will need to understand physics in some way. Granted there are some occupations and professions that do not require the depth of understanding necessary for engineering applications, but all fields of work utilize and apply these concepts. With a thorough understanding of mechanics, heat, sound, and electricity, you carry with you the building blocks for almost any career. Should you find it necessary or desirable to change careers either before or after graduation, you will be able to draw from a general base of science and mathematics. By taking this course seriously and by devoting an unusual amount of time and energy, you will have less trouble in the future. In your later coursework, and on the job, you will be riding the crest of the wave instead of merely staying afloat in an angry sea.

WHAT IS PHYSICS?

Even if you have previously taken courses in high school physics, you probably still have a rather "fuzzy" idea of what *physics* really means and how it might differ, for example, from *science*. For our purpose, the sciences may be divided between *biological* and *physical*. The biological sciences deal with living things. The physical sciences deal primarily with the nonliving sides of nature.

__Physics__ can be defined as the science that investigates the fundamental concepts of matter, energy, and space and the relationships between them.

In terms of this broad definition, there are no clear boundaries between the many physical sciences. This is evident from the overlapping fields of biophysics, chemical physics, astrophysics, geophysics, electrochemistry, and so forth.

The goal of this textbook is to provide a basic introduction to the world of physics. The emphasis is on applications, and the broad field of physics will be narrowed to the essential concepts that underlie all technical knowledge. You will study mechanics, heat, light, sound, electricity, and atomic structure. The most basic of these topics, and probably the most important for beginning students, is mechanics.

Mechanics is concerned with the position (statics) and motion (dynamics) of matter in space. *Statics* represents the study of physics associated with bodies at rest. *Dynamics* is concerned with a description of motion and its causes. In each case, the engineer or technician is concerned with measuring and describing physical quantities in terms of their cause and effect.

An engineer, for example, uses physical principles to determine which type of bridge structure will be the most efficient for a given situation. The concern is for the *effect* of forces. If the completed bridge should fail, the *cause* of failure must be analyzed to apply this knowledge to future construction. It is important to note that by *cause* the scientist means the sequence of physical events leading to an *effect*.

WHAT PART IS PLAYED BY MATHEMATICS?

Mathematics serves many purposes. It is philosophy, art, metaphysics, and logic. These values are subordinate, however, to its main value as a tool for the scientist, engineer, or technician. One of the rewards of a first course in physics is the growing awareness of the relevance of mathematics. A study of physics reveals specific applications of basic mathematics.

Suppose you wish to predict how long it takes to stop a car traveling at a given speed. You might record the initial speed, the change in speed, and the distance and time required to stop the car. When all these facts are recorded, the data might be used to establish a tentative relationship. We cannot do this without the tools of mathematics.

If you completed such an experiment, your measurements plus a knowledge of mathematics would lead you to the following relationship:

$$s = vt + \tfrac{1}{2}at^2$$

where s = stopping distance
v = initial speed
t = stopping time
a = rate of change in speed

This statement is a *workable hypothesis*. From this equation we can predict the stopping distance for other vehicles. When it has been used long enough for us to be reasonably sure that it is true, we call it a *scientific* *theory*. In other words, any scientific theory is just a workable hypothesis that has stood the test of time.

Thus, we can see that mathematics is useful in deriving formulas that describe physical events accurately. Mathematics plays an even larger role in solving such formulas for specific quantities.

For example, in the above formula, it would be a relatively simple matter to find values for s, v, and a when the other quantities are given, but the solution for t involves a more specialized knowledge of mathematics. How easily you derive or solve a theoretical relationship depends on your background in mathematics.

A review of the mathematics required for this text is presented in Appendix A. If you are unfamiliar with any of the topics discussed, you should study this appendix carefully. Particular attention should be given to the sections on powers of 10, literal equations, and trigonometry. Skill in applying the tools of mathematics will largely determine your success in any physics course.

HOW SHOULD I STUDY PHYSICS?

Reading technical material is different from other reading. Attention to specific meanings of words must be given if the material is to be understood. Graphs, drawings, charts, and photographs are often included in technical literature. They are always helpful and may even be essential to the description of physical events. You should study them thoroughly so that you understand the principles clearly.

Much of what you learn will be from classroom lectures and experiments. The beginning student often asks: How can I concentrate fully on the lecture and at the same time take accurate notes? Of course, it may not be possible to understand fully all the concepts presented and still take complete notes. You must learn to note only the significant portions of each lesson. Make sure you listen attentively to the explanation of various topics. Learn to recognize key words like *work*, *force*, *energy*, and *momentum*.

Adequate preparation before class should give you a good idea of which portions of the lecture are covered in the text and which are not. If a problem or definition is in the text, it is usually better to jot down a key word and concentrate fully on what the instructor is saying. These notes can be expanded later.

Organization skills and study habits are essential to success in a beginning physics course. Therefore, you should compile a neat and comprehensive notebook using both lectures and the textbook as source material. At the risk of being too specific, the author recommends a loose-leaf filler notebook with dividers. Possible sections might be labeled as *handouts*, *exams*, *problems*, *labs*, and *notes*. If your study materials are well organized, it will be easier for you to successfully review for tests.

CHAPTER 2

TECHNICAL MEASUREMENT AND VECTORS

OBJECTIVES

After completing this chapter, you should be able to:

1. *Write the base units for mass, length, and time in SI and U.S. Customary System (USCS) units.*
2. *Define and apply the SI prefixes that indicate multiples of base units.*
3. *Convert from one unit to another unit for the same quantity when given the necessary definitions.*
4. *Define a vector quantity and a scalar quantity and give examples of each.*
5. *Determine the components of a given vector.*
6. *Find the resultant of two or more vectors.*

The application of physics, whether in the shop or in a technical laboratory, always requires measurements of some kind. An automobile mechanic might be measuring the diameter or *bore* of an engine cylinder. Refrigeration technicians might be concerned with volume, pressure, and temperature measurements. Electricians use instruments that measure electric resistance and current, and mechanical engineers are concerned about the effects of forces whose magnitudes must be accurately determined. In fact, it is difficult to imagine any occupation that is not involved with the measurement of some physical quantity.

In the process of physical measurement, we are often concerned with the direction as well as the magnitude of a particular quantity. The length of a wooden rafter is determined by the angle it makes with the horizontal. The direction of an applied force determines its effectiveness in producing a displacement. The direction in which a conveyor belt moves is often just as important as the speed with which it moves. Such physical quantities as *displacement, force,* and *velocity* are often encountered in industry. In this chapter, the concept of *vectors* is introduced to permit the study of both the magnitude and the direction of physical quantities.

2-1 PHYSICAL QUANTITIES

The language of physics and technology is universal. Facts and laws must be expressed in an accurate and consistent manner if everyone is to mean exactly the same thing by the same term. For example, suppose an engine is said to have a piston displacement of 3.28 liters (200 cubic inches). Two questions must be answered if this statement is to be understood: (1) How is the *piston displacement* measured, and (2) what is the *liter?*

Piston displacement is the volume that the piston displaces, or "sweeps out," as it moves from the bottom of the cylinder to the top. It is really not a displacement in the usual sense of the word; it is a volume. A standard measure for volume that is easily recognized throughout the world is the liter. Therefore, when an engine has a label on it that reads "piston displacement = 3.28 liters," all mechanics will give the same meaning to the label.

In the above example, the piston displacement (volume) is an example of a *physical quantity*. Notice that this quantity was defined by describing the procedure for its measurement. In physics, all quantities are defined in this manner. Other examples of physical quantities are length, weight, time, speed, force, and mass.

A physical quantity is measured by comparison with some known standard. For example, we might need to know the length of a metal bar. With appropriate instruments we might determine the length of the bar to be 4 meters. The bar does not contain 4 things called "meters"; it is merely compared with the length of some standard known as a "meter." The length could also be represented as 13.1 ft or 4.37 yards if we used other known measures.

The *magnitude* of a physical quantity is given by a *number* and a *unit* of measure. Both are necessary because either the number or the unit by itself is meaningless. Except for pure numbers and fractions, it is necessary to include the unit with the number when listing the magnitude of any quantity.

> *The* ***magnitude*** *of a physical quantity is specified completely by a number and a unit, for example, 20 meters or 40 liters.*

Since there are many different measures for the same quantity, we need a way of keeping track of the exact size of particular units. To do this, it is necessary to establish standard measures for specific quantities. A *standard* is a permanent or easily determined physical record of the size of a unit of measurement. For example, the standard for measuring electrical resistance, the *ohm*, might be defined by comparison with a standard resistor whose resistance is accurately known. Thus, a resistance of 20 ohms would be 20 times as great as that of a standard 1-ohm resistor.

Remember that every physical quantity is defined by telling how it is measured. Depending on the measuring device, each quantity can be