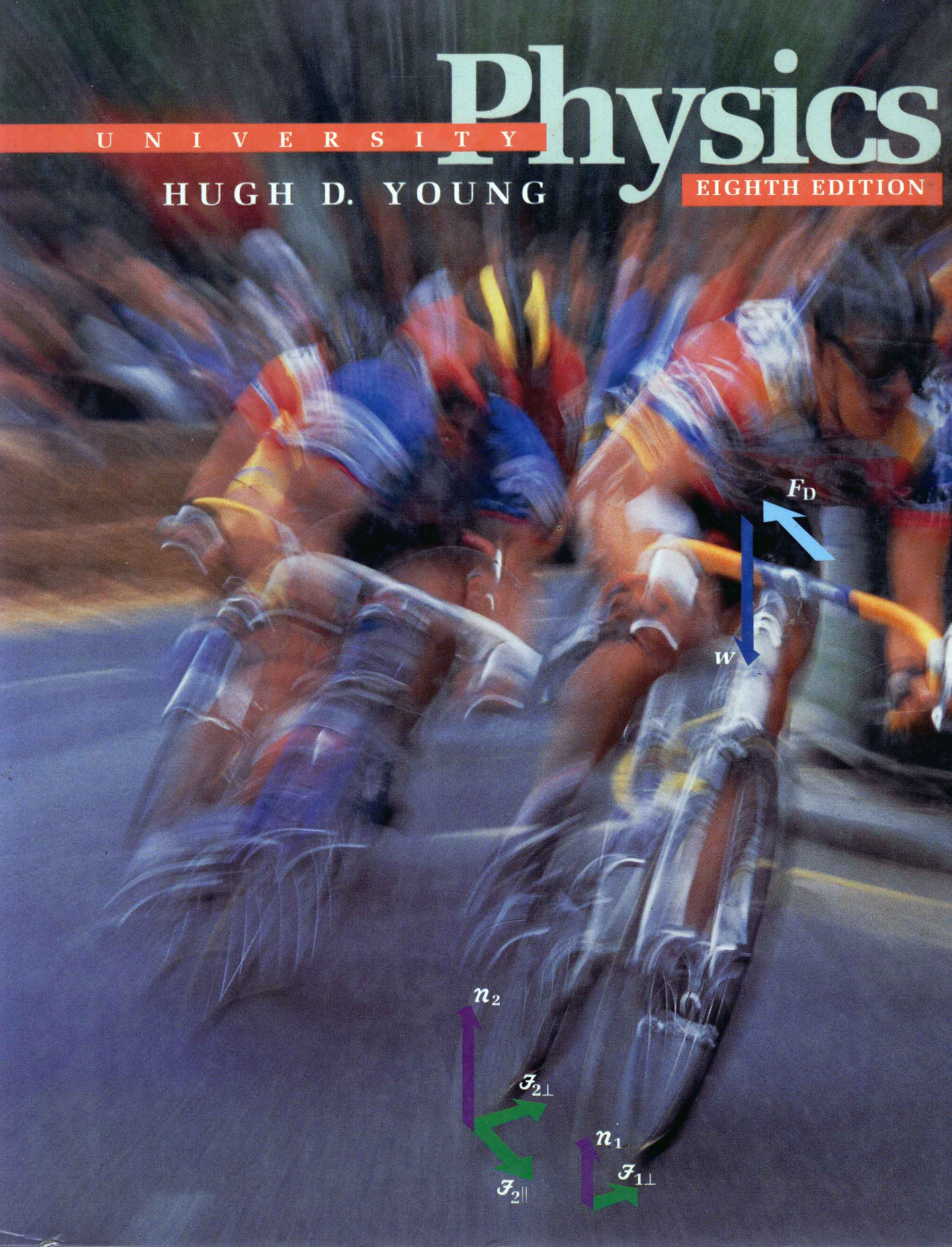


U N I V E R S I T Y

Physics

HUGH D. YOUNG

EIGHTH EDITION



U N I V E R S I T Y

Physics

EIGHTH EDITION

HUGH D. YOUNG

Carnegie-Mellon University

江苏工业学院图书馆
藏书章



Addison-Wesley Publishing Company

Reading, Massachusetts • Menlo Park, California • New York

Don Mills, Ontario • Wokingham, England • Amsterdam • Bonn • Sydney

Singapore • Tokyo • Madrid • San Juan • Milan • Paris

CONTRIBUTORS

T. R. Sandin, *North Carolina A&T State University*
Principal editorial consultant; first draft author for modern physics
chapters and modern physics case studies

A. Lewis Ford, *Texas A&M University*
Author for end-of-chapter problem sets

Lawrence Coleman, *University of California-Davis*
Major contributor to end-of-chapter problem sets

Craig Watkins, *Massachusetts Institute of Technology*
Principal proofreader and problem checker

Marvin DeJong, *College of the Ozarks*
First draft author for computational physics case studies

Michael Simon, *Housatonic Community College*
First draft author for extended applications case studies

William Cloud, *Eastern Illinois University*
Proofreader

EDITORIAL BOARD

Robert Hallock, *University of Massachusetts-Amherst*

Leonard Kahn, *University of Rhode Island*

Sanford Kern, *Colorado State University*

CONTRIBUTORS OF NEW PROBLEMS

Marie Baehr, *Elmhurst College*

Robert Cunningham, *Tri-State University*

David Groh, *Morningside College*

Virgil Highland, *Temple University*

David Smith, *Virginia Highlands Community College*

Jay Strieb, *Villanova University*

David Willey, *University of Pittsburgh-Johnstown*

Mark Williams, *Salisbury State University*

Unit Conversion Factors

LENGTH

1 m = 100 cm = 1000 mm = $10^6 \mu\text{m}$ = 10^9 nm
 1 km = 1000 m = 0.6214 mi
 1 m = 3.281 ft = 39.37 in.
 1 cm = 0.3937 in.
 1 in. = 2.540 cm
 1 ft = 30.48 cm
 1 yd = 91.44 cm
 1 mi = 5280 ft = 1.609 km
 1 Å = 10^{-10} m = 10^{-8} cm = 10^{-1} nm
 1 nautical mile = 6080 ft
 1 light year = $9.461 \times 10^{15} \text{ m}$

AREA

1 cm² = 0.155 in²
 1 m² = 10^4 cm^2 = 10.76 ft²
 1 in² = 6.452 cm²
 1 ft² = 144 in² = 0.0929 m²

VOLUME

1 liter = 1000 cm³ = 10^{-3} m^3 = 0.03531 ft³ = 61.02 in³
 1 ft³ = 0.02832 m³ = 28.32 liters = 7.477 gallons
 1 gallon = 3.788 liters

TIME

1 min = 60 s
 1 hr = 3600 s
 1 da = 86,400 s
 1 yr = 365.24 da = $3.156 \times 10^7 \text{ s}$

ANGLE

1 rad = 57.30° = $180^\circ/\pi$
 1° = 0.01745 rad = $\pi/180 \text{ rad}$
 1 revolution = 360° = $2\pi \text{ rad}$
 1 rev/min (rpm) = 0.1047 rad/s

SPEED

1 m/s = 3.281 ft/s
 1 ft/s = 0.3048 m/s
 1 mi/min = 60 mi/hr = 88 ft/s
 1 km/hr = 0.2778 m/s = 0.6214 mi/hr
 1 mi/hr = 1.466 ft/s = 0.4470 m/s = 1.609 km/hr
 1 furlong/fortnight = $1.662 \times 10^{-4} \text{ m/s}$

ACCELERATION

1 m/s² = 100 cm/s² = 3.281 ft/s²
 1 cm/s² = 0.01 m/s² = 0.03281 ft/s²
 1 ft/s² = 0.3048 m/s² = 30.48 cm/s²
 1 mi/hr · s = 1.467 ft/s²

MASS

1 kg = 10^3 g = 0.0685 slug
 1 g = $6.85 \times 10^{-5} \text{ slug}$
 1 slug = 14.59 kg
 1 u = $1.661 \times 10^{-27} \text{ kg}$
 1 kg has a weight of 2.205 lb when $g = 9.80 \text{ m/s}^2$

FORCE

1 N = 10^5 dyn = 0.2248 lb
 1 lb = 4.448 N = $4.448 \times 10^5 \text{ dyn}$

PRESSURE

1 Pa = 1 N/m² = $1.451 \times 10^{-4} \text{ lb/in}^2$ = 0.209 lb/ft²
 1 bar = 10^5 Pa
 1 lb/in² = 6891 Pa
 1 lb/ft² = 47.85 Pa
 1 atm = $1.013 \times 10^5 \text{ Pa}$ = 1.013 bar
 = 14.7 lb/in² = 2117 lb/ft²
 1 mm Hg = 1 torr = 133.3 Pa

ENERGY

1 J = 10^7 ergs = 0.239 cal
 1 cal = 4.186 J (based on 15° calorie)
 1 ft · lb = 1.356 J
 1 Btu = 1055 J = 252 cal = 778 ft · lb
 1 eV = $1.602 \times 10^{-19} \text{ J}$
 1 kWh = $3.600 \times 10^6 \text{ J}$

MASS-ENERGY EQUIVALENCE

1 kg ↔ $8.988 \times 10^{16} \text{ J}$
 1 u ↔ 931.5 MeV
 1 eV ↔ $1.073 \times 10^{-9} \text{ u}$

POWER

1 W = 1 J/s
 1 hp = 746 W = 550 ft · lb/s
 1 Btu/hr = 0.293 W

Index of Tables

Breaking strengths	111	
Breaking stresses	305	
Compressibilities of liquids	302	
Densities	382	
Dielectric constants	698	
Dielectric strength, insulators	702	
Elastic constants	300	
Force magnitudes	85	
Fractions of molecules with speeds less than v/v_{rms}	471	
Friction, coefficients of	120	
Heat capacities, gases	467	
Heat capacities, gases, at low pressure	495	
Heat capacities, solids and liquids	427	
Heats of fusion and vaporization	429	
Index of refraction	950	
International system of units	1101	
Linear and angular motion, comparison	238	
Linear expansion, coefficients	421	
Magnetic susceptibilities	823	
Mathematical relations	1104	
Moments of inertia	243	
Periodic table of elements	1106	
Prefixes for powers of 10	7	
Resistivities	717	
Resistivity, temperature coefficients	718	
Resistors, color code	721	
Sound intensity levels	590	
Speeds of sound	550	
Surface tension	390	
Symbols for circuit diagrams	724	
Triple-point data	473	
Units of force, mass, and acceleration	93	
Variations of g with latitude and elevation	336	
Velocity magnitudes	32	
Volume expansion, coefficients	421	

UNIVERSITY Physics

EIGHTH EDITION



The motion of a bicycle and its rider can be analyzed by considering the forces acting on the system. The downward force due to gravity (the weight, w) is balanced by the upward normal forces (n_1 and n_2) applied to the tires by the road. There is no net vertical force, so the vertical motion does not change. The forward force $F_{2\parallel}$ acting on the rear wheel, related to the forces the rider applies to the pedals, is partially offset by the drag force (F_D) due to air resistance. If $F_{2\parallel}$ is greater in magnitude than F_D , the system has a forward acceleration. As the rider leans into the turn, the road exerts sideways frictional forces ($F_{1\perp}$ and $F_{2\perp}$) on the tires, directed toward the center of the curve. These forces cause the direction of the velocity to change as the system rounds the turn.

REPRINTED WITH CORRECTIONS, JUNE 1992

Copyright © 1992 by Addison-Wesley Publishing Company, Inc.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior written permission of the publisher. Printed in the United States of America.

ISBN 0-201-19651-4

2 3 4 5 6 7 8 9 10-VH-95949392

Sponsoring Editor: Stuart Johnson

Development Editor: David M. Chelton

Senior Production Supervisor: Kazia Navas

Managing Editor: Mary Clare McEwing

Art Development Editor: Mary Hill

Freelance Editorial/Production Services:

Jane E. Hoover, Lifland et al., Bookmakers

Design Director: Marshall Henrichs

Text Designer: Carl Smizer

Art Consultant: Meredith Nightingale

Technical Art Consultant: Loretta Bailey

Technical Art Supervisor: Joe Vetere

Illustrators: James A. Bryant, George V. Kelvin,

Gary Torrisi, Darwen and Vally Hennings

Electronic Art Source: ST Associates

Copieditor: Barbara Willette

Layout Artist: Lorraine Hodsdon

Photo Researchers: Laurie PiSierra, Mitchell Hammond

Editorial Assistant: Mitchell Hammond

Permissions Editor: Mary Dyer

Senior Marketing Manager: Susan Howell

Composition and Separations Buyer: Sarah McCracken

Manufacturing Manager: Roy Logan

Compositor: Typo-Graphics, Inc.

Separator: Lehigh Colortronics

Printer: Von Hoffmann Press, Inc.

Text and photo credits appear on page 1131, which constitutes a continuation of the copyright page.

Library of Congress Cataloging-in-Publication Data

Young, Hugh D.

University physics. — 8th ed. / Hugh D. Young
p. cm.

Rev. ed. of: University physics / Francis W. Sears, Mark W. Zemansky, Hugh D. Young, 7th ed. c1987.

Includes index.

ISBN 0-201-19651-4 :

1. Physics. I. Sears, Francis Weston, 1898- University physics. II. Title

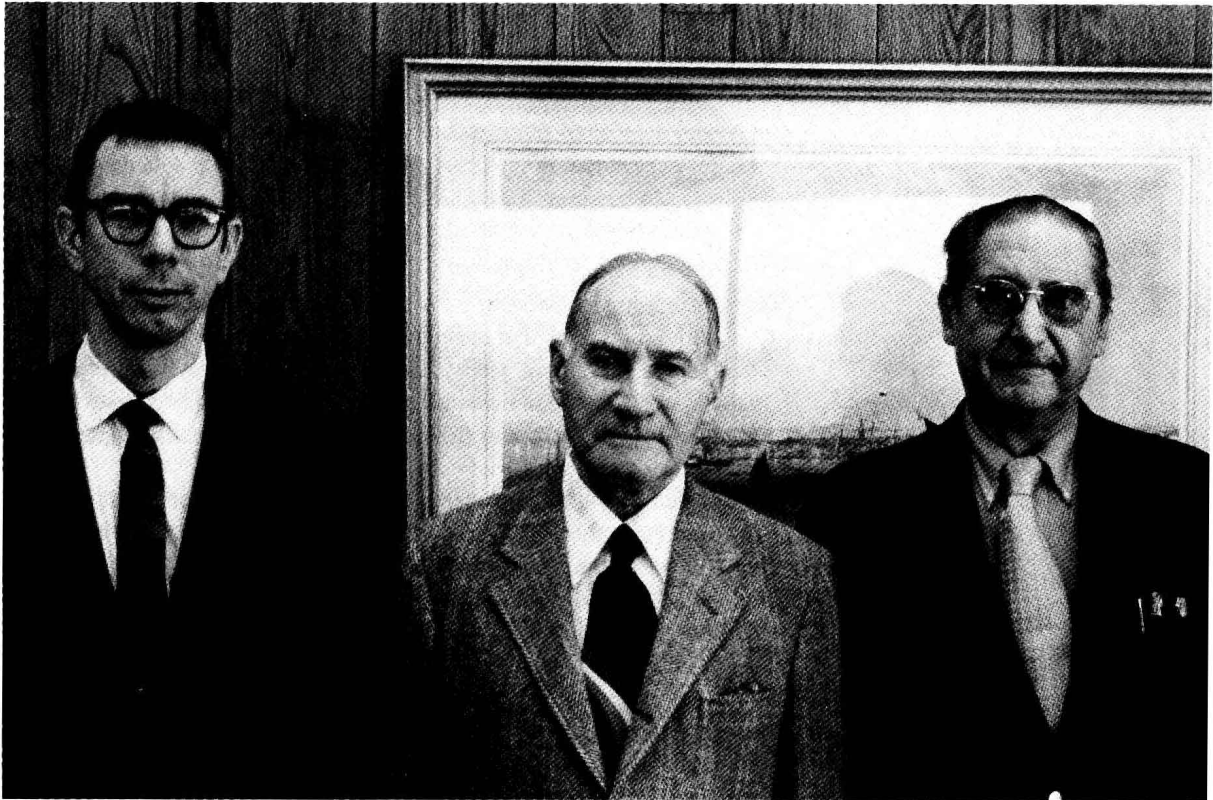
QC21.2.Y67 1990

530 — dc20

91-28689

CIP

Dedication

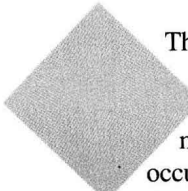


Hugh D. Young, Mark W. Zemansky, Francis W. Sears—1972

I would like to dedicate this new edition to the memory of Francis Sears and Mark Zemansky. Both were shining examples of excellence in physics teaching, and both were stalwart leaders in the physics teaching community throughout their professional lives. The very first edition of this book provided a rock-solid foundation on which all the later editions rest. When I became a co-author, beginning with the fifth edition, they firmly but kindly guided my hand, teaching me how to improve and update the book without ruining what was already good about it. I will never forget their kindness or their helpfulness. Thank you, Francis and Mark; I love you both.

H. D. Y.

Preface



This new edition of *University Physics* represents a significant new stage in the evolution of a book that has played a prominent role in introductory physics education for over 40 years. This comprehensive revision reflects (a) the major changes in the philosophy of introductory physics courses that have occurred over these years, and (b) the changing backgrounds and needs of the students who take these courses.

I have tried very hard to preserve the qualities and features that users of earlier editions have found valuable. The basic goal is unchanged: to provide a broad, rigorous introduction to physics at the beginning college level for students who are currently learning elementary calculus. The most important objectives are the development of physical intuition and problem-solving skills.

The prose style is considerably more relaxed than in earlier editions. Without being colloquial or excessively familiar, I try to talk to the student as a partner in learning, not as an audience to be lectured to from atop a platform. I have found that this new style makes it a lot easier for me to convey my own excitement and enthusiasm about the beauty and intellectual challenge of physics than a more formal style would allow.

Physics educators face several major challenges today. One is to persuade students that the study of physics is meaningful and relevant to their professional preparation and to their lives. Another is to help them develop physical intuition and modeling skills along with problem-solving ability. While addressing these challenges, I would like to show the student as clearly as possible the beauty and fundamental unity of all branches of physics. The ways I have addressed these problems are shown in the following features of the new edition.

Chapter Organization

There is always danger that the student will get lost in what may seem like a blizzard of detail. To help avoid this, each chapter begins with a list of Key Concepts to give the student perspective and guideposts through the chapter. Then, an opening paragraph gives specific examples of the chapter's content and connects it with what has come before. At the end of each chapter is a Summary, including a list of Key Terms that the student should have learned to use, and a synopsis of the most important principles introduced in the chapter, with the associated Key Equations.

Contents

Here are the most significant changes in the organization of the new edition:

- The material on mechanical energy is divided into two chapters, the first on the work-energy theorem and applications, the second on potential energy and conservation of energy.
- The momentum chapter has been reorganized. It now begins with conservation of momentum and its applications to collision problems. The concept of impulse is introduced later.
- The treatment of rigid body motion is divided into two chapters. The first includes rotational kinematics and kinetic energy; the second includes the relation of torque to angular acceleration and angular momentum.
- The treatment of elasticity has been shortened and combined with the material on equilibrium.
- Gravitation and the motions of planets and satellites have been placed in a separate chapter, which also includes an expanded treatment of Kepler's laws and gravitational potential energy.
- The material on thermal phenomena and thermodynamics has been completely rewritten and considerably shortened, now comprising four chapters rather than the previous seven. The microscopic viewpoint, including kinetic theory of gases, is woven through the entire discussion rather than appearing as a separate chapter.
- The treatment of interference and diffraction has been expanded somewhat and divided into two chapters.

Problems

The end-of-chapter problem collections have been extensively revised and enlarged. The problems are again grouped into three categories: *Exercises*, single-concept problems that can be keyed to specific sections of the text; *Problems*, usually requiring two or more nontrivial steps; and *Challenge Problems*, intended to challenge the strongest students. The number of problems has grown by 480; the total number is now 2300. The revision of the problem collections was carried out by Prof. A. Lewis Ford (Texas A&M University) with the assistance of Mr. Craig Watkins (M.I.T.).

Problem-Solving Strategy

Problem-Solving Strategy sections originated with the seventh edition (1987) of this book and have since been imitated in several other books. They have proved to be a very substantial help, especially to the many earnest but bewildered students who "understood the material but couldn't do the problems."

Examples

Each Problem-Solving Strategy section is followed immediately by one or more worked-out examples that illustrate the strategy. The number of examples has grown by 195 to a total of 486. Many are drawn from familiar, real-life situations related to the student's own experience. I have tried to emphasize the relevance of physics in a broad range of familiar situations, including applications to engineering, biology, astronomy, medicine, and many other areas.

Example solutions always begin with a statement of the general principles to be used and, when necessary, a discussion of the reason for choosing them. Heavy emphasis is placed on *modeling*—showing the student how to begin with a seemingly complex situation, make simplifying assumptions when needed, apply the appropriate

physical principles, and evaluate the final result. Does it make sense? Is it what you expected? How can you check it?

Illustrations

All the illustrations have been completely redone to take advantage of the new four-color format. In addition to giving the book greatly enhanced visual appeal for the student, the full-color treatment serves several vital pedagogical functions.

- Vectors are color-coded; each vector quantity has a characteristic color. Multiple graphs drawn on the same axis system are color-coded, and various materials in a diagram can be distinguished by color.
- Applications to a wide variety of real-world situations are made much more vivid by the use of full-color photographs and illustrations, often appearing side-by-side with analytic diagrams.
- The various pedagogical features of the book, such as introductions, examples, strategies, and summaries are easily recognizable by their distinctive color treatment.

Mathematical Level

The mathematical level has not changed substantially from previous editions, but I have increased somewhat the use of unit vectors and calculus in worked-out examples. There are also more problems involving unit vectors and calculus. Some of the challenge problems invite students to stretch their mathematical ability, especially in situations that require numerical approximations.

Units and Notation

In this edition SI units are used exclusively. English unit conversions are included where appropriate. The joule is used as the standard unit of energy of all forms, including heat. In examples, units and correct significant figures are always carried through all stages of numerical calculations. As usual, boldface symbols are used for vector quantities, and in addition boldface $+$, $-$, and $=$ signs are used to remind the student at every opportunity of the crucial distinctions between operations with vectors and those with numbers.

Enrichment

- **Case Studies:** I have resisted the temptation to include lengthy essays on topics unrelated to the chapters in which they appear. Instead, I have included 13 optional sections called Case Studies, each building on the material of its chapter. Some (Neutrinos, Black Holes, Photons) emphasize connections between classical and modern physics. Others (Automotive Power, Energy Resources, Power Distribution Systems) have an engineering flavor; still others (Baseball Trajectories, Chaos, Field Maps) emphasize computer simulations and include computer exercises for the student. All case studies have corresponding end-of-chapter problems.

- **Building Physical Intuition:** Twelve full-page layouts combine photographs, diagrams, and text to help build intuition for individual key concepts such as free-body diagrams, energy diagrams, entropy, and electromagnetic waves. These pages will help students build conceptual bridges between basic principles of physics and the world around them—to help them learn to think like physicists.

Flexibility

This book is adaptable to a wide variety of course outlines. There is plenty of material for an intensive three-semester course. Most instructors will find that there is too much material for a one-year course, but the format makes it easy to tailor the book to any of a variety of one-year course plans by omitting certain chapters or sections. For example, any or all of the chapters on relativity, fluid mechanics, acoustics, electromagnetic waves, optical instruments, and several others can be omitted without loss of continuity. In addition, some sections that are unusually challenging or somewhat out of the mainstream have been identified with an asterisk preceding the section title. These too may be omitted without loss of continuity.

In any case, I hope no one will feel constrained to work straight through the book from cover to cover. Many chapters are of course inherently sequential in nature, but within this general limitation I would encourage instructors to select the chapters that fit their needs, omitting material that is not appropriate for the objectives of a particular course.

Extended Version

This new edition is published in two versions. The regular version includes 39 chapters, ending with Relativity, and omits the modern physics material that was in Chapters 41 through 44 of the seventh edition. The Extended Version adds seven completely new chapters on modern physics. They include all the topics in the old Chapters 41 through 44 and considerable additional material, concluding with a chapter on particle physics and cosmology.

Supplements

A textbook should stand on its own feet. Yet many students benefit from supplementary materials designed to be used with the text. With this thought in mind, we offer a Study Guide and a Solutions Manual.

- The Study Guide, prepared by Profs. James R. Gaines and William F. Palmer, includes for each chapter a statement of objectives, a review of central concepts, problem-solving hints, additional worked-out examples and a short quiz.
- The Solutions Manual, prepared by Prof. A. Lewis Ford, includes completely worked-out solutions for about two-thirds of the odd-numbered problems in the book. (Answers to all odd-numbered problems are listed at the end of the book.)

We also offer several aids for the instructor:

- The Instructor's Manual contains answers to all even-numbered problems and class discussion questions. This is available only to instructors.
- OmniTest is an algorithm-driven computerized testing system that enables instructors to generate tests effortlessly. It also allows instructors to add their own test items and edit existing items with an easy to use, on screen "What-You-See-Is-What-You-Get" text editor.

ACKNOWLEDGMENTS

I want to extend my heartfelt thanks to my colleagues at Carnegie-Mellon, especially Profs. Robert Kraemer, Bruce Sherwood, Helmut Vogel, and Brian Quinn, for many stimulating discussions about physics pedagogy and for their support and encouragement during the writing of this new edition. I am equally indebted to the many generations of Carnegie-Mellon students who have helped me learn what good

teaching and good writing are, by showing me what works and what doesn't. It is always a joy and a privilege to express my gratitude to my wife Alice and our children Gretchen and Rebecca for their love, support, and emotional sustenance during the writing of the new edition. May all men and women be blessed with love such as theirs.

As always, I welcome communications from students and professors, especially when they concern errors or deficiencies that you find in this edition. I have spent a lot of time and effort writing the best book I know how to write. It has been a labor of love; undergraduate teaching is the main focus of my professional life, and this edition is a direct outgrowth of my love of teaching. I hope it will help you to teach and learn physics. In turn, you can help me by letting me know what still needs to be improved!

*Pittsburgh, Pennsylvania
November, 1991*

H. D. Y.

Reviewers

Edward Adelson, Ohio State University
Harold Bale, University of North Dakota
John Barach, Vanderbilt University
Paul Baum, CUNY–Queens College
Robert Boeke, William Rainey Harper College
Tony Buffa, Cal Poly–San Luis Obispo
Roger Clapp, University of South Florida
Leonard Cohen, Drexel University
W. R. Coker, University of Texas–Austin
David Cook, Lawrence University
Larry Curtis, University of Toledo
George Dixon, Oklahoma State University
Boyd Edwards, West Virginia University
William Fasnacht, US Naval Academy
Neil Fletcher, Florida State University
Solomon Gartenhaus, Purdue University
Ron Gautreau, New Jersey Institute of Technology
John Gruber, San Jose State University
Graham Gutsche, US Naval Academy
Keith Honey, West Virginia Institute of Technology
Gregory Hood, Tidewater Community College

Alvin Jenkins, North Carolina State University
John Karchek, GMI Engineering & Management Institute
Elihu Lubkin, University of Wisconsin–Milwaukee
Jeffrey Mallow, Loyola University
Robert Marcini, Memphis State University
David Markowitz, University of Connecticut
Lawrence McIntyre, University of Arizona
Arnold Perlmutter, University of Miami
Ronald Poling, University of Minnesota
R. J. Peterson, University of Colorado–Boulder
Michael Rapport, Anne Arundel Community College
Ross Spencer, Brigham Young University
Edward Strother, Florida Institute of Technology
Albert Stwertka, US Merchant Marine Academy
Martin Tiersten, CUNY–City College
Somdev Tyagi, Drexel University
Thomas Wiggins, Pennsylvania State University
Stanley Williams, Iowa State University
Suzanne Willis, Northern Illinois University
James Wood, Palm Beach Junior College

Contents

1

Models, measurements, and vectors 1

1-1	Introduction	3
1-2	Idealized models	4
1-3	Standards and units	5
	Building physical intuition:	
	Relative sizes	8
1-4	Unit consistency and conversions	10
1-5	Precision and significant figures	11
1-6	Estimates and order of magnitude	13
1-7	Vectors and vector addition	14
1-8	Components of vectors	17
1-9	Unit vectors	20
1-10	Products of vectors	21
	Summary	24
	Problems	25

2

Motion along a straight line 29

2-1	Average velocity	31
2-2	Instantaneous velocity	33
2-3	Average and instantaneous acceleration	35
2-4	Motion with constant acceleration	39
2-5	Freely falling bodies	42
* 2-6	Velocity and coordinate by integration	45
2-7	Relative velocity along a straight line	46
	Summary	49
	Problems	50

3

Motion in a plane 57

3-1	The velocity vector	59
3-2	The acceleration vector	61
3-3	Projectile motion	63
3-4	Uniform circular motion	70
3-5	Relative velocity	72
3-6	Baseball trajectories:	
	A case study in computer modeling	74
	Summary	76
	Problems	77

4

Newton's laws of motion 83

4-1	Force	85
4-2	Newton's first law	87
4-3	Mass and Newton's second law	89
4-4	Mass and weight	94
4-5	Newton's third law	96
4-6	Using Newton's laws	98
	Building physical intuition:	
	Free-body diagrams	99
	Summary	102
	Problems	102

5

Applications of Newton's laws 107

5-1	Equilibrium of a particle	109
5-2	Applications of Newton's second law	113
5-3	Contact forces and friction	119
5-4	Dynamics of circular motion	127
5-5	Motion in a vertical circle	131
* 5-6	Forces in nature	132
	Summary	133
	Problems	134

6

Work and kinetic energy 145

6-1	Conservation of energy	147
6-2	Work	148
6-3	Work done by a varying force	151
6-4	Work and kinetic energy	155
6-5	Power	159
6-6	Automotive power:	
	A case study in energy relations	161
	Summary	163
	Problems	164

7

Conservation of energy 169

7-1	Potential energy and conservative forces	171
7-2	Gravitational potential energy	172
7-3	Elastic potential energy	179
7-4	Conservative and nonconservative forces	182
* 7-5	Force and potential energy	184
* 7-6	Energy diagrams	186
* 7-7	Internal work and energy	188
	Building physical intuition:	
	Potential energy diagrams	189
	Summary	190
	Problems	191

8

Momentum and impulse 196

8-1	Momentum	198
8-2	Conservation of momentum	200
8-3	Inelastic collisions	203
8-4	Elastic collisions	206
8-5	Impulse	210
8-6	Center of mass	213
8-7	Motion of the center of mass	215
* 8-8	Rocket propulsion	217
8-9	The neutrino:	
	A case study in modern physics	220
	Summary	222
	Problems	223

9

Rotational motion 232

9-1	Angular velocity and acceleration	234
9-2	Rotation with constant angular acceleration	237
9-3	Velocity and acceleration relations	238
9-4	Kinetic energy of rotation	241
* 9-5	Moment-of-inertia calculations	245
* 9-6	Parallel-axis theorem	247
	Summary	250
	Problems	251



10

Dynamics of rotational motion

10-1	Torque	258
10-2	Torque and angular acceleration	260
10-3	Rotation about a moving axis	264
10-4	Work and power in rotational motion	268
10-5	Angular momentum	270
10-6	Conservation of angular momentum	273
10-7	Gyroscopes	276
	Summary	279
	Problems	280

11

Equilibrium and elasticity

11-1	Conditions for equilibrium	289
11-2	Center of gravity	289
11-3	Solving equilibrium problems	292
11-4	Couples	296
11-5	Tensile stress and strain	297
	Building physical intuition:	
	Equilibrium and stress	299
11-6	Bulk stress and strain	301
11-7	Shear stress and strain	302
11-8	Elasticity and plasticity	304
	Summary	306
	Problems	307

12

Gravitation

12-1	Newton's law of gravitation	317
12-2	Weight	319
12-3	Gravitational field	322
12-4	Gravitational potential energy	324
12-5	Satellite motion	326
* 12-6	Kepler's laws	329
* 12-7	Spherical mass distribution	331
* 12-8	Effect of the earth's rotation on the acceleration due to gravity	334
12-9	Black holes: A case study in modern physics	337
	Summary	340
	Problems	341

256

287

315

13

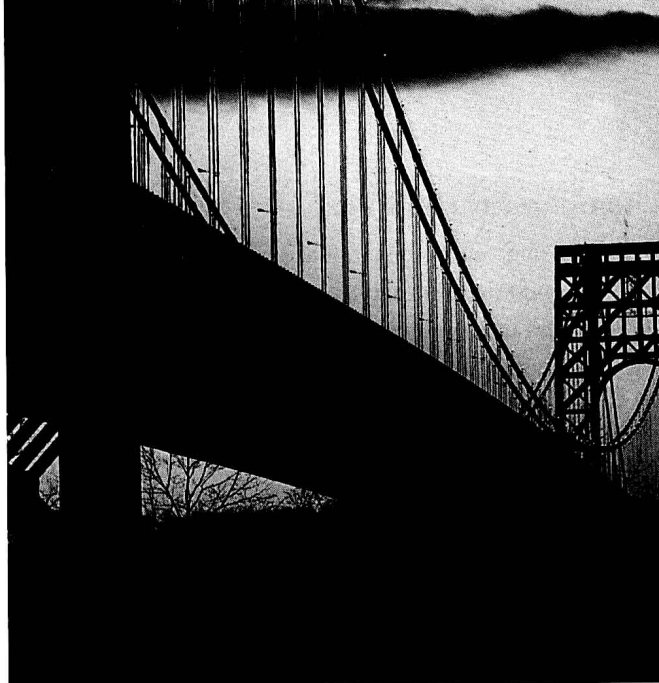
Periodic motion

13-1	Basic concepts	347
13-2	Energy in simple harmonic motion	349
13-3	Equations of simple harmonic motion	354
13-4	Circle of reference	359
13-5	The simple pendulum	360
13-6	The physical pendulum	361
13-7	Damped oscillations	363
* 13-8	Forced oscillations and resonance	365
13-9	Chaos: A case study in dynamic analysis	367
	Summary	372
	Problems	374

14

Fluid mechanics

14-1	Density	382
14-2	Pressure in a fluid	383
14-3	Buoyancy	387
14-4	Surface tension	389
14-5	Fluid flow	393
	Building physical intuition:	
	Shape and drag in fluid flow	395
14-6	Bernoulli's equation	396
14-7	Real fluids	400
	Summary	405
	Problems	406



15

Temperature and heat	413
15-1 Temperature and thermal equilibrium	415
15-2 Thermometers and temperature scales	416
15-3 Gas thermometers and the Kelvin scale	418
15-4 Thermal expansion	420
15-5 Quantity of heat	424
15-6 Calorimetry	428
15-7 Mechanisms of heat transfer	432
15-8 Integrated circuits: A case study in heat transfer	439
Summary	441
Problems	442

16

Thermal properties of matter	450
16-1 Equations of state	452
16-2 Molecular properties of matter	457
16-3 Kinetic-molecular model of an ideal gas	460
16-4 Heat capacities	466
* 16-5 Molecular speeds	469
16-6 Phases of matter	472
Summary	475
Problems	476

17

The first law of thermodynamics	481
17-1 Energy, heat, and work	483
17-2 Work done during volume changes	484
17-3 Heat transfer during volume changes	486
17-4 Internal energy and the first law	487
17-5 Thermodynamic processes	491
17-6 Internal energy of an ideal gas	493
17-7 Heat capacities of an ideal gas	494
17-8 Adiabatic processes for an ideal gas	497
Summary	499
Problems	500

18

The second law of thermodynamics	504
18-1 Directions of thermodynamic processes	506
18-2 Heat engines	507
18-3 Internal-combustion engines	509
18-4 Refrigerators	512
18-5 The second law of thermodynamics	514
18-6 The Carnot cycle	515
* 18-7 Entropy	520
Building physical intuition: Entropy and disorder	523
* 18-8 The Kelvin temperature scale	526
18-9 Energy resources: A case study in thermodynamics	527
Summary	529
Problems	530

