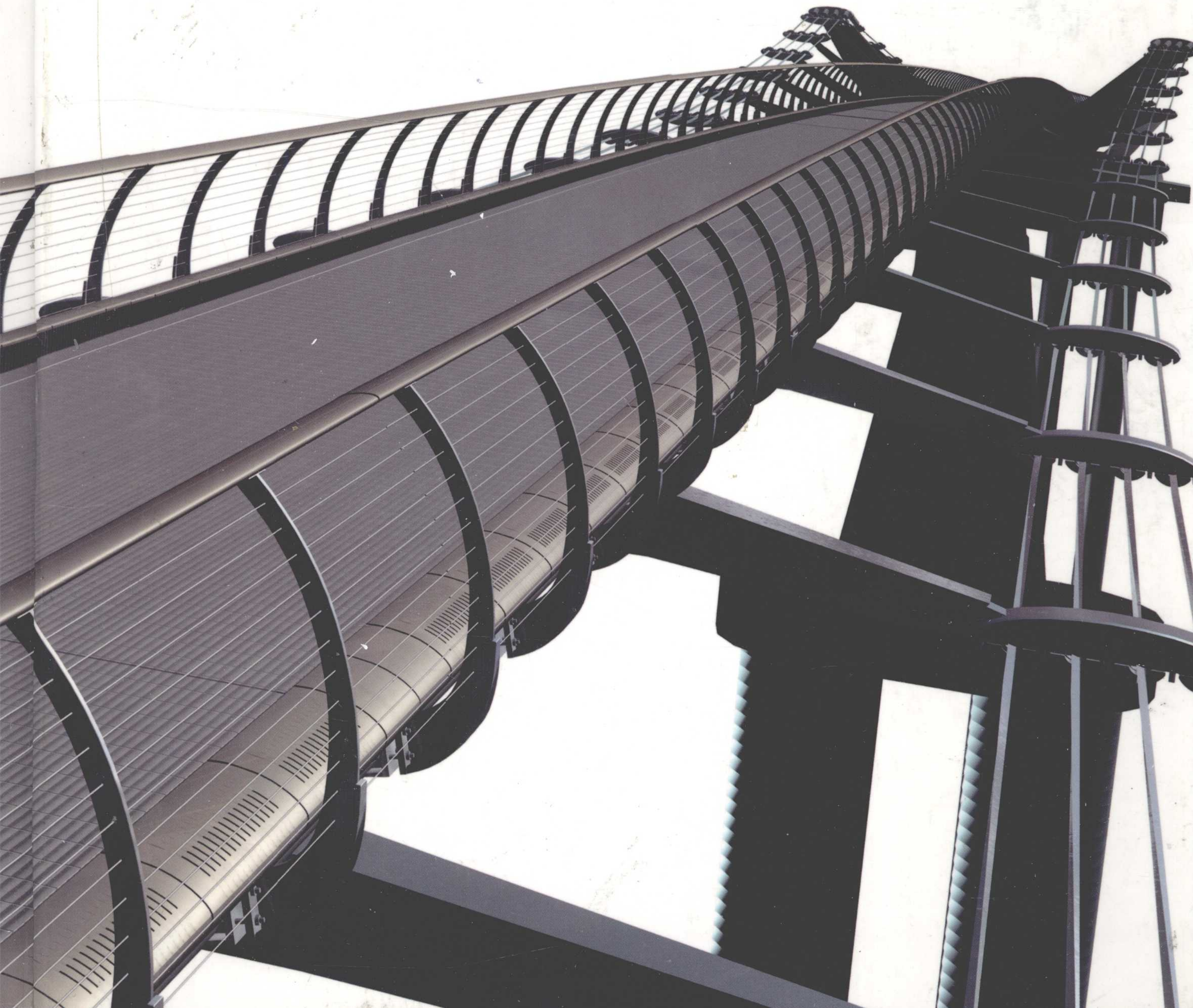
Sears and Zemansky's

UNIVERSITY PHYSICS

11th Edition

Young & Freedman



Sears and Zemansky's

UNIVERSITY PHYSICS

11th Edition

HUGH D. YOUNG
CARNEGIE MELLON UNIVERSITY

ROGER A. FREEDMAN
UNIVERSITY OF CALIFORNIA, SANTA BARBARA

CONTRIBUTING AUTHOR
A. LEWIS FORD
TEXAS A&M UNIVERSITY

PEARSON
Addison Wesley

San Francisco Boston New York
Cape Town Hong Kong London Madrid Mexico City
Montreal Munich Paris Singapore Sydney Tokyo Toronto

Executive Editor: Adam Black, Ph.D.
Development Editors: David Chelton, Alice Houston
Project Editors: Nancy Benton, Richard Dal Porto
Production Editor, Art Coordinator, Copyeditor, Illustrator, Photo Editor, Permissions Editor, Proofreader, Compositor: Thompson Steele, Inc.
Media Producer: Claire Masson
Marketing Manager: Christy Lawrence
Director of Marketing: Stacy Treco
Art Director: Blake Kim
Manufacturing Supervisor: Vivian McDougal
Text and Cover Designer: Mark Ong, Side by Side Studios
Cover Printer: Phoenix Color Corporation
Printer and Binder: R.R. Donnelley & Sons

Cover Photo: Image of London's Millennium Bridge
created by Cimex Media, Ltd. http://www.cimexmedia.com
Photo Credits: see page A19

Library of Congress Cataloging-in-Publication Data

Young, Hugh D.
Sears and Zemansky's university physics: with modern physics. — 11th ed. / Hugh D. Young, Roger A. Freedman; contributing author, A. Lewis Ford.
p. cm.
Includes bibliographical references and index.
ISBN 0-8053-8768-4 (alk, paper)
1. Physics. I. Title: University physics. II. Freedman, Roger A. III. Sears, Francis Weston, 1898–1975. University physics. IV. Title.

QC21.3.Y68 2004
530—dc21

2003049555

0-8053-8768-4 Standard with Mastering Physics
0-8053-9183-5 Standard without Mastering Physics

12345678910 — DOW —06 05 04 03
www.aw.com/bc

PREFACE

This book is the product of more than half a century of innovation in physics education. When the first edition of *University Physics* by Francis W. Sears and Mark W. Zemansky appeared in 1949, it was revolutionary among calculus-based physics textbooks in its emphasis on the fundamental principles of physics and how to apply them. The success of *University Physics* with generations of students and educators throughout the world is a testament to the merits of this approach. In preparing this new Eleventh Edition, we have further enhanced and developed *University Physics* to emphasize two key objectives: helping students develop conceptual understanding, and helping them build strong problem-solving skills.

New to This Edition

■ A **new arrangement of topics** places the chapters on mechanical waves (15 and 16) immediately after the chapters on oscillations and fluids and before the chapters on thermodynamics. The wave chapters have been rearranged to eliminate repetition of topics. The discussion of displacement current has been moved to Chapter 29 to follow the presentation of electromagnetic induction. The chapters on geometric optics and optical instruments have been streamlined into a single Chapter 34. Chapter 39 has an expanded discussion of the Schrödinger equation. Some of the optional sections from the Tenth Edition of *University Physics* have been moved to the companion web site.

■ A totally revised **art program** helps students better visualize key concepts. More discussion has been placed *on* the figures themselves, and consistent colors for each kind of vector quantity are used throughout the book. In the discussion of mechanics, color and design have been streamlined to help students identify the object of interest. New photographs throughout the book illustrate the applications of physics to the natural world and to today's technology.

■ A research-based, **step-by-step approach to problem solving** is used throughout the book. Called **ISEE**—an acronym for *Identify, Set up, Execute,* and *Evaluate*—this approach gives students a global strategy for solving physics problems of all kinds. The ISEE approach is used in *all* Problem-Solving Strategy boxes and in *all* worked examples. Educational research indicates that this consistent approach helps students build their confidence in attacking new problems.

■ To help students check their comprehension of the material, there are **Chapter Opening Questions** at the beginning of each chapter and **Test Your Understanding Questions** at the end of almost every chapter section. The answers to the questions are found at the end of the chapter.

■ New **visual chapter summaries** reinforce the key ideas in each chapter. They help students consolidate and connect important concepts by matching a descriptive explanation, a mathematical representation, and a thumbnail sketch in an easy-to-review grid.

- **Careful use of subscripts** in kinematics, dynamics, and elsewhere makes it easier for students to distinguish between signed quantities such as velocity v_x and magnitudes such as speed v.

- There are over **600 new end-of-chapter problems,** with an emphasis on context-rich problems, bringing the total problem count to more than 3700.

- Accompanying *University Physics* are **two new web-based tools** for teaching and learning physics. **MasteringPhysics™** is a research-proven online tutorial and homework assignment system. MasteringPhysics™ includes an extensive library of entirely new and carefully tested problems that can be used for student assignments. These problems include *Skill Builders* (detailed worked examples that focus on conceptual understanding or key skills, and include multiple hint-giving options) and *Tutoring Problems* (standard multi-step homework problems that give on-demand hints and individualized feedback based on the student's particular answers). *End-of-Chapter Problems* (the majority of the end-of-chapter problems from *University Physics*) are also provided in the system with algorithmically generated variables and fewer hints to more accurately replicate a testing environment. **ActivPhysics OnLine** provides a comprehensive library of more than 220 applets and accompanying interactive activities that cover topics from mechanics through modern physics. It includes interactive conceptual exercises that encourage students to confront misconceptions, reason qualitatively, and think critically.

Key Features of *University Physics*

Standard, Extended, and Split Versions: This edition is available in three versions. The Standard version (ISBN 0-8053-8768-4) includes 37 chapters, ending with the special theory of relativity. The Extended version (ISBN 0-8053-8684-X) adds seven chapters on modern physics, including the physics of atoms, molecules, condensed matter, nuclei, and elementary particles. The Split version includes all 44 chapters in three volumes. Volume 1 (ISBN 0-8053-8767-6, Chapters 1–20) covers mechanics, waves, and thermodynamics; Volume 2 (ISBN 0-8053-8766-8, Chapters 21–37) covers electricity and magnetism, optics, and relativity; and Volume 3 (ISBN 0-8053-8765-X, Chapters 37–44) covers modern physics.

A Guide for the Student: Many physics students experience difficulty simply because they don't know how to use their textbook. A section entitled "How to Succeed in Physics by Really Trying," which follows this preface, is a "user's manual" to all the features of this book. This section, written by Professor Mark Hollabaugh (Normandale Community College), also gives a number of helpful study hints. *Every* student should read this section!

Chapter Organization: The first section of each chapter is an *Introduction* that gives specific examples of the chapter's content and connects it with what has come before. There is also a *Chapter Opening Question* to make the reader think about the subject matter of the chapter ahead. (To find the answer to the question, look for the ? icon.) Most sections end with a *Test Your Understanding Ques-*

tion, which can be conceptual or quantitative in nature. At the end of the last section of the chapter is a *Visual Chapter Summary* of the most important principles in the chapter, as well as a list of *Key Terms* with reference to the page number where each term is introduced. The answers to the Chapter Opening Question and Test Your Understanding Questions are on the page following the Key Terms.

Questions and Problems: At the end of each chapter is a collection of *Discussion Questions* that probe and extend the student's conceptual understanding. Following these are *Exercises,* which are single-concept problems keyed to specific sections of the text; *Problems,* usually requiring one or two nontrivial steps; and *Challenge Problems,* intended to challenge the strongest students. The problems include applications to such diverse fields as astrophysics, biology, and aerodynamics. Many problems have a conceptual part in which students must discuss and explain their results. The new questions, exercises, and problems for this edition were created and organized by Professor A. Lewis Ford (Texas A&M University) with contributions from Wayne Anderson (Sacramento City College) and Rich Gottfried (Frederick Community College).

Problem-Solving Strategies and Worked Examples: Throughout the book, *Problem-Solving Strategy* boxes provide students with specific tactics for solving particular types of problems. They address the needs of any student who's ever felt that they "understand the concepts but can't do the problems."

All Problem-Solving Strategy boxes follow the ISEE approach (Identify, Set up, Execute, and Evaluate) to solving problems. This approach helps students see how to begin with a seemingly complex situation, identify the relevant physical concepts, decide what tools are needed to solve the problem, carry out the solution, and then evaluate whether the result makes sense.

Each Problem-Solving Strategy box is followed by one or more worked-out *Examples* that illustrate the strategy. Many other worked-out Examples are found in each chapter. Like the Problem-Solving Strategy boxes, all of the quantitative Examples use the ISEE approach. Several of the examples are purely qualitative, and are labeled as *Conceptual Examples;* see, for instance, Conceptual Examples 6.6 (Comparing kinetic energies, p. 218), 8.1 (Momentum versus kinetic energy, p. 286) and 20.7 (A reversible adiabatic process, p. 775).

"Caution" paragraphs: Two decades of physics education research have revealed a number of conceptual pitfalls that commonly plague beginning physics students. These include the ideas that force is required for motion, that electric current is "used up" as it goes around a circuit, and that the product of an object's mass and its acceleration is itself a force. The "Caution" paragraphs alert students to these and other pitfalls, and explain why the wrong way to think about a certain situation (which may have occurred to the student first) is indeed wrong. (See, for example, pp. 132, 182, and 629.)

Notation and units: Students often have a hard time keeping track of which quantities are vectors and which are not. We use boldface italic symbols with an arrow on top for vector quantities, such as $\vec{\boldsymbol{v}}$, $\vec{\boldsymbol{a}}$, and $\vec{\boldsymbol{F}}$; unit vectors such as $\hat{\boldsymbol{\imath}}$, have a caret on top. Boldface $\boldsymbol{+}$, $\boldsymbol{-}$, $\boldsymbol{\times}$, and $\boldsymbol{=}$ signs are used in vector equations to emphasize the distinction between vector and scalar mathematical operations.

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.

Flexibility: The book is adaptable to a wide variety of course outlines. There is plenty of material for a three-semester or a five-quarter course. Most instructors will find that there is too much material for a one-year course, but it is easy to tailor the book to a variety of one-year course plans by omitting certain chapters or sections. For example, any or all of the chapters on fluid mechanics, sound and hearing, electromagnetic waves, or relativity can be omitted without loss of continuity. In any case, no instructor should feel constrained to work straight through the entire book.

OnLine Supplements for Students and Instructors

MasteringPhysics™ (www.masteringphysics.com) is a sophisticated online tutoring and homework system developed specially for courses using *University Physics.* Originally developed by Professor David Pritchard and collaborators at MIT, MasteringPhysics™ provides students with individualized online tutoring by responding to their wrong answers and providing hints for solving multi-step problems when they get stuck. It gives them immediate and up-to-date assessment of their progress, and shows where they need to practice more. MasteringPhysics™ provides instructors with a fast and effective way to assign tried-and-tested online homework assignments that comprise a range of problem types. The powerful post-assignment diagnostics allow instructors to assess the progress of their class as a whole and individual students, and quickly identify areas of difficulty.

ActivPhysics OnLine (www.aw.com/young11) was developed by Professors Alan Van Heuvelen and Paul D'Alessandris. It provides simulations and accompanying conceptual exercises from mechanics, waves, thermodynamics, electricity and magnetism, and modern physics. Icons throughout the book indicate which ActivPhysics simulations and exercises correspond to various sections of *University Physics.*

The Addison Wesley Tutor Center (www.aw.com/tutorcenter) provides one-on-one tutoring via telephone, fax, email, or interactive web site during evening hours and on weekends. Qualified college instructors answer questions and provide instruction regarding MasteringPhysics™ as well as examples, exercises, and other content from *University Physics.*

The Companion Web Site (www.aw.com/young11) includes additional study material as well as in-depth discussions of physics topics not included in *University Physics.*

Additional Student Supplements

The **Study Guide,** prepared by Professor James R. Gaines and William F. Palmer, reinforces the text's emphasis on problem-solving strategies and student misconceptions. *The Study Guide for Volume 1* (ISBN 0-8053-8778-1) covers Chapters 1–20, and the *Study Guide for Volumes 2 and 3* (ISBN 0-8053-8743-9) covers Chapters 21–44.

The **Student Solutions Manual,** prepared by Professor A. Lewis Ford, includes careful, step-by-step solutions for most of the odd-numbered exercises and problems in *University Physics,* following the same ISEE approach used in the Problem-Solving Strategy boxes and in the Examples. (The answers for all odd-numbered problems are found in *University Physics* following the Appendices.) The *Student Solutions Manual for Volume 1* (ISBN 0-8053-8777-3) covers Chapters 1–20, and the *Student Solutions Manual for Volumes 2 and 3* (ISBN 0-8053-8696-3) covers Chapters 21–44.

Additional Instructor Supplements

The **Instructor's Solutions Manual,** prepared by Professor A. Lewis Ford, contains worked-out solutions to all exercises, problems, and challenge problems. (It is available to qualifying instructors only.) The *Instructor's Solutions Manual for Volume 1* (ISBN 0-8053-8775-7) covers Chapters 1–20, and the *Instructor's Solutions Manual for Volumes 2 and 3* (ISBN 0-8053-8776-5) covers Chapters 21–44. The complete text of both printed manuals is also available in Word format on the cross-platform *Instructor's Solutions Manual* CD-ROM (ISBN 0-8053-8774-9).

The **Test Bank** is available in both print and electronic formats. The *Printed Test Bank* (ISBN 0-8053-8772-2) includes more than 1500 problems. All of these problems are included in the cross-platform *Computerized Test Bank* CD-ROM (ISBN 0-8053-8771-4); more than half of the problems on the CD-ROM now offer algorithmically generated functionality thanks to Benjamin Grinstein (University of California, San Diego).

Five Easy Lessons: Strategies for Successful Physics Teaching (ISBN 0-8053-8702-1), written by Professor Randall Knight (California Polytechnic State University, San Luis Obispo), is packed with creative ideas on how to enhance any physics course. It is an invaluable companion for both novice and veteran physics instructors.

The **Simulation and Image Presentation CD-ROM** (ISBN 0-8053-8769-2) includes a library of more than 220 simulation applets from ActivPhysics OnLine. These make it easy to illustrate challenging physics concepts in class in a dynamic way. The CD-ROM also includes all of the illustrations (excluding photographs) from *University Physics,* all chapter summaries, Problem-Solving Strategy boxes, and key equations. All these items can easily be exported into lecture-presentation programs such as PowerPoint®, or posted online. A set of **Transparency Acetates** (ISBN 0-8053-8773-0) with more than 200 illustrations from *University Physics* is also available.

Acknowledgments

We would like to thank the hundreds of reviewers and colleagues who have offered valuable comments and suggestions over the life of this textbook. The continuing success of *University Physics* is due in large measure to their contributions.

Edward Adelson (Ohio State University), Ralph Alexander (University of Missouri at Rolla), J. G. Anderson, R. S. Anderson, Wayne Anderson (Sacramento City College), Alex Azima (Lansing Community College), Dilip Balamore (Nassau Community College), Harold Bale (University of North Dakota), Arun Bansil (Northeastern University), John Barach (Vanderbilt University), J. D. Barnett, H. H. Barschall, Albert Bartlett (University of Colorado), Paul Baum (CUNY, Queens College), Frederick Becchetti (University of Michigan), B. Bederson, Lev I. Berger (San Diego State University),

Robert Boeke (William Rainey Harper College), S. Borowitz, A. C. Braden, James Brooks (Boston University), Nicholas E. Brown (California Polytechnic State University, San Luis Obispo), Tony Buffa (California Polytechnic State University, San Luis Obispo), A. Capecelatro, Michael Cardamone (Pennsylvania State University), Duane Carmony (Purdue University), Troy Carter (UCLA), P. Catranides, John Cerne (SUNY at Buffalo), Roger Clapp (University of South Florida), William M. Cloud (Eastern Illinois University), Leonard Cohen (Drexel University), W. R. Coker (University of Texas, Austin), Malcolm D. Cole (University of Missouri at Rolla), H. Conrad, David Cook (Lawrence University), Gayl Cook (University of Colorado), Hans Courant (University of Minnesota), Bruce A. Craver (University of Dayton), Larry Curtis (University of Toledo), Jai Dahiya (Southeast Missouri State University), Steve Detweiler (University of Florida), George Dixon (Oklahoma State University), Donald S. Duncan, Boyd Edwards (West Virginia University), Robert Eisenstein (Carnegie Mellon University), Amy Emerson Missourn (Virginia Institute of Technology), William Faissler (Northeastern University), William Fasnacht (U.S. Naval Academy), Paul Feldker (St. Louis Community College), Carlos Figueroa (Cabrillo College), L. H. Fisher, Neil Fletcher (Florida State University), Robert Folk, Peter Fong (Emory University), A. Lewis Ford (Texas A&M University), D. Frantszog, James R. Gaines (Ohio State University), Solomon Gartenhaus (Purdue University), Ron Gautreau (New Jersey Institute of Technology), J. David Gavenda (University of Texas, Austin), Dennis Gay (University of North Florida), James Gerhart (University of Washington), N. S. Gingrich, J. L. Glathart, S. Goodwin, Rich Gottfried (Frederick Community College), Walter S. Gray (University of Michigan), Paul Gresser (University of Maryland), Benjamin Grinstein (UC San Diego), Howard Grotch (Pennsylvania State University), John Gruber (San Jose State University), Graham D. Gutsche (U.S. Naval Academy), Michael J. Harrison (Michigan State University), Harold Hart (Western Illinois University), Howard Hayden (University of Connecticut), Carl Helrich (Goshen College), Laurent Hodges (Iowa State University), C. D. Hodgman, Michael Hones (Villanova University), Keith Honey (West Virginia Institute of Technology), Gregory Hood (Tidewater Community College), John Hubisz (North Carolina State University), M. Iona, John Jaszczak (Michigan Technical University), Alvin Jenkins (North Carolina State University), Robert P. Johnson (UC Santa Cruz), Lorella Jones (University of Illinois), John Karchek (GMI Engineering & Management Institute), Thomas Keil (Worcester Polytechnic Institute), Robert Kraemer (Carnegie Mellon University), Jean P. Krisch (University of Michigan), Robert A. Kromhout, Charles Lane (Berry College), Robert J. Lee, Alfred Leitner (Rensselaer Polytechnic University), Gerald P. Lietz (De Paul University), Gordon Lind (Utah State University), S. Livingston, Elihu Lubkin (University of Wisconsin, Milwaukee), Robert Luke (Boise State University), David Lynch (Iowa State University), Michael Lysak (San Bernardino Valley College), Jeffrey Mallow (Loyola University), Robert Mania (Kentucky State University), Robert Marchina (University of Memphis), David Markowitz (University of Connecticut), R. J. Maurer, Oren Maxwell (Florida International University), Joseph L. McCauley (University of Houston), T. K. McCubbin, Jr. (Pennsylvania State University), Charles McFarland (University of Missouri at Rolla), James Mcguire (Tulane University), Lawrence McIntyre (University of Arizona), Fredric Messing (Carnegie-Mellon University), Thomas Meyer (Texas A&M University), Andre Mirabelli (St. Peter's College, New Jersey), Herbert Muether (S.U.N.Y., Stony Brook), Jack Munsee (California State University, Long Beach), Lorenzo Narducci (Drexel University), Van E. Neie (Purdue University), David A. Nordling (U. S. Naval Academy), Benedict Oh (Pennsylvania State University), L. O. Olsen, Jim Pannell (DeVry Institute of Technology), W. F. Parks (University of Missouri), Jerry Peacher (University of Missouri at Rolla), Arnold Perlmutter (University of Miami), Lennart Peterson (University of Florida), R. J. Peterson (University of Colorado, Boulder), R. Pinkston, Ronald Poling (University of Minnesota), J. G. Potter, C. W. Price (Millersville University), Francis Prosser (University of Kansas), Shelden H. Radin, Michael Rapport (Anne Arundel Community College), R. Resnick, James A. Richards, Jr., John S. Risley (North Carolina State University), Francesc Roig (University of California, Santa Barbara), T. L. Rokoske, Richard Roth (Eastern Michigan University), Carl Rotter (University of West Virginia), S. Clark Rowland (Andrews University), Rajarshi Roy (Georgia Institute of Technology), Russell A. Roy (Santa Fe Community College), Bruce Schumm (UC Santa Cruz), Melvin Schwartz (St. John's University), F. A. Scott, L. W. Seagondollar, Stan Shepherd (Pennsylvania State University), Douglas Sherman (San Jose State), Bruce Sherwood (Carnegie Mellon University), Hugh Siefkin (Greenville College), C. P. Slichter, Charles W. Smith, Malcolm Smith (University of Lowell), Ross Spencer (Brigham Young University), Julien Sprott (University of Wisconsin), Victor Stanionis (Iona College), James Stith (American Institute of Physics), Chuck Stone (North Carolina A&T State University), Edward Strother (Florida Institute of Technology), Conley Stutz (Bradley University), Albert Stwertka (U.S. Merchant Marine Academy), Martin Tiersten (CUNY, City College), David Toot (Alfred University), Somdev Tyagi (Drexel University), F. Verbrugge, Helmut Vogel (Carnegie Mellon University), Robert Webb (Texas A & M), Thomas Weber (Iowa State University), M. Russell Wehr, (Pennsylvania State University), Robert Weidman (Michigan Technical University), Dan Whalen (UC San Diego), Lester V. Whitney, Thomas Wiggins (Pennsylvania State University), George Williams (University of Utah), John Williams (Auburn University), Stanley Williams (Iowa State University), Jack Willis, Suzanne Willis (Northern Illinois University), Robert Wilson (San Bernardino Valley College), L. Wolfenstein, James Wood (Palm Beach Junior College), Lowell Wood (University of Houston), R. E. Worley, D. H. Ziebell (Manatee Community College), George O. Zimmerman (Boston University)

In addition, we both have individual acknowledgments we would like to make.

I want to extend my heartfelt thanks to my colleagues at Carnegie Mellon, especially Professors Robert Kraemer, Bruce Sherwood, Ruth Chabay, Helmut Vogel, and Brian Quinn, for many stimulating discussions about physics pedagogy and for their support and encouragement during the writing of several successive editions of this book. 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 several successive editions of this book. May all men and women be blessed with love such as theirs. — H. D. Y.

I would like to thank my past and present colleagues at UCSB, including Francesc Roig, Elisabeth Nicol, Al Nash, and Carl Gwinn, for their wholehearted support and for many helpful discussions. I owe a special debt of gratitude to my early teachers Willa Ramsay, Peter Zimmerman, William Little, Alan Schwettman, and Dirk Walecka for showing me what clear and engaging physics teaching is all about, and to Stuart Johnson for inviting me to become a co-author of *University Physics* beginning with the 9th edition. I want to express special thanks to Adam Black and Nancy Benton at Addison Wesley for their superb editorial guidance and vision, to David Chelton for aiding in the development of this edition through his many valuable suggestions and constant good humor, and to Nancy Freihofer of Thompson Steele for shepherding this book through the Byzantine production process. I want to thank my father for his continued love and support and for keeping a space open on his bookshelf for this book. Most of all, I want to express my gratitude and love to my wife Caroline, to whom I dedicate my contributions to this book. Hey, Caroline, the new edition's done at last — let's go flying! — R. A. F.

PLEASE TELL US WHAT YOU THINK!

We welcome communications from students and professors, especially concerning errors or deficiencies that you find in this edition. We have devoted a lot of time and effort to writing the best book we know how to write, and we hope it will help you to teach and learn physics. In turn, you can help us by letting us know what still needs to be improved! Please feel free to contact us either electronically or by ordinary mail. Your comments will be greatly appreciated.

April 2003

Hugh D. Young
Department of Physics
Carnegie Mellon University
Pittsburgh, Pennsylvania 15213
hdy@andrew.cmu.edu

Roger A. Freedman
Department of Physics
University of California, Santa Barbara
Santa Barbara, California 93106-9530
airboy@physics.ucsb.edu
http://www.physics.ucsb.edu/~airboy/

HOW TO SUCCEED IN PHYSICS BY REALLY TRYING

Mark Hollabaugh, Normandale Community College

Physics encompasses the large and the small, the old and the new. From the atom to galaxies, from electrical circuitry to aerodynamics, physics is very much a part of the world around us. You probably are taking this introductory course in calculus-based physics because it is required for subsequent courses you plan to take in preparation for a career in science or engineering. Your professor wants you to learn physics and to enjoy the experience. He or she is very interested in helping you learn this fascinating subject. That is part of the reason your professor chose this textbook for your course. That is also the reason why Drs. Young and Freedman asked me to write this introductory section. We want you to succeed!

The purpose of this section of *University Physics* is to give you some ideas that will assist your learning. Specific suggestions on how to use the textbook will follow a brief discussion of general study habits and strategies.

Preparation for This Course

If you had high school physics, you will probably learn concepts faster than those who have not because you will be familiar with the language of physics. If English is a second language for you, keep a glossary of new terms that you encounter and make sure you understand how they are used in physics. Likewise, if you are farther along in your mathematics courses, you will pick up the mathematical aspects of physics faster. Even if your mathematics is adequate, you may find a book such as Arnold D. Pickar's *Preparing for General Physics: Math Skill Drills and Other Useful Help (Calculus Version)* to be useful. Your professor may actually assign sections of this math review to assist your learning.

Learning to Learn

Each of us has a different learning style and a preferred means of learning. Understanding your own learning style will help you to focus on aspects of physics that may give you difficulty and to use those components of your course that will help you overcome the difficulty. Obviously you will want to spend more time on those aspects that give you the most trouble. If you learn by hearing, lectures will be very important. If you learn by explaining, then working with other students will be useful to you. If solving problems is difficult for you, spend more time learning how to solve problems. Also, it is important to understand and develop good study habits. Perhaps the most important thing you can do for yourself is to set aside adequate, regularly scheduled, study time in a distraction-free environment.

Answer the following questions for yourself:

- Am I able to use fundamental mathematical concepts from algebra, geometry and trigonometry? (If not, plan a program of review with help from your professor.)
- In similar courses, what activity has given me the most trouble? (Spend more time on this.) What has been the easiest for me? (Do this first; it will help to build your confidence.)
- Do I understand the material better if I read the book before or after the lecture? (You may learn best by skimming the material, going to lecture, and then undertaking an in-depth reading.)

- Do I spend adequate time in studying physics? (A rule of thumb for a class like this is to devote, on the average, 2.5 hours out of class for each hour in class. For a course meeting 5 hours each week, that means you should spend about 10 to 15 hours per week studying physics.)
- Do I study physics every day? (Spread that 10 to 15 hours out over an entire week!) At what time of the day am I at my best for studying physics? (Pick a specific time of the day and stick to it.)
- Do I work in a quiet place where I can maintain my focus? (Distractions will break your routine and cause you to miss important points.)

Working with Others

Scientists or engineers seldom work in isolation from one another but rather work cooperatively. You will learn more physics and have more fun doing it if you work with other students. Some professors may formalize the use of cooperative learning or facilitate the formation of study groups. You may wish to form your own informal study group with members of your class who live in your neighborhood or dorm. If you have access to e-mail, use it to keep in touch with one another. Your study group is an excellent resource when reviewing for exams.

Lectures and Taking Notes

An important component of any college course is the lecture. In physics this is especially important because your professor will frequently do demonstrations of physical principles, run computer simulations, or show video clips. All of these are learning activities that will help you to understand the basic principles of physics. Don't miss lectures, and if for some reason you do, ask a friend or member of your study group to provide you with notes and let you know what happened.

Take your class notes in outline form, and fill in the details later. It can be very difficult to take word for word notes, so just write down key ideas. Your professor may use a diagram from the textbook. Leave a space in your notes and just add the diagram later. After class, edit your notes, filling in any gaps or omissions and noting things you need to study further. Make references to the textbook by page, equation number, or section number.

Make sure you ask questions in class, or see your professor during office hours. Remember the only "dumb" question is the one that is not asked. Your college may also have teaching assistants or peer tutors who are available to help you with difficulties you may have.

Examinations

Taking an examination is stressful. But if you feel adequately prepared and are well-rested, your stress will be lessened. Preparing for an exam is a continual process; it begins the moment the last exam is over. You should immediately go over the exam and understand any mistakes you made. If you worked a problem and made substantial errors, try this: Take a piece of paper and divide it down the middle with a line from top to bottom. In one column, write the proper solution to the problem. In the other column, write what you did and why, if you know, and why your solution was incorrect. If you are uncertain why you made your mistake, or how to avoid making it again, talk with your professor. Physics continually builds on fundamental ideas and it is important to correct any misunderstandings immediately. Warning: While cramming at the last minute may get you through the *present* exam, you will not adequately retain the concepts for use on the *next* exam.

Using Your Textbook

Now let's take a look at specific features of *University Physics* that will help you understand the concepts of physics. At its heart, physics is not equations and numbers. Physics is a way of looking at the universe and understanding how the universe works and how its various parts relate to each other. And although solving quantitative problems is an important part of physics, it is equally important for you to understand concepts qualitatively. Your textbook will help you in both areas.

First of all, don't be afraid to write in your book. It is more important for you to learn the concepts of physics than to keep your book in pristine condition. Write in the margins, make cross references. Take notes in your notebook as you read. *University Physics* is your primary "reference book" for this course. Refer to it often to help you understand the concepts you hear in lecture. Become familiar with the contents of the appendices and end papers.

Test Your Understanding

You are driving your car on a country road when a mosquito splatters itself on the windshield. Which has the greater magnitude, the force that the car exerted on the mosquito or the force that the mosquito exerted on the car? Or are the magnitudes the same? If they are different, how can you reconcile this fact with Newton's third law? If they are equal, why is the mosquito splattered while the car is undamaged?

Chapter Opening Questions and Test Your Understanding Questions

Each chapter of *University Physics* opens with a photograph, and next to that photograph is a question. As you read the chapter, try to figure out the answer to this question. You'll also find a *Test Your Understanding* question at the end of most sections of the book. These are designed to help you check if you've understood a key concept that's just been presented. If you can't see how to answer the question, you may need to read the section again with more care. (You'll find the answers to both kinds of questions toward the end of the chapter, but you'll get the most benefit if you figure out the answers yourself!)

Example 5.8

Straight-line motion with friction

Suppose the wind is once again blowing steadily in the $+x$-direction as in Example 5.6, so that the iceboat has a constant acceleration $a_x = 1.5\text{ m/s}^2$. Now, however, there is a constant horizontal friction force with magnitude 100 N that opposes the motion of the iceboat. In this case, what force F_W must the wind exert on the iceboat?

SOLUTION

IDENTIFY: Once again the target variable is F_W. We are given the acceleration, so to find F_W all we need is Newton's second law.

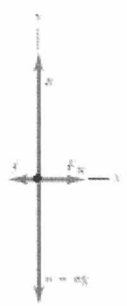
SET UP: Figure 5.9 shows the new free-body diagram. The only difference from Fig. 5.7b is the addition of the friction force $\vec{f}$, which points opposite to the motion. (Note that its *magnitude*, $f = 100$ N, is a positive quantity but that its *component* in the x-direction is negative, equal to $-f$ or -100 N.)

EXECUTE: There are now two forces (the force of the wind and the friction force) that have x-components. The x-component of Newton's second law gives

$$\sum F_x = F_W + (-f) = ma_x$$

$$F_W = ma_x + f = (200\text{ kg})(1.5\text{ m/s}^2) + (100\text{ N}) = 400\text{ N}$$

EVALUATE: Because there is friction, a greater force F_W is needed than in Example 5.6. We need 100 N to overcome friction and 300 N more to give the iceboat the necessary acceleration.



5.9 Free-body diagram for the iceboat and rider with a frictional force $\vec{f}$ opposing the motion.

Worked Examples

Your professor will work example problems in class to illustrate the application of the concepts of physics to real-world problems. You should work through all the examples in the textbook, filling in any missing steps, and making note of things you don't understand. Get help with the concepts that confuse you!

Problem-Solving Strategies

One of the features of *University Physics* that first caught my eye as a teacher were the *Problem-Solving Strategy* boxes. This is the advice I would give to a student who came to me for help with a physics problem. Physics teachers approach a problem in a very systematic and logical manner. These boxes will help you as a beginning problem solver to do the same by following a systematic problem-solving strategy called ISEE—Identify, Set up, Execute, and Evaluate. Study these suggestions in great detail and implement them. In many cases these strategy boxes will tell you how to visualize an abstract concept. Finally, use the ISEE approach consistently. It will help you build confidence in tackling new problems.

> **Problem-Solving Strategy** **Conservation of Momentum**
>
> **IDENTIFY** *the relevant concepts:* Before applying conservation of momentum to a problem, you must first decide whether momentum *is* conserved! This will be true *only* if the vector sum of the external forces acting on the system of particles is zero. If this is not the case, you can't use conservation of momentum.
>
> **SET UP** *the problem using the following steps:*
> 1. Define a coordinate system. Make a sketch showing the coordinate axes, including the positive direction for each. Often it is easiest to choose the x-axis to have the direction of one of the initial velocities. Make sure you are using an inertial frame of reference. Most of the problems in this chapter deal with two-dimensional situations, in which the vectors have only x- and y-components; all of the following statements can be generalized to include z-components when necessary.
> 2. Treat each body as a particle. Draw "before" and "after" sketches, and include vectors on each to represent all known velocities. Label the vectors with magnitudes, angles, components, or whatever information is given, and give each unknown magnitude, angle, or component an algebraic symbol. You may find it helpful to use the subscripts 1 and 2 for velocities before and after the interaction, respectively; if you use these subscripts, use letters (not numbers) to label each particle.
> 3. As always, identify the target variable(s) from among the unknowns.
>
> **EXECUTE** *the solution as follows:*
> 1. Write an equation in terms of symbols equating the total *initial* x-component of momentum (that is, before the interaction) to the total *final* x-component of momentum (that is, after the interaction), using $p_x = mv_x$ for each particle. Write another equation for the y-components, using $p_y = mv_y$ for each particle. Remember that the x- and y-components of velocity or momentum are *never* added together in the same equation! Even when all the velocities lie along a line (such as the x-axis), the components of velocity along this line can be positive or negative; be careful with signs!
> 2. Solve these equations to determine whatever results are required. In some problems you will have to convert from the x- and y-components of a velocity to its magnitude and direction, or the reverse.
> 3. In some problems, energy considerations give additional relationships among the various velocities, as we will see later in this chapter.
>
> **EVALUATE** *your answer:* Does your answer make physical sense? If your target variable is a certain body's momentum, check that the direction of the momentum is reasonable.

Caution!

Educational research has identified misconceptions or misunderstandings that students frequently have when they study physics. Dr. Freedman has added Caution! paragraphs to warn you about these potential pitfalls and help you avoid them.

> **CAUTION** Please note that the quantity $m\vec{a}$ is *not* a force. All that Eqs. (4.7) and (4.8) say is that the vector $m\vec{a}$ is equal in magnitude and direction to the vector sum $\sum\vec{F}$ of all the forces acting on the body. It's incorrect to think of acceleration as a force; rather, acceleration is a result of a nonzero net force. It's "common sense" to think that there is a "force of acceleration" that pushes you back into your seat when your car accelerates forward from rest. But *there is no such force;* instead, your inertia causes you to tend to stay at rest relative to the earth, and the car accelerates around you. The "common sense" confusion arises from trying to apply Newton's second law in a frame of reference where it isn't valid, like the non-inertial reference frame of an accelerating car. We will always examine motion relative to *inertial* frames of reference only.

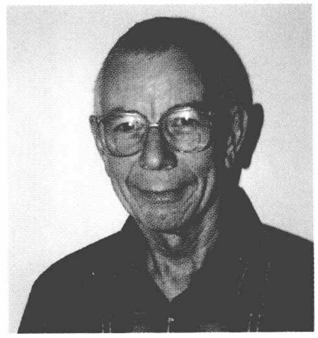
Key Terms, Summary, and Problems

The most important concepts are listed in the *Key Terms.* Keep a glossary of terms in your notebook. Your professor may indicate through the use of course objectives which terms are important for you to know. The *Summary* will give you a quick review of the chapter's main ideas and how they can be represented descriptively (in text), visually (in a figure), and mathematically (with an equation). Use this to make sure you understand how the same concept can be represented in these different ways. Everything else can be derived from the general equations provided in the summary.

If your professor assigns *Problems* at the end of the chapter, make sure you work them carefully with other students. If solutions are available, do not look at the answer until you have struggled with the problem and compared your answer with someone else's. If the two of you agree on the answer, then look at the solution. If you have made a mistake, go back and rework the problem. You will note that the *Exercises* are keyed to specific sections of the chapter and are easier. Work on these before you attempt the *Problems* or *Challenge Problems* which typically use multiple concepts.

Well, there you have it. We hope these suggestions will benefit your study of physics. Strive for understanding and excellence, and be persistent in your learning.

ABOUT THE AUTHORS



Hugh D. Young is Professor of Physics at Carnegie Mellon University in Pittsburgh, PA. He attended Carnegie Mellon for both undergraduate and graduate study and earned his Ph.D. in fundamental particle theory under the direction of the late Richard Cutkosky. He joined the faculty of Carnegie Mellon in 1956, and has also spent two years as a Visiting Professor at the University of California at Berkeley.

Prof. Young's career has centered entirely around undergraduate education. He has written several undergraduate-level textbooks, and in 1973 he became a coauthor with Francis Sears and Mark Zemansky for their well-known introductory texts. With their deaths, he assumed full responsibility for new editions of these books until joined by Prof. Freedman for *University Physics*.

Prof. Young is an enthusiastic skier, climber, and hiker. He also served for several years as Associate Organist at St. Paul's Cathedral in Pittsburgh, and has played numerous organ recitals in the Pittsburgh area. Prof. Young and his wife Alice usually travel extensively in the summer, especially in Europe and in the desert canyon country of southern Utah.

Roger A. Freedman is a Lecturer in Physics at the University of California, Santa Barbara. Dr. Freedman was an undergraduate at the University of California campuses in San Diego and Los Angeles, and did his doctoral research in nuclear theory at Stanford University under the direction of Professor J. Dirk Walecka. He came to UCSB in 1981 after three years teaching and doing research at the University of Washington.

At UCSB, Dr. Freedman has taught in both the Department of Physics and the College of Creative Studies, a branch of the university intended for highly gifted and motivated undergraduates. He has published research in nuclear physics, elementary particle physics, and laser physics. In recent years, he has helped to develop computer-based tools for learning introductory physics and astronomy.

When not in the classroom or slaving over a computer, Dr. Freedman can be found either flying (he holds a commercial pilot's license) or driving with his wife, Caroline, in their 1960 Nash Metropolitan convertible.

A. Lewis Ford is Professor of Physics at Texas A&M University. He received a B.A. from Rice University in 1968 and a Ph.D. in chemical physics from the University of Texas at Austin in 1972. After a one-year postdoc at Harvard University, he joined the Texas A&M physics faculty in 1973 and has been there ever since. Professor Ford's research area is theoretical atomic physics, with a specialization in atomic collisions. At Texas A&M he has taught a variety of undergraduate and graduate courses, but primarily introductory physics.

CONTENTS

MECHANICS