

PROBLEM-SOLVING STRATEGIES

Extended Edition includes Chapters 1–44. Standard Edition includes Chapters 1–37.

Three-volume edition: Volume 1 includes Chapters 1–20, Volume 2 includes Chapters 21–37, and Volume 3 includes Chapters 37–44.

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SEARS AND ZEMANSKY'S

UNIVERSITY PHYSICS

12TH EDITION

HUGH D. YOUNG

CARNEGIE MELLON UNIVERSITY

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ABOUT THE AUTHORS



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Prof. Young's career has centered entirely around undergraduate education. He has written several undergraduate-level textbooks, and in 1973 he became a co-author 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.



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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.

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TO THE STUDENT

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 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.

TO THE INSTRUCTOR

PREFACE

This book is the product of more than half a century of leadership and innovation in physics education. When the first edition of *University Physics* by Francis W. Sears and Mark W. Zemansky was published 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 (several million) students and educators around the world is a testament to the merits of this approach, and to the many innovations it has introduced subsequently.

In preparing this new Twelfth Edition, we have further enhanced and developed *University Physics* to assimilate the best ideas from education research with enhanced problem-solving instruction, pioneering visual and conceptual pedagogy, the first systematically enhanced problems, and the most pedagogically proven and widely used online homework and tutorial system in the world.

New to This Edition

- **Problem solving.** The acclaimed, research-based **four-step problem-solving framework** (Identify, Set Up, Execute, and Evaluate) is now used throughout every Worked Example, chapter-specific Problem-Solving Strategy, and every Solution in the Instructor and Student Solutions Manuals. Worked Examples now incorporate black-and-white Pencil Sketches to focus students on this critical step—one that research shows students otherwise tend to skip when illustrated with highly rendered figures.
- **Instruction followed by practice.** A streamlined and systematic learning path of instruction followed by practice includes **Learning Goals** at the start of each chapter and **Visual Chapter Summaries** that consolidate each concept in words, math, and figures. Popular **Test Your Understanding** conceptual questions at the end of each section now use **multiple-choice and ranking formats** to allow students to instantly check their knowledge.
- **Instructional power of figures.** The instructional power of figures is enhanced using the research-proven technique of “**annotation**” (chalkboard-style commentary integrated into the figure to guide the student in interpreting the figure) and by **streamlined use of color and detail** (in mechanics, for example, color is used to focus the student on the object of interest while the rest of the image is in grayscale and without distracting detail).
- **Enhanced end-of-chapter problems.** Renowned for providing the most wide-ranging and best-tested problems available, the Twelfth Edition goes still further: It provides **the first library of physics problems systematically enhanced** based on student performance nationally. Using this analysis, more than 800 new problems make up the entire library of 3700.
- **MasteringPhysics™** (www.masteringphysics.com). Launched with the Eleventh Edition, MasteringPhysics is now the most widely adopted, educationally proven, and technically advanced online homework and tutorial system in the world. For the Twelfth Edition, MasteringPhysics provides a wealth of new content and technological enhancements. In addition to a library of more than 1200 tutorials and all the end-of-chapter problems, MasteringPhysics

Standard, Extended, and Three-Volume Editions

With MasteringPhysics™:

- **Standard Edition:** Chapters 1–37
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now also provides specific tutorials for every Problem-Solving Strategy and key Test Your Understanding questions from each chapter. Answer types include algebraic, numerical, and multiple-choice answers, as well as ranking, sorting, graph drawing, vector drawing, and ray tracing.

Key Features of *University Physics*

A Guide for the Student Many physics students experience difficulty simply because they don't know how to use their textbook. The section entitled "How to Succeed in Physics by Really Trying," which precedes 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 are also a *Chapter Opening Question* and a list of *Learning Goals* 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 Question*, 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 follow 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 Wayne Anderson (Sacramento City College), Laird Kramer (Florida International University), and Charlie Hibbard.

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 students who have 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 6.5 (Comparing kinetic energies, p. 191), 8.1 (Momentum versus kinetic energy, p. 251) and 20.7 (A reversible adiabatic process, p. 693).

"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. 118, 159, and 559.)

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{v} , \vec{a} , and \vec{F} ; unit vectors such as \hat{i} , have a caret on top. Boldface $+$, $-$, \times , and $=$ 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.

Instructor Supplements

The **Instructor Solutions Manuals**, prepared by A. Lewis Ford (Texas A&M University), contain complete and detailed solutions to all end-of-chapter problems. All solutions follow consistently the same Identify/Set Up/Execute/Evaluate problem-solving framework used in the textbook. The *Instructor Solutions Manual for Volume 1* (ISBN 0-321-49968-9) covers Chapters 1–20, and the *Instructor Solutions Manual for Volumes 2 and 3* (ISBN 0-321-49210-2) covers Chapters 21–44.

The cross-platform **Media Manager CD-ROM** (ISBN 0-321-49916-6) provides a comprehensive library of more than 220 applets from ActivPhysics OnLine™ as well as all line figures from the textbook in JPEG format. In addition, all the key equations, Problem-Solving Strategies, tables, and chapter summaries are provided in editable Word format. In-class weekly multiple-choice questions for use with various Classroom Response Systems (CRS) are also provided, based on the Test Your Understanding questions in the text. The CD-ROM also provides the Instructor Solutions Manual in convenient editable Word format and as PDFs.

MasteringPhysics™ (www.masteringphysics.com) is the most advanced, educationally effective, and widely used physics homework and tutorial system in the world. It provides instructors with a library of extensively pretested end-of-chapter problems and rich, Socratic tutorials that incorporate a wide variety of answer types, wrong-answer feedback, and adaptive help (comprising hints or simpler sub-problems upon request). MasteringPhysics™ allows instructors to quickly build wide-ranging homework assignments of just the right difficulty and duration and provides them with efficient tools to analyze class trends—or the work of any student—in unprecedented detail and to compare the results either with the national average or with the performance of previous classes.

Five Easy Lessons: Strategies for Successful Physics Teaching (ISBN 0-8053-8702-1) by Randall D. 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 **Transparency Acetates** (ISBN 0-321-50034-2) contain more than 200 key figures from *University Physics*, Twelfth Edition, in full color.

The **Printed Test Bank** (ISBN 0-321-50035-0) provides more than 2000 multiple-choice questions.

The **Computerized Test Bank** (ISBN 0-321-50126-8) includes all of the questions from the Printed Test Bank on a cross-platform CD-ROM. More than half the questions have numerical values that can be randomly assigned for each student.

Student Supplements

The **Study Guide**, by James R. Gaines, William F. Palmer, and Laird Kramer, reinforces the text's emphasis on problem-solving strategies and student misconceptions. The *Study Guide for Volume 1* (ISBN 0-321-50033-4) covers Chapters 1–20, and the *Study Guide for Volumes 2 and 3* (ISBN 0-321-50037-7) covers Chapters 21–44.

The **Student Solutions Manual**, by A. Lewis Ford (Texas A&M University), contains detailed, step-by-step solutions to more than half of the odd-numbered end-of-chapter problems from the textbook. All solutions follow consistently the same Identify/Set Up/Execute/Evaluate problem-solving framework used in the textbook. The *Student Solutions Manual for Volume 1* (ISBN 0-321-50063-6) covers Chapters 1–20, and the *Student Solutions Manual for Volumes 2 and 3* (ISBN 0-321-50038-5) covers Chapters 21–44.



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ActivPhysics OnLine™ (www.masteringphysics.com), now included in the self-study area of MasteringPhysics, provides the most comprehensive library of applets and applet-based tutorials available. ActivPhysics OnLine was created by the educational pioneer Alan Van Heuvelen of Rutgers. Throughout *University Physics*, Twelfth Edition, in-margin icons direct the student to specific applets in ActivPhysics OnLine in for additional interactive help.

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The **Addison-Wesley Tutor Center** (www.aw.com/tutorcenter) provides one-on-one tutoring via telephone, fax, e-mail, or interactive website. Qualified instructors

answer questions and provide instruction with examples, problems, and other content from *University Physics*, Twelfth Edition, as well as help with MasteringPhysics™.

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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.

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