时代教育·国外高校优秀教材精选

Addison Wesley

（英文版·原书第10版）

西尔斯物理学

Sears and Zemansky's University Physics

（美）休 D. 杨（Hugh D. Young）
罗杰 A. 弗里德曼（Roger A. Freedman） 著

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出版说明

随着我国加入WTO，国际间的竞争越来越激烈，而国际间的竞争实际上也就是人才的竞争、教育的竞争。为了加快培养具有国际竞争力的高水平技术人才，加快我国教育改革的步伐，教育部近来出台了一系列倡导高校开展双语教学、引进原版教材的政策。以此为契机，机械工业出版社拟于近期推出一系列国外影印版教材，其内容涉及高等学校公共基础课，以及机、电、信息领域的专业基础课和专业课。

引进国外优秀原版教材，在有条件的学校推动开展英语授课或双语教学，自然也引进了先进的教学思想和教学方法，这对提高我国自编教材的水平，加强学生的英语实际应用能力，使我国的高等教育尽快与国际接轨，必将起到积极的推动作用。

为了做好教材的引进工作，机械工业出版社特别成立了由著名专家组成的国外高校优秀教材审定委员会。这些专家对实施双语教学做了深入细致的调查研究，对引进原版教材提出许多建设性意见，并慎重地对每一本将要引进的原版教材一审再审，精选再精选，确认教材本身的质量水平，以及权威性和先进性，以期所引进的原版教材能适应我国学生的外语水平和学习特点。在引进工作中，审定委员会还结合我国高校教学课程体系的设置和要求，对原版教材的教学思想和方法的先进性、科学性严格把关，同时尽量考虑原版教材的系统性和经济性。

这套教材出版后，我们将根据各高校的双语教学计划，举办原版教材的教师培训，及时地将其推荐给各高校选用。希望高校师生在使用教材后及时反馈意见和建议，使我们更好地为教学改革服务。

机械工业出版社

2002年3月

序

本书第 1 版出版于 1949 年，作者是 W. Sears 和 Mark W. Zemansky。不久，就以《西尔斯物理学》之名被翻译成中文在中国出版。当时该书受到我国大学物理教师的关注并作为教学参考书。后因“学苏”而被搁置一旁。但是在大学物理教学中已留下相当的影响。至今我国物理教材中的一些讲法和习题都是渊源于该书。

1973 年，本书主要作者休 D. 杨成为 Sears 和 Zemansky 的合作者参加本书的第 5 版的编写。后来，Sears 和 Zemansky 相继去世，从第 8 版起，由 Young 单独署名。本次影印的是第 10 版，又有新作者罗杰 A. 弗里德曼加入。半个世纪以来，新老作者们辛苦耕耘，认真负责，对本书作了不断改进。目前本书在美国是一本普遍认可而被广泛采用的大学物理学教科书。

本书内容包含大学物理课程的基本内容，有力学（包括流体力学）、热学、振动与波、电磁学、光学（包括几何光学和波动光学）、狭义相对论等。

本书从第 1 版开始就重视概念原理的讲解。对诸如牛顿定律、热力学定律、高斯定律、光的干涉和衍射、相对论时空观等都作了很明晰的解释。本版在这一方面又有所改进。

本书的另一特点是非常注意教给学生解答物理习题的方法。除配有大量的合适的例题外，还特别在适当的地方总结列出如何利用原理解答习题的思路和步骤（Problem-solving strategies），并且在学生容易发生误解和错误的地方及时提醒学生注意（Caution）。这无疑对学生有很大帮助。本书各章都附有大量习题，有使学生建立信心的比较容易的题，有一般难度的题，还有较高难度的题（challenge problems）。使学生由易到难，通过实践学会解题的方法，进而牢固地掌握概念和原理。

本书很注意联系实际。无论在原理部分，还是在例题、习题中，都联系了大量的实际事例。还特设“特例研究（Case Study）”专栏，较详细地讲述实例。从汽车到火箭，从攀岩到蹦极，从太阳系到星云，从恐龙走步到人的耳朵、眼睛，从航天飞行器到彩色电视，从黑洞到光子等等，应有尽有。这不但可使学生了解知识的应用，而且可以大大激发学生的学习兴趣，开阔学生的眼界。这对提高教学质量都是非常重要的。

本书行文通顺，清晰准确，而且附有大量原理图或实物照片。这些对学生

了解和掌握所讲内容都是十分有帮助的。

本书需要学生具备微积分的基本知识。就其内容的深度看来，适用于我国各类一般工科院校。我们相信，本书的影印出版及被采用将大大有助于英语授课工作的开展。

张三慧
清华大学物理系
2002 年 3 月

Unit Conversion Factors

LENGTH

1 m = 100 cm = 1000 mm = 10^6 μm = 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 = 9.461×10^{15} m

AREA

1 cm^2 = 0.155 in^2
1 m^2 = 10^4 cm^2 = 10.76 ft^2
1 $in.^2$ = 6.452 cm^2
1 ft = 144 $in.^2$ = 0.0929 m^2

VOLUME

1 liter = 1000 cm^3 = 10^{-3} m^3 = 0.03531 ft^3 = 61.02 $in.^3$
1 ft^3 = 0.02832 m^3 = 28.32 liters = 7.477 gallons
1 gallon = 3.788 liters

TIME

1 min = 60 s
1 h = 3600 s
1 d = 86,400 s
1 y = 365.24 d = 3.156×10^7 s

ANGLE

1 rad = 57.30° = 180°/π
1° = 0.01745 rad = π/180 rad
1 revolution = 360° = 2π 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/h = 88 ft/s
1 km/h = 0.2778 m/s = 0.6214 mi/h
1 mi/h = 1.466 ft/s = 0.4470 m/s = 1.609 km/h
1 furlong/fortnight = 1.662×10^{-4} m/s

ACCELERATION

1 m/s^2 = 100 cm/s^2 = 3.281 ft/s^2
1 cm/s^2 = 0.01 m/s^2 = 0.03281 ft/s^2
1 ft/s^2 = 0.3048 m/s^2 = 30.48 cm/s^2
1 mi/h · s = 1.467 ft/s^2

MASS

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

FORCE

1 N = 10^5 dyn = 0.2248 lb
1 lb = 4.448 N = 4.448×10^5 dyn

PRESSURE

1 Pa = 1 N/m^2 = 1.450×10^{-4} lb/$in.^2$ = 0.209 lb/ft^2
1 bar = 10^5 Pa
1 lb/$in.^2$ = 6895 Pa
1 lb/ft^2 = 47.88 Pa
1 atm = 1.013×10^5 Pa = 1.013 bar
= 14.7 lb/$in.^2$ = 2117 lb/ft^2
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 = 1.602×10^{-19} J
1 kWh = 3.600×10^6 J

MASS–ENERGY EQUIVALENCE

1 kg $\leftrightarrow$ 8.988×10^{16} J
1 u $\leftrightarrow$ 931.5 MeV
1 eV $\leftrightarrow$ 1.074×10^{-9} u

POWER

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

Index of Tables

- For users of the three-volume edition, pages 1-668 (Chapters 1-21) are in Volume 1; pages 669-1230 (Chapters 22-39) are in Volume 2; and pages 1231-1460 (Chapters 40-46) are in Volume 3.
- Pages 1231-1460 (Chapters 40-46) are not in the Standard Version of this textbook.

PREFACE

This book is the product of a half 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 in its emphasis on the fundamental principles of physics and how to apply them. This Commemorative Tenth Edition continues to emphasize principles and applications as it provides today's students with a broad, rigorous, yet accessible introduction to calculus-based physics. The success of *University Physics* with generations of students and educators in all parts of the world is a testament to the merits of this approach.

Two key objectives guided the writing of this text: helping students develop physical intuition, and helping them build strong problem-solving skills. Also reflected throughout are the results of two decades of research in physics education on the conceptual pitfalls that commonly plague beginning physics students. These pitfalls include the notions that force is required for motion, that electric current is "used up" as it goes around a circuit, and that the product of a body's mass and its acceleration is itself a force. A key focus of this edition is to discuss not only the correct way to analyze a situation or solve a problem, but also the reason why the wrong way (which may have occurred to the student first) is indeed wrong.

The prose style of the book continues to be relaxed and conversational, without being colloquial or excessively familiar. We see the student as our partner in learning, not as an audience to be lectured to from atop a platform. This style makes it much easier for us to convey to the student our own excitement and enthusiasm for the beauty, intellectual challenge, and fundamental unity of physics.

In preparing the Tenth Edition, we have relied heavily on the comments of a great many faculty and students on how best to help them meet the challenges of physics education. Based on these comments, we have designed the following features of this edition.

A GUIDE FOR THE STUDENT

Many physics students experience difficulty simply because they don't know how to make the best use of their textbook. A section entitled "How to Succeed in Physics by Really Trying," which follows this preface, serves as 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. We strongly encourage *every* student to read this section!

CHAPTER ORGANIZATION

The *Introduction* to each chapter 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* of the most important principles introduced in the chapter, along with the associated *Key Equations*. The summary also includes a list of *Key Terms* that the student should have learned to use, with references to the page on which each term is first introduced.

CONTENTS

Some of the most significant content features of this edition include:

- In Chapter 2, motion diagrams help students to distinguish between position, velocity, and acceleration in one-dimensional motion (see pp. 40–41).
- Chapter 12 has been updated with new data on the supermassive black hole at the center of our Milky Way galaxy.
- We discuss the microscopic interpretation of entropy in Chapter 18.
- A qualitative introduction to the ideas behind Gauss's law is given in Chapter 23.
- Chapter 28 on magnetic fields and forces explains the attraction and repulsion of magnets and magnetic materials.
- The discussion of electromagnetic induction in Chapter 30 and of inductance in Chapter 31 has been rewritten to make these essential but challenging concepts more accessible to students.
- Every chapter now includes a selection of photographs that illustrate how physical principles manifest themselves in the natural world and in our technological society.

QUESTIONS AND PROBLEMS

At the end of each chapter is a collection of *Discussion Questions,* intended to probe and extend the student's conceptual understanding, followed by an extensive set of problems. The problems have been revised and their number increased, including many new problems drawn from astrophysics, biology, and aerodynamics. Many problems have a conceptual part in which students must discuss and explain their results. The problems are grouped into *Exercises,* which are single-concept problems keyed to specific sections of the text; *Problems,* usually requiring two or more nontrivial steps; and *Challenge Problems,* intended to challenge the strongest students. Many new questions, exercises, and problems, especially for Chapters 38, 41, 42, 43, 44, and 45, were suggested by Professor A. Lewis Ford (Texas A&M University) and Professor Tom Sandin (North Carolina A&T State University).

PROBLEM-SOLVING STRATEGIES

Problem-Solving Strategy sections, an extremely popular feature of the book, have been retained and strengthened. 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." (See, for example, pp. 110, 121, and 171.)

EXAMPLES

Each *Problem-Solving Strategy* section is followed immediately by one or more worked-out examples that illustrate the strategy. Several of these are purely qualitative, such as Examples 6–6 (Comparing kinetic energies, p. 173), 8–1 (Momentum vs. kinetic energy, p. 230), and 18–7 (Isentropic processes, p. 576). Many examples are drawn from real-life situations relevant to the student's own experience. Units and correct significant figures in examples are always carried through all stages of numerical calculations.

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. We emphasize modeling in physics, showing the student how to begin with a seemingly complex situation, make simplifying assumptions, apply the appropriate physical principles, and evaluate the final result. Does it make sense? Is it what you expected? How can you check it?

"CAUTION" PARAGRAPHS

In the text of each chapter we have labeled certain paragraphs with the word **CAUTION.** These paragraphs alert the student to common misconceptions or to points of potential confusion. (See, for example, pp. 102, 140, and 167.) We think of them as being similar to the flagged paragraphs in the user's manual for a power drill or a VCR, describing potential sources of trouble when using the equipment.

ACTIVPHYSICS LINKS

An important and unique supplement to *University Physics* is the set of *ActivPhysics 1* and *ActivPhysics 2* CD-ROMs and workbooks, developed by Professors Alan Van Heuvelen and Paul D'Alessandris and published by Addison Wesley Longman. By combining carefully designed interactive simulations with proven pedagogy, *ActivPhysics* helps students become adept at solving problems about dynamic physical phenomena. Icons throughout the text of *University Physics* indicate which of the 200-plus exercises in *ActivPhysics* correspond to specific topics in this book. Exercises 1.1 through 10.10 appear in *ActivPhysics 1,* while Exercises 11.1 through 20.4 are in *ActivPhysics 2.* For more information about the *ActivPhysics* CD-ROMs (compatible with both Macintosh and Windows) and workbooks, see below under "Supplements."

CASE STUDIES

We have included 10 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, Electric Potential Maps) emphasize computer simulations and include computer exercises for the student. All case studies have corresponding end-of-chapter problems.

NOTATION AND UNITS

Students often have a hard time keeping track of which quantities are vectors and which are not. In this edition, we use boldface italic symbols with an arrow on top for vector quantities, such as $\vec{v}$, $\vec{a}$, and $\vec{F}$; unit vectors have a caret on top, such as $\hat{\imath}$. Boldface **+**, **−**, **×**, and **=** signs are used in vector equations to emphasize the distinction between these operations and operations with ordinary numbers.

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.

FLEXIBILITY

The book is adaptable to a wide variety of course outlines. There is plenty of material for an intensive three-semester or 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 relativity, fluid mechanics, acoustics, electromagnetic waves, optical instruments, and several other topics can be omitted without loss of continuity. 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. In any case, no one should feel constrained to work straight through the entire book. We encourage instructors to select the chapters that fit their needs, omitting material that is not appropriate for the objectives of a particular course.

STANDARD, EXTENDED, AND SPLIT VERSIONS

This edition is available in three versions. The Standard version (ISBN 0–201–60322–5) includes 39 chapters, ending with the special theory of relativity. The Extended version (ISBN 0–201–60336–5) adds seven chapters on modern physics, including the physics of atoms, molecules, condensed matter, nuclei, and elementary particles. The Split version includes all 46 chapters in three softbound volumes: Volume 1, Chapters 1–21 (ISBN 0–201–60329–2); Volume 2, Chapters 22–39 (ISBN 0–201–60335–7); and Volume 3, Chapters 40–46 (ISBN 0–201–65663–9).

SUPPLEMENTS

For the Student: The *Online Course Companion Web site* (http://www.awlonline.com/young) offers problem solving tips, interactive quizzes, key concepts for each chapter of *University Physics,* a glossary, tips for success in physics, web links to applications of physical concepts, and much more.

The *ActivPhysics* CD-ROMs and workbooks, developed by Professors Alan Van Heuvelen and Paul D'Alessandris, use interactive simulations and multiple representations to help students become better physics problem-solvers. The CD-ROMs are compatible with both Macintosh and Windows. *ActivPhysics 1* (ISBN 0–201–69482–4) covers the topics of Chapters 1–21, and *ActivPhysics 2* (ISBN 0–201–36111–6) covers the material found in Chapters 22–46. As mentioned above, icons in the text of *University Physics* show the connections between topics in the book and exercises in *ActivPhysics.*

The *Study Guide,* prepared by Professors 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 0–201–61835–4) covers Chapters 1–21, and the *Study Guide for Volumes 2 and 3* (ISBN 0–201–61834–6) covers Chapters 22–46.

The *Student Solutions Manual,* prepared by Professor A. Lewis Ford, includes completely worked-out solutions for about two-thirds of the odd-numbered problems in *University Physics.* (Answers to all odd-numbered problems are found in this book following the Appendices.) The *Student Solutions Manual for Volume 1* (ISBN 0–201–64394–4) covers Chapters 1–21, and the *Student Solutions Manual for Volumes 2 and 3* (ISBN 0–201–64395–2) covers Chapters 22–46.

For the Instructor: The *Instructor's Solutions Manual,* prepared by Professor Mark Hollabaugh and Dr. Thomas D. Gutierrez, contains worked-out solutions to all exercises, problems, and challenge problems. The *Instructor's Solutions Manual for Volume 1* covers Chapters 1–21 (ISBN 0–201–61836–2) and the *Instructor's Solution Manual for Volumes 2 and 3* covers Chapters 22–46 (ISBN 0–201–61837–0). It is also available as a cross-platform CD-ROM (ISBN 0–201–65679–5). With the CD-ROM, you can read, edit, and print any solutions you choose, as well as post them on your secure, password-protected class web site.

The *Instructor's Guide for an Active Learning Classroom* (ISBN 0–201–65676–0) offers quick strategies for tailoring your course to include active learning techniques. This supplement is ideal for instructors who want to integrate these techniques into their course, but do not have time to create a new teaching plan.

The *Online Course Companion Web site* (http://www.awlonline.com/young) makes it easy to put your course syllabus and assignments on the web and password-protect your course information. Through the site, students can submit assignments to you or your teaching assistants.

The *Instructor's Presentation CD-ROM* contains the full-color line art figures from the text. Images may be exported into other programs, such as PowerPoint.

The *Overhead Transparencies* (ISBN 0–201–61833–8) include 200 four-color figures from the text. These are on acetate for use on an overhead projector.

The *Test Item File* (ISBN 0–201–60344–6), written by Dr. Elliot Farber and Professor Michael Browne, includes multiple-choice and short-answer problems. The accompanying TestGen software (ISBN 0–201–65662–0), compatible with both Macintosh and Windows, makes it easy to edit these test items, assemble them into an exam, and generate an answer key.

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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 by ordinary mail or electronically. Your comments will be greatly appreciated.

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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