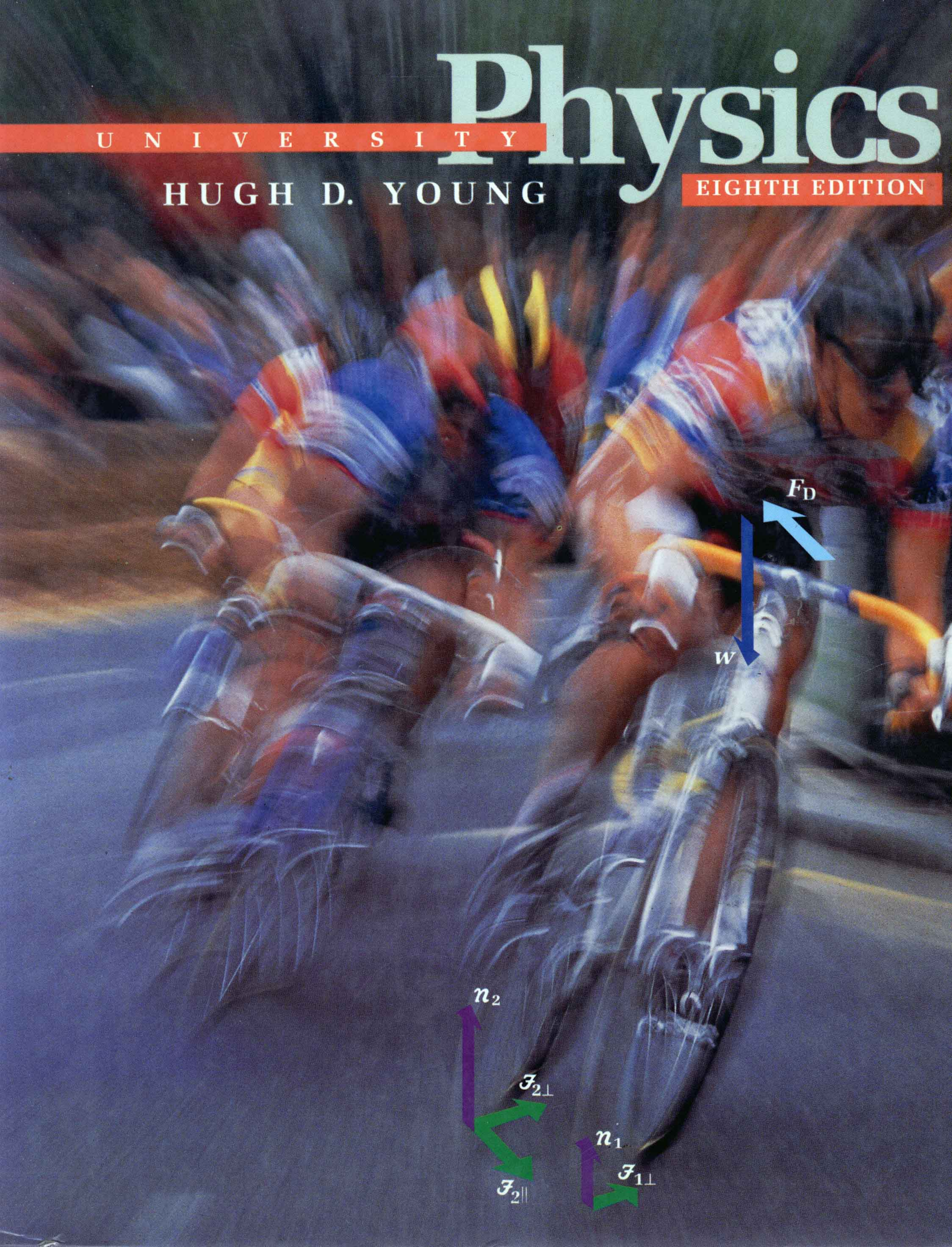
UNIVERSITY Physics

HUGH D. YOUNG

EIGHTH EDITION



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EIGHTH EDITION

HUGH D. YOUNG
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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^2 = 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 hr = 3600 s
1 da = 86,400 s
1 yr = 365.24 da = 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/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 = 1.662×10^{-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/hr · 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 = 1.451×10^{-4} lb/in^2 = 0.209 lb/ft^2
1 bar = 10^5 Pa
1 lb/in^2 = 6891 Pa
1 lb/ft^2 = 47.85 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 ↔ 8.988×10^{16} J
1 u ↔ 931.5 MeV
1 eV ↔ 1.073×10^{-9} u

POWER

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

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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 $\mathcal{F}_{2\parallel}$ 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 $\mathcal{F}_{2\parallel}$ 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 ($\mathcal{F}_{1\perp}$ and $\mathcal{F}_{2\perp}$) 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.

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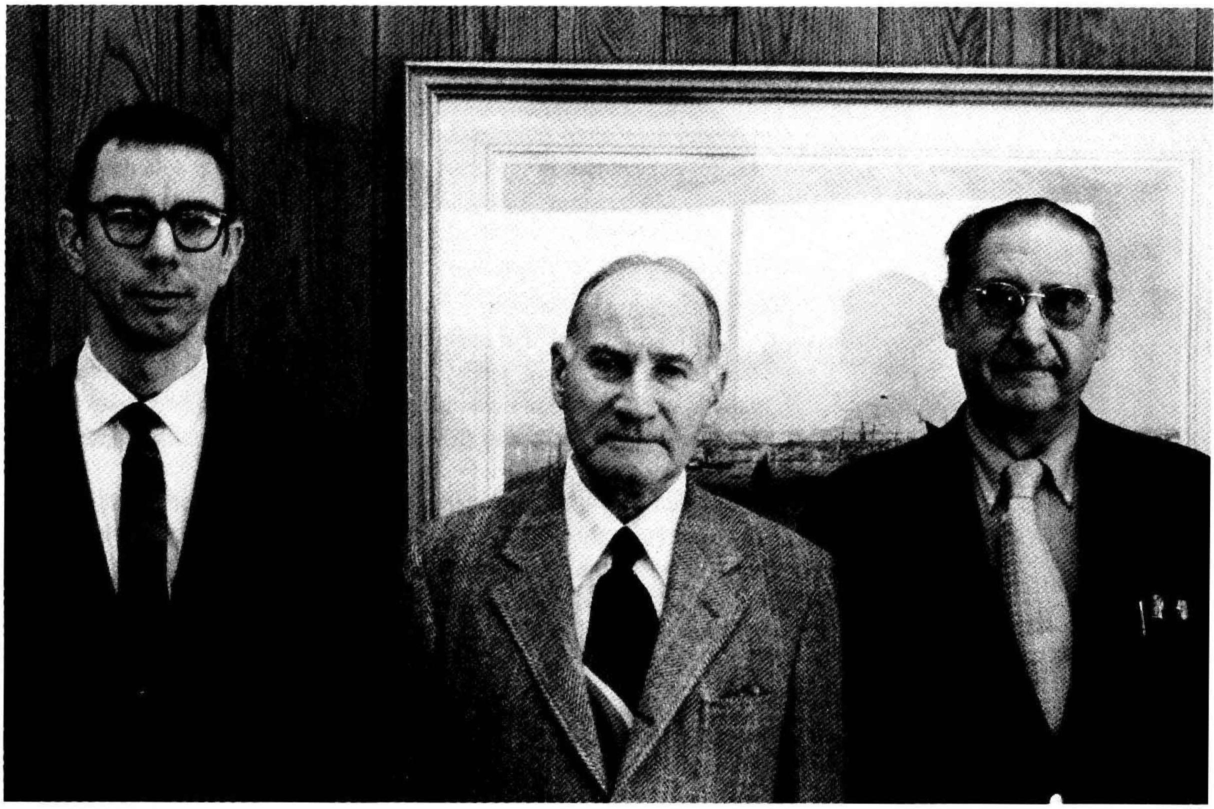
Dedication



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 H. D. Y.
November, 1991

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