Preface

What's New?

Lots! Much is new and unseen before. Here are the big four:

1. Multiple-choice Questions added to the end of each Chapter. They are not the usual type. These are called **MisConceptual Questions** because the responses (*a*, *b*, *c*, *d*, etc.) are intended to include common student misconceptions. Thus they are as much, or more, a learning experience than simply a testing experience.

2. **Search and Learn Problems** at the very end of each Chapter, after the other Problems. Some are pretty hard, others are fairly easy. They are intended to encourage students to go back and reread some part or parts of the text, and in this search for an answer they will hopefully learn more—if only because they have to read some material again.

3. **Chapter-Opening Questions** (COQ) that start each Chapter, a sort of "stimulant." Each is multiple choice, with responses including common misconceptions—to get preconceived notions out on the table right at the start. Where the relevant material is covered in the text, students find an Exercise asking them to return to the COQ to rethink and answer again.

4. **Digital.** Biggest of all. Crucial new applications. Today we are surrounded by digital electronics. How does it work? If you try to find out, say on the Internet, you won't find much physics: you may find shallow hand-waving with no real content, or some heavy jargon whose basis might take months or years to understand. So, for the first time, I have tried to explain
   - The basis of digital in bits and bytes, how analog gets transformed into digital, sampling rate, bit depth, quantization error, compression, noise (Section 17–10).
   - How digital TV works, including how each pixel is addressed for each frame, data stream, refresh rate (Section 17–11).
   - Semiconductor computer memory, DRAM, and flash (Section 21–8).
   - Digital cameras and sensors—revised and expanded Section 25–1.
   - New semiconductor physics, some of which is used in digital devices, including LED and OLED—how they work and what their uses are—plus more on transistors (MOSFET), chips, and technology generation as in 22-nm technology (Sections 29–9, 10, 11).

Besides those above, this new seventh edition includes

5. ***New topics, new applications, principal revisions.***
   - *You* can measure the Earth's radius (Section 1–7).
   - Improved graphical analysis of linear motion (Section 2–8).
   - Planets (how first seen), heliocentric, geocentric (Section 5–8).
   - The Moon's orbit around the Earth: its phases and periods with diagram (Section 5–9).
   - Explanation of lake level change when large rock thrown from boat (Example 10–11).

- Biology and medicine, including:
  - Blood measurements (flow, sugar)—Chapters 10, 12, 14, 19, 20, 21;
  - Trees help offset CO_2 buildup—Chapter 15;
  - Pulse oximeter—Chapter 29;
  - Proton therapy—Chapter 31;
  - Radon exposure calculation—Chapter 31;
  - Cell phone use and brain—Chapter 31.
- Colors as seen underwater (Section 24–4).
- Soap film sequence of colors explained (Section 24–8).
- Solar sails (Section 22–6).
- Lots on sports.
- Symmetry—more emphasis and using italics or bold face to make visible.
- Flat screens (Sections 17–11, 24–11).
- Free-electron theory of metals, Fermi gas, Fermi level. New Section 29–6.
- Semiconductor devices—new details on diodes, LEDs, OLEDs, solar cells, compound semiconductors, diode lasers, MOSFET transistors, chips, 22-nm technology (Sections 29–9, 10, 11).
- Cross section (Chapter 31).
- Length of an object is a script ℓ rather than normal l, which looks like 1 or I (moment of inertia, current), as in $F = I\ell B$. Capital L is for angular momentum, latent heat, inductance, dimensions of length $[L]$.

6. ***New photographs*** taken by students and instructors (we asked).
7. ***Page layout***: More than in previous editions, serious attention to how each page is formatted. Important derivations and Examples are on facing pages: no turning a page back in the middle of a derivation or Example. Throughout, readers see, on two facing pages, an important slice of physics.
8. ***Greater clarity***: No topic, no paragraph in this book was overlooked in the search to improve the clarity and conciseness of the presentation. Phrases and sentences that may slow down the principal argument have been eliminated: keep to the essentials at first, give the elaborations later.
9. Much use has been made of physics education research. See the new powerful pedagogic features listed first.
10. ***Examples modified***: More math steps are spelled out, and many new Examples added. About 10% of all Examples are Estimation Examples.
11. ***This Book is Shorter*** than other complete full-service books at this level. Shorter explanations are easier to understand and more likely to be read.
12. ***Cosmological Revolution***: With generous help from top experts in the field, readers have the latest results.

See the World through Eyes that Know Physics

I was motivated from the beginning to write a textbook different from the others which present physics as a sequence of facts, like a catalog: "Here are the facts and you better learn them." Instead of beginning formally and dogmatically, I have sought to begin each topic with concrete observations and experiences students can relate to: start with specifics, and after go to the great generalizations and the more formal aspects of a topic, showing *why* we believe what we believe. This approach reflects how science is actually practiced.

The ultimate aim is to give students a thorough understanding of the basic concepts of physics in all its aspects, from mechanics to modern physics. A second objective is to show students how useful physics is in their own everyday lives and in their future professions by means of interesting applications to biology, medicine, architecture, and more.

Also, much effort has gone into techniques and approaches for solving problems: worked-out Examples, Problem Solving sections (Sections 2–6, 3–6, 4–7, 4–8, 6–7, 6–9, 8–6, 9–2, 13–7, 14–4, and 16–6), and Problem Solving Strategies (pages 30, 57, 60, 88, 115, 141, 158, 184, 211, 234, 399, 436, 456, 534, 568, 594, 655, 666, and 697).

This textbook is especially suited for students taking a one-year introductory course in physics that uses algebra and trigonometry but not calculus.[†] Many of these students are majoring in biology or premed, as well as architecture, technology, and the earth and environmental sciences. Many applications to these fields are intended to answer that common student query: "Why must I study physics?" The answer is that physics is fundamental to a full understanding of these fields, and here they can see how. Physics is everywhere around us in the everyday world. It is the goal of this book to help students "see the world through eyes that know physics."

A major effort has been made to not throw too much material at students reading the first few chapters. The basics have to be learned first. Many aspects can come later, when students are less overloaded and more prepared. If we don't overwhelm students with too much detail, especially at the start, maybe they can find physics interesting, fun, and helpful—and those who were afraid may lose their fear.

Chapter 1 is *not* a throwaway. It is fundamental to physics to realize that every measurement has an *uncertainty*, and how significant figures are used. Converting units and being able to make rapid *estimates* are also basic.

Mathematics can be an obstacle to students. I have aimed at including all steps in a derivation. Important mathematical tools, such as addition of vectors and trigonometry, are incorporated in the text where first needed, so they come with a context rather than in a scary introductory Chapter. Appendices contain a review of algebra and geometry (plus a few advanced topics).

Color is used pedagogically to bring out the physics. Different types of vectors are given different colors (see the chart on page xix).

Sections marked with a star * are considered optional. These contain slightly more advanced physics material, or material not usually covered in typical courses and/or interesting applications; they contain no material needed in later Chapters (except perhaps in later optional Sections).

For a brief course, all optional material could be dropped as well as significant parts of Chapters 1, 10, 12, 22, 28, 29, 32, and selected parts of Chapters 7, 8, 9, 15, 21, 24, 25, 31. Topics not covered in class can be a valuable resource for later study by students. Indeed, this text can serve as a useful reference for years because of its wide range of coverage.

[†]It is fine to take a calculus course. But mixing calculus with physics for these students may often mean not learning the physics because of stumbling over the calculus.

Thanks

Many physics professors provided input or direct feedback on every aspect of this textbook. They are listed below, and I owe each a debt of gratitude.

Edward Adelson, The Ohio State University
Lorraine Allen, United States Coast Guard Academy
Zaven Altounian, McGill University
Leon Amstutz, Taylor University
David T. Bannon, Oregon State University
Bruce Barnett, Johns Hopkins University
Michael Barnett, Lawrence Berkeley Lab
Anand Batra, Howard University
Cornelius Bennhold, George Washington University
Bruce Birkett, University of California Berkeley
Robert Boivin, Auburn University
Subir Bose, University of Central Florida
David Branning, Trinity College
Meade Brooks, Collin County Community College
Bruce Bunker, University of Notre Dame
Grant Bunker, Illinois Institute of Technology
Wayne Carr, Stevens Institute of Technology
Charles Chiu, University of Texas Austin
Roger N. Clark, U. S. Geological Survey
Russell Clark, University of Pittsburgh
Robert Coakley, University of Southern Maine
David Curott, University of North Alabama
Biman Das, SUNY Potsdam
Bob Davis, Taylor University
Kaushik De, University of Texas Arlington
Michael Dennin, University of California Irvine
Karim Diff, Santa Fe College
Kathy Dimiduk, Cornell University
John DiNardo, Drexel University
Scott Dudley, United States Air Force Academy
Paul Dyke
John Essick, Reed College
Kim Farah, Lasell College
Cassandra Fesen, Dartmouth College
Leonard Finegold, Drexel University
Alex Filippenko, University of California Berkeley
Richard Firestone, Lawrence Berkeley Lab
Allen Flora, Hood College
Mike Fortner, Northern Illinois University
Tom Furtak, Colorado School of Mines
Edward Gibson, California State University Sacramento
John Hardy, Texas A&M
Thomas Hemmick, State University of New York Stonybrook
J. Erik Hendrickson, University of Wisconsin Eau Claire
Laurent Hodges, Iowa State University
David Hogg, New York University
Mark Hollabaugh, Normandale Community College
Andy Hollerman, University of Louisiana at Lafayette
Russell Holmes, University of Minnesota Twin Cities
William Hopzapfel, University of California Berkeley
Chenming Hu, University of California Berkeley
Bob Jacobsen, University of California Berkeley
Arthur W. John, Northeastern University
Teruki Kamon, Texas A&M
Daryao Khatri, University of the District of Columbia
Tsu-Jae King Liu, University of California Berkeley
Richard Kronenfeld, South Mountain Community College
Jay Kunze, Idaho State University
Jim LaBelle, Dartmouth College
Amer Lahamer, Berea College
David Lamp, Texas Tech University
Kevin Lear, SpatialGraphics.com
Ran Li, Kent State University
M.A.K. Lodhi, Texas Tech
Lisa Madewell, University of Wisconsin
Bruce Mason, University of Oklahoma
Mark Mattson, James Madison University
Dan Mazilu, Washington and Lee University
Linda McDonald, North Park College
Bill McNairy, Duke University
Jo Ann Merrell, Saddleback College
Raj Mohanty, Boston University
Giuseppe Molesini, Istituto Nazionale di Ottica Florence
Wouter Montfrooij, University of Missouri
Eric Moore, Frostburg State University
Lisa K. Morris, Washington State University
Blaine Norum, University of Virginia
Lauren Novatne, Reedley College
Alexandria Oakes, Eastern Michigan University
Ralph Oberly, Marshall University
Michael Ottinger, Missouri Western State University
Lyman Page, Princeton and WMAP
Laurence Palmer, University of Maryland
Bruce Partridge, Haverford College
R. Daryl Pedigo, University of Washington
Robert Pelcovitz, Brown University
Saul Perlmutter, University of California Berkeley
Vahe Peroomian, UCLA
Harvey Picker, Trinity College
Amy Pope, Clemson University
James Rabchuk, Western Illinois University
Michele Rallis, Ohio State University
Paul Richards, University of California Berkeley
Peter Riley, University of Texas Austin
Dennis Rioux, University of Wisconsin Oshkosh
John Rollino, Rutgers University
Larry Rowan, University of North Carolina Chapel Hill
Arthur Schmidt, Northwestern University
Cindy Schwarz-Rachmilowitz, Vassar College
Peter Sheldon, Randolph-Macon Woman's College
Natalia A. Sidorovskaia, University of Louisiana at Lafayette
James Siegrist, University of California Berkeley
Christopher Sirola, University of Southern Mississippi
Earl Skelton, Georgetown University
George Smoot, University of California Berkeley
David Snoke, University of Pittsburgh
Stanley Sobolewski, Indiana University of Pennsylvania
Mark Sprague, East Carolina University
Michael Strauss, University of Oklahoma
Laszlo Takac, University of Maryland Baltimore Co.
Leo Takahashi, Pennsylvania State University
Richard Taylor, University of Oregon
Oswald Tekyi-Mensah, Alabama State University
Franklin D. Trumpy, Des Moines Area Community College
Ray Turner, Clemson University
Som Tyagi, Drexel University
David Vakil, El Camino College
Trina VanAusdal, Salt Lake Community College
John Vasut, Baylor University
Robert Webb, Texas A&M
Robert Weidman, Michigan Technological University
Edward A. Whittaker, Stevens Institute of Technology
Lisa M. Will, San Diego City College
Suzanne Willis, Northern Illinois University
John Wolbeck, Orange County Community College
Stanley George Wojcicki, Stanford University
Mark Worthy, Mississippi State University
Edward Wright, UCLA and WMAP
Todd Young, Wayne State College
William Younger, College of the Albemarle
Hsiao-Ling Zhou, Georgia State University
Michael Ziegler, The Ohio State University
Ulrich Zurcher, Cleveland State University

New photographs were offered by Professors Vickie Frohne (Holy Cross Coll.), Guillermo Gonzales (Grove City Coll.), Martin Hackworth (Idaho State U.), Walter H. G. Lewin (MIT), Nicholas Murgo (NEIT), Melissa Vigil (Marquette U.), Brian Woodahl (Indiana U. at Indianapolis), and Gary Wysin (Kansas State U.). New photographs shot by students are from the AAPT photo contest: Matt Buck, (John Burroughs School), Matthew Claspill (Helias H. S.), Greg Gentile (West Forsyth H. S.), Shilpa Hampole (Notre Dame H. S.), Sarah Lampen (John Burroughs School), Mrinalini Modak (Fayetteville–Manlius H. S.), Joey Moro (Ithaca H. S.), and Anna Russell and Annacy Wilson (both Tamalpais H. S.).

I owe special thanks to Prof. Bob Davis for much valuable input, and especially for working out all the Problems and producing the Solutions Manual for all Problems, as well as for providing the answers to odd-numbered Problems at the back of the book. Many thanks also to J. Erik Hendrickson who collaborated with Bob Davis on the solutions, and to the team they managed (Profs. Karim Diff, Thomas Hemmick, Lauren Novatne, Michael Ottinger, and Trina VanAusdal).

I am grateful to Profs. Lorraine Allen, David Bannon, Robert Coakley, Kathy Dimiduk, John Essick, Dan Mazilu, John Rollino, Cindy Schwarz, Earl Skelton, Michael Strauss, Ray Turner, Suzanne Willis, and Todd Young, who helped with developing the new MisConceptual Questions and Search and Learn Problems, and offered other significant clarifications.

Crucial for rooting out errors, as well as providing excellent suggestions, were Profs. Lorraine Allen, Kathy Dimiduk, Michael Strauss, Ray Turner, and David Vakil. A huge thank you to them and to Prof. Giuseppe Molesini for his suggestions and his exceptional photographs for optics.

For Chapters 32 and 33 on Particle Physics and Cosmology and Astrophysics, I was fortunate to receive generous input from some of the top experts in the field, to whom I owe a debt of gratitude: Saul Perlmutter, George Smoot, Paul Richards, Alex Filippenko, James Siegrist, and William Hopzapfel (UC Berkeley), Lyman Page (Princeton and WMAP), Edward Wright (UCLA and WMAP), Michael Strauss (University of Oklahoma), and Bob Jacobsen (UC Berkeley; so helpful in many areas, including digital and pedagogy).

I also wish to thank Profs. Howard Shugart, Chair Frances Hellman, and many others at the University of California, Berkeley, Physics Department for helpful discussions, and for hospitality. Thanks also to Profs. Tito Arecchi, Giuseppe Molesini, and Riccardo Meucci at the Istituto Nazionale di Ottica, Florence, Italy.

Finally, I am grateful to the many people at Pearson Education with whom I worked on this project, especially Paul Corey and the ever-perspicacious Karen Karlin.

The final responsibility for all errors lies with me. I welcome comments, corrections, and suggestions as soon as possible to benefit students for the next reprint.

D.C.G.

email: Jim.Smith@Pearson.com
Post: Jim Smith
1301 Sansome Street
San Francisco, CA 94111

About the Author

Douglas C. Giancoli obtained his BA in physics (summa cum laude) from UC Berkeley, his MS in physics at MIT, and his PhD in elementary particle physics back at UC Berkeley. He spent 2 years as a post-doctoral fellow at UC Berkeley's Virus lab developing skills in molecular biology and biophysics. His mentors include Nobel winners Emilio Segrè and Donald Glaser.

He has taught a wide range of undergraduate courses, traditional as well as innovative ones, and continues to update his textbooks meticulously, seeking ways to better provide an understanding of physics for students.

Doug's favorite spare-time activity is the outdoors, especially climbing peaks. He says climbing peaks is like learning physics: it takes effort and the rewards are great.

To Students

HOW TO STUDY

1. Read the Chapter. Learn new vocabulary and notation. Try to respond to questions and exercises as they occur.
2. Attend all class meetings. Listen. Take notes, especially about aspects you do not remember seeing in the book. Ask questions (everyone wants to, but maybe you will have the courage). You will get more out of class if you read the Chapter first.
3. Read the Chapter again, paying attention to details. Follow derivations and worked-out Examples. Absorb their logic. Answer Exercises and as many of the end-of-Chapter Questions as you can, and all MisConceptual Questions.
4. Solve at least 10 to 20 end of Chapter Problems, especially those assigned. In doing Problems you find out what you learned and what you didn't. Discuss them with other students. Problem solving is one of the great learning tools. Don't just look for a formula—it might be the wrong one.

NOTES ON THE FORMAT AND PROBLEM SOLVING

1. Sections marked with a star (*) are considered **optional**. They can be omitted without interrupting the main flow of topics. No later material depends on them except possibly later starred Sections. They may be fun to read, though.
2. The customary **conventions** are used: symbols for quantities (such as m for mass) are italicized, whereas units (such as m for meter) are not italicized. Symbols for vectors are shown in boldface with a small arrow above: $\vec{\mathbf{F}}$.
3. Few equations are valid in all situations. Where practical, the **limitations** of important equations are stated in square brackets next to the equation. The equations that represent the great laws of physics are displayed with a tan background, as are a few other indispensable equations.
4. At the end of each Chapter is a set of **Questions** you should try to answer. Attempt all the multiple-choice **MisConceptual Questions**. Most important are **Problems** which are ranked as Level I, II, or III, according to estimated difficulty. Level I Problems are easiest, Level II are standard Problems, and Level III are "challenge problems." These ranked Problems are arranged by Section, but Problems for a given Section may depend on earlier material too. There follows a group of **General Problems**, not arranged by Section or ranked. Problems that relate to optional Sections are starred (*). Answers to odd-numbered Problems are given at the end of the book. **Search and Learn Problems** at the end are meant to encourage you to return to parts of the text to find needed detail, and at the same time help you to learn.
5. Being able to solve **Problems** is a crucial part of learning physics, and provides a powerful means for understanding the concepts and principles. This book contains many aids to problem solving: (a) worked-out **Examples**, including an Approach and Solution, which should be studied as an integral part of the text; (b) some of the worked-out Examples are **Estimation Examples**, which show how rough or approximate results can be obtained even if the given data are sparse (see Section 1–7); (c) **Problem Solving Strategies** placed throughout the text to suggest a step-by-step approach to problem solving for a particular topic—but remember that the basics remain the same; most of these "Strategies" are followed by an Example that is solved by explicitly following the suggested steps; (d) special problem-solving Sections; (e) "Problem Solving" marginal notes which refer to hints within the text for solving Problems; (f) **Exercises** within the text that you should work out immediately, and then check your response against the answer given at the bottom of the last page of that Chapter; (g) the Problems themselves at the end of each Chapter (point 4 above).
6. **Conceptual Examples** pose a question which hopefully starts you to think and come up with a response. Give yourself a little time to come up with your own response before reading the Response given.
7. **Math** review, plus additional topics, are found in Appendices. Useful **data**, **conversion factors**, and math **formulas** are found inside the front and back covers.

USE OF COLOR

Vectors

- A general vector
  - resultant vector (sum) is slightly thicker
  - components of any vector are dashed
- Displacement ($\vec{\mathbf{D}}, \vec{\mathbf{r}}$)
- Velocity ($\vec{\mathbf{v}}$)
- Acceleration ($\vec{\mathbf{a}}$)
- Force ($\vec{\mathbf{F}}$)
  - Force on second object
  - or third object in same figure
- Momentum ($\vec{\mathbf{p}}$ or $m\vec{\mathbf{v}}$)
- Angular momentum ($\vec{\mathbf{L}}$)
- Angular velocity ($\vec{\boldsymbol{\omega}}$)
- Torque ($\vec{\boldsymbol{\tau}}$)
- Electric field ($\vec{\mathbf{E}}$)
- Magnetic field ($\vec{\mathbf{B}}$)

Electricity and magnetism

- Electric field lines
- Equipotential lines
- Magnetic field lines
- Electric charge (+) or +
- Electric charge (–) or –

Electric circuit symbols

- Wire, with switch S
- Resistor
- Capacitor
- Inductor
- Battery
- Ground

Optics

- Light rays
- Object
- Real image (dashed)
- Virtual image (dashed and paler)

Other

- Energy level (atom, etc.)
- Measurement lines |←1.0 m→|
- Path of a moving object
- Direction of motion or current