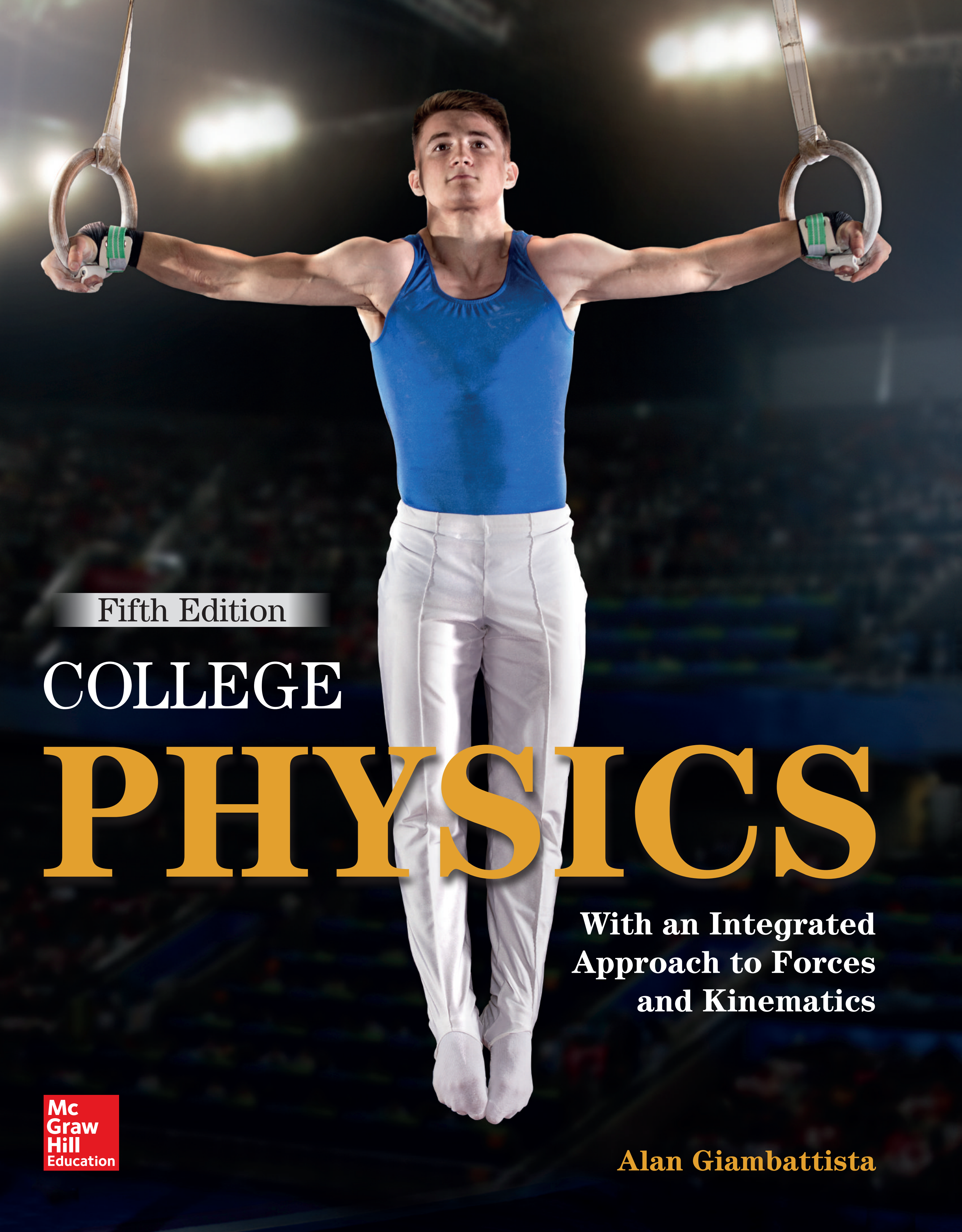

Fifth Edition

COLLEGE PHYSICS

With an Integrated Approach to Forces and Kinematics

Alan Giambattista

Mc Graw Hill Education

FIFTH EDITION

College Physics

With an Integrated Approach to Forces and Kinematics

Alan Giambattista

Cornell University

McGraw Hill Education

COLLEGE PHYSICS: WITH AN INTEGRATED APPROACH TO FORCES AND KINEMATICS, FIFTH EDITION

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About the Author

Alan Giambattista hails from northern New Jersey. His teaching career got an early start when his fourth-grade teacher, Anne Berry, handed the class over to him to teach a few lessons about atoms and molecules. At Brigham Young University, he studied piano performance and physics. After graduate work at Cornell University, he joined the physics faculty and has taught introductory physics there for nearly three decades.

Alan still appears in concert regularly as a pianist and harpsichordist. When the long upstate New York winter is finally over, he is eager to get out on Cayuga Lake's waves of blue for Sunday sailboat races. Alan met his wife Marion in a singing group and they have been making beautiful music together ever since. They live in an 1824 parsonage built for an abolitionist minister, which is now surrounded by an organic dairy farm. Besides taking care of the house, cats, and gardens, they love to travel together, especially to Italy. They also love to spoil their adorable grandchildren, Ivy and Leo.

Photo by Melvin Cabili

Dedication

For Ivy and Leo

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Preface

College Physics is intended for a two-semester college course in introductory physics using algebra and trigonometry. The main goals for this book are:

- to present the basic concepts of physics that students need to know for later courses and future careers,
- to emphasize that physics is a tool for understanding the real world, and
- to teach transferable problem-solving skills that students can use throughout their lives.

NEW TO THE FIFTH EDITION

Although the fundamental philosophy of the book has not changed, many improvements have been made based on detailed feedback from instructors and students using the fourth edition. Some of the most important updates include:

- The comprehensive math review, found in **Appendix A,** has been expanded for this edition. A new section **A.8 (Sinusoidal Functions of Time)** provides support for important topics such as oscillations, waves, Faraday's law, and interference. **Section A.6 (Geometry)** has been rewritten to emphasize the skills most relevant to physics problems. **Math skills** have been added to the **Concepts and Skills to Review** on the chapter opener pages. New references to **Appendix A** have been added to the text.
- The visual presentation has been streamlined. The content of tips and warnings found in marginal icons and text highlighting, has been moved into **Problem-Solving Strategy** boxes and/or into the end-of-chapter **Master the Concepts** boxes, as appropriate.
- **Concepts and Skills to Review** lists are now more prominently featured on the chapter opener page.
- Coverage of the following topics has been added or expanded based on the 2015 revision of the MCAT® exam: mechanical advantage, turbulence, surface tension, attenuation of sound waves, paramagnetism and diamagnetism, circular polarization, and lens aberrations.
- **Review & Synthesis** problems appear at the end of every chapter (starting with Chapter 4) instead of after related groups of chapters.
- Many of the figure legends have been expanded to help students learn more from the illustrations.

Notable revisions to the text include:

- **Example 1.9** has been expanded to demonstrate an alternative method of performing dimensional analysis. New problems have been added to Chapter 1 to give students more practice using ratios and proportions.
- **Example 2.13** has been rewritten to focus more clearly on Newton's third law.
- **Section 3.5** on relative velocity and reference frames has been revised to emphasize that velocity of A relative to B is the vector difference of the two velocities as measured in a common reference frame.
- **Section 4.6** (Apparent Weight) no longer develops a formula for apparent weight. Instead, the section emphasizes fundamental skills (drawing an FBD and analyzing the forces) and summarizes the procedure in a new Problem-Solving Strategy box.
- In **Chapter 5**, the Problem-Solving Strategies for uniform and nonuniform circular motion have been revised to show a parallel structure. A new figure shows the forces acting on a car traveling around a banked curve.

- **Chapter 6** has new Problem-Solving Strategies for work done by a constant force and for mechanical energy.
- In **Section 8.2**, the discussion of the lever arm has been clarified.
- **Section 11.5** (Mathematical Description of a Wave) has been rewritten to be more accessible.
- **Sections 12.7 and 12.8** (Beats, The Doppler Effect) have been rewritten. Formulating the Doppler effect in terms of relative velocities makes an arbitrary sign convention unnecessary.
- **Sections 15.5–15.7** contain improved explanations of heat engines and heat pumps.
- A table of circuit symbols is now included at the end of **Chapter 18**.
- **Section 19.10** has been rewritten to provide a more complete description of paramagnetism and diagmagnetism.
- **Chapter 20**'s treatment of inductance has been streamlined, with the quantitative material on mutual inductance moved into an online supplement. Chapter 20 has gained 10 new end-of-chapter problems on Faraday's law.
- **Section 22.7** now includes a description of circular polarization.
- New **Figure 23.47** is a ray diagram for the formation of a virtual image by a converging lens.
- **Section 24.3** describes astigmatism of the eye. **Section 24.7** contains an expanded explanation of lens aberrations.
- **Chapter 25** simplifies the discussion of phase differences for constructive and destructive interference.
- **Chapter 30** mentions the observation of gravitational waves by the LIGO collaboration.

A CONCEPTS-FIRST APPROACH

Some students approach introductory physics with the idea that physics is just the memorization of a long list of equations and the ability to plug numbers into those equations. *College Physics* emphasizes that a relatively small number of basic physics concepts are applied to a wide variety of situations. Physics education research has shown that students do not automatically acquire conceptual understanding; the concepts must be explained and the students given a chance to grapple with them. The presentation in *College Physics* blends conceptual understanding with analytical skills. The "concepts-first" approach helps students develop intuition about how physics works; the "formulas" and problem-solving techniques serve as *tools for applying the concepts.* The **Conceptual Examples** and **Conceptual Practice Problems** in the text and a variety of ranking tasks and **Conceptual** and **Multiple-Choice Questions** at the end of each chapter give students a chance to check and to enhance their conceptual understanding.

AN INTEGRATED APPROACH TO FORCES AND KINEMATICS

As part of the concepts-first approach, the organization of this text differs in a few places from that of most textbooks. The most prominent of these the treatment of forces and motion. In *College Physics,* the central theme of Chapters 2–4 is Newton's laws of motion. Chapter 2 sets the conceptual framework by introducing forces and Newton's laws. Kinematics is then introduced in Chapters 3 and 4 as a tool to understand how forces affect motion.

Interaction pairs, the concept behind Newton's third law, are built in from the start (see Section 2.1). Force is used as a prototypical vector quantity—intuitively, when two or more forces act on an object, the effect depends on the directions of the forces as well as on the magnitudes. Introducing forces earlier gives students more practice with the crucial skills they need to analyze forces, construct free-body diagrams, and add forces as vectors to find the net force. In Chapter 2, these skills are practiced in *equilibrium situations only*. No rates of change to grapple with yet and no quadratic equations to solve!

One benefit of this approach is that Chapter 2 contains very few "formulas"; instead it teaches physics *concepts* and necessary math *skills*. The beginning of the text sets up student expectations that are hard to change later. Beginning with forces helps students see that physics is not about manipulating equations, but rather is about reasoning skills and fundamental concepts.

Chapter 3 begins to address the question: How does an object move when the net force acting on it is *nonzero*? Newton's second law provides the *motivation* for defining acceleration, and the kinematics is integrated into the context of Newton's laws. The students have already learned about vector quantities, so there's no need to go through kinematics twice (once in one dimension and then again in two or three dimensions). Correct and consistent vector notation is used even when an object moves along a straight line. For example, components are carefully distinguished from magnitudes by writing "$v_x = -5$ m/s" and never "$v = -5$ m/s," even if the object moves only along the x-axis. Several professors, after trying this approach, reported a reduction in the number of students struggling with vector components.

Within the framework of Newton's laws set in Chapter 2, the motivation for the definition of acceleration is clear. The kinematic quantities are introduced in Chapter 3, and the students learn how the forces acting on an object affect its motion. Many of the examples and problems in Chapter 3 involve the *connection* between kinematics and the forces acting on an object. Students continue to practice crucial skills they learned in Chapter 2, such as analyzing forces and constructing free-body diagrams.

Chapter 4 then examines an important case—what happens when the net force is *constant*? This is presented as a continuation of what came before—students continue to analyze forces and use Newton's second law. The idealized motion of a projectile is presented as just that—an idealization that is *approximately* true when forces other than gravity are negligible. The text reinforces the idea that physics explains how the real world works, not give the impression that physics is a self-contained system unconnected from reality.

INTRODUCING CONCEPTS INTUITIVELY

Key concepts and quantities are introduced in an informal and intuitive way, using a concrete example to establish why the concept or quantity is useful. Concepts motivated in this way are easier for students to grasp and remember than are concepts introduced by seemingly arbitrary, formal definitions.

For example, in Chapter 8, the idea of rotational inertia emerges in a natural way from the concept of rotational kinetic energy. Students can understand that a rotating rigid body has kinetic energy due to the motion of its particles. The text discusses why it is useful to be able to write this kinetic energy in terms of a single quantity common to all the particles (the angular speed), rather than as a sum involving particles with many different speeds. When students understand why rotational inertia is defined the way it is, they are better prepared to move on to the more difficult concepts of torque and angular momentum.

The text avoids presenting definitions or formulas without motivation. When an equation is not derived in the text, a conceptual explanation or a plausibility argument is given. For example, Section 9.9 introduces Poiseuille's law with two identical pipes in series to show why the volume flow rate must be proportional to the pressure drop per unit length. The text then discusses why $\Delta V/\Delta t$ is proportional to the fourth power of the radius (rather than to r^2, as it would be for an ideal fluid).

Similarly, the definitions of the displacement and velocity vectors can seem arbitrary and counterintuitive to students if introduced without any motivation. Therefore, presentation of the kinematic quantities is preceded by an introduction to Newton's laws, so students know that forces determine how the state of motion of an object changes. The conceptual groundwork for a concept is particularly important when its name is a common English word such as *velocity* or *work*.

DESIGNED FOR ACTIVE LEARNING

Previous editions of *College Physics* have been tested for over 15 years in Cornell's nontraditional course, where students rely on the textbook as their primary source of information because there are no lectures. The text is therefore well suited to use in flipped classrooms and other nontraditional course formats. Nonetheless, completeness and clarity are equally advantageous when the book is used in a more traditional classroom setting. *College Physics* frees the instructor from having to try to "cover" everything. The instructor can then tailor class time to more important student needs—reinforcing difficult concepts, working through Example problems, engaging the students in peer instruction and cooperative learning activities, describing applications, or presenting demonstrations.

WRITTEN IN A CLEAR AND FRIENDLY STYLE

College Physics was developed specifically for the algebra/trig-based course; it's not a spinoff of a calculus-based text for engineers or physics majors. The writing is intended to be down-to-earth and conversational in tone—the kind of language an experienced teacher uses when sitting at a table working one-on-one with a student. Students should feel confident that they can learn by studying the textbook.

Although learning correct physics terminology is essential, *College Physics* avoids *unnecessary* jargon—terminology that just gets in the way of the student's understanding. For example, the term *centripetal force* does not appear in the book, since its use sometimes leads students to add a spurious "centripetal force" to their free-body diagrams. *Radial component of acceleration* is preferred over *centripetal acceleration* because it is less likely to introduce or reinforce misconceptions.

MCAT® SUPPORT

Coverage of topics such as mechanical advantage, turbulence, surface tension, attenuation of sound waves, magnetic materials, and circular polarization has been expanded or added to this edition based on the 2015 revision of the MCAT® exam. Students who plan to take the MCAT® can rest assured that *all* the physics topics on that exam are included in the text.

PROVIDING STUDENTS WITH THE TOOLS THEY NEED

Problem-Solving Approach

Problem-solving skills are central to an introductory physics course. These skills are illustrated in the Example problems. Lists of problem-solving strategies can be useful; *College Physics* presents such strategies when appropriate. However, the most elusive skills—perhaps the most important ones—are subtle points that defy being put into a neat list. To develop real problem-solving expertise, students must learn how to think critically and analytically. Problem solving is a multidimensional, complex process; an algorithmic approach is not adequate to instill real problem-solving skills.

An important problem-solving skill that many students need to practice is extracting information from a graph or sketching a graph without plotting individual data points. Graphs often help students visualize physical relationships more clearly than they can with algebra alone. Graphs and sketches are emphasized in the text, in worked examples, and in the problems.

Strategy Each Example begins with a discussion—in language that the students can understand—of the *strategy* to be used in solving the problem. The strategy illustrates the kind of analytical thinking students must do when attacking a problem: How do I decide what approach to use? What laws of physics apply to the problem and which of them are *useful* in this solution? What clues are given in the statement of the question? What information is implied rather than stated outright? If there are several valid approaches, how do I determine which is the most efficient? What assumptions can I make? What kind of sketch or graph might help me solve the problem? Is a simplification or approximation called for? If so, how can I tell if the simplification is valid? Can I make a preliminary estimate of the answer? Only after considering these questions can the student effectively solve the problem.

Solution Next comes the detailed *solution* to the problem. Explanations are intermingled with equations and step-by-step calculations to help the student understand the approach used to solve the problem.

Discussion The numerical or algebraic answer is not the end of the problem; the Examples end with a *discussion.* Students must learn how to determine whether their answer is consistent and reasonable by checking the order of magnitude of the answer, comparing the answer with a preliminary estimate, verifying the units, and doing an independent calculation when more than one approach is feasible. When several different approaches are possible, the discussion looks at the advantages and disadvantages of each approach. The discussion generalizes the problem-solving techniques used in the solution, examines special cases, and considers "what if" scenarios.

Practice Problem After each Example, a Practice Problem gives students a chance to gain experience using the same physics principles and problem-solving tools. By comparing their answers with those provided at the end of each chapter, students can gauge their understanding and decide whether to move on to the next section.

Using Approximation, Estimation, and Proportional Reasoning

College Physics is forthright about the constant use of simplified models and approximations in solving physics problems. One of the most difficult aspects of problem solving that students need to learn is that some kind of simplified model or approximation is usually required. The text discusses how to know when it is reasonable to ignore friction, treat g as constant, ignore viscosity, treat a charged object as a point charge, or ignore diffraction.

Some Examples and Problems require the student to make an estimate—a useful skill both in physics problem solving and in many other fields. Proportional reasoning is used as not only an elegant shortcut but also as a means to understanding patterns. Examples and problems frequently use percentages and ratios to give students practice in using and understanding them.

Helping Students See the Relevance of Physics in Their Lives

Students in an introductory college physics course have a wide range of backgrounds and interests. To stimulate interest in physics, the text describes many applications relevant to students' lives and aligned with their interests. Examples and end-of-chapter problems that involve applications help students learn that they can answer questions *of interest to them* using physics concepts and skills. The text, Examples, and end-of-chapter problems draw from the everyday world; from familiar technological applications; and from other fields, such as biology, medicine, archaeology, astronomy, sports, environmental science, and geophysics. An icon ( ) identifies applications from the biological or medical sciences.

Everyday Physics Demos give students an opportunity to explore and see physics principles operate in their everyday lives. These activities are chosen for their simplicity and for their effectiveness in demonstrating physics principles.

Each **Chapter Opener** includes a photo and vignette, designed to capture student interest and maintain it throughout the chapter. The vignette describes the situation shown in the photo and asks the student to consider the relevant physics. The vignette topic is then discussed at the appropriate place within the chapter text.

Focusing on the Concepts

A marginal **Connections** box helps students understand that what may seem like a new concept may really be an extension, application, or specialized form of a concept previously introduced. The goal is for students to view physics as a small set of fundamental concepts that can be applied in many different situations, rather than as a collection of loosely related facts or equations. By identifying areas where important concepts are revisited, the Connections return the focus to core concepts.

The exercises in the **Review & Synthesis** sections help students see how the concepts in the previously covered group of chapters are interrelated. These exercises are also intended to help students prepare for tests, in which they must solve problems without having the section or chapter title given as a clue.

Checkpoint questions encourage students to pause and test their understanding of the concept explored within the current section. The answers to the Checkpoints are found at the end of the chapter so that students can confirm their knowledge without jumping too quickly to the provided answer.

Support for Essential Math Skills

In an introductory college physics course, students need to be confident using algebra, geometry, and trigonometry to solve problems. Weak math skills present a major obstacle to success in the course. Instructors seldom (if ever) feel they have enough class time to do enough math review. To help students review on their own and to serve as a comprehensive reference, *College Physics* provides an exceptionally detailed **Mathematics Review** (Appendix A). For the fifth edition, more frequent references to Appendix A have been added to the text, especially in the early chapters, to encourage students to use the Appendix to reinforce their math skills. Appendix A has been expanded to include a new section on Sinusoidal Functions of Time.

While revising the Mathematics Review, the author also contributed to a major revision of the ALEKS® *Math Prep for College Physics* course by selecting learning objectives that align with the specific math skills most used in college physics.

Student Solutions Manual

The *Student Solutions Manual* contains complete worked-out solutions to selected end-of-chapter problems and questions, and to selected Review & Synthesis problems. The solutions in this manual follow the problem-solving strategy outlined in the text's Examples and also guide students in creating diagrams for their own solutions.

DIGITAL RESOURCES

ALEKS® *Math Prep for College Physics*

ALEKS *Math Prep for College Physics* is a web-based program that provides targeted coverage of critical mathematics material necessary for student success in *College Physics.* ALEKS uses artificial intelligence and adaptive questioning to assess precisely a student's preparedness and deliver personalized instruction on the exact topics the student is most ready to learn. Through comprehensive explanations, practice, and feedback, ALEKS enables students to quickly fill individual knowledge gaps in order to build a strong foundation of critical math skills.

Use ALEKS *Math Prep for College Physics* during the first six weeks of the term to see improved student confidence and performance, as well as fewer dropouts.

ALEKS *Math Prep for College Physics* Features:

- **Artificial Intelligence:** Targets gaps in student knowledge
- **Individualized Assessment and Learning:** Ensure student mastery
- **Adaptive, Open-Response Environment:** Avoids multiple-choice questions
- **Dynamic, Automated Reports:** Monitor student and class progress

McGraw-Hill Connect®

Connect is a digital teaching and learning environment that improves student performance over a variety of critical outcomes; it is easy to use; and it is proven effective. Connect empowers students by continually adapting to deliver precisely what they need, when they need it, and how they need it, so class time is more engaging and effective.

INSTRUCTOR RESOURCES

Build instructional materials wherever, whenever, and however you want!

Accessed through the instructor resources in Connect is, an online digital library containing photos, artwork, interactives, clicker questions, and other media types can be used to create customized lectures, visually enhanced tests and quizzes, compelling course websites, or attractive printed support materials. Assets are copyrighted by McGraw-Hill Higher Education, but can be used by instructors for classroom purposes. The visual resources in this collection include

- **Art** Full-color digital files of all illustrations in the book can be readily incorporated into lecture presentations, exams, or custom-made classroom materials.
- **Photos** The photos collection contains digital files of photographs from the text, which can be reproduced for multiple classroom uses.
- **Workbook** The workbook contains questions and ideas for classroom exercises that will get students thinking about physics in new and comprehensive ways.

Students are led to discover physics for themselves, leading to a deeper intuitive understanding of the material.

- **Lecture PowerPoints** Ready-made presentations combine art and lecture notes for each chapter of the text.
- **Test Bank** A comprehensive bank of test questions that accompanies *College Physics* is available for instructors to create their own quizzes and exams. These same questions are also available and assignable through Connect for online tests.
- **Instructor's Resource Guide** The guide includes many unique assets for instructors, such as demonstrations, suggested reform ideas from physics education research, and ideas for incorporating just-in-time teaching techniques.
- **Instructor's Solutions Manual** The accompanying Instructor's Solutions Manual includes answers to the end-of-chapter Conceptual Questions and complete, worked-out solutions for all the end-of-chapter Problems from the text.