Cutnell & Johnson Physics

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Eleventh Edition

DAVID YOUNG

SHANE STADLER

Louisiana State University

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This book is printed on acid-free paper.

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Main Text Binder Version: 9781119391869
Volume 1: 9781119460190
Volume 2: 9781119460176

The inside back cover will contain printing identification and country of origin if omitted from this page. In addition, if the ISBN on the back cover differs from the ISBN on this page, the one on the back cover is correct.

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

About the Authors

Courtesy David Young

Courtesy Shane Stadler

DAVID YOUNG received his Ph.D. in experimental condensed matter physics from Florida State University in 1998. He then held a post-doc position in the Department of Chemistry and the Princeton Materials Institute at Princeton University before joining the faculty in the Department of Physics and Astronomy at Louisiana State University in 2000. His research focuses on the synthesis and characterization of high-quality single crystals of novel electronic and magnetic materials. The goal of his research group is to understand the physics of electrons in materials under extreme conditions, i.e., at temperatures close to absolute zero, in high magnetic fields, and under high pressure. He is the coauthor of over 200 research publications that have appeared in peer-reviewed journals, such as *Physical Review B, Physical Review Letters*, and *Nature*. Professor Young has taught introductory physics with the Cutnell & Johnson text since he was a senior undergraduate over 20 years ago. He routinely lectures to large sections, often in excess of 300 students. To engage such a large number of students, he uses *WileyPLUS*, electronic response systems, tutorial-style recitation sessions, and in-class demonstrations. Professor Young has received multiple awards for outstanding teaching of undergraduates. David enjoys spending his free time with his family, playing basketball, and working on his house.

I would like to thank my family for their continuous love and support.
—David Young

SHANE STADLER Shane Stadler earned a Ph.D. in experimental condensed matter physics from Tulane University in 1998. Afterwards, he accepted a National Research Council Postdoctoral Fellowship with the Naval Research Laboratory in Washington, DC, where he conducted research on artificially structured magnetic materials. Three years later, he joined the faculty in the Department of Physics at Southern Illinois University (the home institution of John Cutnell and Ken Johnson, the original authors of this textbook), before joining the Department of Physics and Astronomy at Louisiana State University in 2008. His research group studies novel magnetic materials for applications in the areas of spintronics and magnetic cooling.

Over the past fifteen years, Professor Stadler has taught the full spectrum of physics courses, from physics for students outside the sciences, to graduate-level physics courses, such as classical electrodynamics. He teaches classes that range from fewer than ten students to those with enrollments of over 300. His educational interests are focused on developing teaching tools and methods that apply to both small and large classes, and which are applicable to emerging teaching strategies, such as "flipping the classroom."

In his spare time, Shane writes science fiction/thriller novels.

I would like to thank my parents, George and Elissa, for their constant support and encouragement. —Shane Stadler

Dear Students and Instructors:

Welcome to college physics! To the students: We know there is a negative stigma associated with physics, and you yourself may harbor some trepidation as you begin this course. But fear not! We're here to help. Whether you're worried about your math proficiency, understanding the concepts, or developing your problem-solving skills, the resources available to you are designed to address all of these areas and more. Research has shown that learning styles vary greatly among students. Maybe some of you have a more visual preference, or auditory preference, or some other preferred learning modality. In any case, the resources available to you in this course will satisfy all of these preferences and improve your chance of success. Take a moment to explore below what the textbook and online course have to offer. We suspect that, as you continue to improve throughout the course, some of that initial trepidation will be replaced with excitement.

To start, we have created a new learning medium specific to this book in the form of a comprehensive set of *LECTURE VIDEOS* – one for every section (259 in all). These animated lectures (created and narrated by the authors) are 2–10 minutes in length, and explain the basic concepts and learning objectives of each section. They are assignable within WileyPLUS and can be paired with follow-up questions that are gradable. In addition to supplementing traditional lecturing, the videos can be used in a variety of ways, including flipping the classroom, a complete set of lectures for online courses, and reviewing for exams. Next, we have enhanced "The Physics of …" examples by increasing the bio-inspired examples by 40%. Although they are of general instructional value, they are also similar to what premed students will encounter in the *Chemical and Physical Foundations of Biological Systems Passages* section of the MCAT. Finally, we have introduced new "team problems" in the end-of-chapter problems that are designed for group problem-solving exercises. These are context-rich problems of medium difficulty designed for group cooperation, but may also be tackled by the individual student.

One of the great strengths of this text is the synergistic relationship it develops between problem solving and conceptual understanding. For instance, available in *WileyPLUS* are animated *Chalkboard Videos*, which consist of short (2–3 min) videos demonstrating step-by-step practical solutions to typical homework problems. Also available are numerous *Guided Online (GO) Tutorials* that implement a step-by-step pedagogical approach, which provides students a low-stakes environment for refining their problem solving skills. One of the most important techniques developed in the text for solving problems involving multiple forces is the *free-body diagram* (FBD). Many problems in the force-intensive chapters, such as chapters 4 and 18, take advantage of the new FBD capabilities now available online in *WileyPLUS*, where students can construct the FBD's for a select number of problems and be graded on them. Finally, *ORION*, an online adaptive learning environment, is seamlessly integrated into *WileyPLUS* for Cutnell & Johnson.

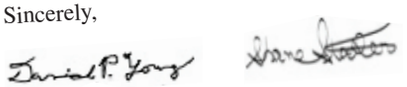
The content and functionality of *WileyPLUS*, and the adaptive learning environment of *ORION* (see below), will provide students with all the resources they need to be successful in the course.

- The *Lecture Videos* created by the authors for each section include questions with intelligent feedback when a student enters the wrong answer.
- The multi-step *GO Tutorial* problems created in *WileyPLUS* are designed to provide targeted, intelligent feedback.
- The *Free-body Diagram* vector drawing tools provide students an easy way to enter answers requiring vector drawing, and also provide enhanced feedback.
- *Chalkboard Video Solutions* take the students step-by-step through the solution and the thought process of the authors. Problem-solving strategies are discussed, and common misconceptions and potential pitfalls are addressed. The students can then apply these techniques to solve similar, but different problems.

All of these features are designed to encourage students to remain within the *WileyPLUS* environment, as opposed to pursuing the "pay-for solutions" websites that short circuit the learning process. To the students – We strongly recommend that you take this honest approach to the course. Take full advantage of the many features and learning resources that accompany the text and the online content. Be engaged with the material and push yourself to work through the exercises. Physics may not be the easiest subject to understand, but with the Wiley resources at your disposal and your hard work, you CAN be successful.

We are immensely grateful to all of you who have provided feedback as we've worked on this new edition, and to our students who have taught us how to teach. Thank you for your guidance, and keep the feedback coming. Best wishes for success in this course and wherever your major may take you!

Sincerely,



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Our Vision and the WileyPLUS with ORION Advantage

Our Vision

Our goal is to provide students with the skills they need to succeed in this course, and instructors with the tools they need to develop those skills.

Skills Development

One of the great strengths of this text is the synergistic relationship between conceptual understanding, problem solving, and establishing relevance. We identify here some of the core features of the text that support these synergies.

Conceptual Understanding Students often regard physics as a collection of equations that can be used blindly to solve problems. However, a good problem-solving technique does not begin with equations. It starts with a firm grasp of physics concepts and how they fit together to provide a coherent description of natural phenomena. Helping students develop a conceptual understanding of physics principles is a primary goal of this text. The features in the text that work toward this goal are:

- *Lecture Videos* (one for each section of the text)
- *Conceptual Examples*
- *Concepts & Calculations* problems (now with video solutions)
- *Focus on Concepts* homework material
- *Check Your Understanding* questions
- *Concept Simulations* (an online feature)

Problem Solving The ability to reason in an organized and mathematically correct manner is essential to solving problems, and helping students to improve their reasoning skills is also one of our primary goals. To this end, we have included the following features:

- *Math Skills boxes* for just-in-time delivery of math support
- *Explicit reasoning steps* in all examples
- *Reasoning Strategies* for solving certain classes of problems
- *Analyzing Multiple-Concept Problems*
- *Video Support and Tutorials* (in *WileyPLUS*)
  - Physics Demonstration Videos
  - Video Help
  - Concept Simulations
- *Problem Solving Insights*

Relevance Since it is always easier to learn something new if it can be related to day-to-day living, we want to show students that physics principles come into play over and over again in their lives. To emphasize this goal, we have included a wide range of applications of physics principles. Many of these applications are biomedical in nature (for example, wireless capsule endoscopy). Others deal with modern technology (for example, 3-D movies). Still others focus on things that we take for granted in our lives (for example, household plumbing). To call attention to the applications we have used the label The Physics of.

The WileyPLUS with ORION Advantage

WileyPLUS is an innovative, research-based online environment for effective teaching and learning. The hallmark of *WileyPLUS* with ORION for this text is that the media- and text-based resources are all created by the authors of the project, providing a seamless presentation of content.

WileyPLUS builds students' confidence because it takes the guesswork out of studying by providing students with a clear roadmap: **what to do, how to do it, if they did it right**.

With *WileyPLUS*, our efficacy research shows that students improve their outcomes by as much as one letter grade. *WileyPLUS* helps students take more initiative, so you'll have greater impact on their achievement in the classroom and beyond.

With *WileyPLUS*, instructors receive:

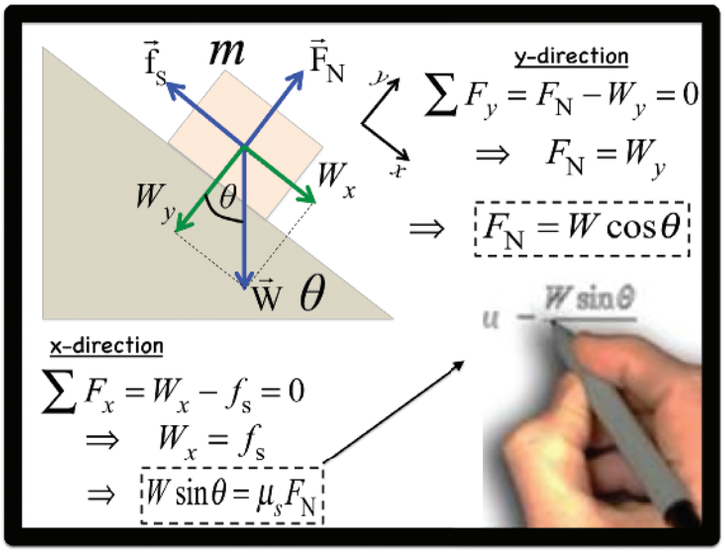
- **WileyPLUS Quickstart:** *WileyPLUS* comes with a pre-created course plan designed by the author team exclusively for this course. The course plan includes both conceptual assignments and problem-solving assignments, and is found in the Quickstart menu.
- **Breadth and Depth of Assessment:** *WileyPLUS* contains a wealth of online questions and problems for creating online homework and assessment including:
  - ALL end-of-chapter questions, plus favorites from past editions not found in the printed text, coded algorithmically, each with at least one form of instructor-controlled question assistance (GO tutorials, hints, link to text, video help)
  - Simulation, animation, and video-based questions
  - Free body and vector drawing questions
  - Test bank questions
- **Gradebook:** *WileyPLUS* provides instant access to reports on trends in class performance, student use of course materials, and progress toward learning objectives, thereby helping instructors' decisions and driving classroom discussion.

With *WileyPLUS*, students receive:

- The complete digital textbook, saving students up to 60% off the cost of a printed text
- Question assistance, including links to relevant sections in the online digital textbook
- Immediate feedback and proof of progress, 24/7
- Integrated, multimedia resources—including animations, simulations, video demonstrations, and much more—that provide multiple study paths and encourage more active learning
- GO Tutorials
- Chalkboard Videos
- Free Body Diagram/Vector Drawing Questions

New to WileyPlus for the Eleventh Edition

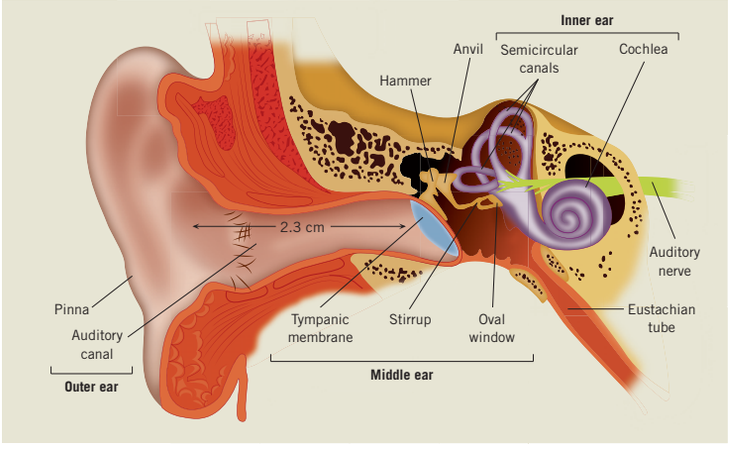
Lecture Videos Short video lectures (259 in all!) have been created and are narrated by the authors for *every section* of the book. These animated lectures are 2–10 minutes in length, and introduce the basic concepts and learning objectives of each section. Each video is accompanied by questions that can be assigned and graded within WileyPLUS, which are designed to check the students' understanding of the video lecture content. Other than providing another learning medium that can be accessed by the students at their convenience, these videos are designed to accommodate other learning strategies. For instance, an instructor can create a full video lecture by building a sequence of videos, section by section, and assigning corresponding questions that the students must complete before class. This functionality is well suited for "flipping the classroom," although it also serves a purpose for conventional lecturing, such as reading quizzes that can be administered outside of lecture. The videos also serve well for reviewing before exams. This comprehensive set of customizable lectures and questions is also suitable for online courses, where students otherwise rely solely on written content.



Team Problems In each chapter we have introduced two new "team problems" in the end-of-chapter problems that are designed for group problem-solving exercises. These are context-rich problems of medium difficulty designed for group cooperation, but may also be tackled by the individual student. Many of these problems read like parts of an adventure story, where the student (or their team) is the main character. The motivation for each problem is clear and personal—the pronoun "you" is used throughout, and the problem statements often start with "You and your team need to …". Pictures and diagrams are not given with these problems except in rare cases. Students must visualize the problems and discuss strategies with their team members to solve them. The problems require two or more steps/multiple concepts (hence the "medium" difficulty level) and may require basic principles learned earlier. Sometimes, there is no specific target variable given, but rather questions like *Will it work?* or *Is it safe?* Suggested solutions are given in the Instructor Solutions Manual.

The Physics of Problems The text now contains 294 real-world application examples that reflect our commitment to showing students how relevant physics is in their lives. Each application is identified in the text with the label The Physics of. A subset of these examples focuses on biomedical applications, and we have increased their number by 40% in the new edition. Students majoring in biomedical and life sciences will find new examples in every chapter covering topics such as cooling the human brain, abdominal aortic aneurysms, the mechanical properties of bone, and many more! The application of physics principles to biomedical problems in these examples is similar to what premed students will encounter in the *Chemical and Physical Foundations of Biological Systems Passages* section of the MCAT. All biomedical examples and end-of-chapter problems will be marked with the BIO icon.

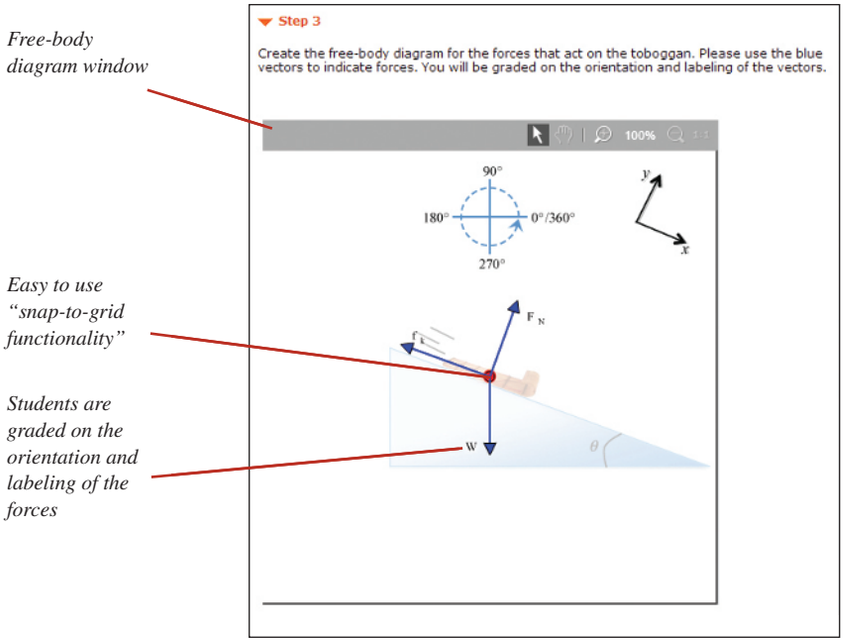
EXAMPLE 7 | BIO The Physics of Hearing Loss—Standing Waves in the Ear



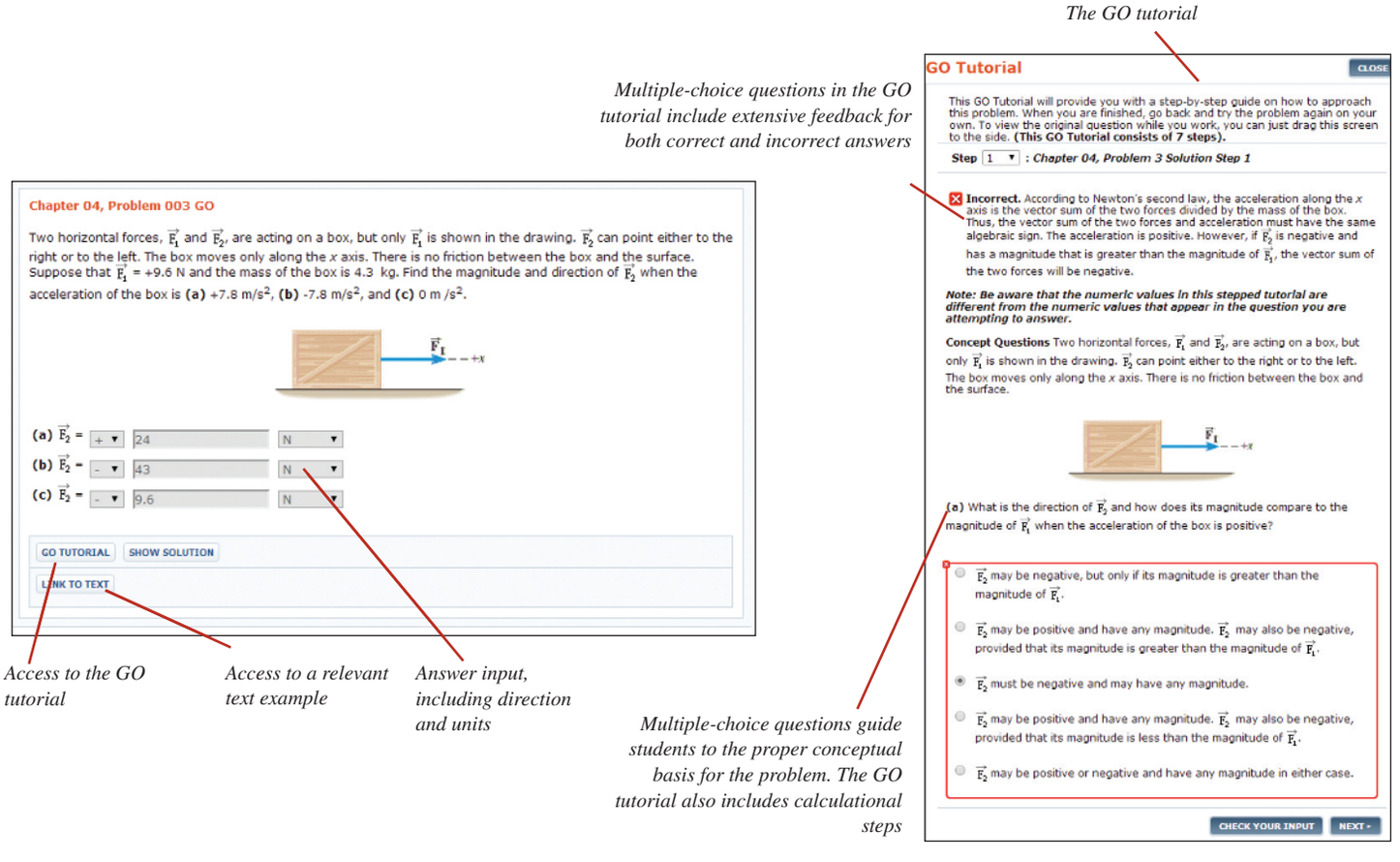
Interactive Graphics The online reading experience within WileyPLUS has been enhanced with the addition of "Interactive Graphics." Several static figures in each chapter have been transformed to include interactive elements. These graphics drive students to be more engaged with the extensive art program and allow them to more easily absorb complex and/or long multi-part figures.

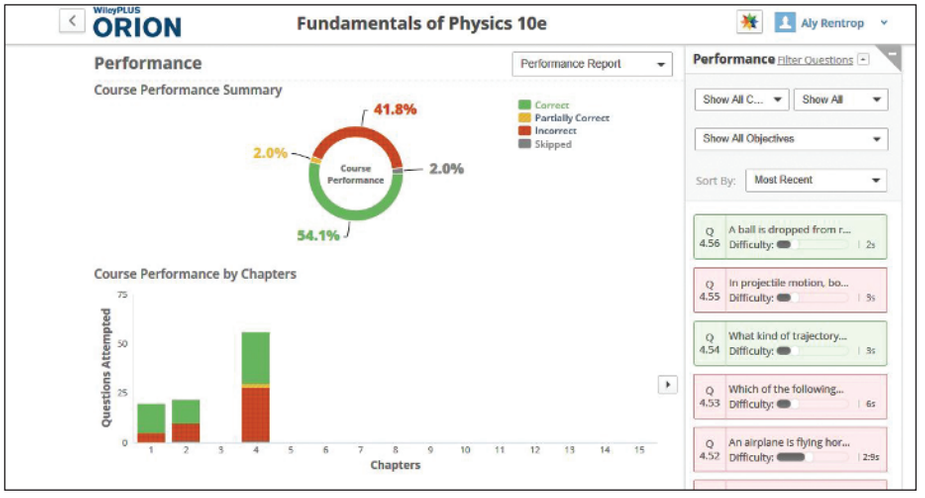
Also Available in *WileyPLUS*

Free-Body Diagram (FBD) Tools For many problems involving multiple forces, an interactive free-body diagram tool in *WileyPLUS* is used to construct the diagram. It is essential for students to practice drawing FBDs, as that is the critical first step in solving many equilibrium and non-equilibrium problems with Newton's second law.



GO Tutorial Problems Some of the homework problems found in the collection at the end of each chapter are marked with a special GO icon. All of these problems are available for assignment via an online homework management program such as *WileyPLUS* or WebAssign. There are now 550 GO problems in the tenth edition. Each of these problems in *WileyPLUS* includes a guided tutorial option (not graded) that instructors can make available for student access with or without penalty.





***WileyPLUS* with ORION** provides students with a personal, adaptive learning experience so they can build their proficiency on concepts and use their study time effectively.

Unique to ORION, students begin by taking a quick diagnostic for any chapter. This will determine each student's baseline proficiency on each topic in the chapter. Students see their individual diagnostic report to help them decide what to do next with the help of ORION's recommendations.

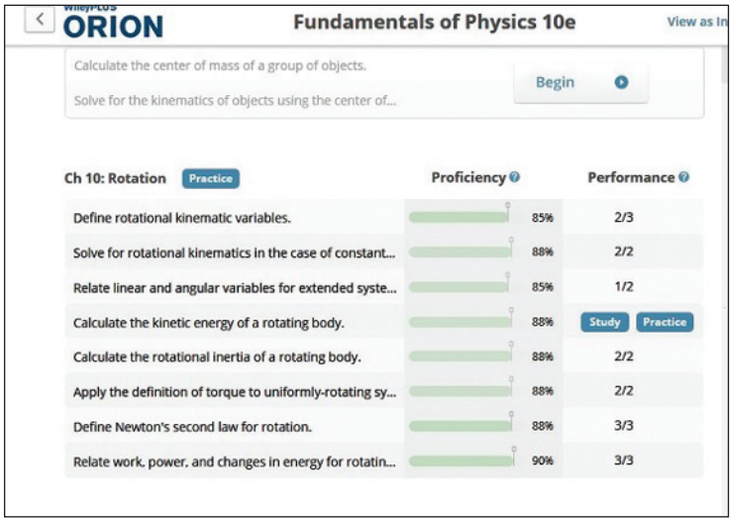
For each topic, students can either Study or Practice. **Study** directs the student to the specific topic they choose in *WileyPLUS,* where they can read from the e-textbook, or use the variety of relevant resources available there. Students can also **Practice**, using questions and feedback powered by ORION's adaptive learning engine. Based on the results of their diagnostic and ongoing practice, ORION will present students with questions appropriate for their current level of understanding, and will continuously adapt to each student, helping them build their proficiency.

ORION includes a number of reports and ongoing recommendations for students to help them maintain their proficiency over time for each topic. Students can easily access ORION from multiple places within *WileyPLUS*. It does not require any additional registration, and there is not any additional cost for students using this adaptive learning system.

About the Adaptive Engine ORION includes a powerful algorithm that feeds questions to students based on their responses to the diagnostic and to the practice questions. Students who answer questions correctly at one difficulty level will soon be given questions at the next difficulty level. If students start to answer some of those questions incorrectly, the system will present questions of lower difficulty. The adaptive engine also takes into account other factors, such as reported confidence levels, time spent on each question, and changes in response options before submitting answers.

The questions used for the adaptive practice are numerous and are not found in the *WileyPLUS* assignment area. This ensures that students will not be encountering questions in ORION that they may also encounter in their *WileyPLUS* assessments.

ORION also offers a number of reporting options available for instructors, so that instructors can easily monitor student usage and performance.



How to access *WileyPLUS* with ORION

To access *WileyPLUS*, students need a *WileyPLUS* registration code. This can be purchased stand-alone or the code can be bundled with the book. For more information and/or to request a *WileyPLUS* demonstration, contact your local Wiley sales representative or visit **www.wileyplus.com**.

Acknowledgments

The publishing world is changing rapidly! The digital age is here, and college textbooks must evolve with the times. How today's students obtain and process information is very different than it was just 10 years ago. Our goal as authors is to provide the best content we can and deliver it to today's students in ways that are both efficient and pedagogically effective. This paradigm shift in textbook publishing from largely print-based media to both print and digital content leads to uncharted waters, and we rely, now more than ever, on a talented team of people who are essential in completing such an enormous and multifaceted project. As the authors, we are immensely grateful for their guidance and insight.

We would like to especially acknowledge Jessica Fiorillo, our Executive Editor. We depend upon her experience and vast knowledge of the industry, as well as her encouragement and suggestions. Creating the new content for this edition has been, at times, tedious, to say the least. Her infectious enthusiasm has kept us going, and we are certainly grateful for that.

We had the pleasure of working with our Production Editor, Elizabeth Swain, on the previous edition of the book and during the early stages of this new edition. She has been a consummate professional during the copy-editing process. While our interaction with Elizabeth was relatively short, considering her long career at Wiley, we and the title have benefited greatly from her hard work and experience.

We owe a tremendous thank you to our Project Manager, Jennifer Yee, for managing our revision timeline and assuming much of the responsibility of a production editor. She did a wonderful job in providing us with up-to-date information throughout the process. We must also acknowledge Mahtab Khan and Suresh Srinivasan with Aptara Corporation, who seamlessly assumed much of the production editor's responsibilities and kept us on track.

We are lucky to work with such a talented Product Design Manager as Geraldine Osnato. She is a "digital diva"! Her expertise with the online environment and her knowledge of the pedagogy combine to form a web-based platform that enhances student learning. Geraldine is so good at her job that there is little possibility she will leave to become a professional bull rider. Thank you also to Lindsey Meyers, Assistant Development Editor, for taking the reins on the new *Interactive Graphics* feature of the online text. Some of the functionality we designed was difficult to implement, but she made it work. Thank you!

We are very fortunate to work with Kristy Ruff, who is the Executive Market Development Manager for Science at Wiley. She understands the needs of our students and promotes the vision of the text by focusing on what we do best—content! This title would not have the success it does without her efforts in guiding the marketing strategy. Thank you, Kristy!

The final and polished version of the text represents the culmination of the efforts by many team members, including Copy Editor and Proofreader, Bret Workman; Senior Photo Editor, Mary Ann Price; Media Specialist, Patricia Gutierrez; Senior Content Manager, Lana Barskaya; Marketing Assistant, Maggie Joest; and Text Designer and Cover Designer, Wendy Lai.

One of the many facets of the book is the extensive supplemental package, including the solutions manuals. We are grateful to Editorial Assistant, Ayantika Chatterjee, and Assistant Development Editor, Lindsey Myers, for the flawless assembly of these important components.

We are also grateful to Ayantika Chatterjee, Editorial Assistant, for help in facilitating the flow of the manuscript through its various production stages.

We owe a special thank you to Petra Recter, who was a former publisher on this title and who now is the Vice President & Director of Science. Thank you for staying committed to the Cutnell franchise, providing us such a great team to improve the text, and being such a strong advocate for the physics program at Wiley.

Last, but certainly not least, we thank the sales representatives of John Wiley & Sons, Inc. You are very special members of our team. Your professionalism and knowledge of the book's features, the online content, and its functionality is pivotal to the success of the book. We are very grateful for your tireless promotional efforts.

We are particularly indebted to Dayna Leaman. More than just our local Account Manager, she is also our friend. You have been supportive on so many levels, and we are absolutely certain that we would not have been afforded this wonderful opportunity had it not been for your support. Managing multiple adoptions across several states is not easy, and we benefit greatly from your hard work. Thank you, Dayna!

Many of our physics colleagues and their students have generously shared their ideas about good pedagogy with us and improved the text by pointing out our errors. For all of their suggestions, we are grateful. They have helped us to write more clearly and accurately and have influenced markedly the evolution of this text. To the reviewers of this and previous editions, we especially owe a large debt of gratitude. Specifically, we thank:

Lai Cao, Baton Rouge Magnet High School
Candee Chambers-Colbeck, Maryville University
Diana Driscoll, Case Western Reserve University
Robert Egler, North Carolina State University
Sambandamurthy Ganapathy, The State University of New York at Buffalo
Joseph Ganem, Loyola University Maryland
Jasper Halekas, University of Iowa
Lilit Haroyan, East Los Angeles College
Klaus Honscheid, Ohio State University
Craig Kleitzing, University of Iowa
Kriton Papavasiliou, Virginia Polytechnic Institute and State University
Payton Parker, Midlothian Heritage High School
Christian Prewitt, Midlothian Heritage High School
Joshua Ravenscraft, Vernon Hills High School and College of Lake County
Brian Schuft, North Carolina A&T State University
Andreas Shalchi, University of Manitoba
Deepshikha Shukla, Rockford University
Jennifer Snyder, San Diego Mesa College
Richard Taylor, University of Oregon
Beth Thacker, Texas Tech University
Anne Topper, Queen's University
David Ulrich, Portland Community College

About the cover: The cover image shows an artist's rendition of a synaptic gap between an axon and a dendrite of a human nerve cell. Just like the wires in the electrical system of your home, the nerve cells make connections in circuits called neural pathways. The transmission of chemical signals between the axon and dendrite relies on the electrical potential difference across the gap, which is a topic in Volume 2 of the text. Our hope is that this book and its resources will help you develop some new neural pathways of your own!

In spite of our best efforts to produce an error-free book, errors no doubt remain. They are solely our responsibility, and we would appreciate hearing of any that you find. We hope that this text makes learning and teaching physics easier and more enjoyable, and we look forward to hearing about your experiences with it. Please feel free to write us care of Physics Editor, Global Education, John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030, or contact the authors at **dyoun14@gmail.com** or **sstadler23@gmail.com**.