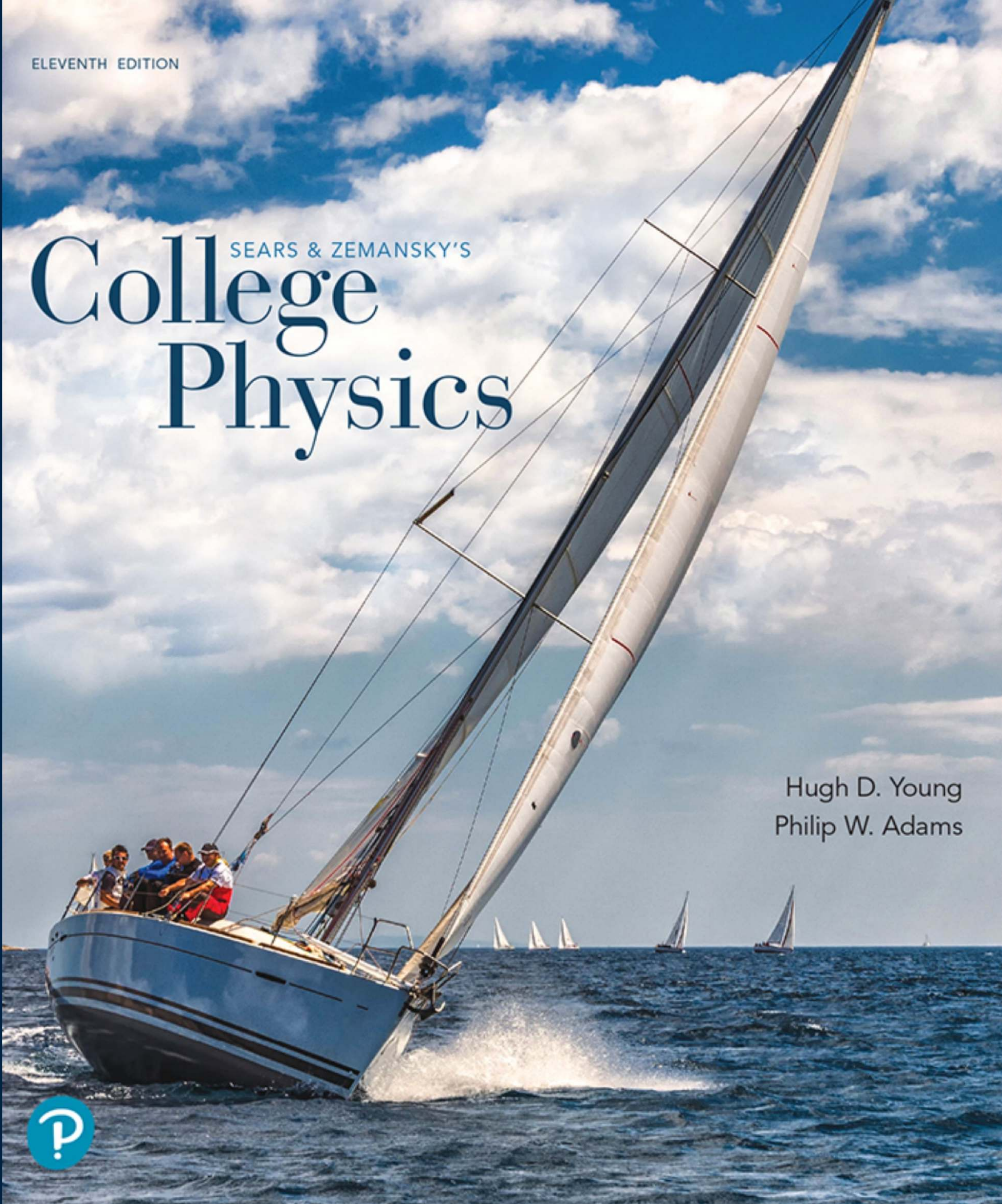

ELEVENTH EDITION

SEARS & ZEMANSKY'S

College Physics

Hugh D. Young
Philip W. Adams

COLLEGE PHYSICS

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SEARS AND ZEMANSKY'S

COLLEGE PHYSICS

ELEVENTH EDITION

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Pearson

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BRIEF CONTENTS

ABOUT THE AUTHORS

Philip W. Adams is a Professor of Physics at Louisiana State University in Baton Rouge, Louisiana. He obtained his Ph.D. in Physics from Rutgers University in 1986 and then held a postdoctoral research position at AT&T Bell Laboratories in Murray Hill, NJ for two years. He joined the faculty of LSU 1988 and has since become an internationally recognized low temperature experimentalist and has published over 90 papers in peer-reviewed scientific journals. He is a Fellow of the American Physical Society and has given many invited presentations on his work at international workshops and conferences on superconductivity and other topics in low temperature condensed matter physics.

Dr. Adams has had a career-long interest in physics education. He has taught introductory physics for engineers and for non-engineers many times in his 30-year tenure at LSU and has been the recipient of numerous teaching awards.

IN MEMORIAM: HUGH YOUNG (1930–2013)

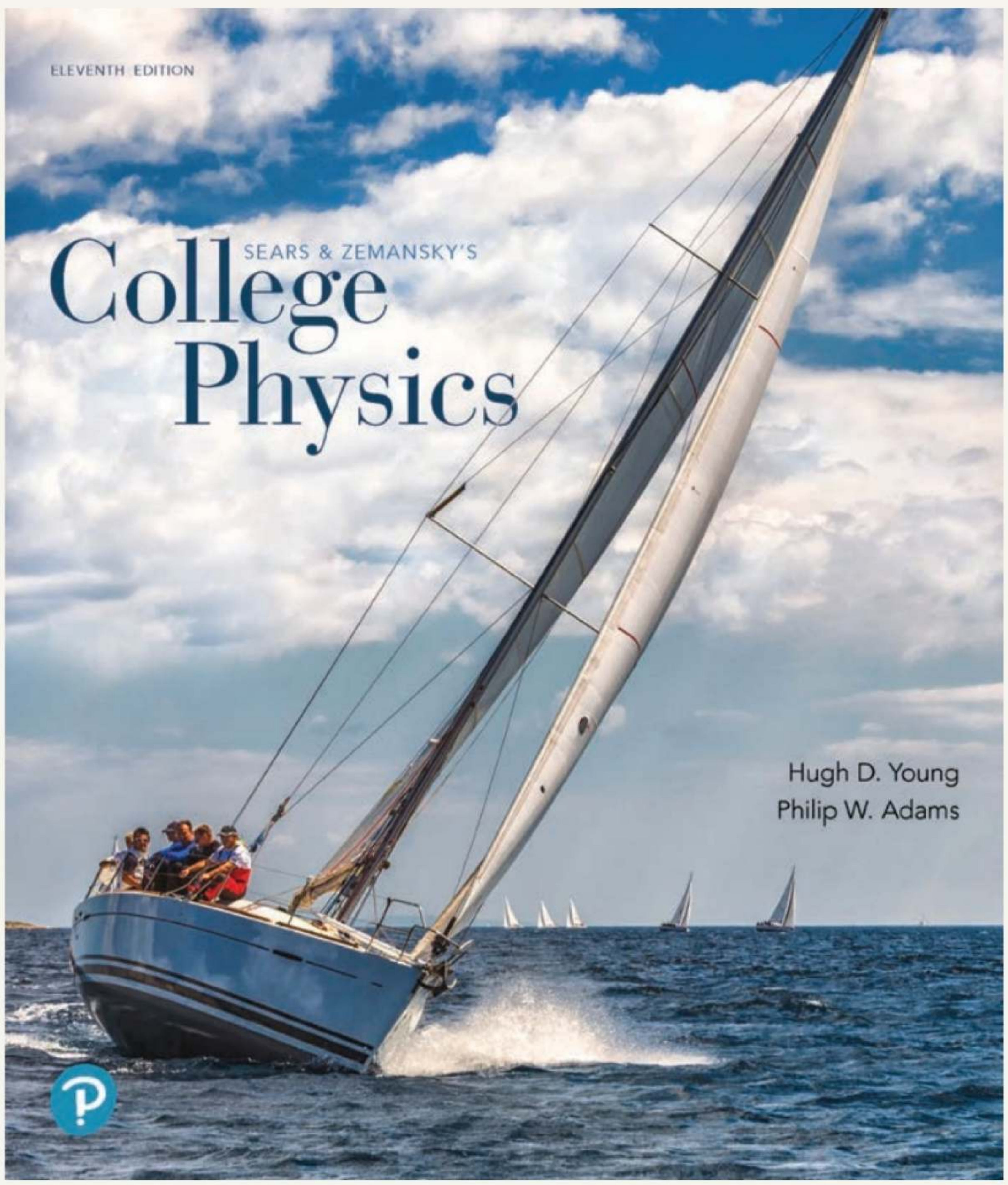
Hugh D. Young was Emeritus Professor of Physics at Carnegie Mellon University. He earned his Ph.D. from Carnegie Mellon in fundamental particle theory under the direction of the late Richard Cutkosky. He also had two visiting professorships at the University of California, Berkeley.

Dr. Young's career was centered entirely on undergraduate education. He wrote several undergraduate-level textbooks, and in 1973 he became a coauthor with Francis Sears and Mark Zemansky of their well-known introductory texts *University Physics* and *College Physics*.

Dr. Young earned a bachelor's degree in organ performance from Carnegie Mellon in 1972 and spent several years as Associate Organist at St. Paul's Cathedral in Pittsburgh. We at Pearson appreciated his professionalism, good nature, and collaboration. He will be missed.

Help students see the connections between problem types and understand how to solve them

The new **11th Edition of *College Physics*** incorporates data from thousands of surveyed students detailing their use and reliance on worked examples, video tutorials, and just-in-time remediation when working homework problems and preparing for exams. Driven by how students actually use the text and media, this edition offers multiple resources to help students see patterns and make connections between problem types, helping them to develop an understanding of problem-solving approaches, rather than simply plugging in an equation. **Mastering Physics** gives students additional problem sets with wrong answer specific feedback, hints, and links end-of-chapter problems directly to the Pearson eText for additional guidance.



Help develop a greater understanding of . . .

Chapter 7 Media Assets

GUIDED PRACTICE

For assigned homework and other learning materials, go to Mastering Physics.

I, II, III: Difficulty levels. DATA: Problems involving real data, scientific evidence, experimental design, and/or statistical reasoning. BIO: Biosciences Problems. SYM: Symbolic Problems. EST: Estimation Problems.

KEY EXAMPLE VARIATION PROBLEMS

Be sure to review EXAMPLE 7.8 before attempting these problems.

VP7.8.1 I A glider with mass $m = 0.2$ kg sits on a frictionless air track. It is connected to a massless spring with force constant $k = 20$ N/m. The glider is initially at $x = 0$, and the spring is relaxed. You then hit the glider with a hammer, which gives it an initial velocity of $v_0 = 5$ m/s in the positive x direction. At what x positions will the speed of the glider be zero?

VP7.8.2 II SYM A mass m is tied to an ideal spring with force constant k and rests on a frictionless surface. The mass moves along the x axis. Assume that $x = 0$ corresponds to the relaxed position of the spring. The mass is pulled out to a position x_m and released. Derive an expression for the positions at which the kinetic energy of the mass is equal to the elastic potential energy of the spring.

VP7.8.3 II A glider has a mass $m = 0.4$ kg. It is attached to a spring with force constant k. The relaxed position of the spring corresponds to $x = 0$. The glider is pulled out to $x = 0.2$ m and then released. If its speed at $x = 0.1$ m is 3 m/s, determine k.

Be sure to review EXAMPLE 7.13 before attempting these problems.

VP7.13.1 I A small box is released from rest at the top of a frictionless inclined plane as shown in Figure 7.36. The horizontal surface at the base of the plane is rough and has a coefficient of kinetic friction $\mu_k = 0.4$. If $H = 10$ m, how far does the box slide on the rough surface before coming to rest, d?

Figure 7.36

VP7.13.2 II SYM A box is released from rest at the top of an inclined plane that makes an angle θ with respect to the horizontal. The length of the plane is L (as measured along its surface), and the coefficient of kinetic friction between the box and the inclined surface is $\mu_k = \frac{1}{2}\tan\theta$. Use conservation of energy to derive an expression for the speed of the box when it reaches the bottom of the inclined plane.

VP7.13.3 II A glider has a mass $m = 0.4$ kg and is resting on a track that has a small but finite coefficient of kinetic friction. It is attached to a spring with force constant $k = 20$ N/m. The relaxed position of the spring corresponds to $x = 0$. The glider is pulled out to $x = 0.2$ m and then released. If its speed is 1.0 m/s when it first reaches $x = 0.1$ m, determine the work done by friction during that segment of the motion.

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NEW! Example Variation Problems build in difficulty by adjusting scenarios, changing the knowns vs. unknowns, and adding complexity and a step of reasoning to provide the most helpful range of related problems that use the same fundamental approach to solve. These scaffolded problem sets help students see patterns and make connections between problems types that can be solved applying the same fundamental principles so that they are less surprised by variations on problems when exam time comes. They are assignable in Mastering Physics.

UPDATED! Worked Examples follow a consistent and explicit global problem-solving strategy drawn from educational research that shows students find access to worked examples at the point of need most helpful. This 3-step approach emphasizes setting up a problem effectively before any attempts to solve it as well as the importance of reflecting on whether the answer is sensible. This focus helps students understand how to solve problems rather than hunting for an equation they can plug in.

EXAMPLE 5.3 Car on a ramp

In this example, we will see how to handle the case of an object resting on an inclined plane. A car with a weight of 1.76×10^4 N rests on the ramp of a trailer (Figure 5.3a). The car's brakes and transmission lock are released; only the cable prevents the car from rolling backward off the trailer. The ramp makes an angle of 26.0° with the horizontal. Find the tension in the cable and the force with which the ramp pushes on the car's tires.

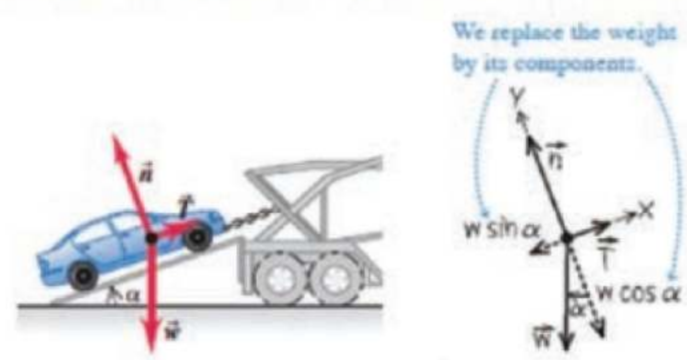

Figure 5.3 (a) Car on ramp (b) Free-body diagram for car

SOLUTION

SET UP Figure 5.3b shows our free-body diagram for the car. The three forces exerted on the car are its weight (magnitude w), the tension in the cable (magnitude T), and the normal force with magnitude n exerted by the ramp. (Because we treat the car as a particle, we can lump the normal forces on the four wheels together as a single force.) We orient our coordinate axes parallel and perpendicular to the ramp, and we replace the weight force by its components.

SOLVE The car is in equilibrium, so we first find the components of each force in our axis system and then apply Newton's first law. To find the components of the weight, we note that the angle α between the ramp and the horizontal is equal to the angle α between the weight vector and the normal to the ramp, as shown. The angle α is *not* measured in the usual way, counterclockwise from the $+x$ axis. To find the components of the weight (w_x and w_y), we use the right triangles in Figure 5.3b. We find that $w_x = -w\sin\alpha$ and $w_y = -w\cos\alpha$. The equilibrium conditions then give us

$$\Sigma F_x = 0, \quad T + (-w\sin\alpha) = 0,$$
$$\Sigma F_y = 0, \quad n + (-w\cos\alpha) = 0.$$

Be sure you understand how the signs are related to our choice of coordinate axis directions. Remember that, by definition, T, w, and n are *magnitudes* of vectors and are therefore positive.

Solving these equations for T and n, we find

$$T = w\sin\alpha,$$
$$n = w\cos\alpha.$$

Finally, inserting the numerical values $w = 1.76 \times 10^4$ N and $\alpha = 26°$, we obtain

$$T = (1.76 \times 10^4\ \text{N})(\sin 26°) = 7.72 \times 10^3\ \text{N},$$
$$n = (1.76 \times 10^4\ \text{N})(\cos 26°) = 1.58 \times 10^3\ \text{N}.$$

REFLECT To check some special cases, note that if the angle α is zero, then $\sin\alpha = 0$ and $\cos\alpha = 1$. In this case, the ramp is horizontal; no cable tension T is needed to hold the car, and the magnitude of the total normal force n is equal to the car's weight. If the angle is 90° (the ramp is vertical), then $\sin\alpha = 1$ and $\cos\alpha = 0$. In that case, the cable tension T equals the weight w and the normal force n is zero.

We also note that our results would still be correct if the car were on a ramp on a car transport trailer traveling down a straight highway at a constant speed of 65 mi/h. Do you see why?

Practice Problem: What ramp angle would be needed in order for the cable tension to equal one-half of the car's weight? *Answer:* 30°.

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Problem-Solving **skills**

BRIDGING PROBLEM

A large pressurized tank is filled with water. The air pressure above the water surface is $p_0 > p_{atm}$. The water has a depth h and density ρ_w. A cube of aluminum with sides of length L and density ρ_{Al} sits on the bottom of the tank (Figure 13.37a). (a) Derive an expression for the pressure at the bottom of the tank. (b) Derive an expression for the normal force between the cube and the bottom of the tank. (c) Should your answer for part (b) depend on p_0? Explain why or why not. (d) A small hole is punched into the wall of the tank at a depth of $h/2$, as shown in Figure 13.37b. What is the speed of the water flowing out of the hole? (Assume that the tank is large enough so that the water velocity inside the tank is near zero.)

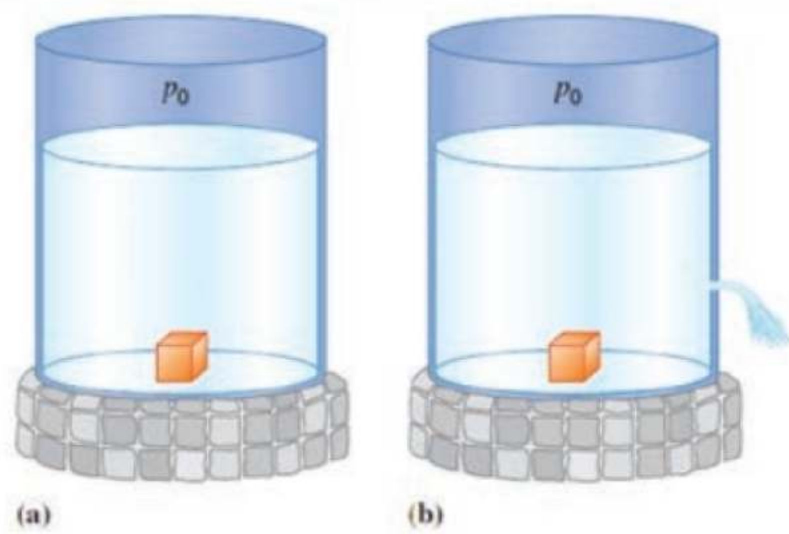

Figure 13.37

Set Up

- Write down the equation for pressure as a function of depth in a liquid.
- Draw a free-body diagram for the aluminum cube and identify all of the forces acting on it.
- Consider what role Pascal's law plays in this problem.
- Write down Bernoulli's equation and identify the pressures and velocities that are appropriate for part (d) of the problem.

Solve

- Solve for the pressure at the bottom of the tank.
- Apply Newton's second law to the cube and solve for the perpendicular force.
- Evaluate the effect of p on the buoyancy force.
- Apply Bernoulli's equation to the flow out of the hole and solve for the speed.

Evaluate

- What effect does the pressure at the top of the tank have on the pressure at the bottom of the tank?
- Would the perpendicular force in part (b) be larger or smaller if the cube were made of lead instead of aluminum? Explain.
- Would the perpendicular force in part (b) be larger or smaller if the liquid in the tank were ethanol instead of water? Explain.
- How would the speed of the escaping water change if the pressure in the tank were lowered so that $p = p_{atm}$?

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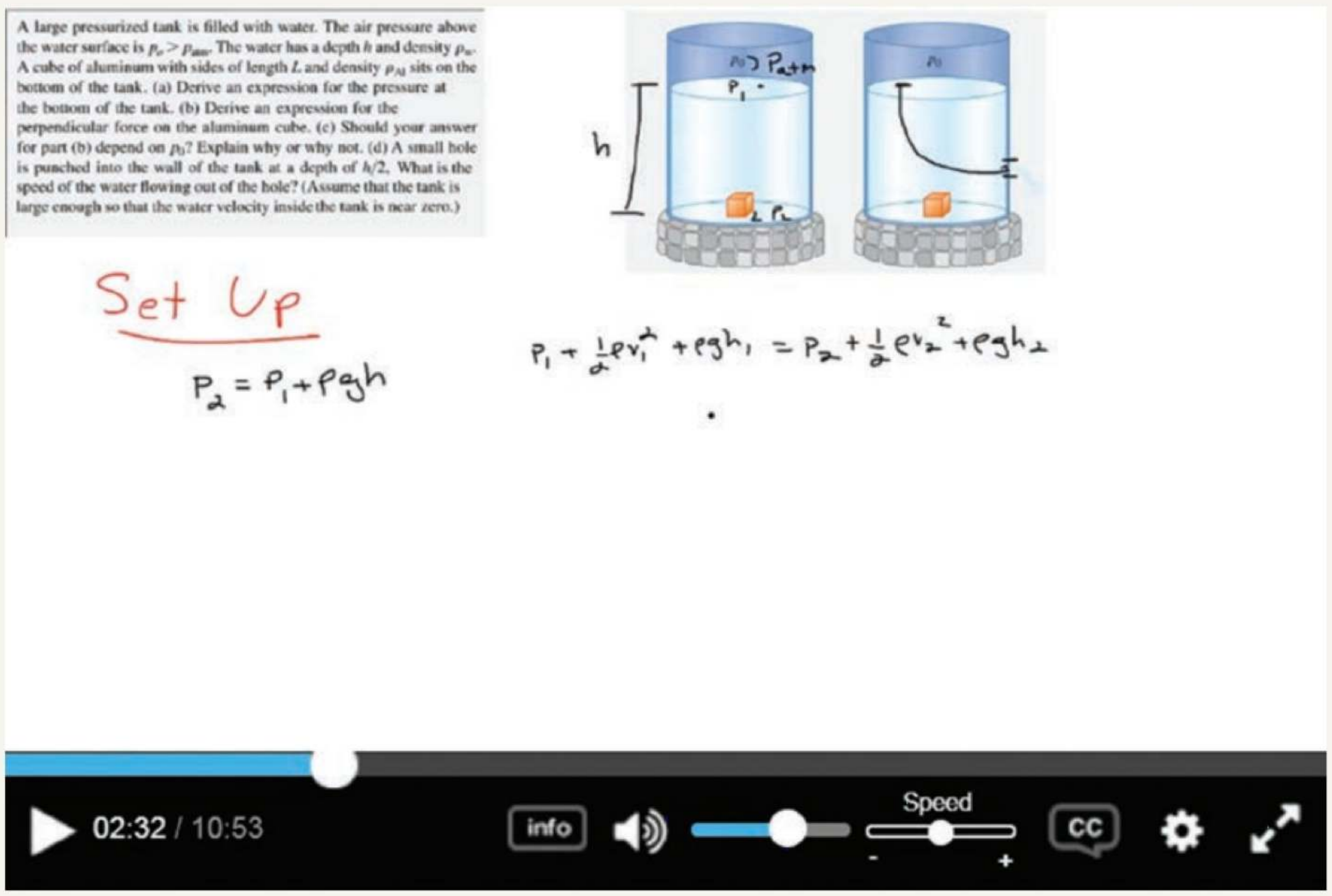
Bridging Problems

at the end of each chapter help students move from single concept worked examples to multi-concept problems. New! Assignable as Tutorials in Mastering Physics.

Video Tutor Solutions (VTSs) for every Example and Bridging Problem in the book

walk students through the problem-solving process, providing a virtual teaching assistant on a round-the-clock basis. New VTSs correspond to new and revised worked examples.



Tools that build conceptual understanding . . .

Test Your Understanding of SECTION 10.1

Torques on a rod

Three forces with equal magnitudes act on the ends of a long, thin rod of length L, as shown in Figure 10.5. The rod is pinned so that it can rotate about its center of mass. Which choice correctly ranks the magnitudes of the torques produced by all three forces, from largest to smallest?

A. $\tau_1 = \tau_2 = \tau_3$
B. $\tau_1 > \tau_3 > \tau_2$
C. $\tau_2 > \tau_3 > \tau_1$

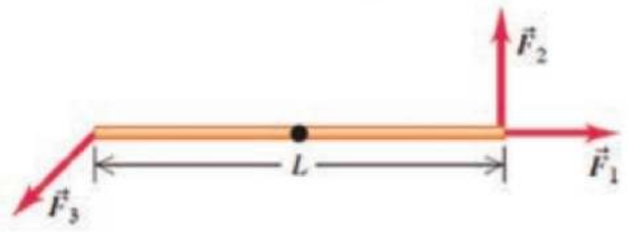


Figure 10.5

SOLUTION Because all three forces have the same magnitude, the force that acts over the longest moment arm produces the greatest torque. Because the line of action of $\vec{F}_1$ runs through the pivot, the first force produces no torque and $\tau_1 = 0$. For $\vec{F}_2$, the line of action is perpendicular to the rod, so the moment arm is $L/2$. Because $\vec{F}_3$ is not perpendicular to the rod, the moment arm must be shorter than $L/2$. Therefore, the correct answer is C.

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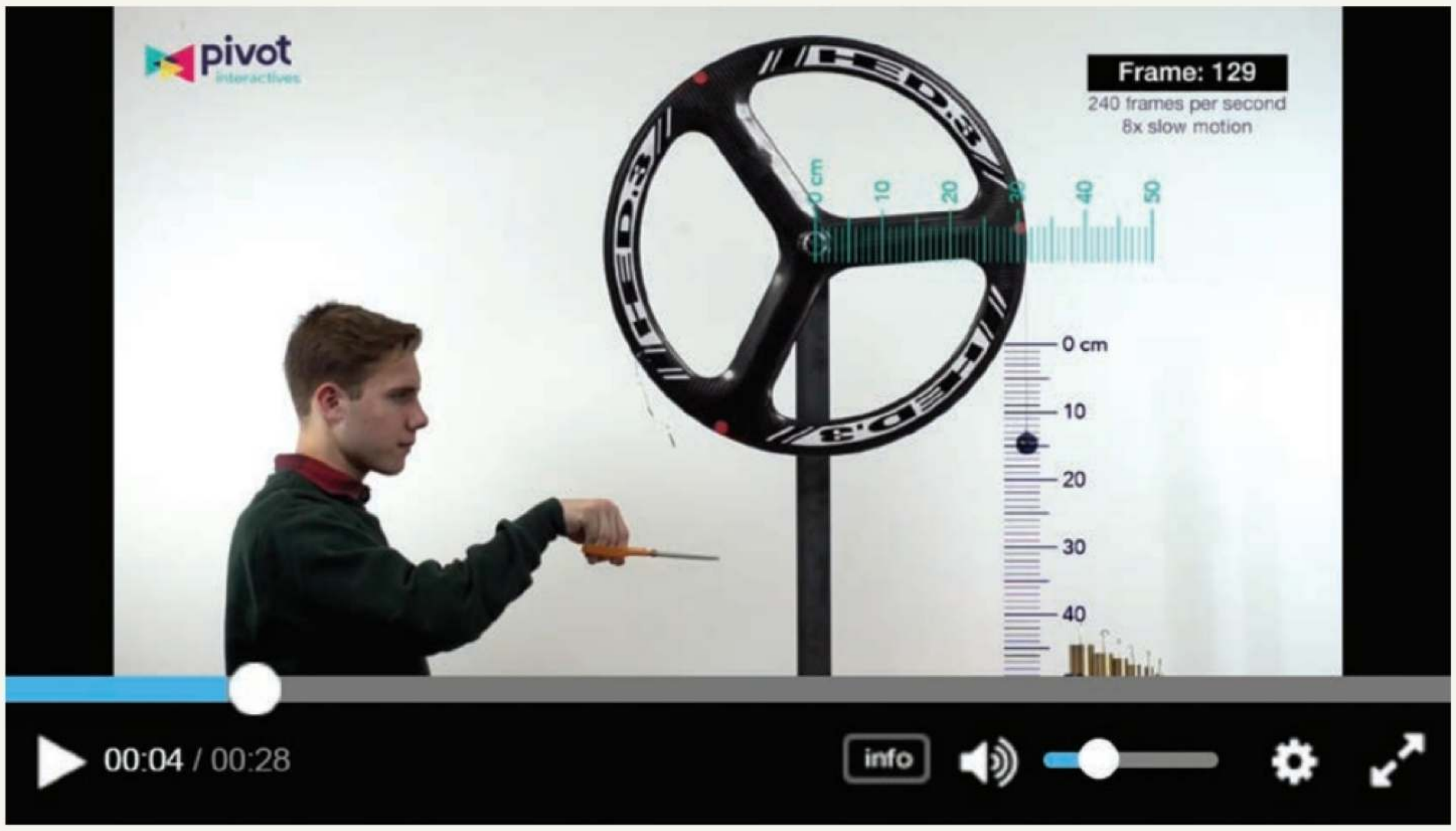
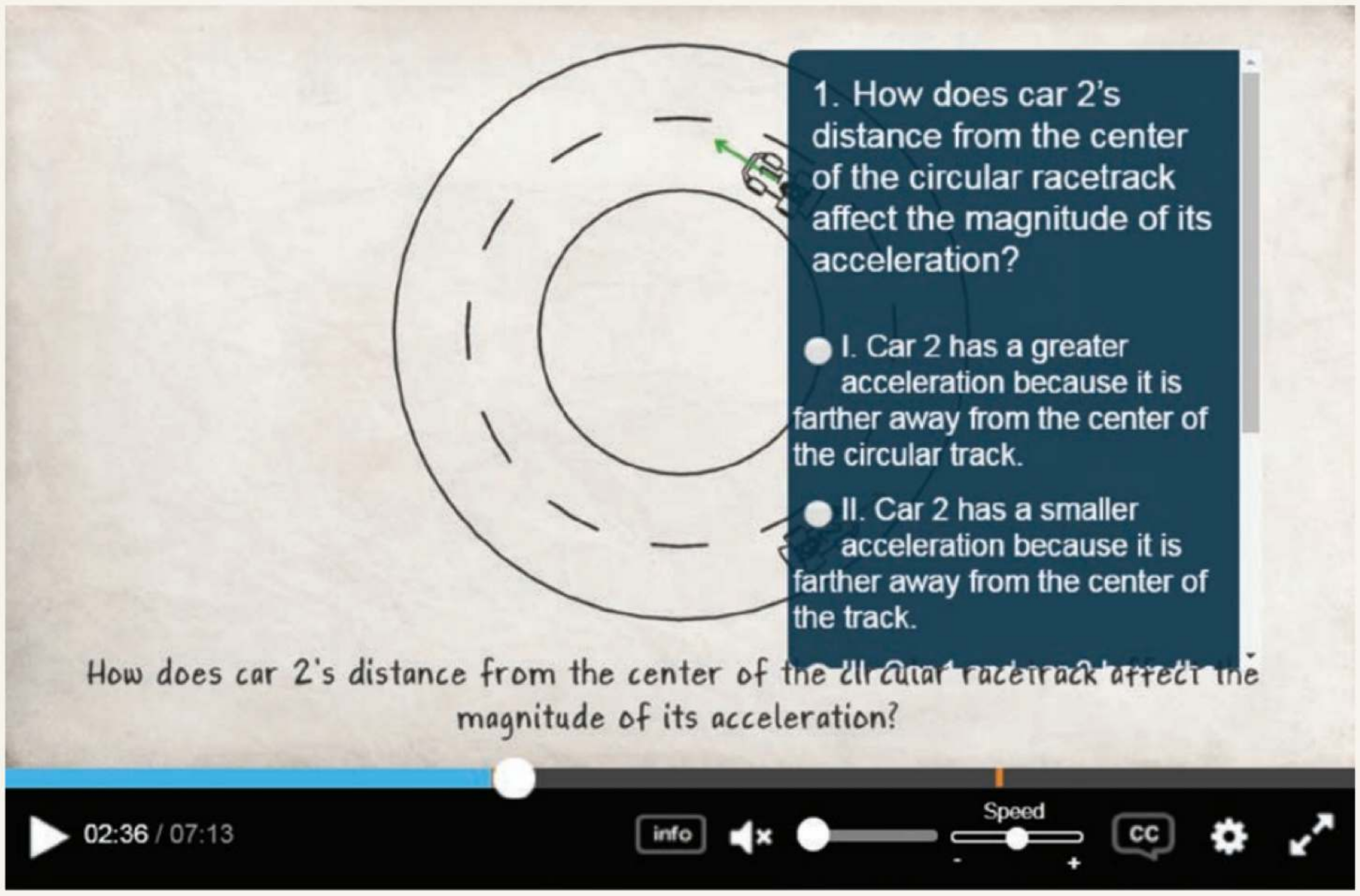
NEW! Test Your Understanding problems are added strategically throughout the chapters, helping students complete an important step of ensuring that their answer makes sense in the real world. Test Your Understanding problems in the eText provide the full solution when students mouseover a problem.



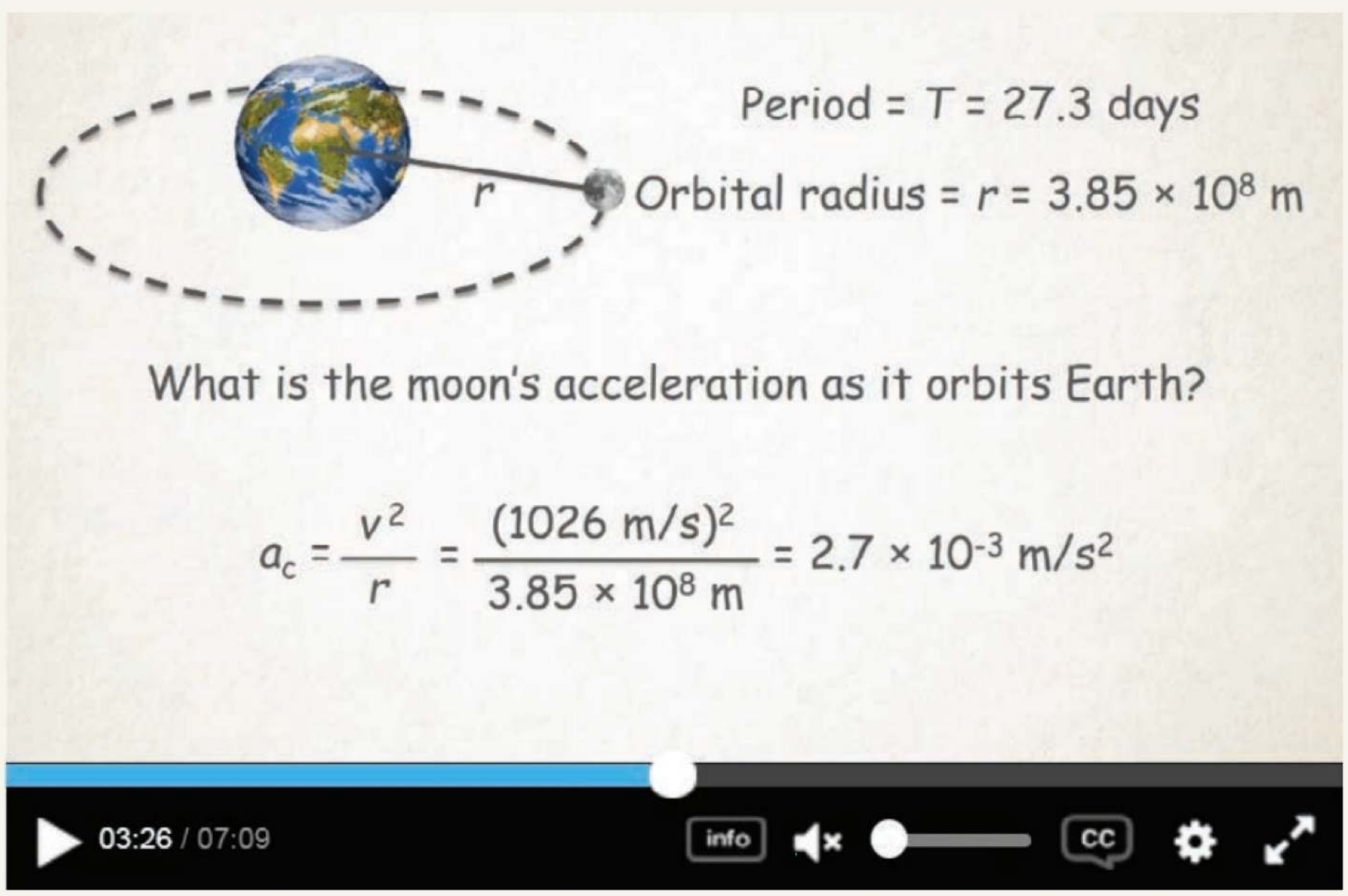
NEW! Direct Measurement Videos show real situations of physical phenomena. Grids, rulers, and frame counters appear as overlays, helping students to make precise measurements of quantities such as position and time. Students then apply these quantities along with physics concepts to solve problems and answer questions about the motion of the objects in the video. The problems are assignable in Mastering and can be used to replace or supplement traditional word problems, or as open-ended questions to help develop problem-solving skills.

even before students come to class



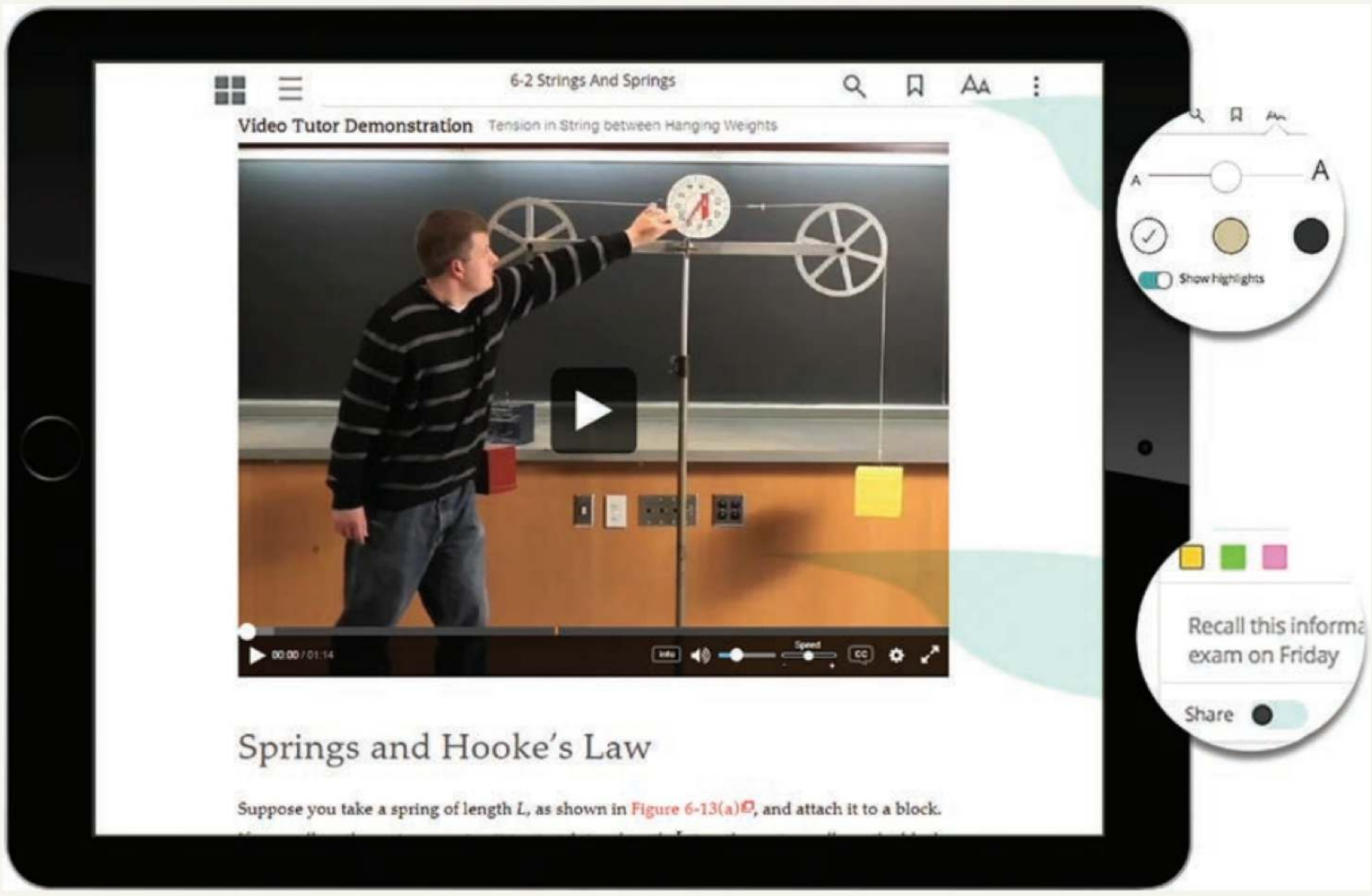
Interactive Pre-lecture Videos provide an introduction to topics with embedded assessment to help students prepare before lecture and to help professors identify student misconceptions.

NEW! 30 Quantitative Pre-lecture Videos now complement the conceptual Interactive Pre-lecture Videos. These videos are designed to expose students to concepts before class and help them learn how problems for a specific concept are worked.

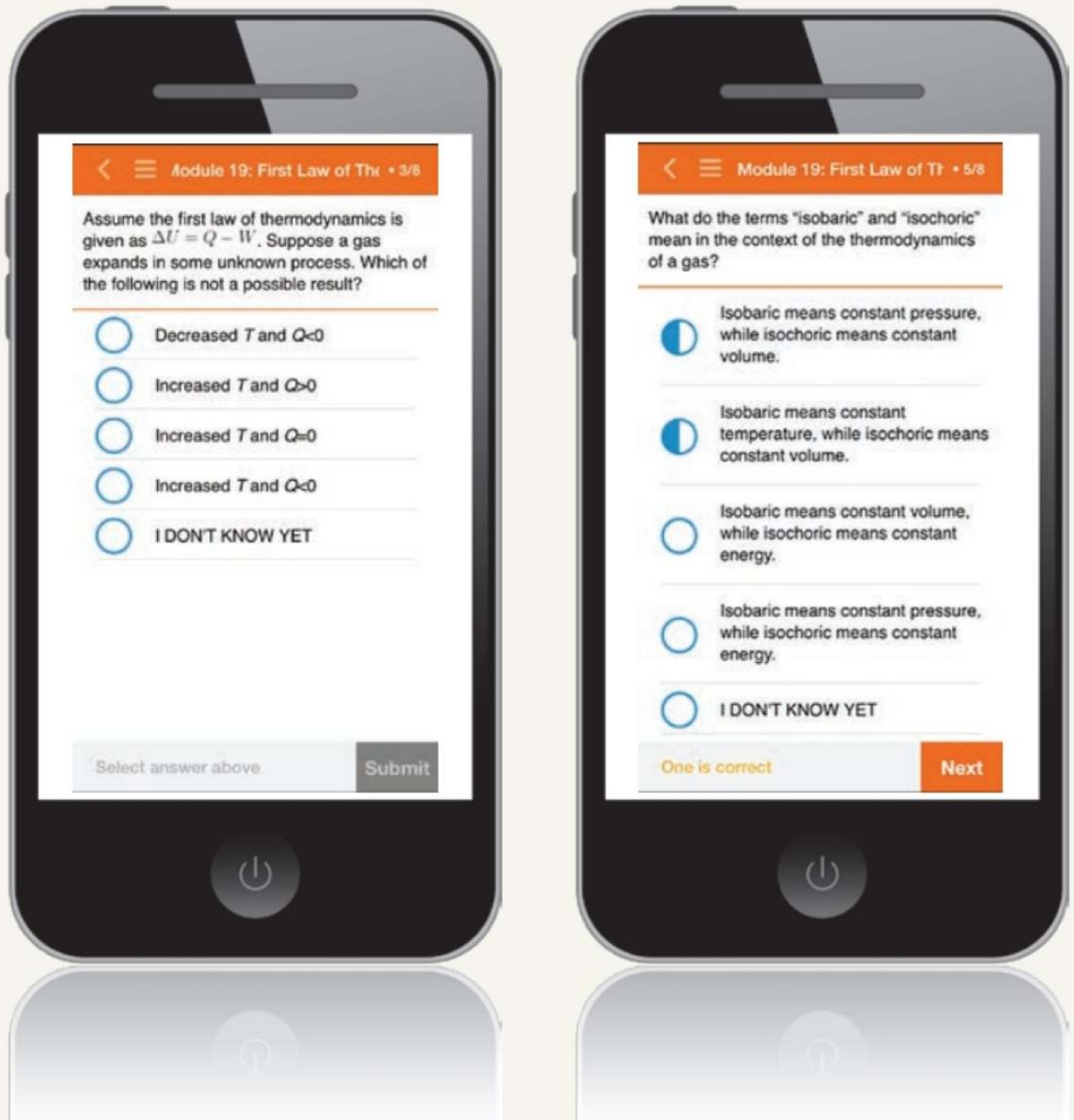


Reach every student . . .

NEW! College Physics is now available in Pearson eText. Pearson eText is a simple-to-use, mobile-optimized, personalized reading experience available within Mastering. It allows students to easily highlight, take notes, and review key vocabulary all in one place—even when offline. Seamlessly integrated videos, rich media, and interactive self-assessment questions engage students and give them access to the help they need, when they need it. Pearson eText is available within Mastering when packaged with a new book; students can also purchase Mastering with Pearson eText online.



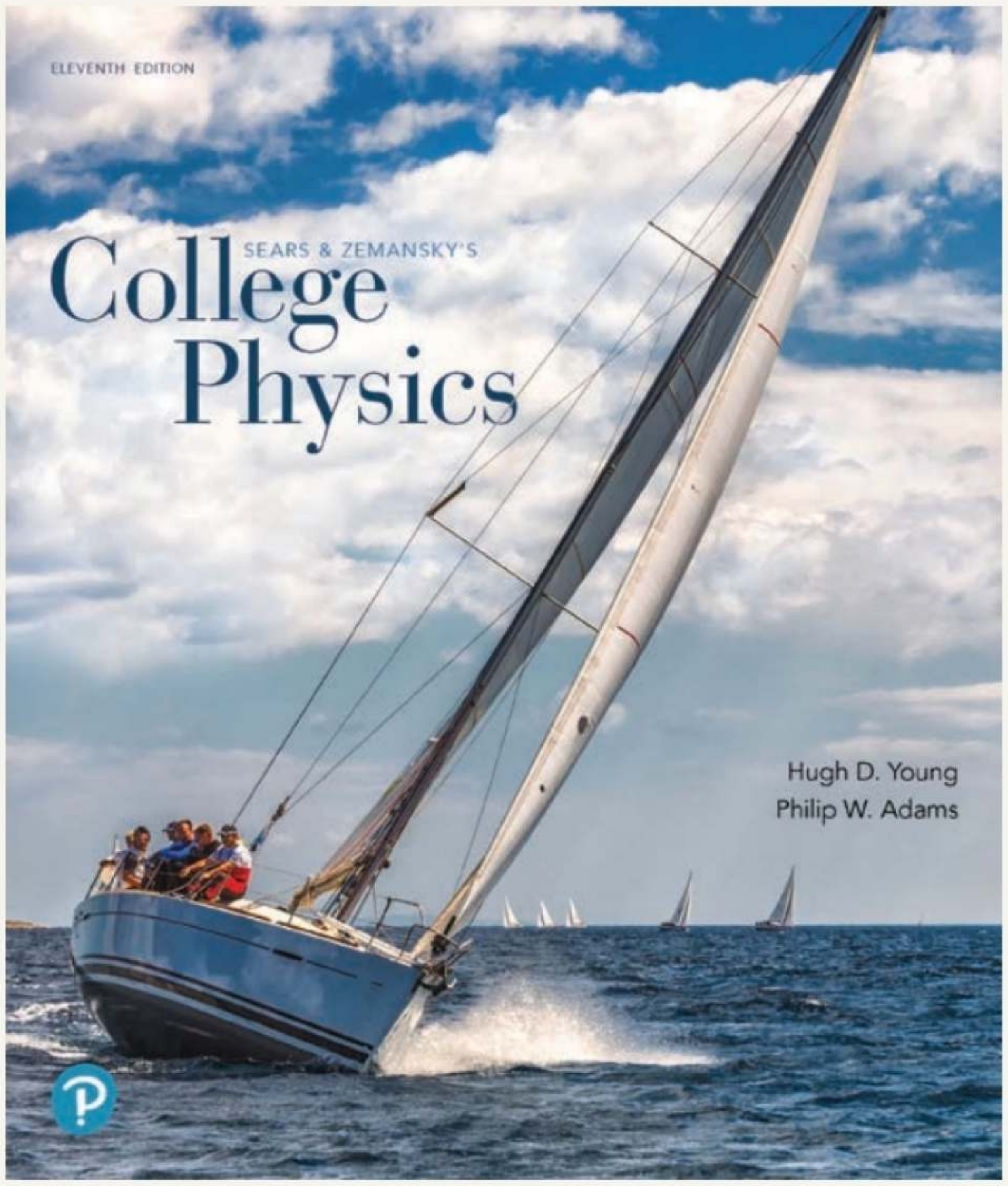
with Mastering Physics



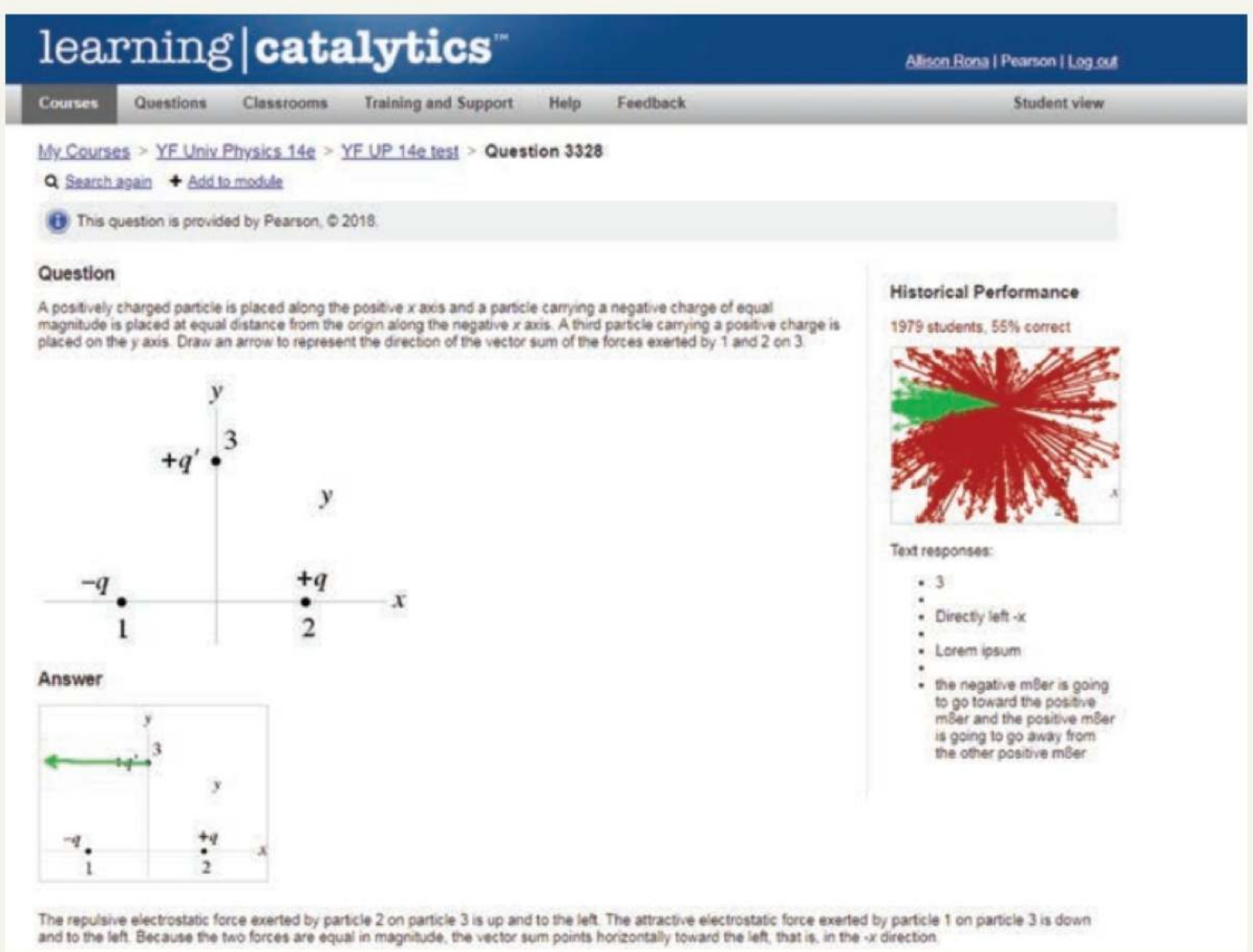
Dynamic Study Modules in Mastering Physics help students study effectively—and at their own pace—by keeping them motivated and engaged. The assignable modules rely on the latest research in cognitive science, using methods—such as adaptivity, gamification, and intermittent rewards—to stimulate learning and improve retention. DSM are available to use on any mobile device.

The Physics Primer relies on videos, hints, and feedback to refresh students' math skills in the context of physics and prepares them for success in the course. These tutorials can be assigned before the course begins or throughout the course as just-in-time remediation. They ensure students practice and maintain their math skills, while tying together mathematical operations and physics analysis.

Instructor support you can rely on



College Physics includes a full suite of instructor support materials in the Instructor Resources area in Mastering Physics. Resources include PowerPoint lecture outlines; all chapter summaries, key equations, and problem-solving strategies from the text; all figures and images from the text; plus a solutions manual and test bank.



Instructors also have access to **Learning Catalytics**. With Learning Catalytics, you'll hear from every student when it matters most. You pose a variety of questions that help students recall ideas, apply concepts, and develop critical-thinking skills. Your students respond using their own smartphones, tablets, or laptops. You can monitor responses with real-time analytics and find out what your students do — and don't — understand. Then, you can adjust your teaching accordingly and even facilitate peer-to-peer learning, helping students stay motivated and engaged.

REAL-WORLD APPLICATIONS

BIO indicates bioscience applications.

TO THE STUDENT

HOW TO SUCCEED IN PHYSICS

"Is physics hard? Is it too hard for me?" Many students are apprehensive about their physics course. However, while the course can be challenging, almost certainly it is *not* too hard for you. If you devote time to the course and use that time wisely, you can succeed.

Here's how to succeed in physics.

1. **Spend time studying.** The rule of thumb for college courses is that you should expect to study about 2 to 3 hours per week for each unit of credit, *in addition* to the time you spend in class. And budget your time: 3 hours every other day is much more effective than 33 hours right before the exam.

   The good news is that physics is consistent. Once you've learned how to tackle one topic, you'll use the same study techniques to tackle the rest of the course. So if you find you need to give the course extra time at first, do so and don't worry—it'll pay dividends as the course progresses.

2. **Don't miss class.** Yes, you could borrow a friend's notes, but listening and participating in class are far more effective. Of course, *participating* means paying active attention, and interacting when you have the chance!

3. **Make this book work for you.** This text is packed with decades of teaching experience—but to make it work for you, you must read and use it *actively*. *Think* about what the text is saying. *Use* the illustrations. Try to *solve* the Test Your Understanding problems on your own, before reading the solutions. If you *underline,* do so thoughtfully and not mechanically.

   Use the Variation Problems to hone your problem solving skills. These problems represent progressive variations on the Key Examples. They are designed to help you recognize and exploit the underlying mathematical similarities of two closely related, yet seemingly completely different, physics problems. This is an important exam skill and it can serve you well!

   A good practice is to skim the chapter before going to class to get a sense for the topic, and then read it carefully and work the examples after class.

4. **Approach physics problems systematically.** While it's important to attend class and use the book, your *real* learning will happen mostly as you work problems—*if* you approach them correctly. Physics problems aren't math problems. You need to approach them in a different way. (If you're "not good at math," this may be good news for you!) What you do before and after solving an equation is more important than the math itself. The worked examples in this book help you develop good habits by consistently following three steps—*Set Up, Solve,* and *Reflect.* (In fact, this global approach will help you with problem solving in all disciplines—chemistry, medicine, business, etc.)

5. **Use campus resources.** If you get stuck, get help. Your professor probably has office hours and email; use them. Use your TA or campus tutoring center if you have one. Partner with a friend to study together. But also try to get unstuck on your own *before* you go for help. That way, you'll benefit more from the help you get.

6. **Honestly assess your level of understanding.** It is crucially important that you honestly acknowledge those concepts and problems that you don't really understand. Too often, students simply tell themselves that they understand a point made in the lecture, or a homework problem, or a concept when, in fact, they don't. Or, even worse, they simply hope that certain questions will not appear on the next exam.

So remember, you *can* succeed in physics. Just devote time to the job, work lots of problems, and get help when you need it. Your book is here to help. Have fun!

SET UP

Think about the physics involved in the situation the problem describes. What information are you given and what do you need to find out? Which physics principles do you need to apply? Almost always you should *draw a sketch* and label it with the relevant known and unknown information. (Many of the worked examples in this book include hand-drawn sketches to coach you on what to draw.)

SOLVE

Based on what you did in Set Up, identify the physics and appropriate equation or equations and do the algebra. Because you started by *thinking about the physics* (and *drawing a diagram*), you'll know which physics equations apply to the situation—you'll avoid the "plug and pray" trap of picking any equation that seems to have the right variables.

REFLECT

Once you have an answer, ask yourself whether it is plausible. If you calculated your weight on the Moon to be 10,423 kg—you must have made a mistake somewhere! Next, check that your answer has the right units. Finally, think about what *you* learned from the problem that will help you later.

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PREFACE

College Physics places equal emphasis on conceptual, qualitative, and quantitative understanding. This classic text gives students a solid understanding of the fundamentals, helps them develop critical thinking, quantitative reasoning, and problem-solving skills, and sparks interest in physics with real-world applications. Informed by physics education research and data of thousands of student users of Mastering Physics, this edition emphasizes learning to solve physics problems in a variety of contexts, and applying physics to the real world.

This text provides a comprehensive introduction to physics. It is intended for students whose mathematics preparation includes high-school algebra and trigonometry but not calculus. The complete text may be taught in a two-semester or three-quarter course, and the book is also adaptable to a wide variety of shorter courses.

NEW TO THIS EDITION

- **83 new Test Your Understanding questions were added to the text.** Now there is a Test Your Understanding box for every quantitative section of the book. These are intended to help students complete the important step of ensuring that their answer makes sense in the real world.
- **New! 180 Example Variation Problems build in difficulty** by adjusting scenarios, changing the knowns vs. unknowns, and adding complexity and a step of reasoning to provide the most helpful range of related problems that use the same fundamental approach to solve. These scaffolded problem sets help students see patterns and make connections between problems types that can be solved by applying the same fundamental principles so that they are less surprised by variations on problems when exam time comes.
- **Proportional Reasoning questions have been further developed.** These are designed to help the students recognize and exploit algebraic relationships between relevant physical quantities. These types of questions commonly appear on physics exams.
- **Streamlined and improved design.** The eleventh edition is more concise than previous editions and now features an open, inviting presentation.
- **Over 70 PhET simulations** are provided in the study area of the Mastering Physics website. These powerful simulations allow students to interact productively with the physics concepts they are learning.
- **Video Tutors bring key content to life throughout the text:**
  - **Over 50 Video Tutor Demonstrations feature interactive "pause-and-predict" demonstrations of key concepts.** The videos actively engage students and help uncover misconceptions.
  - **Video Tutor Solutions accompany every Worked Example and Bridging Problem in the book.** These narrated videos walk students through the problem-solving process, acting as a virtual teaching assistant on a round-the-clock basis. Students can access the Video Tutor Solutions using QR codes conveniently placed in the text, through links in the eText, or through the study area within Mastering Physics.
- **Assignable Mastering Physics activities are based on the Pause and Predict Video Tutors and PhET simulations.**
  - **Video Tutor Demonstrations with assessment allow the student** to extend their understanding by answering a follow-up question.
  - **PhET tutorials prompt students to explore the PhET simulations** and use them to answer questions and solve problems, helping them to make connections between real life phenomena and the underlying physics that explains such phenomena.

Complete and Two-Volume Editions

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- **Volume 2:** Chapters 17–30 (ISBN 978-0-134-98731-6)

KEY FEATURES OF *COLLEGE PHYSICS*

- **A systematic approach to problem solving.** To solve problems with confidence, students must learn to approach problems effectively at a global level, must understand the physics in question, and must acquire the specific skills needed for particular types of problems. The Tenth Edition provides research-proven tools for students to tackle each goal.
    - Expanded Bridging Problems, now available in Mastering Physics, and additional **Practice Problems** provide extra support for students as they learn to solve problems in physics.
    - Each **worked example** follows a consistent and explicit **global problem-solving strategy** drawn from educational research. This three-step approach puts special emphasis on how to **set up** the problem before trying to **solve** it, and the importance of how to **reflect** on whether the answer is sensible.
    - **New - Example Variation Problems** build in difficulty by adjusting scenarios, changing the knowns vs. unknowns, and adding complexity and a step of reasoning to provide the most helpful range of related problems that use the same fundamental approach to solve. These scaffolded problem sets help students see patterns and make connections between problems types that can be solved, applying the same fundamental principles so that they are less surprised by variations on problems when exam time comes. Assignable in Mastering Physics.
    - Worked example solutions model the steps and decisions students should use but often skip. Worked examples include new **pencil diagrams:** hand-drawn diagrams that show exactly what a student should draw in the **set up** step of solving the problem. Also included are practice problems for the worked examples. These practice problems are now assignable in Mastering Physics.
- **Test Your Understanding** problems help students practice their qualitative and quantitative understanding of the physics. These featured problems focus on skills of quantitative and proportional reasoning—skills that are key to success on the MCATs. The TYU's use a multiple-choice format to elicit specific common misconceptions.
- **Problem-solving strategies** sections walk students through tactics for tackling particular types of problems—such as problems requiring Newton's second law or energy conservation—and follow the same 3-step global approach (set up, solve, and reflect).
- **Highly effective figures incorporate the latest ideas from educational research.** Color is used only for strict pedagogical purposes—for instance, in mechanics, **color is used to identify the object of interest,** while all other objects are gray. **Blue annotated comments** guide students in "reading" graphs and figures.
- **Visual chapter summaries** show each concept in words, math, and figures to reinforce how to "translate" between different representations and address different student learning styles.
- **Rich and diverse end-of-chapter problem sets.** *College Physics* features the renowned Sears/Zemansky problems, refined over five decades. We've used data from Mastering Physics to identify the strongest and most successful problems to retain for the tenth edition and we've added new problems. Multiple estimation questions were added to the Conceptual and Estimation Questions section of each chapter.
- Each chapter includes a set of **multiple-choice problems** that test the skills developed by the Test Your Understanding problems in the chapter text. The multiple-choice format elicits specific common misconceptions, enabling students to pinpoint their misunderstandings.
- The General Problems contain many **context-rich problems** that require students to simplify and model more complex real-world situations. Many problems relate to the fields of biology and medicine; these are all labeled BIO.
- **MCAT-style Passage Problems** appear in each chapter and follow the format used in the MCAT exam. These problems require students to investigate multiple aspects of a real-life physical situation, typically biological in nature, as described in a reading passage.

- **Connections of physics to the student's world.** Even more in-margin applications provide diverse, interesting, and self-contained examples of physics at work in the world. Many of these real-world applications are related to the fields of biology and medicine and are labeled BIO.
- **Writing that is easy to follow and rigorous.** The writing is friendly yet focused; it conveys an exact, careful, straightforward understanding of the physics, with an emphasis on the connections between concepts.

INSTRUCTOR SUPPLEMENTS

Note: *For convenience, all of the following instructor supplements can be accessed via Mastering Physics (www.masteringphysics.com).*

Instructor Solutions, prepared by A. Lewis Ford (Texas A&M University) and Brett Kraabel contain complete and detailed solutions to all end-of-chapter problems. All solutions follow consistently the same Set Up/Solve/Reflect problem-solving framework used in the textbook. Download only from the Mastering Physics Instructor Area or from the Instructor Resource Center (www.pearsonhighered.com/irc).

The **Instructor Resource** Collection, available on Mastering Physics, provides all line figures from the textbook in JPEG format. In addition, all the key equations, problem-solving strategies, tables, and chapter summaries are provided in editable Word format. Lecture outlines in PowerPoint are also included, along with over 70 PhET simulations as well as Video Tutor Demonstrations and Video Tutor Solutions.

Mastering Physics® (www.masteringphysics.com) is the most advanced, educationally effective, and widely used physics homework and tutorial system in the world. Eight years in development, it provides instructors with a library of extensively pre-tested end-of-chapter problems and rich, multipart, multistep tutorials that incorporate a wide variety of answer types, wrong answer feedback, individualized help (comprising hints or simpler sub-problems upon request), all driven by the largest metadatabase of student problem-solving in the world. NSF-sponsored published research (and subsequent studies) show that Mastering Physics has dramatic educational results. Mastering Physics allows instructors to build wide-ranging homework assignments of just the right difficulty and length and provides them with efficient tools to analyze both class trends and the work of any student in unprecedented detail.

Mastering Physics routinely provides instant and individualized feedback and guidance to more than 100,000 students every day. A wide range of tools and support makes Mastering Physics fast and easy for instructors and students to learn to use. Extensive class tests show that by the end of their course, an unprecedented eight of nine students recommend Mastering Physics as their preferred way to study physics and do homework.

Mastering Physics enables instructors to:

- Quickly build homework assignments that combine regular end-of-chapter problems and tutoring (through additional multistep tutorial problems that offer wrong-answer feedback and simpler problems upon request).
- Expand homework to include the widest range of automatically graded activities available—from numerical problems with randomized values, through algebraic answers, to free-hand drawing.
- Choose from a wide range of nationally pre-tested problems that provide accurate estimates of time to complete and difficulty.
- After an assignment is completed, quickly identify not only the problems that were the trickiest for students but the individual problem types where students had trouble.
- Compare class results against the system's worldwide average for each problem assigned, to identify issues to be addressed with just-in-time teaching.
- Check the work of individual students in detail, including time spent on each problem, what wrong answers they submitted at each step, how much help they asked for, and how many practice problems they worked.

NEW TO MASTERING PHYSICS

Teach your course your way: Your course is unique. So whether you'd like to build your own auto-graded assignments, foster student engagement during class, or give students anytime, anywhere access, Mastering gives you the flexibility to easily create *your* course to fit *your* needs.

- With **Learning Catalytics,** you'll hear from every student when it matters most. You pose a variety of questions that help students recall ideas, apply concepts, and develop critical-thinking skills. Your students respond using their own smartphones, tablets, or laptops. You can monitor responses with real-time analytics and find out what your students do—and don't—understand. Then, you can adjust your teaching accordingly, and even facilitate peer-to-peer learning, helping students stay motivated and engaged.
- **Dynamic Study Modules** help students study effectively—and at their own pace. How? By keeping them motivated and engaged. The assignable modules rely on the latest research in cognitive science, using methods—such as adaptivity, gamification, and intermittent rewards—to stimulate learning and improve retention. Each module poses a series of questions about a course topic. These question sets adapt to each student's performance and offer personalized, targeted feedback to help them master key concepts.
- **The Physics Primer** relies on videos, hints, and feedback to refresh students' math skills in the context of physics and prepares them for success in the course. These tutorials can be assigned before the course begins or throughout the course as just-in-time remediation. They ensure students practice and maintain their math skills, while tying together mathematical operations and physics analysis.

Empower each learner: Each student learns at a different pace. Personalized learning, including adaptive tools and wrong-answer feedback, pinpoints the precise areas where each student needs practice and gives all students the support they need—when and where they need it—to be successful.

- **New–Direct Measurement Videos** are short videos that show real situations of physical phenomena. Grids, rulers, and frame counters appear as overlays, helping students to make precise measurements of quantities such as position and time. Students then apply these quantities along with physics concepts to solve problems and answer questions about the motion of the objects in the video. The problems are assignable in Mastering and can be used to replace or supplement traditional word problems, or as open-ended questions to help develop problem-solving skills.
- **Interactive Prelecture Videos** provide an introduction to key topics with embedded assessment to help students prepare before lecture and to help professors identify student misconceptions.
- **New–30 Quantitative Pre-lecture Videos** now complement the conceptual Interactive Pre-lecture Videos. These videos are designed to expose students to concepts before class and help them learn how problems for a specific concept are worked.
- **Test Your Understanding** problems in the eText provide the full solution when students mouseover a problem.

Deliver trusted content: We partner with highly respected authors to develop interactive content and course-specific resources that keep students on track and engaged.

- **Video Tutor Demonstrations and Video Tutor Solutions** tie directly to relevant content in the textbook and can be accessed through Mastering Physics or from QR codes in the textbook.
- **Video Tutor Solutions (VTSs) for every Example and Bridging Problem** in the book walk students through the problem-solving process, providing a virtual teaching assistant on a round-the-clock basis. New VTSs correspond to new and revised worked examples.
- **Video Tutor Demonstrations (VTDs)** feature "pause-and-predict" demonstrations of key physics concepts and incorporate assessment to engage students in understanding key concepts. New VTDs build on the existing collection, adding new topics for a more robust set of demonstrations.

- **Pearson eText** is a simple-to-use, mobile-optimized, personalized reading experience available within Mastering. It allows students to easily highlight, take notes, and review key vocabulary all in one place—even when offline. Seamlessly integrated videos and other rich media engage students and give them access to the help they need, when they need it.
- **New–Enhanced End-of-Chapter Questions** provide instructional support when and where students need it including links to the eText, Video Tutor Solutions, math remediation and wrong-answer feedback for homework assignments.

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