SEARS AND ZEMANSKY'S

UNIVERSITY PHYSICS

WITH MODERN PHYSICS

14TH EDITION

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BRIEF CONTENTS

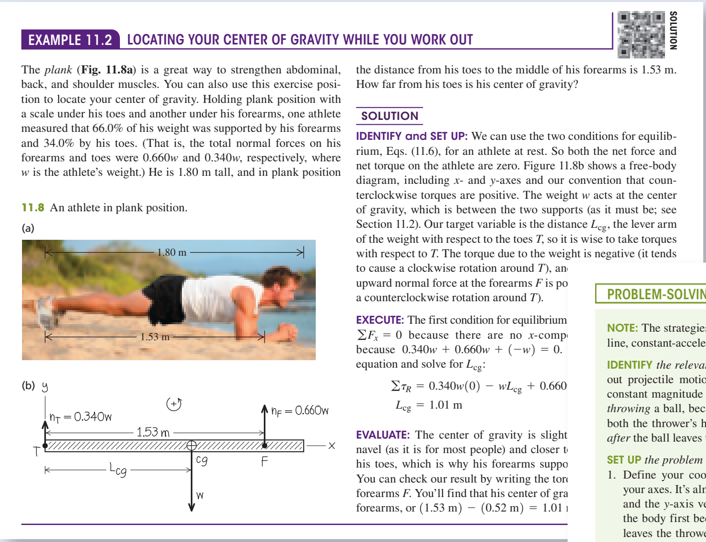
VOLUME 1: Chapters 1–20 • VOLUME 2: Chapters 21–37 • VOLUME 3: Chapters 37–44

THE BENCHMARK FOR CLARITY AND RIGOR

Since its first edition, ***University Physics*** has been renowned for its emphasis on fundamental principles and how to apply them. This text is known for its clear and thorough narrative and for its uniquely broad, deep, and thoughtful set of worked examples—key tools for developing both conceptual understanding and problem-solving skills.

The **Fourteenth Edition** improves the defining features of the text while adding new features influenced by physics education research. A focus on visual learning, new problem types, and pedagogy informed by MasteringPhysics metadata headline the improvements designed to create the best learning resource for today's physics students.

A FOCUS ON PROBLEM SOLVING



EXAMPLE 11.2 LOCATING YOUR CENTER OF GRAVITY WHILE YOU WORK OUT

SOLUTION

The *plank* (**Fig. 11.8a**) is a great way to strengthen abdominal, back, and shoulder muscles. You can also use this exercise position to locate your center of gravity. Holding plank position with a scale under his toes and another under his forearms, one athlete measured that 66.0% of his weight was supported by his forearms and 34.0% by his toes. (That is, the total normal forces on his forearms and toes were $0.660w$ and $0.340w$, respectively, where w is the athlete's weight.) He is 1.80 m tall, and in plank position the distance from his toes to the middle of his forearms is 1.53 m. How far from his toes is his center of gravity?

11.8 An athlete in plank position.

(a) 1.80 m; 1.53 m

(b) y; $n_T = 0.340w$; $n_F = 0.660w$; 1.53 m; T; cg; F; x; L_{cg}; w

SOLUTION

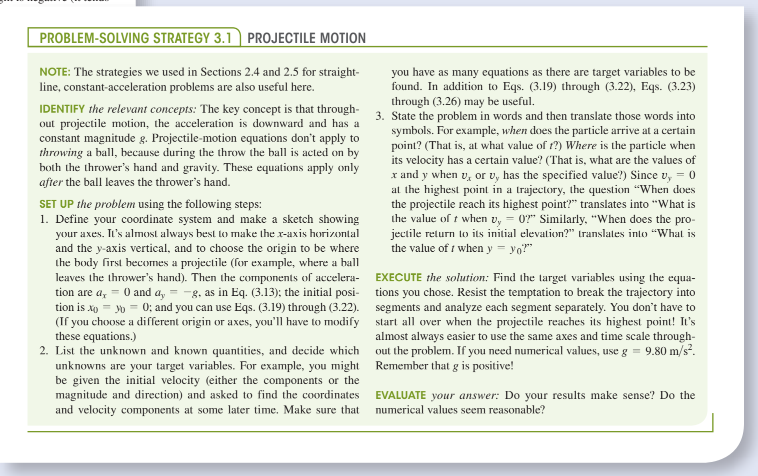
IDENTIFY and SET UP: We can use the two conditions for equilibrium, Eqs. (11.6), for an athlete at rest. So both the net force and net torque on the athlete are zero. Figure 11.8b shows a free-body diagram, including x- and y-axes and our convention that counterclockwise torques are positive. The weight w acts at the center of gravity, which is between the two supports (as it must be; see Section 11.2). Our target variable is the distance L_{cg}, the lever arm of the weight with respect to the toes T, so it is wise to take torques with respect to T. The torque due to the weight is negative (it tends to cause a clockwise rotation around T), an upward normal force at the forearms F is po a counterclockwise rotation around T).

EXECUTE: The first condition for equilibrium $\Sigma F_x = 0$ because there are no x-comp because $0.340w + 0.660w + (-w) = 0$. equation and solve for L_{cg}:

$$\Sigma\tau_R = 0.340w(0) - wL_{cg} + 0.660$$
$$L_{cg} = 1.01 \text{ m}$$

EVALUATE: The center of gravity is slight navel (as it is for most people) and closer t his toes, which is why his forearms suppo You can check our result by writing the tor forearms F. You'll find that his center of gra forearms, or $(1.53 \text{ m}) - (0.52 \text{ m}) = 1.01$

◀ A research-based **PROBLEM-SOLVING APPROACH**—**IDENTIFY, SET UP, EXECUTE, EVALUATE**—is used in every Example and throughout the Student's and Instructor's Solutions Manuals and the Study Guide. This consistent approach teaches students to tackle problems thoughtfully rather than cutting straight to the math.



PROBLEM-SOLVING STRATEGY 3.1 PROJECTILE MOTION

NOTE: The strategies we used in Sections 2.4 and 2.5 for straight-line, constant-acceleration problems are also useful here.

IDENTIFY *the relevant concepts:* The key concept is that throughout projectile motion, the acceleration is downward and has a constant magnitude g. Projectile-motion equations don't apply to *throwing* a ball, because during the throw the ball is acted on by both the thrower's hand and gravity. These equations apply only *after* the ball leaves the thrower's hand.

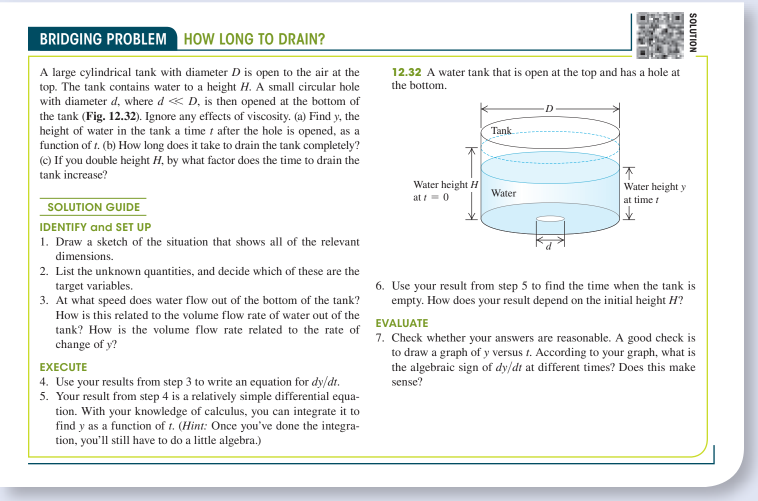
SET UP *the problem* using the following steps:

1. Define your coordinate system and make a sketch showing your axes. It's almost always best to make the x-axis horizontal and the y-axis vertical, and to choose the origin to be where the body first becomes a projectile (for example, where a ball leaves the thrower's hand). Then the components of acceleration are $a_x = 0$ and $a_y = -g$, as in Eq. (3.13); the initial position is $x_0 = y_0 = 0$; and you can use Eqs. (3.19) through (3.22). (If you choose a different origin or axes, you'll have to modify these equations.)
2. List the unknown and known quantities, and decide which unknowns are your target variables. For example, you might be given the initial velocity (either the components or the magnitude and direction) and asked to find the coordinates and velocity components at some later time. Make sure that you have as many equations as there are target variables to be found. In addition to Eqs. (3.19) through (3.22), Eqs. (3.23) through (3.26) may be useful.
3. State the problem in words and then translate those words into symbols. For example, *when* does the particle arrive at a certain point? (That is, at what value of t?) *Where* is the particle when its velocity has a certain value? (That is, what are the values of x and y when v_x or v_y has the specified value?) Since $v_y = 0$ at the highest point in a trajectory, the question "When does the projectile reach its highest point?" translates into "What is the value of t when $v_y = 0$?" Similarly, "When does the projectile return to its initial elevation?" translates into "What is the value of t when $y = y_0$?"

EXECUTE *the solution:* Find the target variables using the equations you chose. Resist the temptation to break the trajectory into segments and analyze each segment separately. You don't have to start all over when the projectile reaches its highest point! It's almost always easier to use the same axes and time scale throughout the problem. If you need numerical values, use $g = 9.80 \text{ m/s}^2$. Remember that g is positive!

EVALUATE *your answer:* Do your results make sense? Do the numerical values seem reasonable?

PROBLEM-SOLVING STRATEGIES ▶ coach students in how to approach specific types of problems.



BRIDGING PROBLEM HOW LONG TO DRAIN?

SOLUTION

A large cylindrical tank with diameter D is open to the air at the top. The tank contains water to a height H. A small circular hole with diameter d, where $d \ll D$, is then opened at the bottom of the tank (**Fig. 12.32**). Ignore any effects of viscosity. (a) Find y, the height of water in the tank a time t after the hole is opened, as a function of t. (b) How long does it take to drain the tank completely? (c) If you double height H, by what factor does the time to drain the tank increase?

SOLUTION GUIDE

IDENTIFY and SET UP

1. Draw a sketch of the situation that shows all of the relevant dimensions.
2. List the unknown quantities, and decide which of these are the target variables.
3. At what speed does water flow out of the bottom of the tank? How is this related to the volume flow rate of water out of the tank? How is the volume flow rate related to the rate of change of y?

EXECUTE

4. Use your results from step 3 to write an equation for dy/dt.
5. Your result from step 4 is a relatively simple differential equation. With your knowledge of calculus, you can integrate it to find y as a function of t. (*Hint:* Once you've done the integration, you'll still have to do a little algebra.)

12.32 A water tank that is open at the top and has a hole at the bottom.

D; Tank; Water height H at $t = 0$; Water; Water height y at time t; d

6. Use your result from step 5 to find the time when the tank is empty. How does your result depend on the initial height H?

EVALUATE

7. Check whether your answers are reasonable. A good check is to draw a graph of y versus t. According to your graph, what is the algebraic sign of dy/dt at different times? Does this make sense?

◀ **BRIDGING PROBLEMS**, which help students move from single-concept worked examples to multi-concept problems at the end of the chapter, have been revised, based on reviewer feedback, ensuring that they are effective and at the appropriate difficulty level.

INFLUENCED BY THE LATEST IN EDUCATION RESEARCH

PEDAGOGY INFORMED BY DATA AND RESEARCH

DATA *SPEAKS*

Gravitation

When students were given a problem about superposition of gravitational forces, more than 60% gave an incorrect response. Common errors:

- Assuming that equal-mass objects *A* and *B* must exert equally strong gravitational attraction on an object *C* (which is not true when *A* and *B* are different distances from *C*).
- Neglecting to account for the vector nature of force. (To add two forces that point in different directions, you can't just add the force magnitudes.)

◀ **DATA SPEAKS SIDEBARS**, based on MasteringPhysics metadata, alert students to the statistically most common mistakes made in solving problems on a given topic.

Coordinates at time t of a **projectile** (positive y-direction is upward, and $x = y = 0$ at $t = 0$)

$$x = (v_0 \cos \alpha_0)t \qquad (3.19)$$

Speed at $t = 0$ · Direction at $t = 0$ · Time

$$y = (v_0 \sin \alpha_0)t - \tfrac{1}{2}gt^2 \qquad (3.20)$$

Velocity components at time t of a **projectile** (positive y-direction is upward)

$$v_x = v_0 \cos \alpha_0 \qquad (3.21)$$

Speed at $t = 0$ · Direction at $t = 0$ · Acceleration due to gravity: Note $g > 0$. · Time

$$v_y = v_0 \sin \alpha_0 - gt \qquad (3.22)$$

▲ All **KEY EQUATIONS ARE NOW ANNOTATED** to help students make a connection between a conceptual and a mathematical understanding of physics.

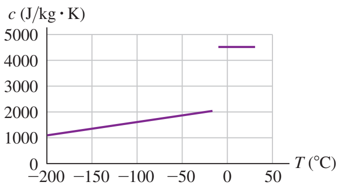
PASSAGE PROBLEMS

BIO PRESERVING CELLS AT COLD TEMPERATURES. In cryopreservation, biological materials are cooled to a very low temperature to slow down chemical reactions that might damage the cells or tissues. It is important to prevent the materials from forming ice crystals during freezing. One method for preventing ice formation is to place the material in a protective solution called a *cryoprotectant*. Stated values of the thermal properties of one cryoprotectant are listed here:

Melting point	−20°C
Latent heat of fusion	2.80×10^5 J/kg
Specific heat (liquid)	4.5×10^3 J/kg · K
Specifi	
Therma	
Therma	

17.117 Careful measurements show that the specific heat of the solid phase depends on temperature (**Fig. P17.117**). How will the actual time needed for this cryoprotectant to come to equilibrium with the cold plate compare with the time predicted by using the values in the table? Assume that all values other than the specific heat (solid) are correct. The actual time (a) will be shorter; (b) will be longer; (c) will be the same; (d) depends on the density of the cryoprotectant.

Figure **P17.117**



▲ Each chapter includes three to five **PASSAGE PROBLEMS**, which follow the format used in the MCATs. These problems require students to investigate multiple aspects of a real-life physical situation, typically biological in nature, as described in a reading passage.

DATA PROBLEMS appear in each chapter. These data-based reasoning problems, many of which are context rich, require students to use experimental evidence, presented in a tabular or graphical format, to formulate conclusions. ▼

9.89 •• **DATA** You are rebuilding a 1965 Chevrolet. To decide whether to replace the flywheel with a newer, lighter-weight one, you want to determine the moment of inertia of the original, 35.6-cm-diameter flywheel. It is not a uniform disk, so you can't use $I = \frac{1}{2}MR^2$ to calculate the moment of inertia. You remove the flywheel from the car and use low-friction bearings to mount it on a horizontal, stationary rod that passes through the center of the flywheel, which can then rotate freely (about 2 m above the ground). After gluing one end of a long piece of flexible fishing line to the rim of the flywheel, you wrap the line a number of turns around the rim and suspend a 5.60-kg metal block from the free end of the line. When you release the block from rest, it descends as the flywheel rotates. With high-speed photography you measure the distance d the block has moved downward as a function of the time since it was released. The equation for the graph shown in **Fig. P9.89** that gives a good fit to the data points is $d = (165 \text{ cm/s}^2)t^2$. (a) Based on the graph, does the block fall with constant acceleration? Explain. (b) Use the graph to calculate the speed of the block when it has descended 1.50 m. (c) Apply conservation of mechanical energy to the system of flywheel and block to calculate the moment of inertia of the flywheel. (d) You are relieved that the fishing line doesn't break. Apply Newton's second law to the block to find the tension in the line as the block descended.

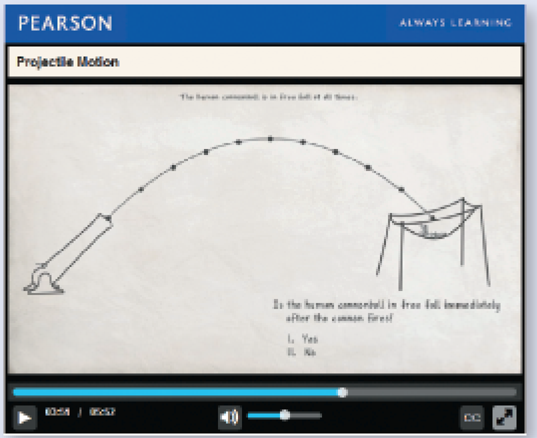
PERSONALIZE LEARNING WITH MASTERINGPHYSICS

MasteringPhysics® from Pearson is the leading online homework, tutorial, and assessment system, designed to improve results by engaging students before, during, and after class with powerful content. Instructors can now ensure that students arrive ready to learn by assigning educationally effective content before class, and encourage critical thinking and retention with in-class resources such as Learning Catalytics. Students can further master concepts after class through traditional and adaptive homework assignments that provide hints and answer-specific feedback. The Mastering gradebook records scores for all automatically graded assignments in one place, while diagnostic tools give instructors access to rich data to assess student understanding and misconceptions.

Mastering brings learning full circle by continuously adapting to each student and making learning more personal than ever—before, during, and after class.

BEFORE CLASS

INTERACTIVE PRE-LECTURE VIDEOS address the rapidly growing movement toward pre-lecture teaching and flipped classrooms. These videos provide a conceptual introduction to key topics. Embedded assessment helps students to prepare before lecture and instructors to identify student misconceptions.

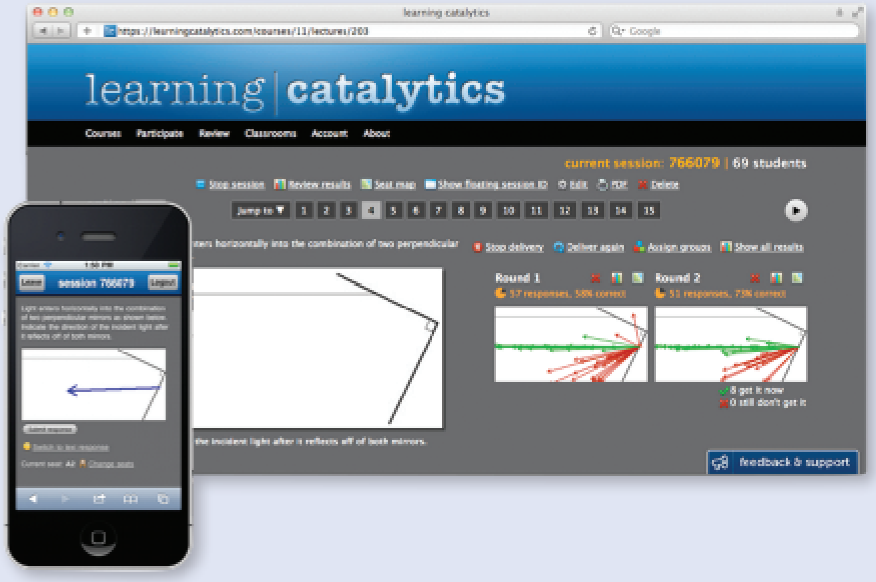


PRE-LECTURE CONCEPT QUESTIONS check familiarity with key concepts, prompting students to do their assigned reading prior to coming to class. These quizzes keep students on track, keep them more engaged in lecture, and help you spot the concepts with which they have the most difficulty. Open-ended essay questions help students identify what they find most difficult about a concept, better informing you and assisting with "just-in-time" teaching.

DURING CLASS

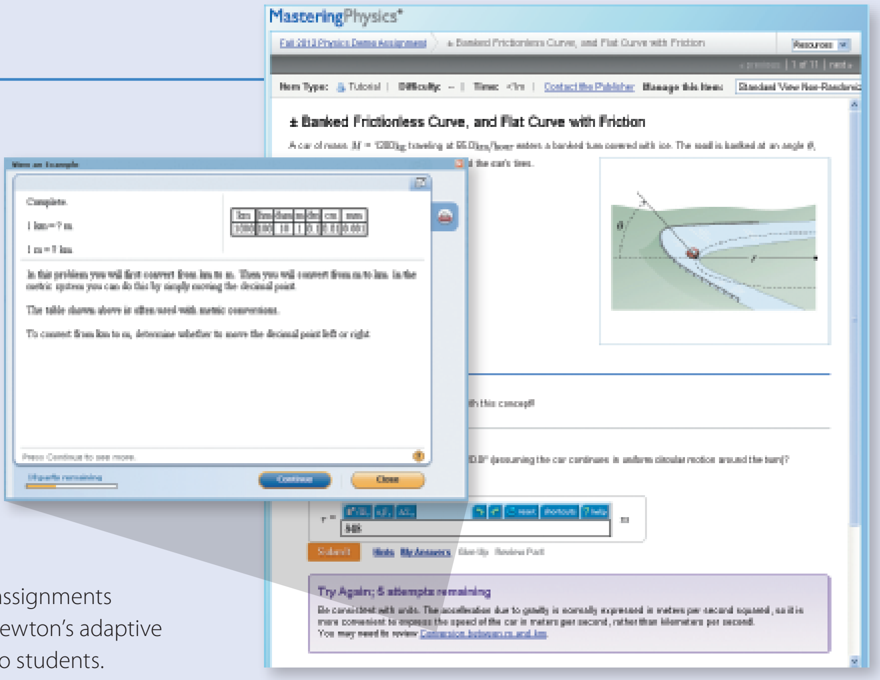
LEARNING CATALYTICS™ is a "bring your own device" student engagement, assessment, and classroom intelligence system. With Learning Catalytics you can:

- Assess students in real time, using open-ended tasks to probe student understanding.
- Understand immediately where students are and adjust your lecture accordingly.
- Improve your students' critical-thinking skills.
- Access rich analytics to understand student performance.
- Add your own questions to make Learning Catalytics fit your course exactly.
- Manage student interactions with intelligent grouping and timing.



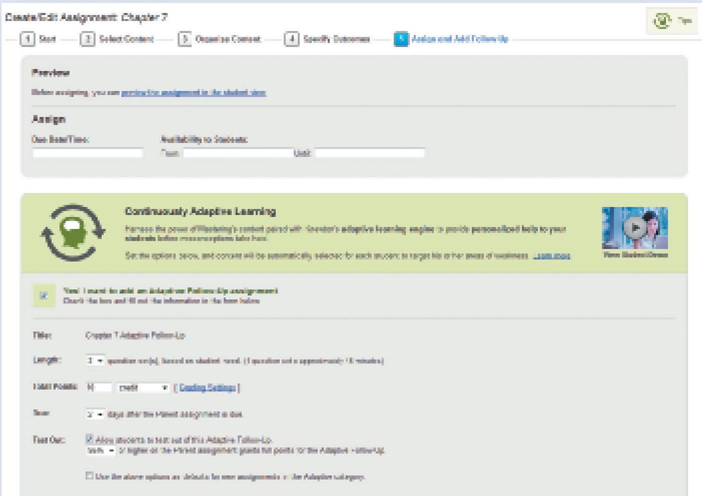
BEFORE, DURING, AND AFTER CLASS

AFTER CLASS

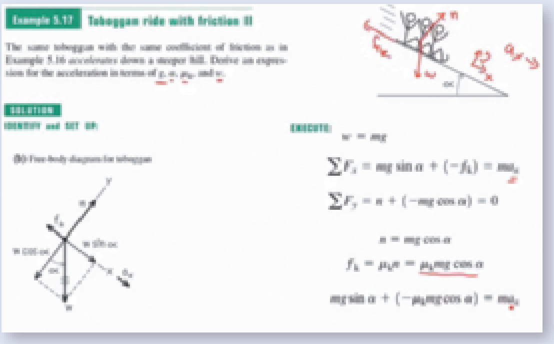


TUTORIALS featuring specific wrong-answer feedback, hints, and a wide variety of educationally effective content guide your students through the toughest topics in physics. The hallmark Hints and Feedback offer instruction similar to what students would experience in an office hour, allowing them to learn from their mistakes without being given the answer. ▶

ADAPTIVE FOLLOW-UPS are personalized assignments that pair Mastering's powerful content with Knewton's adaptive learning engine to provide personalized help to students. These assignments address common student misconceptions and topics students struggled with on assigned homework, including core prerequisite topics. ▼

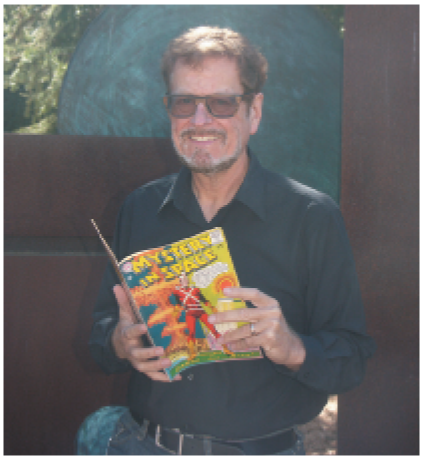


VIDEO TUTOR DEMONSTRATIONS, available in the Study Area and in the Item Library and accessible by QR code in the textbook, feature "pause-and-predict" demonstrations of key physics concepts as assessment to engage students actively in understanding key concepts. New VTDs build on the existing collection, adding new topics for a more robust set of demonstrations. ▼



◀ **VIDEO TUTOR SOLUTIONS** are tied to each worked example and Bridging Problem in the textbook and can be accessed through MasteringPhysics or from QR codes in the textbook. They walk students through the problem-solving process, providing a virtual teaching assistant on a round-the-clock basis.

ABOUT THE AUTHORS



Roger A. Freedman is a Lecturer in Physics at the University of California, Santa Barbara. He was an undergraduate at the University of California campuses in San Diego and Los Angeles and did his doctoral research in nuclear theory at Stanford University under the direction of Professor J. Dirk Walecka. Dr. Freedman came to UCSB in 1981 after three years of teaching and doing research at the University of Washington.

At UCSB, Dr. Freedman has taught in both the Department of Physics and the College of Creative Studies, a branch of the university intended for highly gifted and motivated undergraduates. He has published research in nuclear physics, elementary particle physics, and laser physics. In recent years, he has worked to make physics lectures a more interactive experience through the use of classroom response systems and pre-lecture videos.

In the 1970s Dr. Freedman worked as a comic book letterer and helped organize the San Diego Comic-Con (now the world's largest popular culture convention) during its first few years. Today, when not in the classroom or slaving over a computer, Dr. Freedman can be found either flying (he holds a commercial pilot's license) or with his wife, Caroline, cheering on the rowers of UCSB Men's and Women's Crew.

IN MEMORIAM: HUGH YOUNG (1930–2013)

Hugh D. Young was Emeritus Professor of Physics at Carnegie Mellon University. He earned both his undergraduate and graduate degrees from that university. He earned his Ph.D. in fundamental particle theory under the direction of the late Richard Cutkosky. Dr. Young joined the faculty of Carnegie Mellon in 1956 and retired in 2004. 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 for their well-known introductory textbooks. In addition to his role on Sears and Zemansky's *University Physics,* he was the author of Sears and Zemansky's *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. He often ventured into the wilderness to hike, climb, or go caving with students in Carnegie Mellon's Explorers Club, which he founded as a graduate student and later advised. Dr. Young and his wife, Alice, hosted up to 50 students each year for Thanksgiving dinners in their home.

Always gracious, Dr. Young expressed his appreciation earnestly: "I want to extend my heartfelt thanks to my colleagues at Carnegie Mellon, especially Professors Robert Kraemer, Bruce Sherwood, Ruth Chabay, Helmut Vogel, and Brian Quinn, for many stimulating discussions about physics pedagogy and for their support and encouragement during the writing of several successive editions of this book. I am equally indebted to the many generations of Carnegie Mellon students who have helped me learn what good teaching and good writing are, by showing me what works and what doesn't. It is always a joy and a privilege to express my gratitude to my wife, Alice, and our children, Gretchen and Rebecca, for their love, support, and emotional sustenance during the writing of several successive editions of this book. May all men and women be blessed with love such as theirs." We at Pearson appreciated his professionalism, good nature, and collaboration. He will be missed.

A. Lewis Ford is Professor of Physics at Texas A&M University. He received a B.A. from Rice University in 1968 and a Ph.D. in chemical physics from the University of Texas at Austin in 1972. After a one-year postdoc at Harvard University, he joined the Texas A&M physics faculty in 1973 and has been there ever since. Professor Ford has specialized in theoretical atomic physics—in particular, atomic collisions. At Texas A&M he has taught a variety of undergraduate and graduate courses, but primarily introductory physics.

TO THE STUDENT

HOW TO SUCCEED IN PHYSICS BY REALLY TRYING

***Mark Hollabaugh,** Normandale Community College, Emeritus*

Physics encompasses the large and the small, the old and the new. From the atom to galaxies, from electrical circuitry to aerodynamics, physics is very much a part of the world around us. You probably are taking this introductory course in calculus-based physics because it is required for subsequent courses that you plan to take in preparation for a career in science or engineering. Your professor wants you to learn physics and to enjoy the experience. He or she is very interested in helping you learn this fascinating subject. That is part of the reason your professor chose this textbook for your course. That is also the reason Drs. Young and Freedman asked me to write this introductory section. We want you to succeed!

The purpose of this section of *University Physics* is to give you some ideas that will assist your learning. Specific suggestions on how to use the textbook will follow a brief discussion of general study habits and strategies.

PREPARATION FOR THIS COURSE

If you had high school physics, you will probably learn concepts faster than those who have not because you will be familiar with the language of physics. If English is a second language for you, keep a glossary of new terms that you encounter and make sure you understand how they are used in physics. Likewise, if you are further along in your mathematics courses, you will pick up the mathematical aspects of physics faster. Even if your mathematics is adequate, you may find a book such as Arnold D. Pickar's *Preparing for General Physics: Math Skill Drills and Other Useful Help (Calculus Version)* to be useful. Your professor may assign sections of this math review to assist your learning.

LEARNING TO LEARN

Each of us has a different learning style and a preferred means of learning. Understanding your own learning style will help you to focus on aspects of physics that may give you difficulty and to use those components of your course that will help you overcome the difficulty. Obviously you will want to spend more time on those aspects that give you the most trouble. If you learn by hearing, lectures will be very important. If you learn by explaining, then working with other students will be useful to you. If solving problems is difficult for you, spend more time learning how to solve problems. Also, it is important to understand and develop good study habits. Perhaps the most important thing you can do for yourself is set aside adequate, regularly scheduled study time in a distraction-free environment.

Answer the following questions for yourself:

- Am I able to use fundamental mathematical concepts from algebra, geometry, and trigonometry? (If not, plan a program of review with help from your professor.)
- In similar courses, what activity has given me the most trouble? (Spend more time on this.) What has been the easiest for me? (Do this first; it will build your confidence.)
- Do I understand the material better if I read the book before or after the lecture? (You may learn best by skimming the material, going to lecture, and then undertaking an in-depth reading.)

- Do I spend adequate time studying physics? (A rule of thumb for a class like this is to devote, on average, 2.5 hours out of class for each hour in class. For a course that meets 5 hours each week, that means you should spend about 10 to 15 hours per week studying physics.)
- Do I study physics every day? (Spread that 10 to 15 hours out over an entire week!) At what time of the day am I at my best for studying physics? (Pick a specific time of the day and stick to it.)
- Do I work in a quiet place where I can maintain my focus? (Distractions will break your routine and cause you to miss important points.)

WORKING WITH OTHERS

Scientists or engineers seldom work in isolation from one another but rather work cooperatively. You will learn more physics and have more fun doing it if you work with other students. Some professors may formalize the use of cooperative learning or facilitate the formation of study groups. You may wish to form your own informal study group with members of your class. Use e-mail to keep in touch with one another. Your study group is an excellent resource when you review for exams.

LECTURES AND TAKING NOTES

An important component of any college course is the lecture. In physics this is especially important, because your professor will frequently do demonstrations of physical principles, run computer simulations, or show video clips. All of these are learning activities that will help you understand the basic principles of physics. Don't miss lectures. If for some reason you do, ask a friend or member of your study group to provide you with notes and let you know what happened.

Take your class notes in outline form, and fill in the details later. It can be very difficult to take word-for-word notes, so just write down key ideas. Your professor may use a diagram from the textbook. Leave a space in your notes and add the diagram later. After class, edit your notes, filling in any gaps or omissions and noting things that you need to study further. Make references to the textbook by page, equation number, or section number.

Ask questions in class, or see your professor during office hours. Remember that the only "dumb" question is the one that is not asked. Your college may have teaching assistants or peer tutors who are available to help you with any difficulties.

EXAMINATIONS

Taking an examination is stressful. But if you feel adequately prepared and are well rested, your stress will be lessened. Preparing for an exam is a continuous process; it begins the moment the previous exam is over. You should immediately go over the exam to understand any mistakes you made. If you worked a problem and made substantial errors, try this: Take a piece of paper and divide it down the middle with a line from top to bottom. In one column, write the proper solution to the problem. In the other column, write what you did and why, if you know, and why your solution was incorrect. If you are uncertain why you made your mistake or how to avoid making it again, talk with your professor. Physics constantly builds on fundamental ideas, and it is important to correct any misunderstandings immediately. *Warning:* Although cramming at the last minute may get you through the present exam, you will not adequately retain the concepts for use on the next exam.

TO THE INSTRUCTOR

PREFACE

This book is the product of six and a half decades of leadership and innovation in physics education. When the first edition of *University Physics* by Francis W. Sears and Mark W. Zemansky was published in 1949, it was revolutionary among calculus-based physics textbooks in its emphasis on the fundamental principles of physics and how to apply them. The success of *University Physics* with generations of several million students and educators around the world is a testament to the merits of this approach and to the many innovations it has introduced subsequently.

In preparing this new Fourteenth Edition, we have further augmented and developed *University Physics* to assimilate the best ideas from education research with enhanced problem-solving instruction, pioneering visual and conceptual pedagogy, all-new categories of end-of-chapter problems, and the most pedagogically proven and widely used online homework and tutorial system in the world.

NEW TO THIS EDITION

- **All key equations now include annotations** that describe the equation and explain the meanings of the symbols in the equation. These annotations help promote in-depth processing of information and greater recall.
- **DATA SPEAKS sidebars** in each chapter, based on data captured from thousands of students, alert students to the statistically most common mistakes students make when working problems on related topics in MasteringPhysics.
- **Updated modern physics content** includes sections on quantum measurement (Chapter 40) and quantum entanglement (Chapter 41), as well as recent data on the Higgs boson and cosmic background radiation (Chapter 44).
- **Additional bioscience applications** appear throughout the text, mostly in the form of marginal photos with explanatory captions, to help students see how physics is connected to many breakthroughs and discoveries in the biosciences.
- The **text has been streamlined** with tighter and more focused language.
- **Based on data from MasteringPhysics, changes to the end-of-chapter content** include the following:
  - **25%–30% of problems are new or revised.**
  - Most chapters include **six to ten biosciences-related problems.**
  - The number of **context-rich problems** is increased to facilitate the greater learning gains that they can offer.
  - **Three new DATA problems** appear in each chapter. These typically context-rich, data-based reasoning problems require students to use experimental evidence, presented in a tabular or graphical format, to formulate conclusions.
  - Each chapter now includes **three to five new Passage Problems,** which follow the format that is used in the MCATs. These problems require students to investigate multiple aspects of a real-life physical situation, typically biological in nature, that is described in a reading passage.
- **Looking back at ...** essential past concepts are listed at the beginning of each chapter, so that students know what they need to have mastered before digging into the current chapter.

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- **Volume 2:** Chapters 21–37 (ISBN 978-0-13-397800-1)
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KEY FEATURES OF *UNIVERSITY PHYSICS*

DEMO

- More than 620 **QR codes** throughout the book allow students to use a mobile phone to watch an interactive video of a physics instructor giving a relevant physics demonstration (Video Tutor Demonstration) or showing a narrated and animated worked Example (Video Tutor Solution).

  All of these videos also play directly through links within the Pearson eText as well as the Study Area within MasteringPhysics.
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- Deep and extensive **problem sets** cover a wide range of difficulty (with blue dots to indicate relative difficulty level) and exercise both physical understanding and problem-solving expertise. Many problems are based on complex real-life situations.
- This textbook offers more **Examples** and **Conceptual Examples** than most other leading calculus-based textbooks, allowing students to explore problem-solving challenges that are not addressed in other textbooks.
- A research-based **problem-solving approach (Identify, Set Up, Execute, Evaluate)** is used in every Example as well as in the Problem-Solving Strategies, in the Bridging Problems, and throughout the Instructor's Solutions Manual and the Study Guide. This consistent approach teaches students to tackle problems thoughtfully rather than cutting straight to the math.
- **Problem-Solving Strategies** coach students in how to approach specific types of problems.
- The **figures** use a simplified graphical style to focus on the physics of a situation, and they incorporate more **explanatory annotations** than in the previous edition. Both techniques have been demonstrated to have a strong positive effect on learning.
- Many figures that illustrate Example solutions take the form of black-and-white **pencil sketches,** which directly represent what a student should draw in solving such problems themselves.
- The popular **Caution paragraphs** focus on typical misconceptions and student problem areas.
- End-of-section **Test Your Understanding** questions let students check their grasp of the material and use a multiple-choice or ranking-task format to probe for common misconceptions.
- **Visual Summaries** at the end of each chapter present the key ideas in words, equations, and thumbnail pictures, helping students review more effectively.
- **Approximately 70 PhET simulations** are linked to the Pearson eText and provided in the Study Area of the MasteringPhysics website (with icons in the printed book). These powerful simulations allow students to interact productively with the physics concepts they are learning. PhET clicker questions are also included on the Instructor's Resource DVD.

INSTRUCTOR'S SUPPLEMENTS

Note: *For convenience, all of the following instructor's supplements (except for the Instructor's Resource DVD) can be downloaded from the Instructor Resources Area accessed via MasteringPhysics (www.masteringphysics.com).*

The **Instructor's Solutions Manual,** prepared by A. Lewis Ford (Texas A&M University) and Wayne Anderson, contains complete and detailed solutions to all end-of-chapter problems. All solutions follow consistently the same Identify/Set Up/Execute/Evaluate problem-solving framework used in the textbook. Download only from the MasteringPhysics Instructor Area or from the Instructor Resource Center (www.pearsonhighered.com/irc).

The cross-platform **Instructor's Resource DVD** (978-0-13-398364-7) provides a comprehensive library of approximately 350 applets from ActivPhysics OnLine as well as all art and photos from the textbook in JPEG and PowerPoint formats. In addition, all of the key equations, problem-solving strategies, tables, and chapter summaries are provided in JPEGs and editable Word format, and all of the new Data Speaks boxes are offered in JPEGs. In-class weekly multiple-choice questions for use with various Classroom Response Systems (CRS) are also provided, based on the Test Your Understanding questions and chapter-opening questions in the text. Written by Roger Freedman, many new CRS questions that increase in difficulty level have been added. Lecture outlines and PhET clicker questions, both in PowerPoint format, are also included along with about 70 PhET simulations and the Video Tutor Demonstrations (interactive video demonstrations) that are linked to QR codes throughout the textbook.

MasteringPhysics® (www.masteringphysics.com) from Pearson is the leading online teaching and learning system designed to improve results by engaging students before, during, and after class with powerful content. Ensure that students arrive ready to learn by assigning educationally effective content before class, and encourage critical thinking and retention with in-class resources such as Learning Catalytics. Students can further master concepts after class through traditional homework assignments that provide hints and answer-specific feedback. The Mastering gradebook records scores for all automatically graded assignments, while diagnostic tools give instructors access to rich data to assess student understanding and misconceptions.

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- **Video Tutor Solutions** are linked to QR codes in the textbook. In these videos, which are available in the Study Area of Mastering and in the Pearson eText, an instructor explains and solves each worked example and Bridging Problem.
- **NEW!** An **Alternative Problem Set** in the Item Library of Mastering includes hundreds of new end-of-chapter questions and problems to offer instructors a wealth of options.
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- **PhET Simulations** (from the PhET project at the University of Colorado) are interactive, research-based simulations of physical phenomena. These tutorials, correlated to specific topics in the textbook, are available in the Pearson eText and in the Study Area within www.masteringphysics.com.
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STUDENT'S SUPPLEMENTS

The **Student's Study Guide** by Laird Kramer reinforces the textbook's emphasis on problem-solving strategies and student misconceptions. The *Study Guide for Volume 1* (978-0-13-398361-6) covers Chapters 1–20, and the *Study Guide for Volumes 2 and 3* (978-0-13-398360-9) covers Chapters 21–44.

The **Student's Solutions Manual** by A. Lewis Ford (Texas A&M University) and Wayne Anderson contains detailed, step-by-step solutions to more than half of the odd-numbered end-of-chapter problems from the textbook. All solutions follow consistently the same Identify/Set Up/Execute/Evaluate problem-solving framework used in the textbook. The *Student's Solutions Manual for Volume 1* (978-0-13-398171-1) covers Chapters 1–20, and the *Student's Solutions Manual for Volumes 2 and 3* (978-0-13-396928-3) covers Chapters 21–44.

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Tutorials in Introductory Physics (978-0-13-097069-5) by Lillian C. McDermott and Peter S. Schaffer presents a series of physics tutorials designed by a leading physics education research group. Emphasizing the development of concepts and scientific reasoning skills, the tutorials focus on the specific conceptual and reasoning difficulties that students tend to encounter.

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PLEASE TELL ME WHAT YOU THINK!

I welcome communications from students and professors, especially concerning errors or deficiencies that you find in this edition. The late Hugh Young and I have devoted a lot of time and effort to writing the best book we know how to write, and I hope it will help as you teach and learn physics. In turn, you can help me by letting me know what still needs to be improved! Please feel free to contact me either electronically or by ordinary mail. Your comments will be greatly appreciated.

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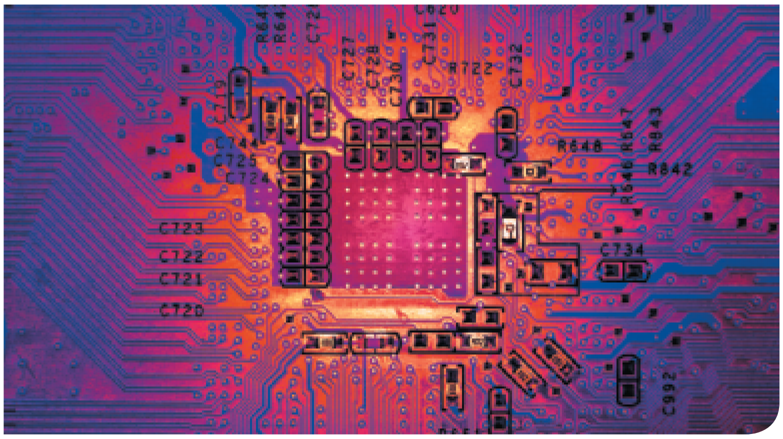

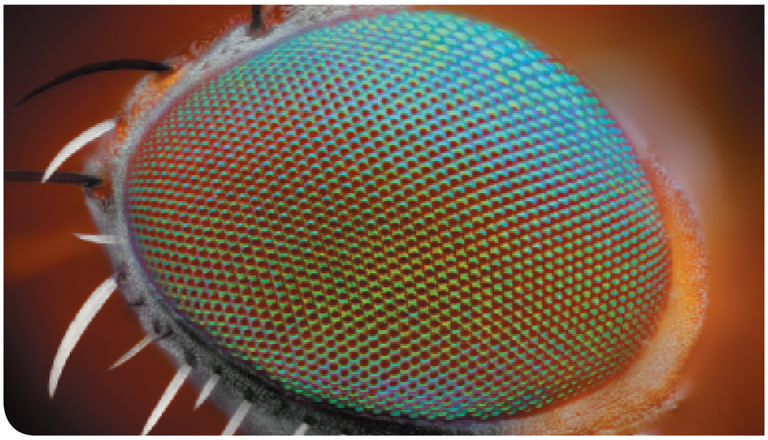

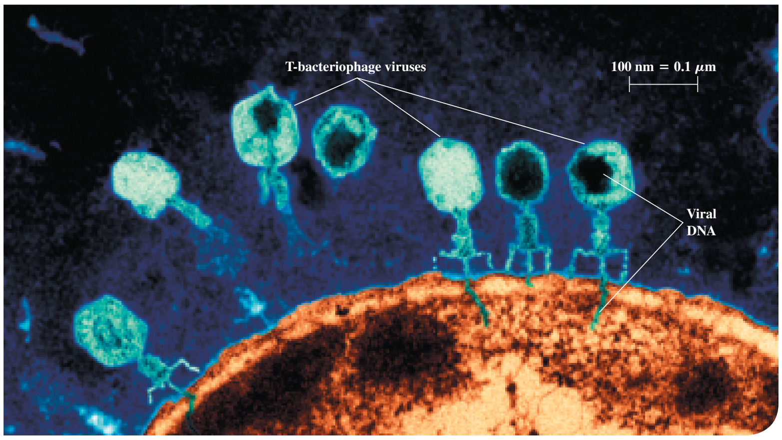

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