

ELEVENTH EDITION

SEARS & ZEMANSKY'S
**College
Physics**

Hugh D. Young
Philip W. Adams





COLLEGE PHYSICS





This page is intentionally left blank



SEARS AND ZEMANSKY'S

COLLEGE PHYSICS

ELEVENTH EDITION

HUGH D. YOUNG
Carnegie Mellon University

PHILIP W. ADAMS
Louisiana State University at Baton Rouge



Courseware Portfolio Manager: Ian Desrosiers
Director of Portfolio Management: Jeanne Zalesky
Content Producer: Chandrika Madhavan
Managing Producer: Kristen Flathman
Courseware Director, Content Development: Barbara Yien
Development Editor: Spencer Cotkin and Ed Dodd
Courseware Editorial Assistant: Frances Lai
Rich Media Content Producer: Keri Rand
Mastering Media Producer: David Hoogewerf
Full-Service Vendor: Integra Software Services Pvt. Ltd.
Copyeditor: Betty Pessagno
Compositor: Integra Software Services Pvt. Ltd.

Design Manager: Mark Ong
Interior Designer: Preston Thomas
Cover Designer: Preston Thomas
Rights & Permissions Project Manager: Beth Brenzel
Rights & Permissions Management: Ben Ferrini
Manufacturing Buyer: Stacey Weinberger
Director of Field Marketing: Tim Galligan
Director of Product Marketing: Allison Rona
Field Marketing Manager: Yez Alayan
Product Marketing Manager: Elizabeth Bell
Cover Photo Credit: technotr, Geary Images

Copyright © 2020, 2016, 2012 Pearson Education, Inc. All Rights Reserved. Printed in the United States of America. This publication is protected by copyright, and permission should be obtained from the publisher prior to any prohibited reproduction, storage in a retrieval system, or transmission in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise. For information regarding permissions, request forms and the appropriate contacts within the Pearson Education Global Rights & Permissions department.

Attributions of third party content appear on page C1-C2, which constitutes an extension of this copyright page.

PEARSON, ALWAYS LEARNING, and Mastering™ Physics are exclusive trademarks in the U.S. and/or other countries owned by Pearson Education, Inc. or its affiliates.

Library of Congress Cataloging-in-Publication Data

Names: Young, Hugh D., author. | Adams, Philip Wayne, author.

Title: College physics / Hugh D. Young and Phillip [i.e. Philip] W. Adams.

Other titles: Some previous editions have title: Sears & Zemansky's college physics

Description: 11th edition. | Hoboken, N.J. : Pearson Higher Education, c2020.

| Includes bibliographical references and index.

Identifiers: LCCN 2018042786 | ISBN 9780134876986 (hardcover : alk. paper) |

ISBN 9780134987323 (pbk. : alk. paper) | ISBN 9780134987316 (pbk. : alk. paper)

Subjects: LCSH: Physics—Textbooks.

Classification: LCC QC23.2 .Y68 2020 | DDC 530—dc23

LC record available at <https://lcn.loc.gov/2018042786>

ISBN 10: 0-134-87698-9; ISBN 13: 978-0-134-87698-6 (Student edition)
ISBN 10: 0-134-98721-7; ISBN 13: 978-0-134-98721-7 (Looseleaf)



www.pearson.com

BRIEF CONTENTS

0	Mathematics Review	0-1
----------	--------------------	-----

MECHANICS

1	Models, Measurements, and Vectors	1
2	Motion Along a Straight Line	27
3	Motion in a Plane	64
4	Newton's Laws of Motion	93
5	Applications of Newton's Laws	120
6	Circular Motion and Gravitation	152
7	Work and Energy	180
8	Momentum	222
9	Rotational Motion	258
10	Dynamics of Rotational Motion	285

PERIODIC MOTION, WAVES, AND FLUIDS

11	Elasticity and Periodic Motion	325
12	Mechanical Waves and Sound	357
13	Fluid Mechanics	397

THERMODYNAMICS

14	Temperature and Heat	429
15	Thermal Properties of Matter	463
16	The Second Law of Thermodynamics	501

ELECTRICITY AND MAGNETISM

17	Electric Charge and Electric Field	529
18	Electric Potential and Capacitance	566
19	Current, Resistance, and Direct-Current Circuits	599
20	Magnetic Field and Magnetic Forces	637
21	Electromagnetic Induction	674
22	Alternating Current	712
23	Electromagnetic Waves	737

LIGHT AND OPTICS

24	Geometric Optics	774
25	Optical Instruments	807
26	Interference and Diffraction	828

MODERN PHYSICS

27	Relativity	862
28	Photons, Electrons, and Atoms	896
29	Atoms, Molecules, and Solids	933
30	Nuclear and High-Energy Physics	963

APPENDICES

A	The International System of Units	A-1
B	The Greek Alphabet	A-3
C	Periodic Table of the Elements	A-4
D	Unit Conversion Factors	A-5
E	Numerical Constants	A-6
	Answers to Odd-Numbered Problems	A-8
	Credits	C-1
	Index	I-1

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)

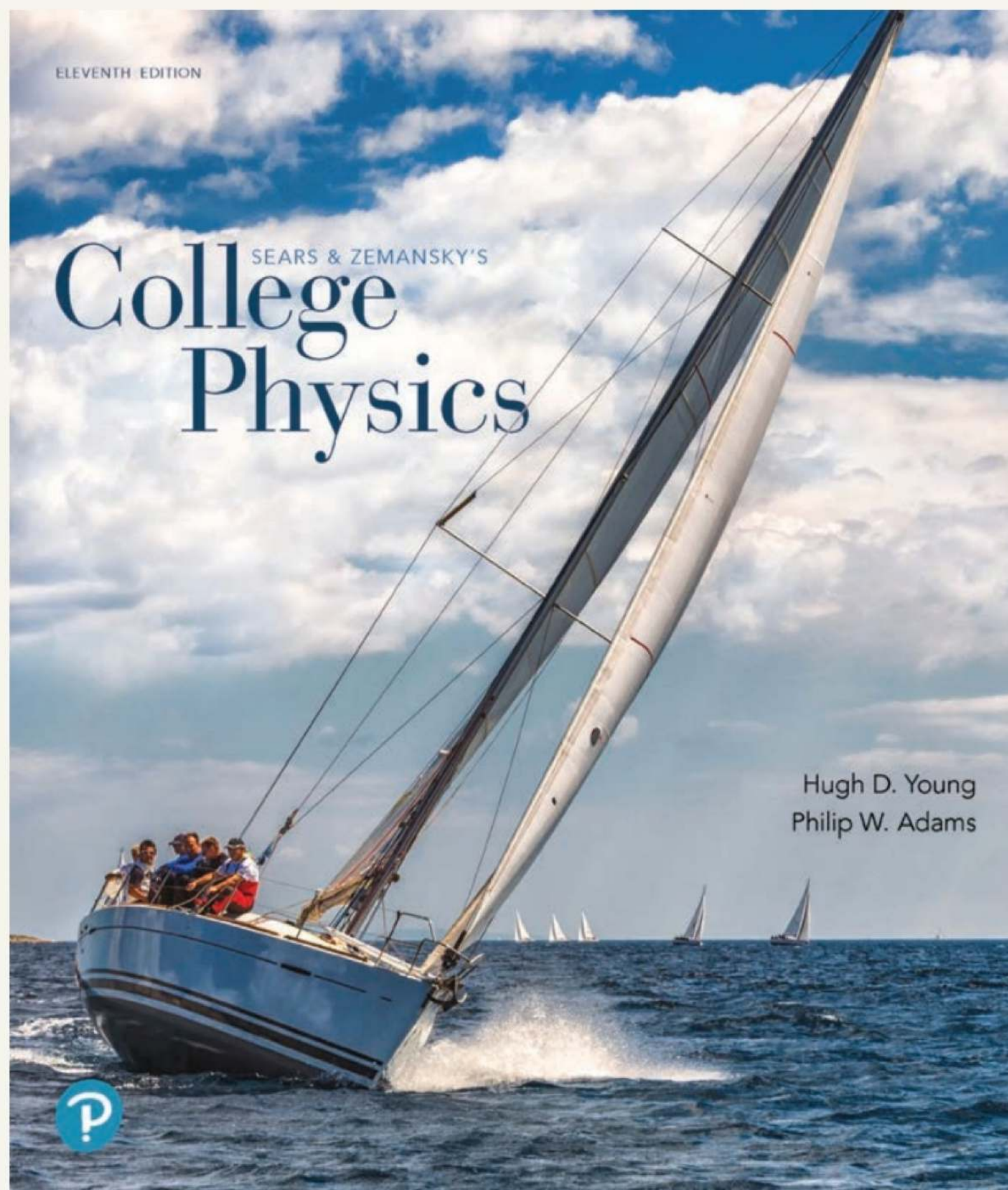
Hugh D. Young was Emeritus Professor of Physics at Carnegie Mellon University. He earned his Ph.D. from Carnegie Mellon in fundamental particle theory under the direction of the late Richard Cutkosky. He also had two visiting professorships at the University of California, Berkeley.

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 . . .

GUIDED PRACTICE

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

Chapter 7 Media Assets



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.

P. 212

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.

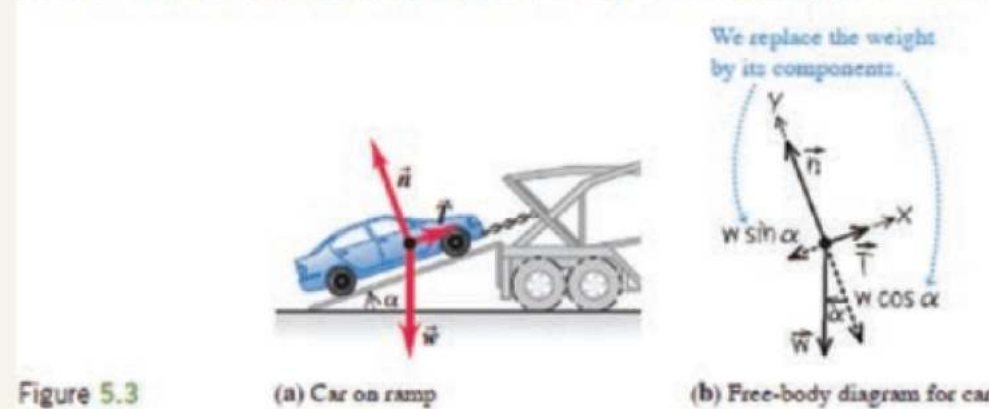


Figure 5.3

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

$$\begin{aligned} \Sigma F_x = 0, & \quad T + (-w \sin \alpha) = 0, \\ \Sigma F_y = 0, & \quad n + (-w \cos \alpha) = 0. \end{aligned}$$

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

$$\begin{aligned} T &= w \sin \alpha, \\ n &= w \cos \alpha. \end{aligned}$$

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

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

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° .

Problem-Solving skills

BRIDGING PROBLEM

A large pressurized tank is filled with water. The air pressure above the water surface is $p_0 > p_{\text{atm}}$. 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.)

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.

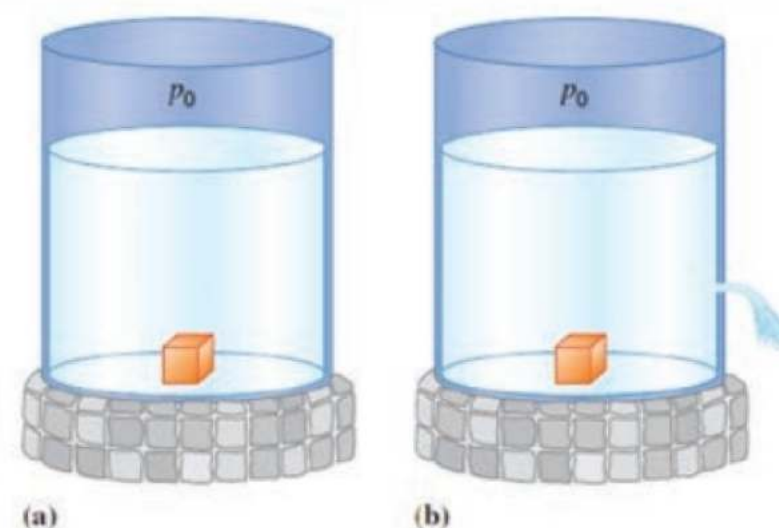


Figure 13.37

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 $p = p_{\text{atm}}$?

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.

P. 422

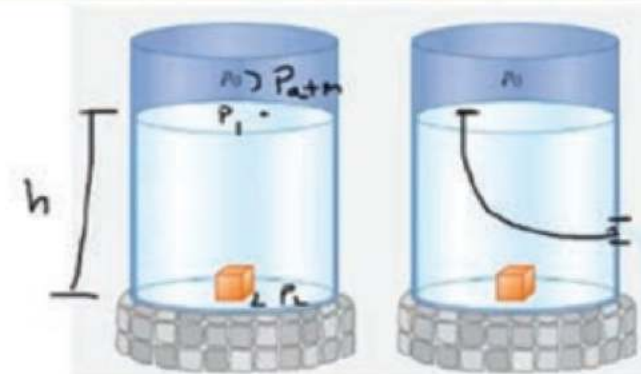
Video Tutor Solutions (VTs) for every Example and Bridging Problem in the book walk students through the problem-solving process, providing a virtual teaching assistant on a round-the-clock basis. New VTs correspond to new and revised worked examples.

A large pressurized tank is filled with water. The air pressure above the water surface is $p_0 > p_{\text{atm}}$. 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. (a) Derive an expression for the pressure at the bottom of the tank. (b) Derive an expression for the perpendicular force on the aluminum cube. (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 $h/2$. 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.)

$$\text{Set Up}$$

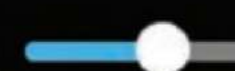
$$P_2 = P_1 + \rho g h$$

$$P_1 + \frac{1}{2} \rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2} \rho v_2^2 + \rho g h_2$$



02:32 / 10:53

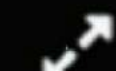
info



Speed



CC



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. $\tau_2 > \tau_3 > \tau_1$

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

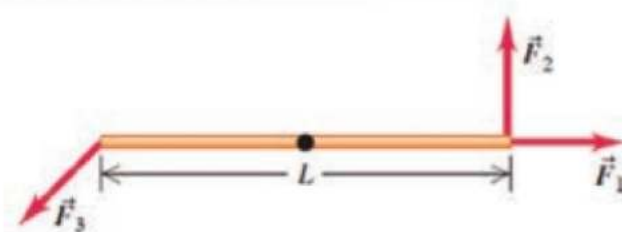


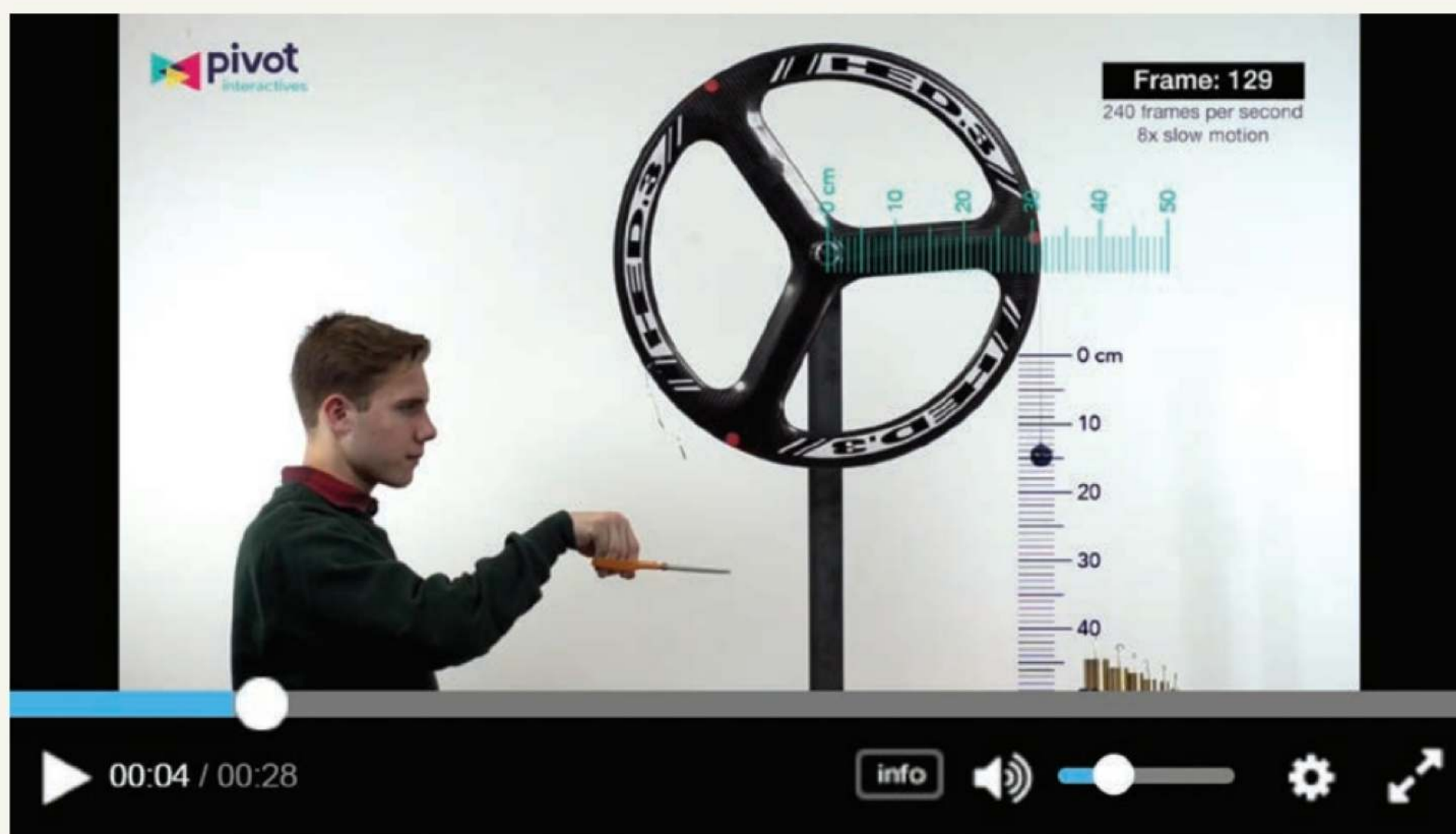
Figure 10.5

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.

P. 287

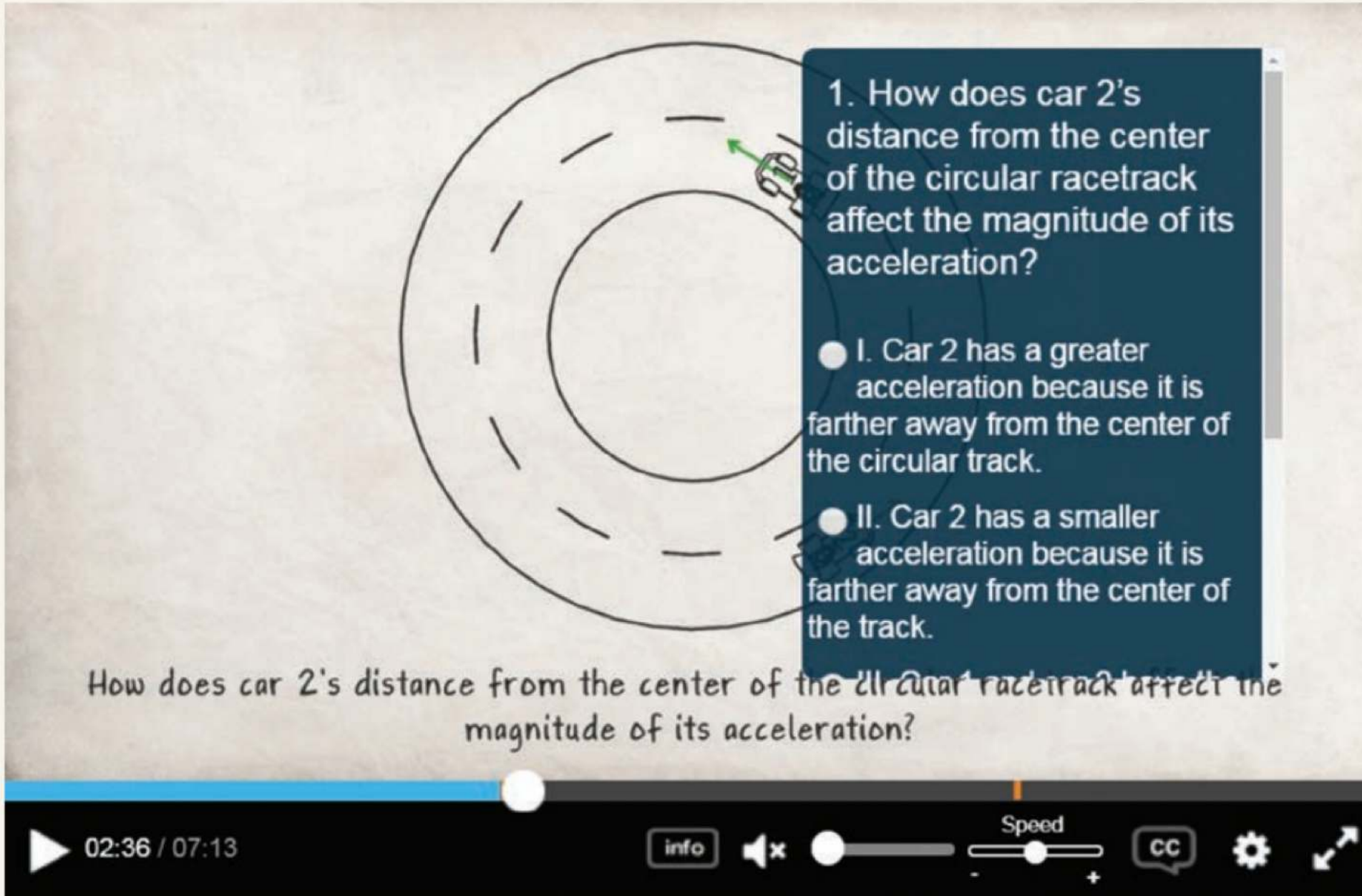
NEW! Test Your Understanding problems

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



1. How does car 2's distance from the center of the circular racetrack affect the magnitude of its acceleration?

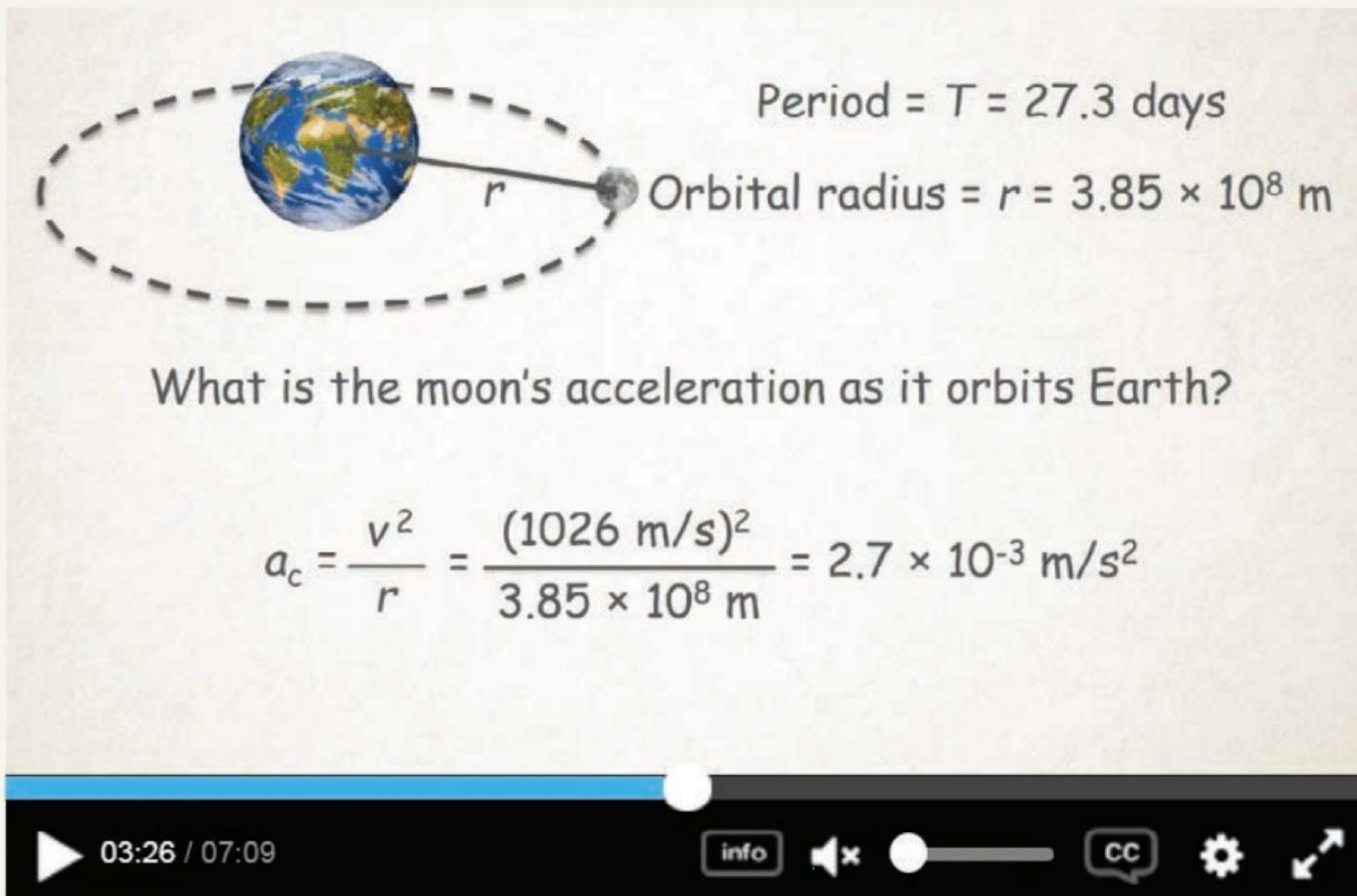
- I. Car 2 has a greater acceleration because it is farther away from the center of the circular track.
- II. Car 2 has a smaller acceleration because it is farther away from the center of the track.

How does car 2's distance from the center of the circular racetrack affect the magnitude of its acceleration?

02:36 / 07:13

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.



Period = $T = 27.3$ days

Orbital radius = $r = 3.85 \times 10^8$ m

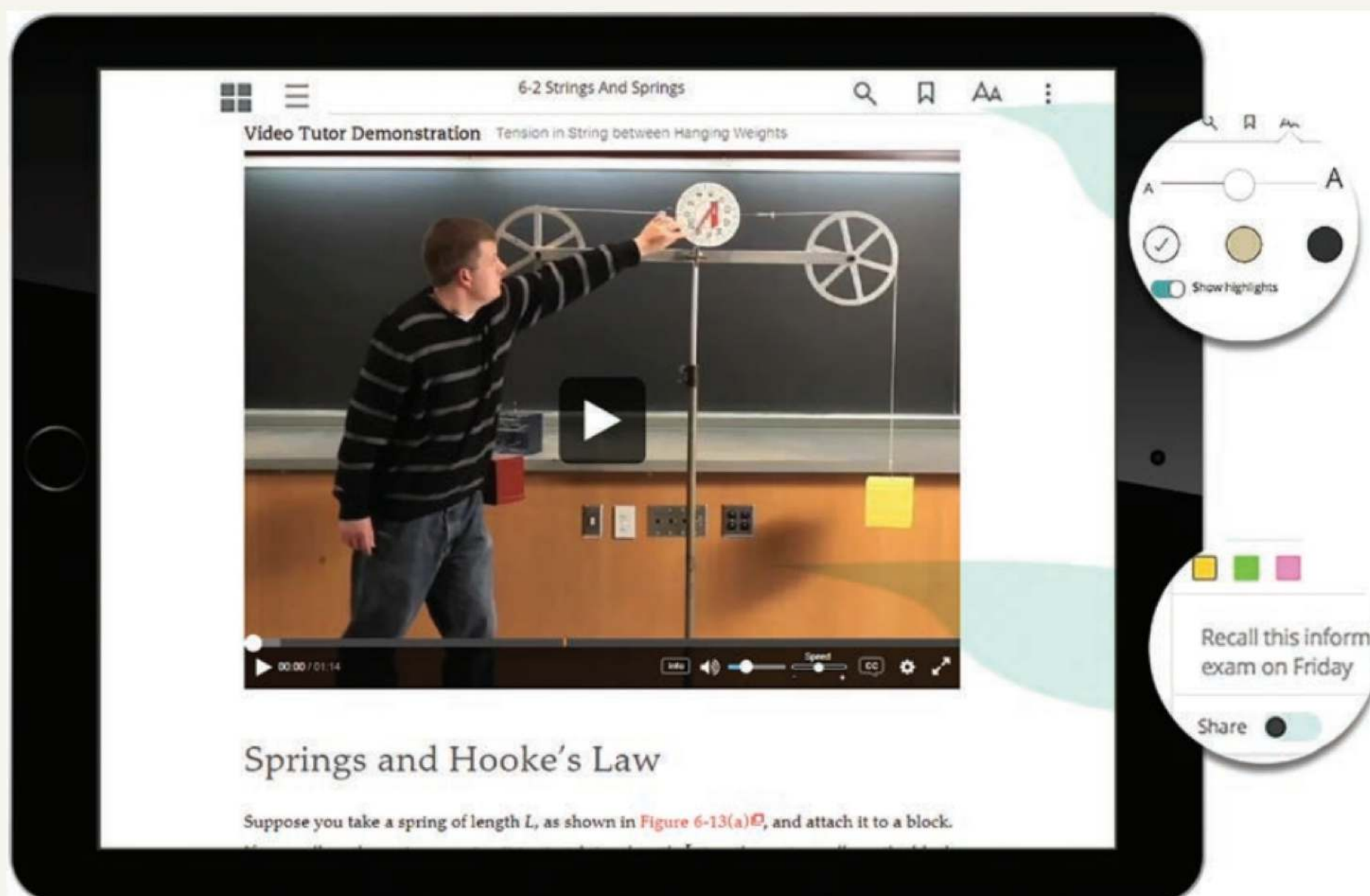
What is the moon's acceleration as it orbits Earth?

$$a_c = \frac{v^2}{r} = \frac{(1026 \text{ m/s})^2}{3.85 \times 10^8 \text{ m}} = 2.7 \times 10^{-3} \text{ m/s}^2$$

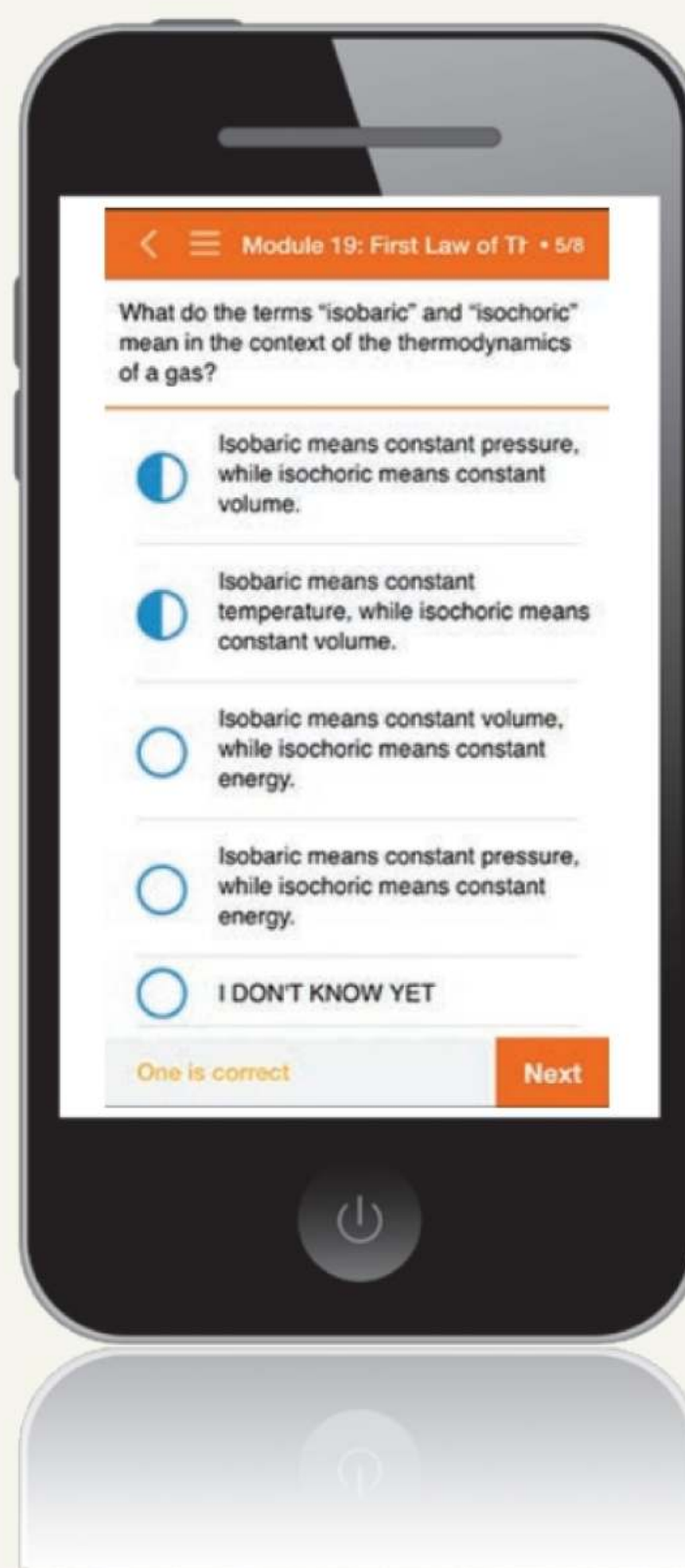
03:26 / 07:09

Reach every student . . .

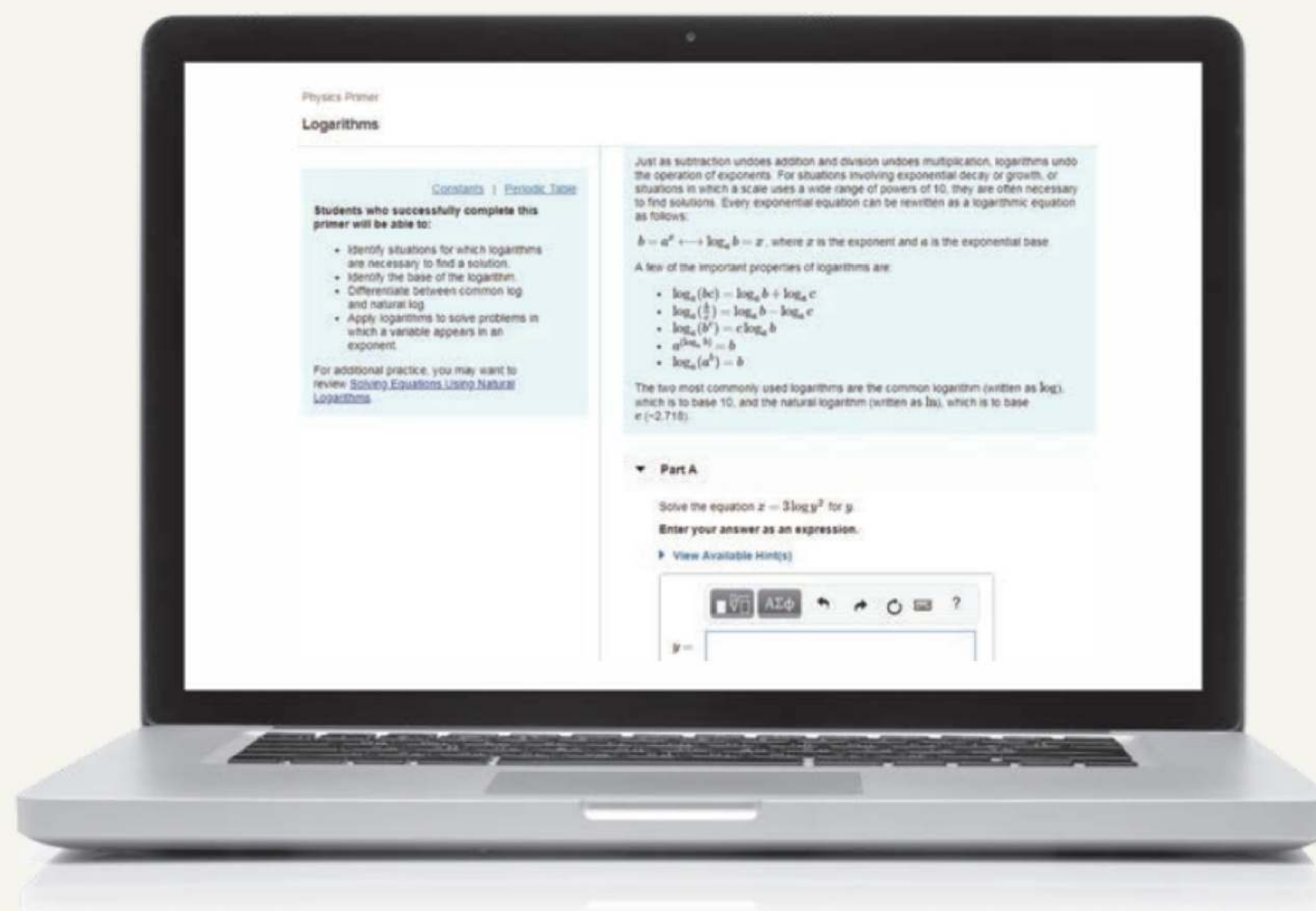
NEW! College Physics is now available in Pearson eText. Pearson eText is a simple-to-use, mobile-optimized, personalized reading experience available within Mastering. It allows students to easily highlight, take notes, and review key vocabulary all in one place—even when offline. Seamlessly integrated 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

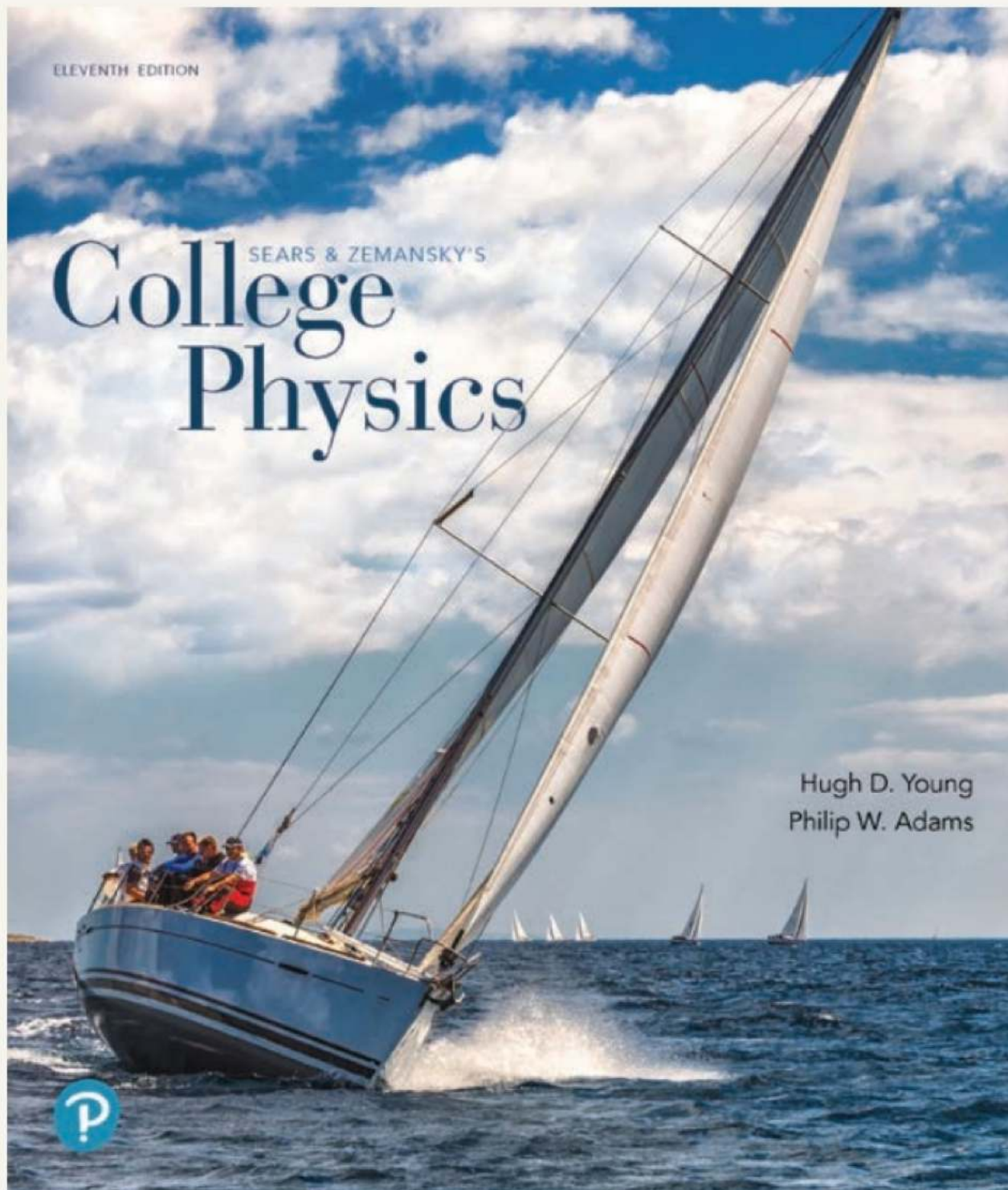


Dynamic Study Modules in Mastering Physics help students study effectively—and at their own pace—by keeping them motivated and engaged. The assignable modules rely on the latest research in cognitive science, using methods—such as adaptivity, gamification, and intermittent rewards—to stimulate learning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

The screenshot shows the Learning Catalytics interface. At the top, it says 'learning | catalytics™' and 'Allison Rona | Pearson | Log out'. Below that are navigation tabs: 'Courses', 'Questions', 'Classrooms', 'Training and Support', 'Help', 'Feedback', and 'Student view'. The main content area shows a question titled 'Question 3328'. The question text is: 'A positively charged particle is placed along the positive x axis and a particle carrying a negative charge of equal magnitude is placed at equal distance from the origin along the negative x axis. A third particle carrying a positive charge is placed on the y axis. Draw an arrow to represent the direction of the vector sum of the forces exerted by 1 and 2 on 3.' Below the text is a diagram of a 2D coordinate system with x and y axes. Three particles are shown: particle 1 (charge -q) on the negative x-axis, particle 2 (charge +q) on the positive x-axis, and particle 3 (charge +q') on the positive y-axis. Below the diagram is an 'Answer' section with a diagram showing a green arrow pointing to the left from particle 3, representing the net force. To the right of the question is a 'Historical Performance' section showing '1979 students, 55% correct' and a chart with many red arrows pointing in various directions, with a green arrow pointing left. Below the chart is a 'Text responses' section with a list of answers: '3', 'Directly left -x', 'Lorem ipsum', and 'the negative m8er is going to go toward the positive m8er and the positive m8er is going to go away from the other positive m8er'. At the bottom of the screenshot, there is a small text box: 'The repulsive electrostatic force exerted by particle 2 on particle 3 is up and to the left. The attractive electrostatic force exerted by particle 1 on particle 3 is down and to the left. Because the two forces are equal in magnitude, the vector sum points horizontally toward the left, that is, in the -x direction.'

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.

- Chapter 1** Physics of sound reproduction 2
Echolocation in bats 3 **BIO**
Mars mission mistakes 6
- Chapter 2** Average velocity on “the crookedest street in the world” 31
Average speed/average velocity of a race car 34
Directions of velocity and acceleration 36
Mechanisms in motor neurons 46 **BIO**
- Chapter 3** A car’s three accelerators 67
Gravisensing in plant roots 68 **BIO**
Ballistic spores 73 **BIO**
Human cannonball as projectile 75
Uniform circular motion in global positioning systems 80
- Chapter 4** Catapult demonstrating Newton’s first law 96
Tablecloth trick: Inertia 97
Compressing cancer cells 100 **BIO**
Bacterial propulsion 105 **BIO**
Biathlete using Newton’s third law 106
Rocket launch 108
- Chapter 5** Crane unloading Very Large Telescope mirror 121
Liquid-filled accelerometer 126
Rock climber using frictional forces 130
Wet roadsaw cutting stone 132
Molecular motors 132 **BIO**
- Chapter 6** Centrifuges and centripetal acceleration 153 **BIO**
Centripetal force in bobsledding 154
Gravity map of the earth 163
Bone loss in space 170 **BIO**
- Chapter 7** Elastic potential energy in kangaroo hopping 183 **BIO**
Reduced air drag on a recumbent bicycle 185
Energy expended in climbing El Capitan 199 **BIO**
Work done by ATP 208 **BIO**
- Chapter 8** Contrecoup brain injury 224 **BIO**
Conservation of momentum in a bowling strike 226
Light sail 235
Scallop jet propulsion 239 **BIO**
Center of mass of a system 243
- Chapter 9** Hand drill demonstrating angular velocity 259
Angular acceleration of the brain and football helmets 262 **BIO**
Velocipede direct-drive bicycle 265
Storing energy in a flywheel 268
Moon orbiting earth 273
- Chapter 10** Balancing on a tightrope 290
Angular acceleration and football helmets 295 **BIO**
Rotating DNA and torque 296 **BIO**
Nanoengineered gears 298
Andaman earthquake’s effects on length of day 300
Spinning dinner plates 304
Rifling in a gun barrel 310
- Chapter 11** Cable-stayed bridge 328
Spring scale 330
Strength of an egg 333 **BIO**
Nanobalance 340
Foucault pendulum 346
- Chapter 12** Earthquakes: Transverse and longitudinal waves 359
Wave generation in a surf pool 360
Bone flutes: Standing waves 375
Prey location by barn owls 381 **BIO**
Use of sonar in search of shipwrecks 382
Doppler radar in meteorology 384
Extracorporeal shock wave lithotripsy 387 **BIO**
- Chapter 13** Densities of liquids 398
Deep-sea animals and pressure 402 **BIO**
Snowshoeing to reduce pressure 403
Floating in the Dead Sea 407 **BIO**
Turbulent flow in a meandering river 412
Roof blown off by hurricane 414
- Chapter 14** Microorganisms living near deep-sea vents 432 **BIO**
Bimaterial strips 434
Ice-tolerant fish 442 **BIO**
Formation of snowflakes 443
Heat stroke and hot tubs 445 **BIO**
Heat transfer and surface area 451 **BIO**
Infrared images of warm-blooded animals 453 **BIO**
Solar farms 453
- Chapter 15** The mole 464
Dust devils 466
Pressurizing aircraft cabins 467 **BIO**
Scuba diving dangers 468 **BIO**
Platinum resistance thermometers 470
Hydrogen gas in planetary atmospheres 474
Venus: An arid furnace 474
Nuclear submarines 482

- Chapter 16** The sun's energy 502
 Geothermal power in Iceland 503
 Biodiesel engines 507 **BIO**
 Ice bars 508
 Photosynthesis 512 **BIO**
 Energy cycles of the earth and its organisms 515 **BIO**
 Zero-power buildings 519
- Chapter 17** Electric charge preceding a lightning strike 530
 Salt water conducts electricity 533
 "Static cling" in DNA 536 **BIO**
 Atom-smashing with Van de Graaff generators 537
 Platypus sensing electric fields 544 **BIO**
 Cells sensitive to electric fields 545 **BIO**
 Fish producing and using an electric field to sense its surroundings 549 **BIO**
 Blocking cell phone signals with Faraday bags 555
- Chapter 18** Microelectromechanical systems 568
 Lightning bolt 570
 Bird perching on power line 573 **BIO**
 Sandia Lab's capacitor bank discharging 578
 Sea urchin contraception 580 **BIO**
 Capacitors in cardiac defibrillators 586 **BIO**
- Chapter 19** Semiconductors 600
 Squid escape behavior 603 **BIO**
 Electric eels 610 **BIO**
 LED bicycle lights 612
 Wrist strap grounding in electronics work 624 **BIO**
- Chapter 20** Magnetotactic bacteria 638 **BIO**
 Magnetic resonance imaging 642 **BIO**
 Microwave ovens 646
 Direct-current motors 654
 Coaxial cable 656
- Chapter 21** Induction cooktop 675
 Using an electromagnetic tether to deorbit satellites 685
 Electric toothbrush rechargers 687
 Automatic garage gates 691
 Step-down transformers 692
 Detecting tiny magnetic fields in the brain 694 **BIO**
 L-C circuits in tuning knobs 700
- Chapter 22** Transcranial alternating current stimulation 715 **BIO**
 Alternating and direct current 719
 Power surge protectors 725
- Chapter 23** Radio antenna 738
 Cerenkov radiation 739
 Why plants are green 741 **BIO**
 Ultraviolet vision in animals 742 **BIO**
 Why the sky is blue 759 **BIO**
 Polarization in marine invertebrates 760 **BIO**
- Chapter 24** Driver's blind spot 779
Tapetum lucidum and eyeshine 781
 Underwater vision 786 **BIO**
- Chapter 25** Cone types in the human retina 808 **BIO**
 Compound eyes 811 **BIO**
 Animals' focusing mechanisms 812 **BIO**
 Eyeglass lenses 812
 X-ray telescope 819
- Chapter 26** Ocean waves 829
 Nonreflective coating on museum cases 838
 Structural colors in hummingbirds 839 **BIO**
 Phase-contrast microscopy 842 **BIO**
 Using diffraction gratings to measure DNA 846 **BIO**
 Modern telescopes using interferometry 851
- Chapter 27** Inertial frame of reference 864
 Time at the finish line 869
 Time travel 872
 Nuclear energy 884
- Chapter 28** Smoke detectors 898
 Fireworks 905
 Ruby lasers 914
 Synchrotron rapid scanning X-ray fluorescence 917 **BIO**
 Boron neutron capture therapy 917 **BIO**
 Electron microscopy 923 **BIO**
- Chapter 29** Carbon-based life 942 **BIO**
 Van der Waals bonds and gecko toes 947 **BIO**
 Diamonds and graphite 951
 Transistors 955
 Using quantum physics to look at living tissues 956 **BIO**
- Chapter 30** Size of nucleus relative to atom 964
 Penetrating power of types of radiation 972 **BIO**
 Radiocarbon dating 977 **BIO**
 Residence time of radionuclides in the body 978 **BIO**
 Gamma-knife radiosurgery 980 **BIO**
 Nuclear medicine: Bone scans 980 **BIO**
 Life on other planets 994 **BIO**

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.



This page is intentionally left blank

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

With Mastering Physics:

- **Complete Edition:** Chapters 0–30 (ISBN 978-0-134-87947-5)

Without Mastering Physics:

- **Complete Edition:** Chapters 0–30 (ISBN 978-0-134-87698-6)
- **Volume 1:** Chapters 0–16 (ISBN 978-0-134-98732-2)
- **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 metadata base 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.

ACKNOWLEDGMENTS

The production of this textbook was truly a collaborative effort, involving authors, editors, students, colleagues, and family. I am deeply indebted to my former editor Nancy Whilton for all the years of support and encouragement. I also owe a great deal to my former colleague and coauthor Ray Chastain for his invaluable insights into the many pedagogic issues that students face in an introductory physics course. This revision would not have been possible without the vision of my current editor Jeanne Zalesky. I would also like to specifically thank my development editors Spencer Cotkin and Ed Dodd for vetting the new content and offering many helpful suggestions, as well as my vendor manager Patricia Walcott, and my project manager Chandrika Madhavan who kept the ship on course. Of course, I must also thank my colleagues in the LSU Department of Physics and Astronomy for the countless discussions, meetings, and arguments that have helped me better understand the goals and challenges of introductory physics education. Finally, I owe a particular debt of gratitude to my wife Elsie Michie, who provided steady encouragement through the long process.

REVIEWERS AND CLASSROOM TESTERS

- Susmita Acharya, *Cardinal Stritch University*
 Miah Adel, *University of Arkansas, Pine Bluff*
 Hamid Aidinejad, *Florida Community College, Jacksonville*
 Ugur Akgun, *Coe College*
 Alice Hawthorne Allen, *Virginia Tech*
 Jim Andrews, *Youngstown State University*
 Sanjeev Arora, *Fort Valley State University*
 Charles Bacon, *Ferris State University*
 Jennifer Blue, *Miami University*
 Thomas Bolland, *Ohio State University*
 Richard Bone, *Florida International University*
 Phillip Broussard, *Covenant College*
 Shea Brown, *University of Iowa*
 David Cardimona, *University of New Mexico*
 Young Choi, *University of Pittsburgh*
 Orion Ciftja, *Prairie View A&M University*
 David Cinabro, *Wayne State University*
 David Cole, *Northern Arizona University*
 Dennis Collins, *Grossmont College*
 Carl Covatto, *Arizona State University*
 Douglas Davidson, *Black Hawk College*
 Lloyd Davis, *Montreat College*
 Diana Driscoll, *Case Western Reserve University*
 Ryan Droste, *Trident Technical College*
 Laurencin Dunbar, *St. Louis Community College, Florissant Valley*
 Alexander Dzyubenko, *California State University, Bakersfield*
 Vernessa Edwards, *Alabama A&M University*
 Robert Ehrlich, *George Mason University*
 Mark Fair, *Grove City College*
 Gregory Falabella, *Wagner College*
 Xiaojuan Fan, *Marshall University*
 Shamanthi Fernando, *Northern Kentucky University*
 Len Feuerhelm, *Oklahoma Christian University*
 Lewis Ford, *Texas A&M University*
 Mario Freamat, *Miami University*
 Carl Frederickson, *University of Central Arkansas*
 Karl Frinkle, *Southeastern Oklahoma State University*
 Richard Gelderman, *Western Kentucky University*
 Mikhail Goloubev, *Bowie State University*
 Juan Gomez, *Bainbridge State College*
 Alan Grafe, *University of Michigan, Flint*
 William Gregg, *Louisiana State University*
 John Gruber, *San Jose State University*
 Robert Hagood, *Washtenaw Community College*
 Ajawad Haija, *Indiana University of Pennsylvania*
 Scott Hildreth, *Chabot College*
 Andy Hollerman, *University of Louisiana, Lafayette*
 Klaus Honscheid, *Ohio State University*
 Kevin Hope, *University of Montevallo*
 John Hubisz, *North Carolina State University*
 Manuel Huerta, *University of Miami*
 Todd Hurt, *Chatham College*
 Shawn Jackson, *University of Arizona*
 Charles Johnson, *South Georgia State College*
 Adam Johnston, *Weber State University*
 Roman Kezerashvili, *New York City College of Technology*
 Ju Kim, *University of North Dakota*
 Jeremy King, *Clemson University*
 David Klassen, *Rowan University*
 Ichishiro Konno, *University of Texas, San Antonio*
 Ikka Koskelo, *San Francisco State University*
 Todd Leif, *Cloud County Community College*
 Jon Levin, *University of Kentucky*
 David Lind, *Florida State University*
 Dean Livelybrooks, *University of Oregon, Eugene*
 Estella Llinas, *University of Pittsburgh, Greensburg*
 Craig Loony, *Merrimack College*
 Rafael Lopez-Mobilia, *University of Texas, San Antonio*
 Barbra Maher, *Red Rocks Community College*
 Dan Mazilu, *Virginia Tech*
 Randy McKee, *Tallahassee Community College*
 Larry McRae, *Berry College*
 William Mendoza, *Jacksonville University*
 Anatoli Mirochnitchenko, *University of Toledo*
 Antonio Mondragon, *Colorado College*
 Charles Myles, *Texas Tech University*
 Austin Napier, *Tufts University*
 Erin O'Connor, *Allan Hancock College*
 Christine O'Leary, *Wallace State College*
 Giovanni Ossola, *New York City College of Technology, CUNY*
 Jason Overby, *College of Charleston*
 James Pazun, *Pfeiffer University*
 Unil Perera, *Georgia State University*
 David Potter, *Austin Community College*
 Michael Pravica, *University of Nevada, Las Vegas*
 Milun Rakovic, *Grand Valley State University*
 Ian Redmount, *Saint Louis University*
 William Robinson, *North Carolina State University*
 Sal Rodano, *Harford Community College*
 Rob Salgado, *Dillard University*
 Desi Saludes, *Hillsborough Community College*
 Tumer Sayman, *Eastern Michigan University*
 Surajit Sen, *SUNY Buffalo*
 Bart Sheinberg, *Houston Community College*
 Natalia Sidorovskaia, *University of Louisiana*
 Chandralekha Singh, *University of Pittsburgh*
 Marlina Slamet, *Sacred Heart University*
 Daniel Smith, *South Carolina State University*
 Gordon Smith, *Western Kentucky University*
 Kenneth Smith, *Pennsylvania State University*
 Zhiyan Song, *Savannah State University*
 Sharon Stephenson, *Gettysburg College*
 Chuck Stone, *North Carolina A&T State University*
 George Strobel, *University of Georgia*
 Chun Fu Su, *Mississippi State University*
 Brenda Subramaniam, *Cypress College*
 Mike Summers, *George Mason University*
 Eric Swanson, *University of Pittsburgh*
 Cynthia Swift, *Santiago Canyon College*
 Devki Talwar, *Indiana University of Pennsylvania*
 Colin Terry, *Ventura College*
 Vladimir Tsifrinovich, *Polytechnic University*

Gajendra Tulsian, *Daytona Beach Community College*
Paige Uozts, *Lander University*
James Vesenka, *University of New England*
Walter Wales, *University of Pennsylvania*
John Wernegreen, *Eastern Kentucky University*
Dan Whitmire, *University of Louisiana, Lafayette*

Luc Wille, *Florida Atlantic University*
Sue Willis, *Northern Illinois University*
Jaehoon Yu, *University of Texas, Arlington*
Nouredine Zettili, *Jacksonville State University*
Bin Zhang, *Arkansas State University*



This page is intentionally left blank

DETAILED CONTENTS

0	MATHEMATICS REVIEW	0-1
0.1	Exponents	0-1
0.2	Scientific Notation and Powers of 10	0-2
0.3	Algebra	0-3
0.4	Algebraic Relationships and Proportional Reasoning	0-6
0.5	Data-Driven Problems	0-9
0.6	Logarithmic and Exponential Functions	0-11
0.7	Areas and Volumes	0-12
0.8	Plane Geometry and Trigonometry	0-12

MECHANICS

1	MODELS, MEASUREMENTS, AND VECTORS	1
1.1	Introduction	1
1.2	Idealized Models	3
1.3	Standards and Units	3
1.4	Dimensional Consistency and Unit Conversions	6
1.5	Precision and Significant Figures	8
1.6	Estimates and Orders of Magnitude	10
1.7	Vectors and Vector Addition	10
1.8	Components of Vectors	14
	Summary	20
	Questions/Exercises/Problems	21
2	MOTION ALONG A STRAIGHT LINE	27
2.1	Displacement and Average Velocity	27
2.2	Instantaneous Velocity	31
2.3	Average and Instantaneous Acceleration	34
2.4	Motion with Constant Acceleration	39
2.5	Constant Acceleration and Proportional Reasoning	45



2.6	Freely Falling Objects	47
2.7	Relative Velocity Along a Straight Line	50
	Summary	53
	Questions/Exercises/Problems	54

3	MOTION IN A PLANE	64
3.1	Velocity in a Plane	64
3.2	Acceleration in a Plane	67
3.3	Projectile Motion	70
3.4	Uniform Circular Motion	78
3.5	Relative Velocity in a Plane	81
	Summary	85
	Questions/Exercises/Problems	86

4	NEWTON'S LAWS OF MOTION	93
4.1	Force	93
4.2	Newton's First Law	96
4.3	Mass and Newton's Second Law	98
4.4	Mass and Weight	103
4.5	Newton's Third Law	106
4.6	Free-Body Diagrams	109
	Summary	113
	Questions/Exercises/Problems	114

5	APPLICATIONS OF NEWTON'S LAWS	120
5.1	Equilibrium of a Particle	120
5.2	Applications of Newton's Second Law	126
5.3	Contact Forces and Friction	130
5.4	Elastic Forces	137
5.5	Forces in Nature	139
	Summary	141
	Questions/Exercises/Problems	142



6 CIRCULAR MOTION AND GRAVITATION 152

6.1	Force in Circular Motion	152
6.2	Motion in a Vertical Circle	158
6.3	Newton's Law of Gravitation	160
6.4	Weight	163
6.5	Satellite Motion	166
	Summary	171
	Questions/Exercises/Problems	173

7 WORK AND ENERGY 180

7.1	An Overview of Energy	180
7.2	Work	185
7.3	Work and Kinetic Energy	189
7.4	Work Done by a Varying Force	193
7.5	Potential Energy	195
7.6	Conservation of Energy	201
7.7	Conservative and Nonconservative Forces	205
7.8	Power	208
	Summary	211
	Questions/Exercises/Problems	212

8 MOMENTUM 222

8.1	Momentum	222
8.2	Conservation of Momentum	225
8.3	Inelastic Collisions	230
8.4	Elastic Collisions	234
8.5	Impulse	237
8.6	Center of Mass	241
8.7	Motion of the Center of Mass	243
8.8	Rocket Propulsion	245
	Summary	248
	Questions/Exercises/Problems	249

**9 ROTATIONAL MOTION 258**

9.1	Angular Velocity and Angular Acceleration	258
9.2	Rotation with Constant Angular Acceleration	262
9.3	Relationship Between Linear and Angular Quantities	264



9.4	Kinetic Energy of Rotation and Moment of Inertia	268
9.5	Rotation About a Moving Axis	273
	Summary	276
	Questions/Exercises/Problems	277

10 DYNAMICS OF ROTATIONAL MOTION 285

10.1	Torque	285
10.2	Torque and Angular Acceleration	288
10.3	Work and Power in Rotational Motion	295
10.4	Angular Momentum	297
10.5	Conservation of Angular Momentum	299
10.6	Equilibrium of a Rigid Body	303
10.7	Vector Nature of Angular Quantities	309
	Summary	313
	Questions/Exercises/Problems	314

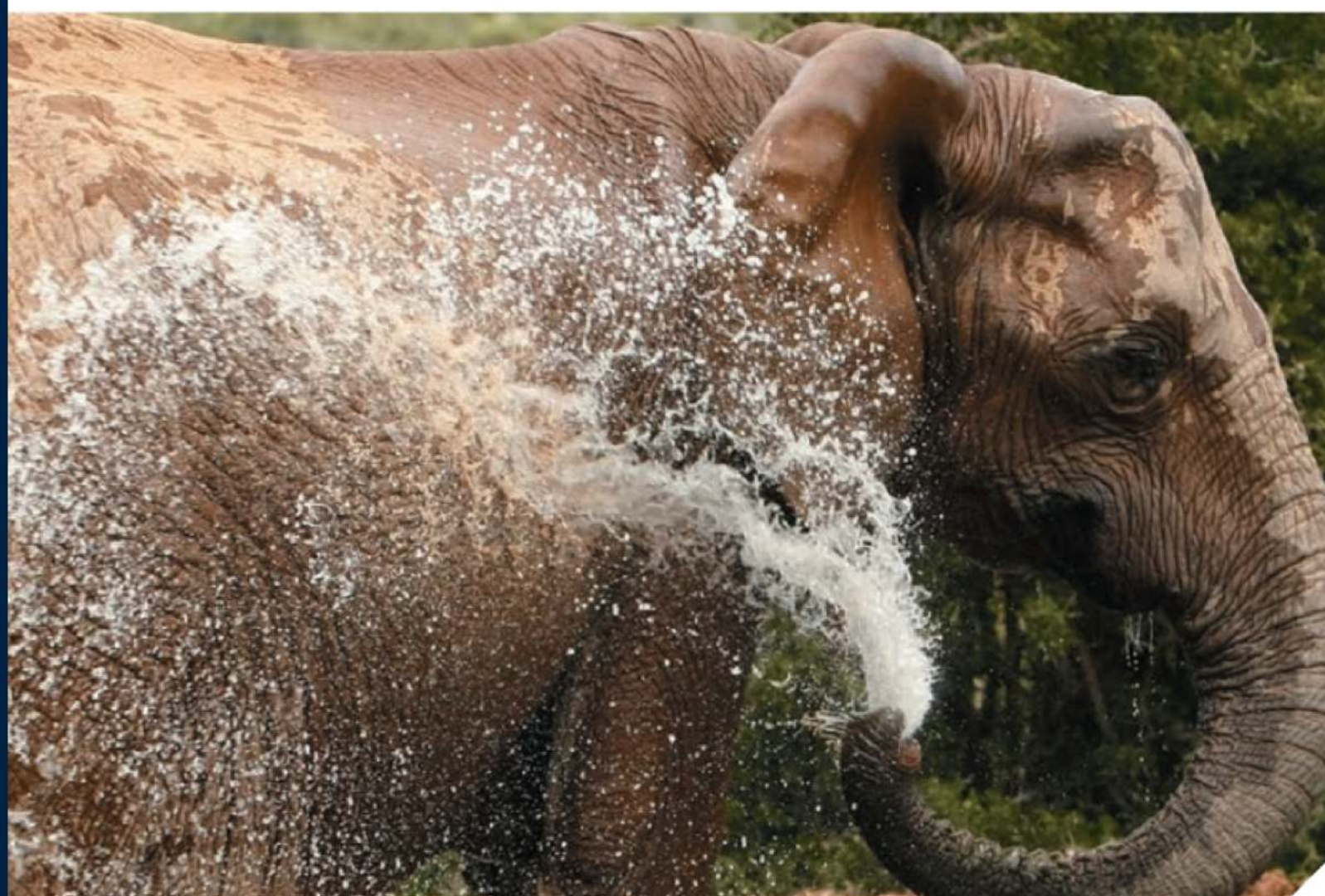
PERIODIC MOTION, WAVES, AND FLUIDS**11 ELASTICITY AND PERIODIC MOTION 325**

11.1	Stress, Strain, and Elastic Deformations	325
11.2	Periodic Motion	333
11.3	Energy in Simple Harmonic Motion	336
11.4	Equations of Simple Harmonic Motion	339
11.5	The Simple Pendulum	345
11.6	Damped and Forced Oscillations	347
	Summary	349
	Questions/Exercises/Problems	350

12 MECHANICAL WAVES AND SOUND 357

12.1	Mechanical Waves	357
12.2	Periodic Mechanical Waves	359
12.3	Wave Speeds	361
12.4	Mathematical Description of a Wave	363
12.5	Reflections and Superposition	364
12.6	Standing Waves and Normal Modes	366
12.7	Longitudinal Standing Waves	371
12.8	Interference	375

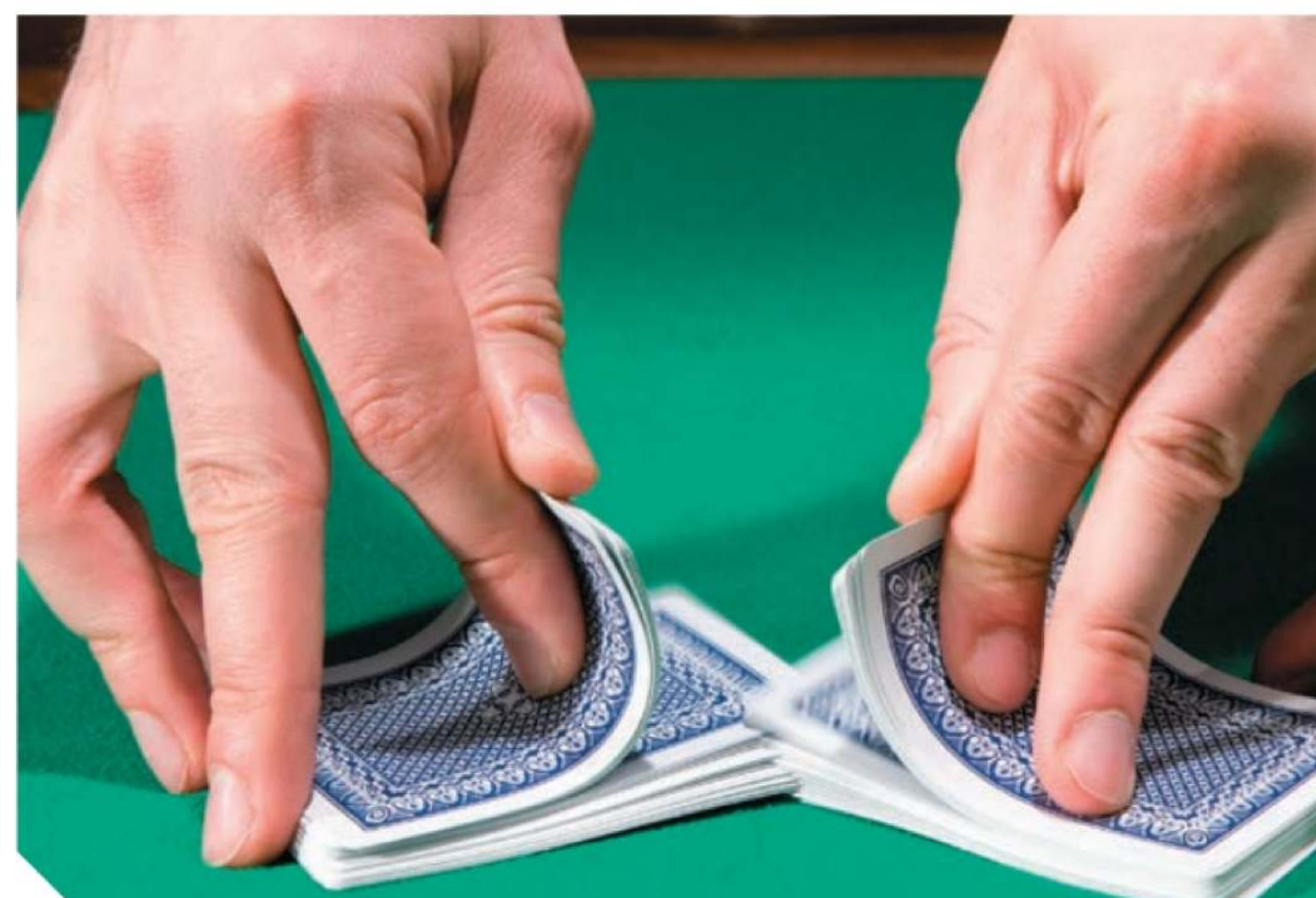
12.9	Sound and Hearing	377
12.10	Sound Intensity	377
12.11	Beats	381
12.12	The Doppler Effect	382
12.13	Applications of Acoustics	386
12.14	Musical Tones	387
	Summary	388
	Questions/Exercises/Problems	390



15	THERMAL PROPERTIES OF MATTER	463
15.1	The Mole and Avogadro's Number	464
15.2	Equations of State	465
15.3	Kinetic Theory of an Ideal Gas	471
15.4	Heat Capacities	477
15.5	The First Law of Thermodynamics	479
15.6	Thermodynamic Processes	486
15.7	Properties of an Ideal Gas	488
	Summary	491
	Questions/Exercises/Problems	493

16	THE SECOND LAW OF THERMODYNAMICS	501
16.1	Directions of Thermodynamic Processes	501
16.2	Heat Engines	503
16.3	Internal Combustion Engines	506
16.4	Refrigerators	507
16.5	The Second Law of Thermodynamics	510
16.6	The Carnot Engine: The Most Efficient Heat Engine	512
16.7	Entropy	515
16.8	The Kelvin Temperature Scale	519
16.9	Energy Resources: A Case Study in Thermodynamics	520
	Summary	522
	Questions/Exercises/Problems	523

13	FLUID MECHANICS	397
13.1	Density	397
13.2	Pressure in a Fluid	399
13.3	Archimedes's Principle: Buoyancy	406
13.4	Surface Tension and Capillarity	409
13.5	Fluid Flow	411
13.6	Bernoulli's Equation	413
13.7	Applications of Bernoulli's Equation	416
13.8	Real Fluids: Viscosity and Turbulence	418
	Summary	420
	Questions/Exercises/Problems	421



THERMODYNAMICS

14	TEMPERATURE AND HEAT	429
14.1	Temperature and Thermal Equilibrium	429
14.2	Temperature Scales	431
14.3	Thermal Expansion	434
14.4	Heat Energy	439
14.5	Phase Changes	442
14.6	Calorimetry	445
14.7	Heat Transfer	447
14.8	Solar Energy and Resource Conservation	453
	Summary	454
	Questions/Exercises/Problems	455

ELECTRICITY AND MAGNETISM

17	ELECTRIC CHARGE AND ELECTRIC FIELD	529
17.1	Electric Charge	529
17.2	Conductors and Insulators	532
17.3	Conservation and Quantization of Charge	535
17.4	Coulomb's Law	535
17.5	Electric Field and Electric Forces	541