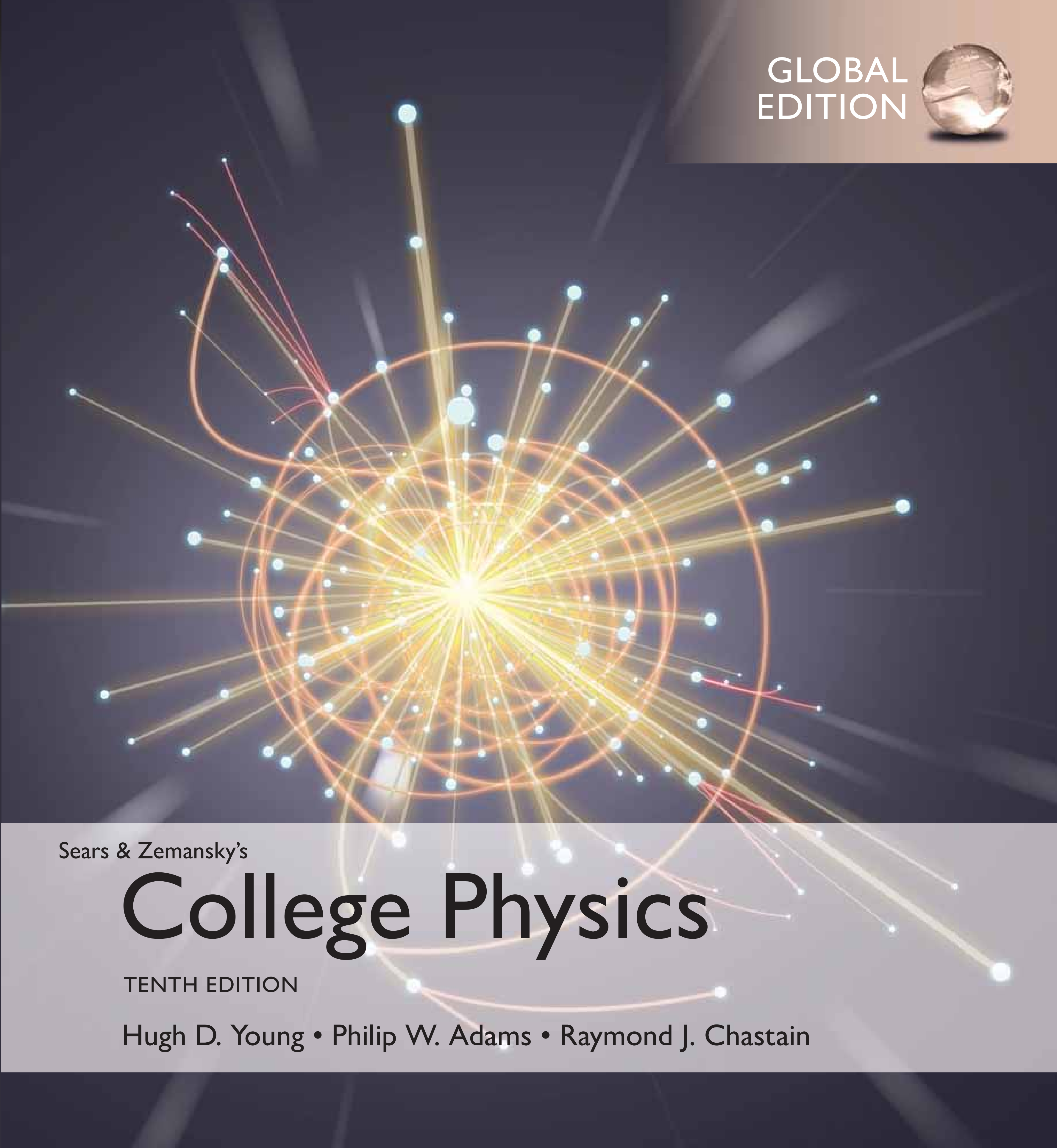

GLOBAL EDITION

Sears & Zemansky's

College Physics

TENTH EDITION

Hugh D. Young • Philip W. Adams • Raymond J. Chastain

ALWAYS LEARNING

PEARSON

College Physics

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PhET Simulations

Available in the Pearson eText and in the Study Area of MasteringPhysics

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. Dr. Adams is an internationally recognized low temperature experimentalist and has published over 70 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 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 25-year tenure at LSU and has been the recipient of numerous teaching awards. Most recently, he helped produce and was, in fact, the narrator for the MasteringPhysics online Video Tutor Solutions for the 13th edition of *University Physics* by Young and Freedman.

Raymond J. Chastain is currently an Assistant Professor of Physics and Astronomy at the University of Louisville. He received his Ph.D. from the University of Georgia working on observational astrochemistry at radio wavelengths. He is currently engaged in physics education research, particularly in investigating the factors that lead to student success in the introductory physics sequence. He is the recent recipient of the Faculty Favorites Teaching Award.

Dr. Chastain's professional career has been dedicated to teaching and student instruction. Prior to his graduate work in physics, Dr. Chastain received a graduate degree in education and worked as a high school teacher. After completing his Ph.D., he returned to the high school classroom for several years before accepting several teaching positions at the college level. He has been involved in multiple programs aimed at improving student learning at both the K–12 and college levels, including several programs working with K–12 teachers to strengthen their understanding of the material they are teaching and the pedagogy used to deliver it.

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.

TENTH EDITION

GLOBAL EDITION

SEARS & ZEMANSKY'S

College Physics

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PEARSON

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Brief Contents

Bringing the best of physics education research to a trusted and classic text

For more than five decades, Sears and Zemansky's ***College Physics*** has provided the most reliable foundation of physics education for students around the world. New coauthors Phil Adams and Ray Chastain have thoroughly revised the **Tenth Edition** by incorporating the latest methods from educational research. New features help students develop greater confidence in solving problems, deepen conceptual understanding, and strengthen quantitative-reasoning skills, while helping them connect what they learn with their other courses. New media resources in MasteringPhysics create an unrivalled learning suite for students and instructors.

RESEARCH-BASED PEDAGOGY

NEW! LEARNING OUTCOMES at the beginning of each chapter give students a roadmap for learning and prepare them for the chapter contents.

By the end of this chapter, you will be able to:

1. Draw a free-body diagram showing the forces acting on an individual object.
2. Solve for unknown quantities (such as magnitudes of forces or accelerations) using Newton's second law in problems involving an individual object or a system of objects connected to each other.
3. Relate the force of friction acting on an object to the normal force exerted on an object in Newton's second law problems.
4. Use Hooke's law to relate the magnitude of the spring force exerted by a spring to the distance from the equilibrium position the spring has been stretched or compressed.

NEW! KEY EQUATIONS are followed by bulleted **"Notes"** to guide students through the math and help them relate quantitative expressions to qualitative concepts.

Definition of average acceleration

The **average acceleration** a_{av} of an object as it moves from x_1 (at time t_1) to x_2 (at time t_2) is a vector quantity whose x component is the ratio of the change in the x component of velocity, $\Delta v_x = v_{2x} - v_{1x}$, to the time interval, $\Delta t = t_2 - t_1$:

$$a_{av,x} = \frac{v_{2x} - v_{1x}}{t_2 - t_1} = \frac{\Delta v_x}{\Delta t}. \qquad (2.3)$$

Units: m/s^2

Notes:

- Average acceleration is a vector.
- It describes how the velocity is changing with time.
- The sign of the average acceleration is not necessarily the same as the sign of the velocity. Furthermore, if the object is slowing down, then it does not necessarily follow that the acceleration is negative. Similarly, if the object is speeding up, it does not necessarily follow that it has positive acceleration.

NEW! An **FAQ** section, based on the everyday expectations of students, appears at the end of every chapter to answer common student questions drawn from the authors' vast teaching experience. The FAQs provide additional instructional scaffolding in the transition from watching to doing.

FREQUENTLY ASKED QUESTIONS

Q: *Can the net force on an object undergoing uniform circular motion ever be zero?*

A: No, there must be a net force pointing toward the center of motion. This force is needed to provide the necessary centripetal acceleration.

Q: *Is the centripetal acceleration always positive?*

A: No; its magnitude is positive but it is a vector, and as such, it must have x and y components, each of which may or may not be negative, depending on your choice of coordinate system.

Q: *Is the r in Newton's law of gravitation (Equation 6.4) a radius?*

A: No! It represents the separation between the centers of two masses, m_1 and m_2.

Q: *Is the gravitational constant G similar to g? Does G also depend on the mass and radius of the earth?*

A: No; G is completely different from g! G is a universal constant of nature and does not depend on anything else.

Q: *Can I use Equation 6.8 for other orbital systems?*

A: Yes; you simply need to replace the earth's mass with whatever central mass you are considering. For instance, to analyze the earth going around the sun, replace the earth's mass with the sun's mass and then r will be the distance to the center of the sun.

Q: *How do I put the mv^2/r term into Newton's second law when I am analyzing a uniform circular-motion problem?*

A: This term goes on the right-hand side of Newton's second law with the appropriate sign, depending on your coordinate system. Remember that the centripetal acceleration must point toward the center of the motion.

New and enhanced features

DEVELOP CONCEPTUAL UNDERSTANDING AND PROBLEM SOLVING SKILLS

NEW! BRIDGING PROBLEMS influenced by physics education research appear at the end of each chapter to help students move from single-concept worked examples to multi-concept problems. These Bridging Problems are also included in MasteringPhysics as Video Tutor Solutions.

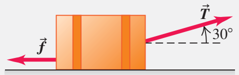
Bridging Problem

Video Tutor Solution

A 10 kg crate is being pulled across the floor by a cable, as shown in Figure 4.29. The friction force between the crate and the floor is f = 19.6 N, and the crate is accelerating to the right at 2 m/s^2. Determine (a) the component of the tension force along the direction of motion, (b) the magnitude of the tension force, (c) the component of the tension force perpendicular to the floor, and (d) the normal force on the crate.

Set Up

- Choose an appropriate coordinate system for this problem.
- Draw a free-body diagram for this system.
- Calculate the x and y components of the forces acting on the crate.
- Write down Newton's second law for each direction.



◄ FIGURE 4.29

Solve

- Use Newton's second law to solve for the component of the tension along the motion.
- Calculate the magnitude of the tension force.
- Calculate the component of the tension perpendicular to the floor.
- Use Newton's second law to solve for the normal force.

Reflect

- What would happen to the crate if the tension was increased by a factor of 10?
- How would the normal force change if the tension force was applied horizontally?
- The normal force can be thought of as an "adjustable" force with a variable magnitude. For what purpose does the force adjust itself?
- Explain your reasoning behind choosing the particular coordinate system you used for this problem.

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.

53. || An astronaut uses a simple pendulum to measure the acceleration DATA of gravity at the surface of a newly discovered planet. The length of the pendulum arm L can be varied between 0.1 m and 0.8 m. The astronaut measures the period of the pendulum motion at a variety of different arm lengths L. Her data are listed here:

L (m)	Period (s)
0.10	0.48
0.22	0.71
0.45	1.02
0.58	1.16
0.75	1.32

Referring to Equation 11.32 as a guide, make a linearized plot of the data by graphing the square of the period as a function of the pendulum arm length. Use a linear "best fit" to the data to determine the acceleration of gravity near the surface of the planet.

NEW! MORE MCAT PREPARATORY MATERIAL supports the revised MCAT releasing in 2015. In addition to more biological and medical applications, we've added 50% more MCAT-style passage problems to the end of chapter problem sets. All passage problems are either new or revised based on the 2015 MCAT guidelines.

Passage Problems

BIO **Human moment of inertia.** The moment of inertia of the human body about an axis through its center of mass is important in the application of biomechanics to sports such as diving and gymnastics. We can measure the body's moment of inertia in a particular position while a person remains in that position on a horizontal turntable, with the body's center of mass on the turntable's rotational axis (Figure 10.80). The turntable with the person on it is then accelerated from rest by a torque produced by using a rope wound around a pulley on the shaft of the turntable. From the measured tension in the rope and the angular acceleration, we can calculate the body's moment of inertia about an axis through its center of mass.

▲ **FIGURE 10.80** Problems 69–72.

69. The moment of inertia of the empty turntable is 1.5 kg · m^2. With a constant torque of 2.5 N · m, the turntable–person system takes 3.0 s to spin from rest to an angular speed of 1.0 rad/s. What is the person's moment of inertia about an axis through her center of mass? Ignore friction in the turntable axle.
    A. 2.5 kg · m^2
    B. 6.0 kg · m^2
    C. 7.5 kg · m^2
    D. 9.0 kg · m^2
70. While the turntable is being accelerated, the person suddenly extends her legs. What happens to the turntable?

WORKED EXAMPLE SOLUTIONS emphasize the steps and decisions students often skip. Most worked examples include **pencil sketches** that show exactly what students should draw in the set-up step of solving the problem. All of these sketches have been revised for this edition. Examples end with a **Practice Problem,** which provides support so that students can begin to tackle problems on their own. Practice Problems are assignable in MasteringPhysics for reinforcement.

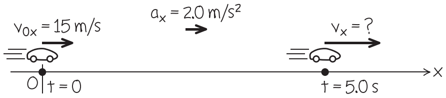
EXAMPLE 2.5 Passing speed

Video Tutor Solution

In this first example of constant accelerated motion, we will simply consider a car that is initially traveling along a straight stretch of highway at 15 m/s. At t = 0 the car begins to accelerate at 2.0 m/s^2 in order to pass a truck. What is the velocity of the car after 5.0 s have elapsed?

SOLUTION

SET UP Figure 2.18 shows what we draw. We take the origin of coordinates to be at the initial position of the car, where $v_x = v_{0x}$ and $t = 0$, and we let the $+x$ direction be the direction of the car's initial velocity. With this coordinate system, $v_{0x} = +15$ m/s and $a_x = +2.0$ m/s^2.



▲ **FIGURE 2.18** The diagram we draw for this problem.

SOLVE The acceleration is constant during the 5.0 s time interval, so we can use Equation 2.6 to find v_x:

$$v_x = v_{0x} + a_x t = 15 \text{ m/s} + (2.0 \text{ m/s}^2)(5.0 \text{ s})$$
$$= 15 \text{ m/s} + 10 \text{ m/s} = 25 \text{ m/s}.$$

REFLECT The velocity and acceleration are in the same direction, so the speed increases. An acceleration of 2.0 m/s^2 means that the velocity increases by 2.0 m/s every second, so in 5.0 s the velocity increases by 10 m/s.

Practice Problem: If the car maintains its constant acceleration, how much additional time does it take the car to reach a velocity of 35 m/s? *Answer:* 5.0 s.

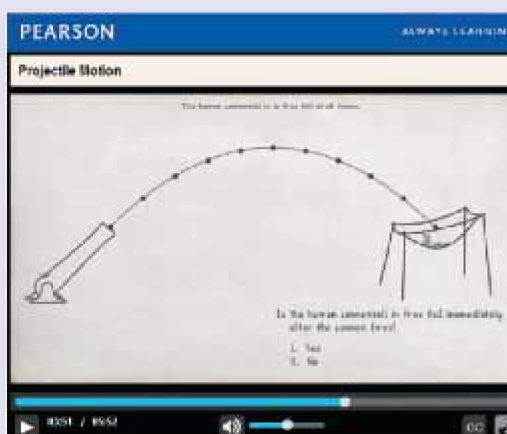
Personalize learning with MasteringPhysics before, during, and after class

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.

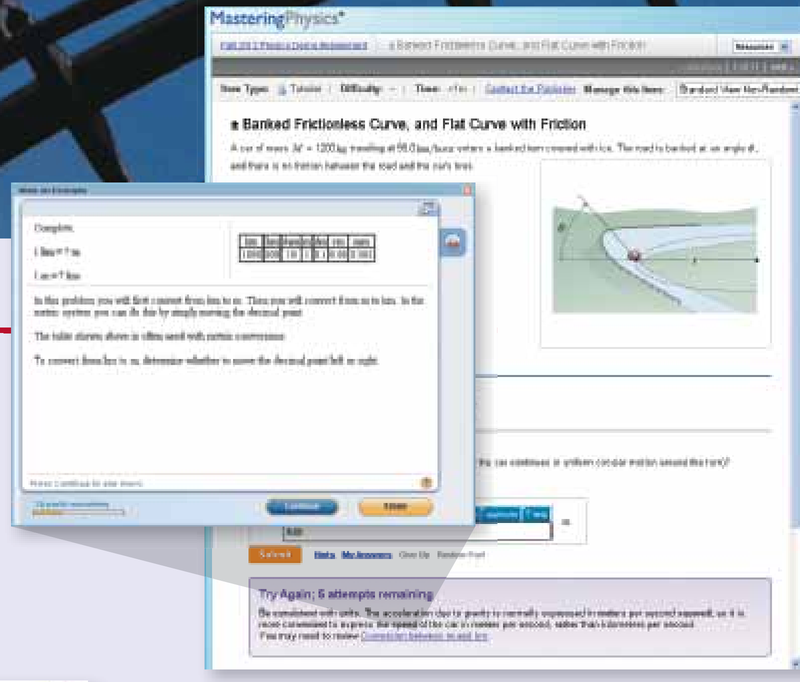


PRE-LECTURE CONCEPT QUESTIONS check familiarity with key concepts, prompting students to do their assigned reading prior to coming to class. These quizzes keep students on track, keep them more engaged in lecture, and help you spot the concepts with which they have the most difficulty. Open-ended essay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

DURING CLASS

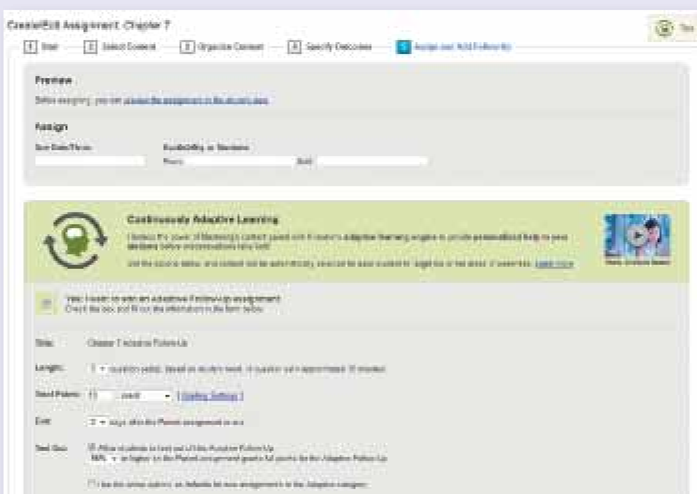
LEARNING CATALYTICS™ is a "bring your own device" student engagement, assessment, and classroom intelligence system. With Learning Catalytics you can:

- 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.



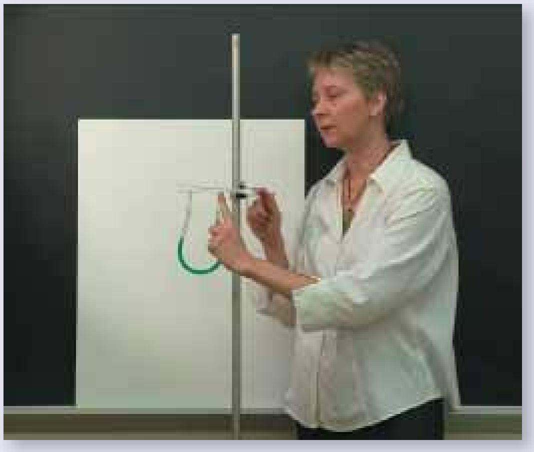
AFTER CLASS

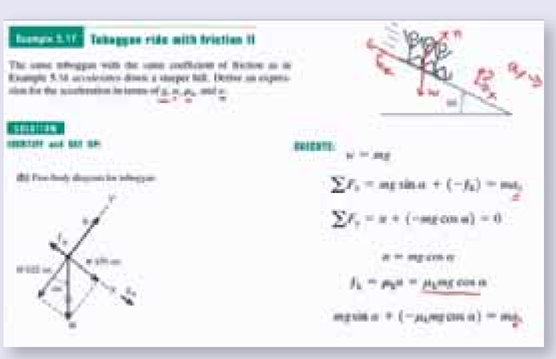
TUTORIALS featuring specific wrong-answer feedback, hints, and a wide variety of educationally effective content guide your students through the toughest topics in physics. The hallmark Hints and Feedback offer instruction similar to what students would experience in an office hour, allowing them to 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.

Real-World Applications

Real-World Applications
(continued)

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 Examples and the Quantitative and Conceptual Analysis problems on your own, before reading the solutions. If you *underline,* do so thoughtfully and not mechanically.

   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.

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

SET UP

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

SOLVE

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

REFLECT

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

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Preface

College Physics, a successful textbook for over half a century, 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, this edition emphasizes solving problems, achieving learning outcomes, 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

- **Chapter 0 (Mathematics Review)** includes a new section on working with data and graphs and solving data-based problems.
- **Learning outcomes** at the beginning of each chapter provide a map to achieving measurable results after studying the chapter.
- **Easy-to-find boxed equations** streamline the presentation. Key equations are followed by "**notes**" that guide students through the math and help them relate quantitative expressions to qualitative concepts.
- **Additional practice problems** accompany worked examples, giving students extra scaffolding to prepare them for doing homework.
- **Streamlined and improved design.** The tenth edition is more concise than previous editions and now features an open, inviting presentation.
- **Over 60 biosciences-related applications, 20 of which are new to this edition,** highlight ways in which physics is manifested in the life sciences, from why plants are green to new techniques for imaging the brain.
- **FAQ sections** at the end of every chapter address the most common student questions. These questions are drawn from the authors' decades of teaching experience.
- **Each end-of-chapter problem set has been carefully curated:**
    - **More than 15% of the problems are new.**
    - **New data-based problems** in every chapter, identified with a DATA icon.
    - **Bridging Problems** provide scaffolding for students as they transition from single-concept worked examples to more challenging end-of-chapter problems.
    - **50% more MCAT-style passage problems.** Every passage problem is either new or revised to prepare students for the 2015 MCAT changes. Most of these passage problems are life science-based.

  The addition of new biological and biomedical real-world applications and problems gives this edition more coverage in the life sciences than nearly every other book on the market. BIO icons mark the location of life science-specific material.

- **Over 70 PhET simulations** are linked to the Pearson eText and are provided in the study area of the MasteringPhysics website (with icons in the print text). These powerful simulations allow students to interact productively with the physics concepts they are learning. PhET clicker questions are also included on the Instructor Resource DVD.
- **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 MasteringPhysics.
- **Assignable MasteringPhysics 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.

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.
  - New **Bridging Problems** 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 transition statements link the content being taught with each worked example.
  - 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 MasteringPhysics.
- **Conceptual Analysis** and **Quantitative Analysis** problems help students practice their qualitative and quantitative understanding of the physics. The Quantitative Analysis problems focus on skills of quantitative and proportional reasoning—skills that are key to success on the MCATs. The CAs and QAs use a multiple-choice format to elicit specific common misconceptions. Many of the CAs and QAs in the tenth edition are new or revised.
- **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 MasteringPhysics to identify the strongest and most successful problems to retain for the tenth edition and we've added new problems. More than 15% of problems are new to this edition.
- Each chapter includes a set of **multiple-choice problems** that test the skills developed by the Qualitative Analysis and Quantitative Analysis 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.
- The text features 50% more Passage Problems, most on life science or medical topics. Each retained Passage Problem has been revised to prepare students for the 2015 MCAT revision.
- **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 downloaded from the Instructor Area, accessed via the top navigation bar of MasteringPhysics (www.masteringphysics.com).*

Instructor Solutions, prepared by A. Lewis Ford (Texas A&M University) and Forrest Newman (Sacramento City College) 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 MasteringPhysics Instructor Area or from the Instructor Resource Center (www.pearsonglobaleditions.com/Young).

The cross-platform **Instructor Resource Material** 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.

MasteringPhysics® (www.masteringphysics.com) is the most advanced, educationally effective, and widely used physics homework and tutorial system in the world. Eight years in development, it provides instructors with a library of extensively pre-tested end-of-chapter problems and rich, multipart, multistep tutorials that incorporate a wide variety of answer types, wrong answer feedback, individualized help (comprising hints or simpler sub-problems upon request), all driven by the largest metadatabase of student problem-solving in the world. NSF-sponsored published research (and subsequent studies) show that MasteringPhysics has dramatic educational results. MasteringPhysics 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.

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MasteringPhysics enables instructors to:

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- Choose from a wide range of nationally pre-tested problems that provide accurate estimates of time to complete and difficulty.
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MP®

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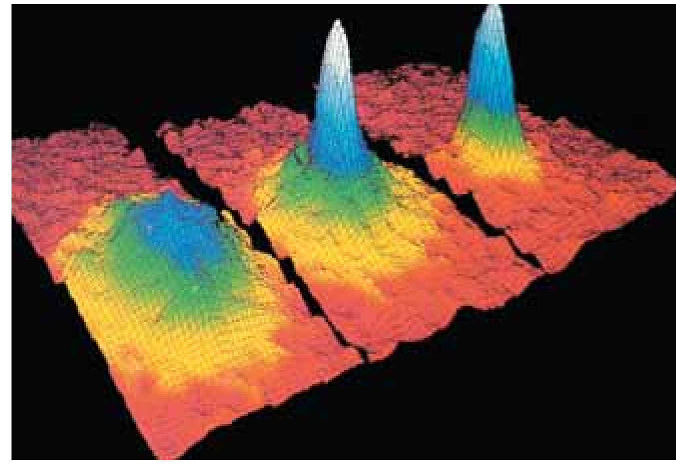

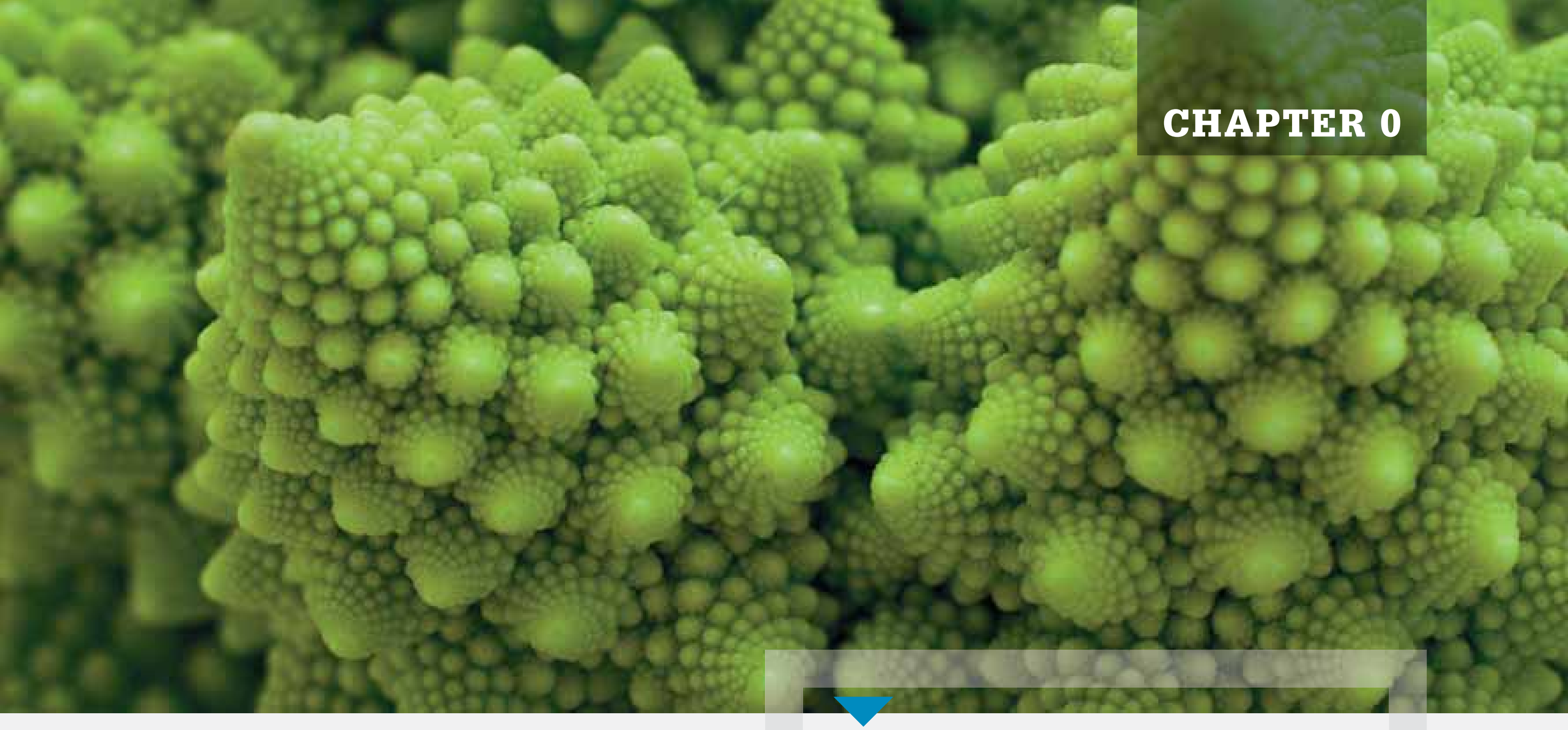

CHAPTER 0

Mathematics Review

The spiral arrangement of buds on this Romanesco broccoli plant is a classic example of how natural processes can give rise to geometrical patterns that can be expressed by means of mathematics. In this chapter, we will review the most important mathematical concepts used in this course.

By the end of this chapter, you will be able to:

1. Use the rules for exponents to simplify algebraic expressions.
2. Express numbers in scientific notation and combine numbers in scientific notation by using addition, subtraction, multiplication, or division.
3. Use the quadratic formula to find both roots for a quadratic equation.
4. Solve a system of two equations with two unknown quantities.
5. Recognize direct, inverse, and inverse-square relationships either algebraically or graphically and solve such a relationship for an unknown quantity.
6. Use tables of data to create linear graphs, which can be used to solve for an unknown quantity.
7. Solve both base-10 logarithm and natural logarithm equations for an unknown quantity.
8. Use geometric expressions to solve for angles, lengths, areas, and volumes in a particular problem.
9. Use trigonometric identities to relate the angles and sides of a right triangle and the law of cosines and the law of sines to relate the angles and sides of any triangle.

Much of the natural world is arranged in patterns that can be described by means of fairly simple mathematics. Like all sciences that seek to explain the natural world, physics relies on a certain amount of mathematics to express its concepts in precise ways. In studying physics, then, you will need some basic math skills in order to understand lectures, read this textbook, and succeed with your homework and on exams. We strongly recommend that you review the material in this chapter and practice with the end-of-chapter problems before you read further. The beauty of physics cannot be fully appreciated if you do not have adequate mastery of basic mathematical skills.

0.1 Exponents

Exponents are used frequently in physics—for example, when describing areas or three-dimensional space. When we write 3^4, the superscript 4 is called an **exponent** and the **base number** 3 is said to be raised to the fourth power. The quantity 3^4 is equal to $3 \times 3 \times 3 \times 3 = 81$. Algebraic symbols can also be raised to a power—for example, x^4. There are special names for the operation when the exponent is 2 or 3. When the exponent is 2, we say that the quantity is **squared;** thus, x^2 means x is squared. When the exponent is 3, the quantity is **cubed;** x^3 means x is cubed.

Note that $x^1 = x$, and the exponent 1 is typically not written. Any quantity raised to the zero power is defined to be unity (that is, 1). Negative exponents are used for reciprocals: $x^{-4} = 1/x^4$.

An exponent can also be a fraction, as in $x^{1/4}$. The exponent $\frac{1}{2}$ is called a **square root,** and the exponent $\frac{1}{3}$ is called a **cube root.** For example, $\sqrt{6}$ can also be written as $6^{1/2}$.

Most calculators have special keys for calculating numbers raised to a power—for instance, a key labeled y^x or one labeled x^2.

Exponents obey several simple rules that follow directly from the meaning of raising a quantity to a power:

1. The product rule: $(x^m)(x^n) = x^{m+n}$.

   For example, $(3^3)(3^2) = 3^5 = 243$. To verify this result, note that $3^3 = 27$, $3^2 = 9$, and $(27)(9) = 243$.

2. The quotient rule: $\dfrac{x^m}{x^n} = x^{m-n}$.

   For example, $\dfrac{3^3}{3^2} = 3^{3-2} = 3^1 = 3$. To verify this result, note that $\dfrac{3^3}{3^2} = \dfrac{27}{9} = 3$.

   A special case of this rule is $\dfrac{x^m}{x^m} = x^{m-m} = x^0 = 1$.

3. The first power rule: $(x^m)^n = x^{mn}$.

   For example, $(2^2)^3 = 2^6 = 64$. To verify this result, note that $2^2 = 4$, so $(2^2)^3 = (4)^3 = 64$.

4. Other power rules:

$$(xy)^m = (x^m)(y^m) \quad \text{and} \quad \left(\frac{x}{y}\right)^m = \frac{x^m}{y^m}.$$

   For example, $(3 \times 2)^4 = 6^4 = 1296$. To verify the first result, note that $3^4 = 81$, $2^4 = 16$, and $(81)(16) = 1296$.

If the base number is negative, it is helpful to know that $(-x)^n = (-1)^n x^n$, and $(-1)^n$ is $+1$ if n is even and -1 if n is odd. You can verify easily the other power rules for any x and y.

EXAMPLE 0.1 Simplifying an exponential expression

Video Tutor Solution

Let's start by simplifying the expression $\dfrac{x^3y^{-3}xy^{4/3}}{x^{-4}y^{1/3}(x^2)^3}$ and calculating its numerical value when $x = 6$ and $y = 3$.

SOLUTION

SET UP AND SOLVE We simplify the expression as follows:

$$\frac{x^3x}{x^{-4}(x^2)^3} = x^3x^1x^4x^{-6} = x^{3+1+4-6} = x^2;$$

$$\frac{y^{-3}y^{4/3}}{y^{1/3}} = y^{-3+\frac{4}{3}-\frac{1}{3}} = y^{-2}.$$

Therefore,

$$\frac{x^3y^{-3}xy^{4/3}}{x^{-4}y^{1/3}(x^2)^3} = x^2y^{-2} = x^2\left(\frac{1}{y}\right)^2 = \left(\frac{x}{y}\right)^2.$$

For $x = 6$ and $y = 3$, $\left(\dfrac{x}{y}\right)^2 = \left(\dfrac{6}{3}\right)^2 = 4$.

CONTINUED