# PREFACE

*Physical Science* is a straightforward, easy-to-read but substantial introduction to the fundamental behavior of matter and energy. It is intended to serve the needs of nonscience majors who are required to complete one or more physical science courses. It introduces basic concepts and key ideas while providing opportunities for students to learn reasoning skills and a new way of thinking about their environment. No prior work in science is assumed. The language, as well as the mathematics, is as simple as can be practical for a college-level science course.

## ORGANIZATION

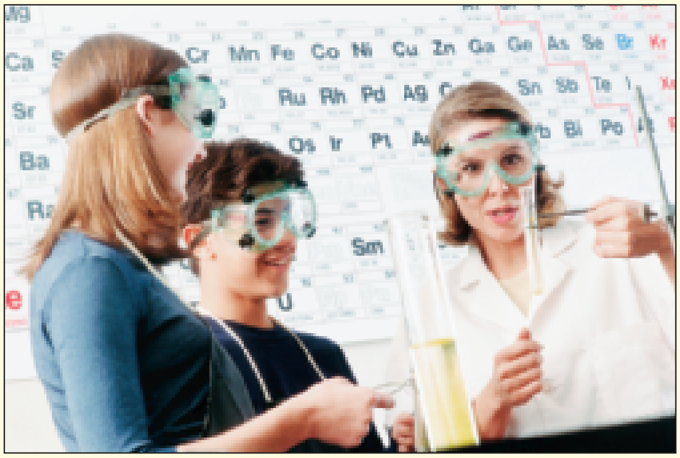
The *Physical Science* sequence of chapters is flexible, and the instructor can determine topic sequence and depth of coverage as needed. The materials are also designed to support a conceptual approach or a combined conceptual and problem-solving approach. With laboratory studies, the text contains enough material for the instructor to select a sequence for a two-semester course. It can also serve as a text in a one-semester astronomy and earth science course or in other combinations.

> **"The text is excellent. I do not think I could have taught the course using any other textbook. I think one reason I really enjoy teaching this course is because of the text. I could say for sure that this is one of the best textbooks I have seen in my career. . . . I love this textbook for the following reasons: (1) it is comprehensive, (2) it is very well written, (3) it is easily readable and comprehendible, (4) it has good graphics."**
> **—Ezat Heydari, Jackson State University**

> **"Thorough, very well put together and containing everything a professor will need for a course in Physical Science."**
> **—Dimitri Tamalis, Florida Memorial University**

## MEETING STUDENT NEEDS

*Physical Science* is based on two fundamental assumptions arrived at as the result of years of experience and observation from teaching the course: (1) that students taking the course often have very limited background and/or aptitude in the natural sciences; and (2) that these types of student will better grasp the ideas and principles of physical science that are discussed with minimal use of technical terminology and detail. In addition, it is critical for the student to see relevant applications of the material to everyday life. Most of these everyday-life applications, such as environmental concerns, are not isolated in an arbitrary chapter; they are discussed where they occur naturally throughout the text.



> **"Tillery continues to do a great job in making the physical sciences come alive to today's students. I have been using this text for over 10 years and have no plans on switching."**
> **—Timothy M. Ritter, The University of North Carolina at Pembroke**

Each chapter presents historical background where appropriate, uses everyday examples in developing concepts, and follows a logical flow of presentation. The historical chronology, of special interest to the humanistically inclined nonscience major, serves to humanize the science being presented. The use of everyday examples appeals to the nonscience major, typically accustomed to reading narration, not scientific technical writing, and also tends to bring relevancy to the material being presented. The logical flow of presentation is helpful to students not accustomed to thinking about relationships between what is being read and previous knowledge learned, a useful skill in understanding the physical sciences. Worked examples help students to integrate concepts and understand the use of relationships called equations. These examples also serve as a model for problem solving; consequently, special attention is given to *complete* unit work and to the clear, fully expressed use of mathematics. Where appropriate, chapters contain one or more activities, called *Concepts Applied,* that use everyday materials rather than specialized laboratory equipment. These activities are intended to bring the science concepts closer to the world of the student. The activities are supplemental and can be done as optional student activities or as demonstrations.

> **"Tillery's Physical Science is an excellent text that can be used for students at all levels of backgrounds and abilities. The text can be used to teach the course by using conceptual approach, or the instructor can use the text to focus on the mathematics of physics topics. The development of the topics is logical and each subject builds on the preceding material. I have used the Tillery texts for over 14 years, and even though I have looked at others, I would not want to change!"**
> **—Wilda Pounds, Northeast Mississippi Community College**

> **"Simply put, Tillery's *Physical Science* is a complete, concise, delightfully written text."**
> **—Pamela Ray, Chattahoochee Valley Community College**

## NEW TO THIS EDITION

Numerous revisions have been made to the text to update the content on current events and to make the text even more user-friendly and relevant for students.

One overall revision has been made to this edition to further enhance the text's focus on developing concepts and building problem-solving skills:

**Case Studies** New interactive Case Studies are available for select chapters of the tenth edition. The Case Study boxed readings expand upon interesting topics in the text and then are further supplemented by the online versions. The online Case Studies are assignable through McGraw-Hill ConnectPlus® and include additional reading, videos, animations, assessment questions and other valuable resources. Some examples include:

Chapter 5 Doppler Effect
Chapter 7 Bioluminous
Chapter 15 Worth the Cost?
Chapter 18 Measuring Plate Movement
Chapter 23 El Nino
Chapter 23 Proxy Data

The list below provides chapter-specific updates:

**Chapter 1** New information on scientific communication has been added to help students further understand how the scientific method is implemented in real life situations.

**Chapter 3** Chapter 3 includes a new illustration and information about calculating work and when the change of position must be in the same direction as the direction of the force. The chapter also includes updated information on energy resources and a new Myths, Mistakes, and Misunderstandings on recycling.

**Chapter 4** New information on energy efficiency has been added. A new figure provides a real-life example of how condensation and evaporation is involved in laundry. A note to clarify the convention of °C and C° has also been added.

**Chapter 7** A new Closer Look on Fiber Optics has been added. Figure 7.7 has been revised to explain how the law of reflection applies to each light ray.

**Chapter 8** A Closer Look on semiconductors has been added to help students make everyday connections with the topic of atomic structures. Additional information has been added to direct students to online resource.

**Chapter 11** Chapter 11 includes a new Science and Society on BPA.

**Chapter 13** New information on the Fukushima I nuclear reactor has been added. The Science and Society on High-Level Nuclear Waste has also been updated with new information.

**Chapter 14** New figures have been added to the sections on The Life of a Star and The Life of a Galaxy.

**Chapter 15** Chapter 15 includes updated information on the Messenger mission and on spacecraft missions to study comets and asteroids as well as new figures of a comet and asteroid.

**Chapter 19** A new Closer Look on Some Recent Earthquakes has been added to update the material with recent events.

**Chapter 22** New and updated information has been added to the Science and Society: Use Wind Energy?

## THE LEARNING SYSTEM

*Physical Science* has an effective combination of innovative learning aids intended to make the student's study of science more effective and enjoyable. This variety of aids is included to help students clearly understand the concepts and principles that serve as the foundation of the physical sciences.

### OVERVIEW

Chapter 1 provides an *overview* or orientation to what the study of physical science in general and this text in particular are all about. It discusses the fundamental methods and techniques used by scientists to study and understand the world around us. It also explains the problem-solving approach used throughout the text so that students can more effectively apply what they have learned.

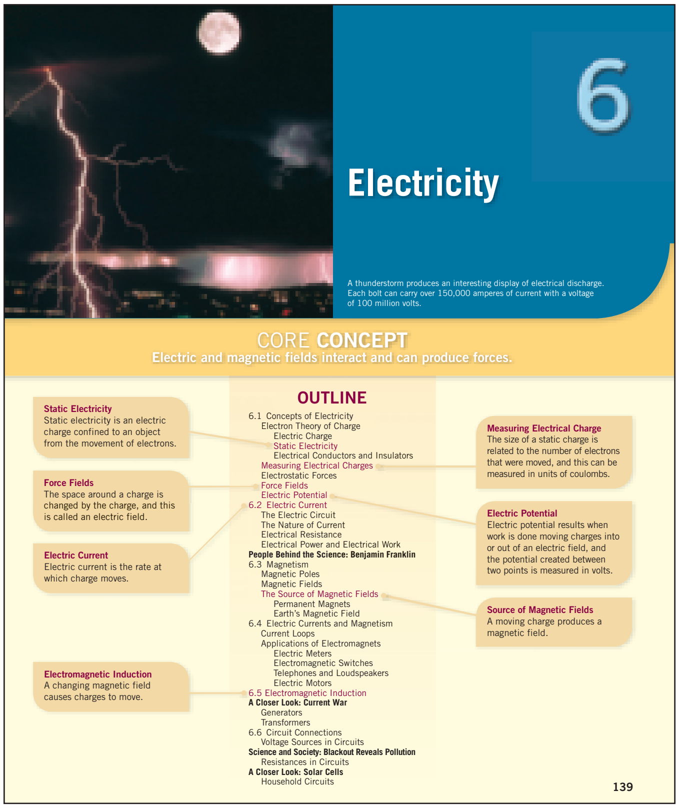
### CHAPTER OPENING TOOLS

### Core Concept and Supporting Concepts

Core and supporting concepts integrate the chapter concepts and the chapter outline. The core and supporting concepts outline and emphasize the concepts at a chapter level. The concepts list is designed to help students focus their studies by identifying the most important topics in the chapter outline.

## Chapter Outline

The chapter outline includes all the major topic headings and subheadings within the body of the chapter. It gives you a quick glimpse of the chapter's contents and helps you locate sections dealing with particular topics.



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**Electricity**

A thunderstorm produces an interesting display of electrical discharge. Each bolt can carry over 150,000 amperes of current with a voltage of 100 million volts.

CORE **CONCEPT**

**Electric and magnetic fields interact and can produce forces.**

**Static Electricity**
Static electricity is an electric charge confined to an object from the movement of electrons.

**Force Fields**
The space around a charge is changed by the charge, and this is called an electric field.

**Electric Current**
Electric current is the rate at which charge moves.

**Electromagnetic Induction**
A changing magnetic field causes charges to move.

**OUTLINE**

- 6.1 Concepts of Electricity
  - Electron Theory of Charge
    - Electric Charge
    - Static Electricity
    - Electrical Conductors and Insulators
  - Measuring Electrical Charges
  - Electrostatic Forces
  - Force Fields
  - Electric Potential
- 6.2 Electric Current
  - The Electric Circuit
  - The Nature of Current
  - Electrical Resistance
  - Electrical Power and Electrical Work
- **People Behind the Science: Benjamin Franklin**
- 6.3 Magnetism
  - Magnetic Poles
  - Magnetic Fields
  - The Source of Magnetic Fields
    - Permanent Magnets
    - Earth's Magnetic Field
- 6.4 Electric Currents and Magnetism
  - Current Loops
  - Applications of Electromagnets
    - Electric Meters
    - Electromagnetic Switches
    - Telephones and Loudspeakers
    - Electric Motors
- 6.5 Electromagnetic Induction
- **A Closer Look: Current War**
  - Generators
  - Transformers
- 6.6 Circuit Connections
  - Voltage Sources in Circuits
- **Science and Society: Blackout Reveals Pollution**
  - Resistances in Circuits
- **A Closer Look: Solar Cells**
  - Household Circuits

**Measuring Electrical Charge**
The size of a static charge is related to the number of electrons that were moved, and this can be measured in units of coulombs.

**Electric Potential**
Electric potential results when work is done moving charges into or out of an electric field, and the potential created between two points is measured in volts.

**Source of Magnetic Fields**
A moving charge produces a magnetic field.

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## Chapter Overview

Each chapter begins with an introductory overview. The overview previews the chapter's contents and what you can expect to learn from reading the chapter. It adds to the general outline of the chapter by introducing you to the concepts to be covered, facilitating the integration of topics, and helping you to stay focused and organized while reading the chapter for the first time. After you read the introduction, browse through the chapter, paying particular attention to the topic headings and illustrations so that you get a feel for the kinds of ideas included within the chapter.

> **"Tillery does a much better job explaining concepts and reinforcing them. I believe his style of presentation is better and more comfortable for the student. His use of the overviews and examples is excellent!"**
>
> **—George T. Davis, Jr., Mississippi Delta Community College**

OVER**VIEW**

Chapters 2–5 have been concerned with *mechanical* concepts, explanations of the motion of objects that exert forces on one another. These concepts were used to explain straight-line motion, the motion of free fall, and the circular motion of objects on Earth as well as the circular motion of planets and satellites. The mechanical concepts were based on Newton's laws of motion and are sometimes referred to as Newtonian physics. The mechanical explanations were then extended into the submicroscopic world of matter through the kinetic molecular theory. The objects of motion were now particles, molecules that exert force on one another, and concepts associated with heat were interpreted as the motion of these particles. In a further extension of Newtonian concepts, mechanical explanations were given for concepts associated with sound, a mechanical disturbance that follows the laws of motion as it moves through the molecules of matter.

You might wonder, as did the scientists of the 1800s, if mechanical interpretations would also explain other natural phenomena such as electricity, chemical reactions, and light. A mechanical model would be very attractive because it already explained so many other facts of nature, and scientists have always looked for basic, unifying theories. Mechanical interpretations were tried, as electricity was considered a moving fluid, and light was considered a mechanical wave moving through a material fluid. There were many unsolved puzzles with such a model, and gradually it was recognized that electricity, light, and chemical reactions could not be explained by mechanical interpretations. Gradually, the point of view changed from a study of particles to a study of the properties of the space around the particles. In this chapter, you will learn about electric charge in terms of the space around particles. This model of electric charge, called the *field model,* will be used to develop concepts about electric current, the electric circuit, and electrical work and power. A relationship between electricity and the fascinating topic of magnetism is discussed next, including what magnetism is and how it is produced. Then the relationship is used to explain the mechanical production of electricity (Figure 6.1), how electricity is measured, and how electricity is used in everyday technological applications.

**6.1 CONCEPTS OF ELECTRICITY**

You are familiar with the use of electricity in many electrical devices such as lights, toasters, radios, and calculators. You are also aware that electricity is used for transportation and for heating and cooling places where you work and live. Many people accept electrical devices as part of their surroundings, with only a hazy notion of how they work. To many people, electricity seems to be magical. Electricity is not magical, and it can be understood, just as we understand any other natural phenomenon. There are theories that explain observations, quantities that can be measured, and relationships between these quantities, or laws, that lead to understanding. All of the observations, measurements, and laws begin with an understanding of *electric charge.*

**ELECTRON THEORY OF CHARGE**

It was a big mystery for thousands of years. No one could figure out why a rubbed piece of amber, which is fossilized tree resin, would attract small pieces of paper (papyrus), thread, and hair. This unexplained attraction was called the *amber effect.* Then about one hundred years ago, J. J. Thomson (1856–1940) found the answer while experimenting with electric currents. From these experiments, Thomson was able to conclude that negatively charged particles were present in all matter and in fact might be the stuff of which matter is made. The amber effect was traced to the movement of these particles, so they were called *electrons* after the Greek word for amber. The word *electricity* is also based on the Greek word for amber.

Today, we understand that the basic unit of matter is the *atom,* which is made up of electrons and other particles such as *protons* and *neutrons.* The atom is considered to have a dense center part called a *nucleus* that contains the closely situated protons and neutrons. The electrons move around the nucleus at some relatively greater distance (Figure 6.2). Details on the nature of protons, neutrons, electrons, and models of how the atom is constructed will be considered in chapter 8. For understanding electricity, you need only consider the protons in the nucleus, the electrons that move around the nucleus, and the fact that electrons can be moved from an atom and caused to move to or from one object to another. Basically, the electrical, light, and chemical phenomena involve the *electrons* and not the more massive nucleus. The massive nuclei remain in a relatively fixed position in a solid, but some of the electrons can move about from atom to atom.

**Electric Charge**

Electrons and protons have a property called electric charge. Electrons have a *negative electric charge,* and protons have a *positive electric charge*. The negative or positive description simply means that these two properties are opposite; it does not mean that one is better than the other. Charge is as fundamental to these subatomic particles as gravity is to masses. This means

140 **CHAPTER 6** Electricity

*6-2*

## EXAMPLES

Each topic discussed within the chapter contains one or more concrete, worked *Examples* of a problem and its solution as it applies to the topic at hand. Through careful study of these examples, students can better appreciate the many uses of problem solving in the physical sciences.

> **"I feel this book is written well for our average student. The images correlate well with the text, and the math problems make excellent use of the dimensional analysis method."**
>
> **—Alan Earhart, Three Rivers Community College**

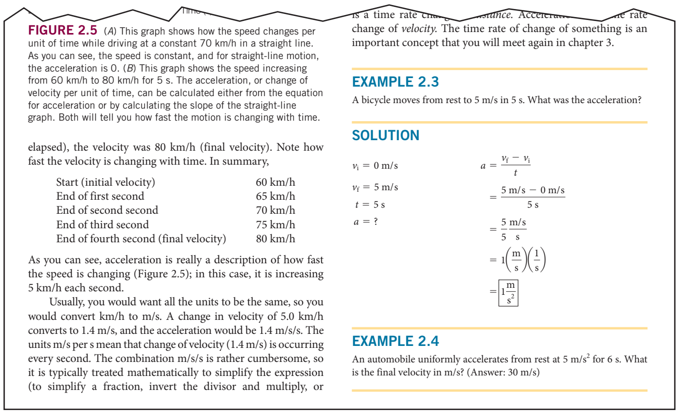


**FIGURE 2.5** (*A*) This graph shows how the speed changes per unit of time while driving at a constant 70 km/h in a straight line. As you can see, the speed is constant, and for straight-line motion, the acceleration is 0. (*B*) This graph shows the speed increasing from 60 km/h to 80 km/h for 5 s. The acceleration, or change of velocity per unit of time, can be calculated either from the equation for acceleration or by calculating the slope of the straight-line graph. Both will tell you how fast the motion is changing with time.

elapsed), the velocity was 80 km/h (final velocity). Note how fast the velocity is changing with time. In summary,

| | |
|---|---|
| Start (initial velocity) | 60 km/h |
| End of first second | 65 km/h |
| End of second second | 70 km/h |
| End of third second | 75 km/h |
| End of fourth second (final velocity) | 80 km/h |

As you can see, acceleration is really a description of how fast the speed is changing (Figure 2.5); in this case, it is increasing 5 km/h each second.

Usually, you would want all the units to be the same, so you would convert km/h to m/s. A change in velocity of 5.0 km/h converts to 1.4 m/s, and the acceleration would be 1.4 m/s/s. The units m/s per s mean that change of velocity (1.4 m/s) is occurring every second. The combination m/s/s is rather cumbersome, so it is typically treated mathematically to simplify the expression (to simplify a fraction, invert the divisor and multiply, or

is a time rate

change of *velocity.* The time rate of change of something is an important concept that you will meet again in chapter 3.

**EXAMPLE 2.3**

A bicycle moves from rest to 5 m/s in 5 s. What was the acceleration?

**SOLUTION**

$v_\mathrm{i} = 0\ \mathrm{m/s}$

$v_\mathrm{f} = 5\ \mathrm{m/s}$

$t = 5\ \mathrm{s}$

$a = ?$

$$\begin{aligned} a &= \frac{v_\mathrm{f} - v_\mathrm{i}}{t} \\ &= \frac{5\ \mathrm{m/s} - 0\ \mathrm{m/s}}{5\ \mathrm{s}} \\ &= \frac{5}{5}\,\frac{\mathrm{m/s}}{\mathrm{s}} \\ &= 1\left(\frac{\mathrm{m}}{\mathrm{s}}\right)\left(\frac{1}{\mathrm{s}}\right) \\ &= \boxed{1\frac{\mathrm{m}}{\mathrm{s}^2}} \end{aligned}$$

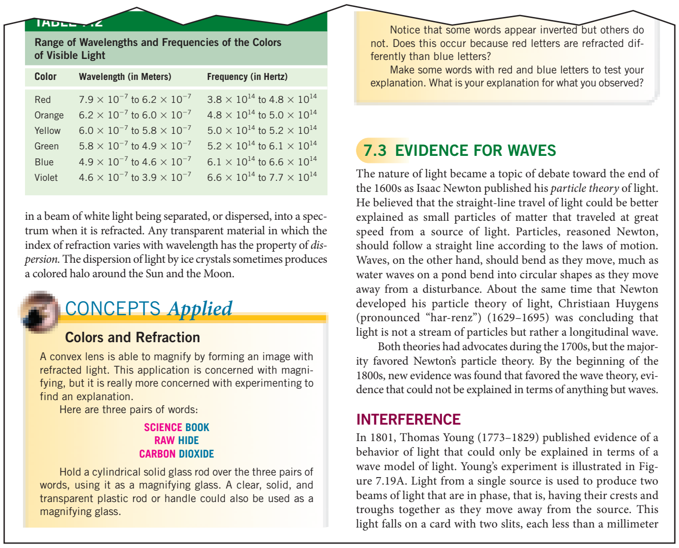
**EXAMPLE 2.4**

An automobile uniformly accelerates from rest at $5\ \mathrm{m/s^2}$ for 6 s. What is the final velocity in m/s? (Answer: 30 m/s)

# APPLYING SCIENCE TO THE REAL WORLD

## Concepts Applied

Each chapter also includes one or more *Concepts Applied* boxes. These activities are simple investigative exercises that students can perform at home or in the classroom to demonstrate important concepts and reinforce understanding of them. This feature also describes the application of those concepts to everyday life.



**Range of Wavelengths and Frequencies of the Colors of Visible Light**

| Color | Wavelength (in Meters) | Frequency (in Hertz) |
|---|---|---|
| Red | $7.9 \times 10^{-7}$ to $6.2 \times 10^{-7}$ | $3.8 \times 10^{14}$ to $4.8 \times 10^{14}$ |
| Orange | $6.2 \times 10^{-7}$ to $6.0 \times 10^{-7}$ | $4.8 \times 10^{14}$ to $5.0 \times 10^{14}$ |
| Yellow | $6.0 \times 10^{-7}$ to $5.8 \times 10^{-7}$ | $5.0 \times 10^{14}$ to $5.2 \times 10^{14}$ |
| Green | $5.8 \times 10^{-7}$ to $4.9 \times 10^{-7}$ | $5.2 \times 10^{14}$ to $6.1 \times 10^{14}$ |
| Blue | $4.9 \times 10^{-7}$ to $4.6 \times 10^{-7}$ | $6.1 \times 10^{14}$ to $6.6 \times 10^{14}$ |
| Violet | $4.6 \times 10^{-7}$ to $3.9 \times 10^{-7}$ | $6.6 \times 10^{14}$ to $7.7 \times 10^{14}$ |

in a beam of white light being separated, or dispersed, into a spectrum when it is refracted. Any transparent material in which the index of refraction varies with wavelength has the property of *dispersion.* The dispersion of light by ice crystals sometimes produces a colored halo around the Sun and the Moon.

### CONCEPTS *Applied*

**Colors and Refraction**

A convex lens is able to magnify by forming an image with refracted light. This application is concerned with magnifying, but it is really more concerned with experimenting to find an explanation.

Here are three pairs of words:

**SCIENCE BOOK**
**RAW HIDE**
**CARBON DIOXIDE**

Hold a cylindrical solid glass rod over the three pairs of words, using it as a magnifying glass. A clear, solid, and transparent plastic rod or handle could also be used as a magnifying glass.

Notice that some words appear inverted but others do not. Does this occur because red letters are refracted differently than blue letters?

Make some words with red and blue letters to test your explanation. What is your explanation for what you observed?

### 7.3 EVIDENCE FOR WAVES

The nature of light became a topic of debate toward the end of the 1600s as Isaac Newton published his *particle theory* of light. He believed that the straight-line travel of light could be better explained as small particles of matter that traveled at great speed from a source of light. Particles, reasoned Newton, should follow a straight line according to the laws of motion. Waves, on the other hand, should bend as they move, much as water waves on a pond bend into circular shapes as they move away from a disturbance. About the same time that Newton developed his particle theory of light, Christiaan Huygens (pronounced "har-renz") (1629–1695) was concluding that light is not a stream of particles but rather a longitudinal wave.

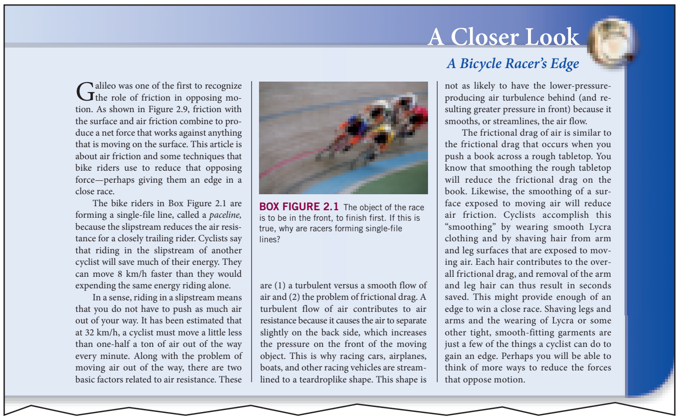
Both theories had advocates during the 1700s, but the majority favored Newton's particle theory. By the beginning of the 1800s, new evidence was found that favored the wave theory, evidence that could not be explained in terms of anything but waves.

### INTERFERENCE

In 1801, Thomas Young (1773–1829) published evidence of a behavior of light that could only be explained in terms of a wave model of light. Young's experiment is illustrated in Figure 7.19A. Light from a single source is used to produce two beams of light that are in phase, that is, having their crests and troughs together as they move away from the source. This light falls on a card with two slits, each less than a millimeter

## Closer Look

One or more boxed *Closer Look* features can be found in each chapter of *Physical Science.* These readings present topics of special human or environmental concern (the use of seat belts, acid rain, and air pollution, for example). In addition to environmental concerns, topics are presented on interesting technological applications (passive solar homes, solar cells, catalytic converters, etc.) or on the cutting edge of scientific research (for example, El Niño and dark energy). All boxed features are informative materials that are supplementary in nature. The *Closer Look* readings serve to underscore the relevance of physical science in confronting the many issues we face daily.



### A Closer Look

*A Bicycle Racer's Edge*

Galileo was one of the first to recognize the role of friction in opposing motion. As shown in Figure 2.9, friction with the surface and air friction combine to produce a net force that works against anything that is moving on the surface. This article is about air friction and some techniques that bike riders use to reduce that opposing force—perhaps giving them an edge in a close race.

The bike riders in Box Figure 2.1 are forming a single-file line, called a *paceline,* because the slipstream reduces the air resistance for a closely trailing rider. Cyclists say that riding in the slipstream of another cyclist will save much of their energy. They can move 8 km/h faster than they would expending the same energy riding alone.

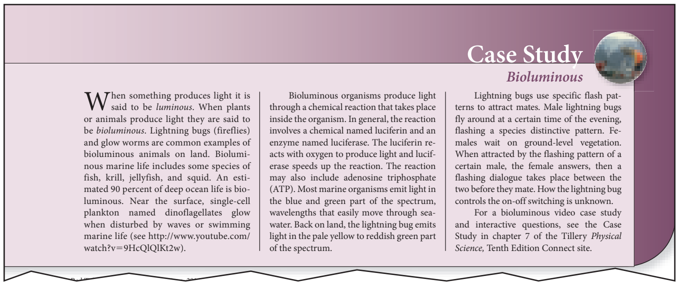
In a sense, riding in a slipstream means that you do not have to push as much air out of your way. It has been estimated that at 32 km/h, a cyclist must move a little less than one-half a ton of air out of the way every minute. Along with the problem of moving air out of the way, there are two basic factors related to air resistance. These are (1) a turbulent versus a smooth flow of air and (2) the problem of frictional drag. A turbulent flow of air contributes to air resistance because it causes the air to separate slightly on the back side, which increases the pressure on the front of the moving object. This is why racing cars, airplanes, boats, and other racing vehicles are streamlined to a teardroplike shape. This shape is not as likely to have the lower-pressure-producing air turbulence behind (and resulting greater pressure in front) because it smooths, or streamlines, the air flow.

**BOX FIGURE 2.1** The object of the race is to be in the front, to finish first. If this is true, why are racers forming single-file lines?

The frictional drag of air is similar to the frictional drag that occurs when you push a book across a rough tabletop. You know that smoothing the rough tabletop will reduce the frictional drag on the book. Likewise, the smoothing of a surface exposed to moving air will reduce air friction. Cyclists accomplish this "smoothing" by wearing smooth Lycra clothing and by shaving hair from arm and leg surfaces that are exposed to moving air. Each hair contributes to the overall frictional drag, and removal of the arm and leg hair can thus result in seconds saved. This might provide enough of an edge to win a close race. Shaving legs and arms and the wearing of Lycra or some other tight, smooth-fitting garments are just a few of the things a cyclist can do to gain an edge. Perhaps you will be able to think of more ways to reduce the forces that oppose motion.

## New! Case Studies

Interactive Case Studies are available for select chapters of the tenth edition. The boxed readings in the text expand upon interesting topics and then are further supplemented by the online versions. The online Case Studies are assignable through ConnectPlus and include additional reading, videos, animations, assessment questions and other valuable resources.



### Case Study

*Bioluminous*

When something produces light it is said to be *luminous*. When plants or animals produce light they are said to be *bioluminous*. Lightning bugs (fireflies) and glow worms are common examples of bioluminous animals on land. Bioluminous marine life includes some species of fish, krill, jellyfish, and squid. An estimated 90 percent of deep ocean life is bioluminous. Near the surface, single-cell plankton named dinoflagellates glow when disturbed by waves or swimming marine life (see http://www.youtube.com/watch?v=9HcQlQlKt2w).

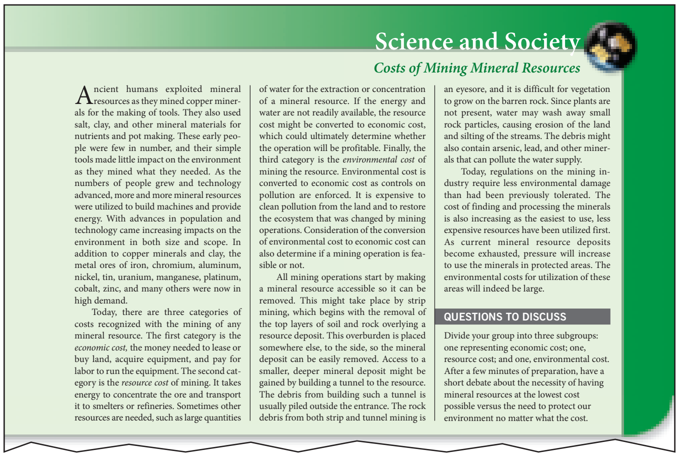
Bioluminous organisms produce light through a chemical reaction that takes place inside the organism. In general, the reaction involves a chemical named luciferin and an enzyme named luciferase. The luciferin reacts with oxygen to produce light and luciferase speeds up the reaction. The reaction may also include adenosine triphosphate (ATP). Most marine organisms emit light in the blue and green part of the spectrum, wavelengths that easily move through seawater. Back on land, the lightning bug emits light in the pale yellow to reddish green part of the spectrum.

Lightning bugs use specific flash patterns to attract mates. Male lightning bugs fly around at a certain time of the evening, flashing a species distinctive pattern. Females wait on ground-level vegetation. When attracted by the flashing pattern of a certain male, the female answers, then a flashing dialogue takes place between the two before they mate. How the lightning bug controls the on-off switching is unknown.

For a bioluminous video case study and interactive questions, see the Case Study in chapter 7 of the Tillery *Physical Science,* Tenth Edition Connect site.

## Science and Society

These readings relate the chapter's content to current societal issues. Many of these boxes also include Questions to Discuss that provide an opportunity to discuss issues with your peers.



### Science and Society

*Costs of Mining Mineral Resources*

Ancient humans exploited mineral resources as they mined copper minerals for the making of tools. They also used salt, clay, and other mineral materials for nutrients and pot making. These early people were few in number, and their simple tools made little impact on the environment as they mined what they needed. As the numbers of people grew and technology advanced, more and more mineral resources were utilized to build machines and provide energy. With advances in population and technology came increasing impacts on the environment in both size and scope. In addition to copper minerals and clay, the metal ores of iron, chromium, aluminum, nickel, tin, uranium, manganese, platinum, cobalt, zinc, and many others were now in high demand.

Today, there are three categories of costs recognized with the mining of any mineral resource. The first category is the *economic cost,* the money needed to lease or buy land, acquire equipment, and pay for labor to run the equipment. The second category is the *resource cost* of mining. It takes energy to concentrate the ore and transport it to smelters or refineries. Sometimes other resources are needed, such as large quantities of water for the extraction or concentration of a mineral resource. If the energy and water are not readily available, the resource cost might be converted to economic cost, which could ultimately determine whether the operation will be profitable. Finally, the third category is the *environmental cost* of mining the resource. Environmental cost is converted to economic cost as controls on pollution are enforced. It is expensive to clean pollution from the land and to restore the ecosystem that was changed by mining operations. Consideration of the conversion of environmental cost to economic cost can also determine if a mining operation is feasible or not.

All mining operations start by making a mineral resource accessible so it can be removed. This might take place by strip mining, which begins with the removal of the top layers of soil and rock overlying a resource deposit. This overburden is placed somewhere else, to the side, so the mineral deposit can be easily removed. Access to a smaller, deeper mineral deposit might be gained by building a tunnel to the resource. The debris from building such a tunnel is usually piled outside the entrance. The rock debris from both strip and tunnel mining is an eyesore, and it is difficult for vegetation to grow on the barren rock. Since plants are not present, water may wash away small rock particles, causing erosion of the land and silting of the streams. The debris might also contain arsenic, lead, and other minerals that can pollute the water supply.

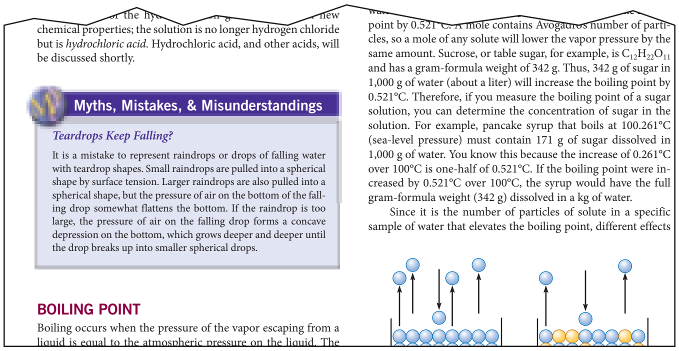
Today, regulations on the mining industry require less environmental damage than had been previously tolerated. The cost of finding and processing the minerals is also increasing as the easiest to use, less expensive resources have been utilized first. As current mineral resource deposits become exhausted, pressure will increase to use the minerals in protected areas. The environmental costs for utilization of these areas will indeed be large.

**QUESTIONS TO DISCUSS**

Divide your group into three subgroups: one representing economic cost; one, resource cost; and one, environmental cost. After a few minutes of preparation, have a short debate about the necessity of having mineral resources at the lowest cost possible versus the need to protect our environment no matter what the cost.

## Myths, Mistakes, and Misunderstandings

These brief boxes provide short, scientific explanations to dispel a societal myth or a home experiment or project that enables you to dispel the myth on your own.



chemical properties; the solution is no longer hydrogen chloride but is *hydrochloric acid*. Hydrochloric acid, and other acids, will be discussed shortly.

### Myths, Mistakes, & Misunderstandings

*Teardrops Keep Falling?*

It is a mistake to represent raindrops or drops of falling water with teardrop shapes. Small raindrops are pulled into a spherical shape by surface tension. Larger raindrops are also pulled into a spherical shape, but the pressure of air on the bottom of the falling drop somewhat flattens the bottom. If the raindrop is too large, the pressure of air on the falling drop forms a concave depression on the bottom, which grows deeper and deeper until the drop breaks up into smaller spherical drops.

### BOILING POINT

Boiling occurs when the pressure of the vapor escaping from a liquid is equal to the atmospheric pressure on the liquid. The

point by 0.521°C. A mole contains Avogadro's number of particles, so a mole of any solute will lower the vapor pressure by the same amount. Sucrose, or table sugar, for example, is $C_{12}H_{22}O_{11}$ and has a gram-formula weight of 342 g. Thus, 342 g of sugar in 1,000 g of water (about a liter) will increase the boiling point by 0.521°C. Therefore, if you measure the boiling point of a sugar solution, you can determine the concentration of sugar in the solution. For example, pancake syrup that boils at 100.261°C (sea-level pressure) must contain 171 g of sugar dissolved in 1,000 g of water. You know this because the increase of 0.261°C over 100°C is one-half of 0.521°C. If the boiling point were increased by 0.521°C over 100°C, the syrup would have the full gram-formula weight (342 g) dissolved in a kg of water.

Since it is the number of particles of solute in a specific sample of water that elevates the boiling point, different effects

## People Behind the Science

Many chapters also have fascinating biographies that spotlight well-known scientists, past or present. From these *People Behind the Science* biographies, students learn about the human side of the science: physical science is indeed relevant, and real people do the research and make the discoveries. These readings present physical science in real-life terms that students can identify with and understand.

> **"The People Behind the Science features help relate the history of science and the contributions of the various individuals."**
>
> **—Richard M. Woolheater, Southeastern Oklahoma State University**

### People Behind the Science

*Florence Bascom (1862–1945)*

Florence Bascom, a U.S. geologist, was an expert in the study of rocks and minerals and founded the geology department at Bryn Mawr College, Pennsylvania. This department was responsible for training the foremost women geologists of the early twentieth century.

Born in Williamstown, Massachusetts, in 1862, Bascom was the youngest of the six children of suffragist and schoolteacher Emma Curtiss Bascom and William Bascom, professor of philosophy at Williams College. Her father, a supporter of suffrage and the education of women, later became president of the University of Wisconsin, to which women were admitted in 1875. Florence Bascom enrolled there in 1877 and with other women was allowed limited access to the facilities but was denied access to classrooms filled with men. In spite of this, she earned a B.A. in 1882, a B.Sc. in 1884, and an M.S. in 1887. When Johns Hopkins University graduate school opened to women in 1889, Bascom was allowed to enroll to study geology on the condition that she sit behind a screen to avoid distracting the male students. With the support of her advisor, George Huntington Williams, and her father, she managed in 1893 to become the second woman to gain a Ph.D. in geology (the first being Mary Holmes at the University of Michigan in 1888).

Bascom's interest in geology had been sparked by a driving tour she took with her father and his friend Edward Orton, a geology professor at Ohio State. It was an exciting time for geologists with new areas opening up all the time. Bascom was also inspired by her teachers at Wisconsin and Johns Hopkins, who were experts in the new fields of metamorphism and crystallography. Bascom's Ph.D. thesis was a study of rocks that had previously been thought to be sediments but that she proved to be metamorphosed lava flows.

While studying for her doctorate, Bascom became a popular teacher, passing on her enthusiasm and rigor to her students. She taught at the Hampton Institute for Negroes and American Indians and at Rockford College before becoming an instructor and associate professor at Ohio State University in geology from 1892 to 1895. Moving to Bryn Mawr College, where geology was considered subordinate to the other sciences, she spent two years teaching in a storeroom while building a considerable collection of fossils, rocks, and minerals. While at Bryn Mawr, she took great pride in passing on her knowledge and training to a generation of women who would become successful. At Bryn Mawr, she rose rapidly, becoming reader (1898), associate professor (1903), professor (1906), and finally professor emeritus from 1928 until her death in 1945 in Northampton, Massachusetts.

Bascom became, in 1896, the first woman to work as a geologist on the U.S. Geological Survey, spending her summers mapping formations in Pennsylvania, Maryland, and New Jersey, and her winters analyzing slides. Her results were published in Geographical Society of America bulletins. In 1924, she became the first woman to be elected a fellow of the Geographical Society and went on, in 1930, to become the first woman vice president. She was associate editor of the *American Geologist* (1896–1905) and achieved a four-star place in the first edition of *American Men and Women of Science* (1906), a sign of how highly regarded she was in her field.

Bascom was the author of over forty research papers. She was an expert on the crystalline rocks of the Appalachian Piedmont, and she published her research on Piedmont geomorphology. Geologists in the Piedmont area still value her contributions, and she is still a powerful model for women seeking status in the field of geology today.

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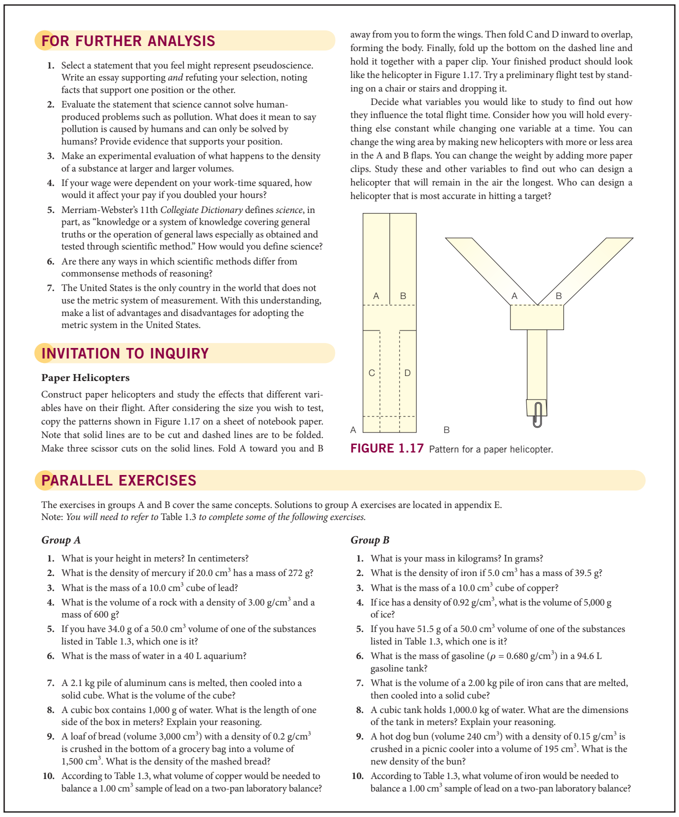
## END-OF-CHAPTER FEATURES

At the end of each chapter, students will find the following materials:

- *Summary:* highlights the key elements of the chapter.
- *Summary of Equations:* reinforces retention of the equations presented.
- *Key Terms:* gives page references for finding the terms defined within the context of the chapter reading.
- *Applying the Concepts:* tests comprehension of the material covered with a multiple-choice quiz.
- *Questions for Thought:* challenges students to demonstrate their understanding of the topics.
- *Parallel Exercises:* reinforce problem-solving skills. There are two groups of parallel exercises, Group A and Group B. The Group A parallel exercises have complete solutions worked out, along with useful comments, in appendix E. The Group B parallel exercises are similar to those in Group A but do not contain answers in the text. By working through the Group A parallel exercises and checking the solutions in appendix E, students will gain confidence in tackling the parallel exercises in Group B and thus reinforce their problem-solving skills.
- *For Further Analysis:* includes exercises containing analysis or discussion questions, independent investigations, and activities intended to emphasize critical thinking skills and societal issues and to develop a deeper understanding of the chapter content.
- *Invitation to Inquiry:* includes exercises that consist of short, open-ended activities that allow you to apply investigative skills to the material in the chapter.

> **"The most outstanding feature of Tillery's *Physical Science* is the use of the Group A Parallel Exercises. Prior to this text, I cannot count the number of times I have heard students state that they understood the material when presented in class, but when they tried the homework on their own, they were unable to remember what to do. The Group A problems with the complete solution were the perfect reminder for most of the students. I also believe that Tillery's presentation of the material addresses the topics with a rigor necessary for a college-level course but is easily understandable for my students without being too simplistic. The material is challenging but not too overwhelming."**
>
> **—J. Dennis Hawk, Navarro College**



### FOR FURTHER ANALYSIS

1. Select a statement that you feel might represent pseudoscience. Write an essay supporting *and* refuting your selection, noting facts that support one position or the other.
2. Evaluate the statement that science cannot solve human-produced problems such as pollution. What does it mean to say pollution is caused by humans and can only be solved by humans? Provide evidence that supports your position.
3. Make an experimental evaluation of what happens to the density of a substance at larger and larger volumes.
4. If your wage were dependent on your work-time squared, how would it affect your pay if you doubled your hours?
5. Merriam-Webster's 11th *Collegiate Dictionary* defines *science*, in part, as "knowledge or a system of knowledge covering general truths or the operation of general laws especially as obtained and tested through scientific method." How would you define science?
6. Are there any ways in which scientific methods differ from commonsense methods of reasoning?
7. The United States is the only country in the world that does not use the metric system of measurement. With this understanding, make a list of advantages and disadvantages for adopting the metric system in the United States.

### INVITATION TO INQUIRY

**Paper Helicopters**

Construct paper helicopters and study the effects that different variables have on their flight. After considering the size you wish to test, copy the patterns shown in Figure 1.17 on a sheet of notebook paper. Note that solid lines are to be cut and dashed lines are to be folded. Make three scissor cuts on the solid lines. Fold A toward you and B away from you to form the wings. Then fold C and D inward to overlap, forming the body. Finally, fold up the bottom on the dashed line and hold it together with a paper clip. Your finished product should look like the helicopter in Figure 1.17. Try a preliminary flight test by standing on a chair or stairs and dropping it.

Decide what variables you would like to study to find out how they influence the total flight time. Consider how you will hold everything else constant while changing one variable at a time. You can change the wing area by making new helicopters with more or less area in the A and B flaps. You can change the weight by adding more paper clips. Study these and other variables to find out who can design a helicopter that will remain in the air the longest. Who can design a helicopter that is most accurate in hitting a target?

**FIGURE 1.17** Pattern for a paper helicopter.

### PARALLEL EXERCISES

The exercises in groups A and B cover the same concepts. Solutions to group A exercises are located in appendix E.
Note: *You will need to refer to* Table 1.3 *to complete some of the following exercises.*

*Group A*

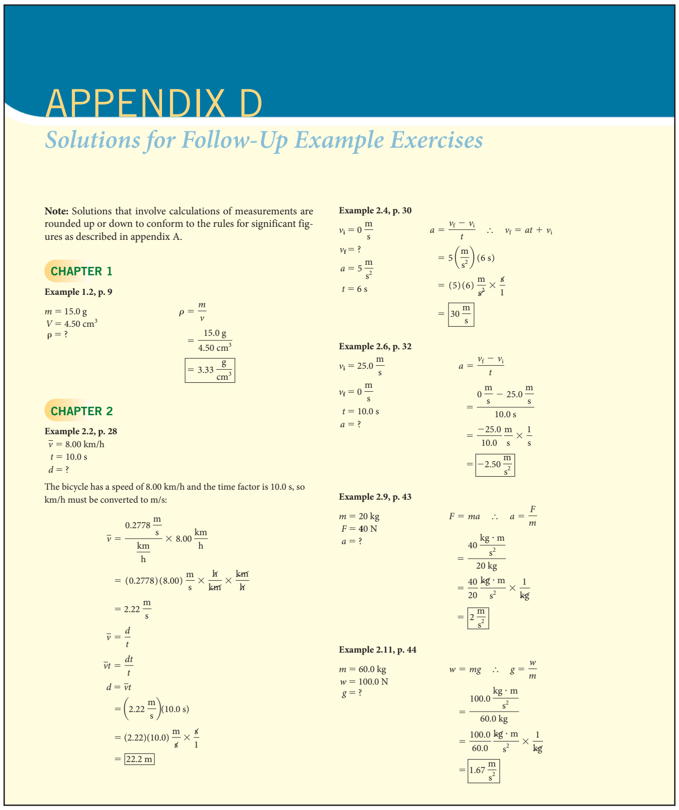
1. What is your height in meters? In centimeters?
2. What is the density of mercury if $20.0\text{ cm}^3$ has a mass of 272 g?
3. What is the mass of a $10.0\text{ cm}^3$ cube of lead?
4. What is the volume of a rock with a density of $3.00\text{ g/cm}^3$ and a mass of 600 g?
5. If you have 34.0 g of a $50.0\text{ cm}^3$ volume of one of the substances listed in Table 1.3, which one is it?
6. What is the mass of water in a 40 L aquarium?
7. A 2.1 kg pile of aluminum cans is melted, then cooled into a solid cube. What is the volume of the cube?
8. A cubic box contains 1,000 g of water. What is the length of one side of the box in meters? Explain your reasoning.
9. A loaf of bread (volume $3{,}000\text{ cm}^3$) with a density of $0.2\text{ g/cm}^3$ is crushed in the bottom of a grocery bag into a volume of $1{,}500\text{ cm}^3$. What is the density of the mashed bread?
10. According to Table 1.3, what volume of copper would be needed to balance a $1.00\text{ cm}^3$ sample of lead on a two-pan laboratory balance?

*Group B*

1. What is your mass in kilograms? In grams?
2. What is the density of iron if $5.0\text{ cm}^3$ has a mass of 39.5 g?
3. What is the mass of a $10.0\text{ cm}^3$ cube of copper?
4. If ice has a density of $0.92\text{ g/cm}^3$, what is the volume of 5,000 g of ice?
5. If you have 51.5 g of a $50.0\text{ cm}^3$ volume of one of the substances listed in Table 1.3, which one is it?
6. What is the mass of gasoline ($\rho = 0.680\text{ g/cm}^3$) in a 94.6 L gasoline tank?
7. What is the volume of a 2.00 kg pile of iron cans that are melted, then cooled into a solid cube?
8. A cubic tank holds 1,000.0 kg of water. What are the dimensions of the tank in meters? Explain your reasoning.
9. A hot dog bun (volume $240\text{ cm}^3$) with a density of $0.15\text{ g/cm}^3$ is crushed in a picnic cooler into a volume of $195\text{ cm}^3$. What is the new density of the bun?
10. According to Table 1.3, what volume of iron would be needed to balance a $1.00\text{ cm}^3$ sample of lead on a two-pan laboratory balance?

## END-OF-TEXT MATERIALS

Appendices providing math review, additional background details, solubility and humidity charts, solutions for the in-chapter follow-up examples, and solutions for the Group A Parallel Exercises can be found at the back of the text. There is also a Glossary of all key terms, an index, and special tables printed on the inside covers for reference use.



APPENDIX D

*Solutions for Follow-Up Example Exercises*

**Note:** Solutions that involve calculations of measurements are rounded up or down to conform to the rules for significant figures as described in appendix A.

**CHAPTER 1**

**Example 1.2, p. 9**

$m = 15.0$ g
$V = 4.50\ \text{cm}^3$
$\rho = ?$

$$\rho = \frac{m}{v}$$
$$= \frac{15.0\ \text{g}}{4.50\ \text{cm}^3}$$
$$\boxed{= 3.33\ \frac{\text{g}}{\text{cm}^3}}$$

**CHAPTER 2**

**Example 2.2, p. 28**

$\bar{v} = 8.00$ km/h
$t = 10.0$ s
$d = ?$

The bicycle has a speed of 8.00 km/h and the time factor is 10.0 s, so km/h must be converted to m/s:

$$\bar{v} = \frac{0.2778\ \frac{\text{m}}{\text{s}}}{\frac{\text{km}}{\text{h}}} \times 8.00\ \frac{\text{km}}{\text{h}}$$
$$= (0.2778)(8.00)\ \frac{\text{m}}{\text{s}} \times \frac{\cancel{\text{h}}}{\cancel{\text{km}}} \times \frac{\cancel{\text{km}}}{\cancel{\text{h}}}$$
$$= 2.22\ \frac{\text{m}}{\text{s}}$$
$$\bar{v} = \frac{d}{t}$$
$$\bar{v}t = \frac{dt}{t}$$
$$d = \bar{v}t$$
$$= \left(2.22\ \frac{\text{m}}{\text{s}}\right)(10.0\ \text{s})$$
$$= (2.22)(10.0)\ \frac{\text{m}}{\cancel{\text{s}}} \times \frac{\cancel{\text{s}}}{1}$$
$$= \boxed{22.2\ \text{m}}$$

**Example 2.4, p. 30**

$v_i = 0\ \frac{\text{m}}{\text{s}}$
$v_f = ?$
$a = 5\ \frac{\text{m}}{\text{s}^2}$
$t = 6$ s

$$a = \frac{v_f - v_i}{t} \quad \therefore \quad v_f = at + v_i$$
$$= 5\left(\frac{\text{m}}{\text{s}^2}\right)(6\ \text{s})$$
$$= (5)(6)\ \frac{\text{m}}{\cancel{\text{s}^2}} \times \frac{\cancel{\text{s}}}{1}$$
$$= \boxed{30\ \frac{\text{m}}{\text{s}}}$$

**Example 2.6, p. 32**

$v_i = 25.0\ \frac{\text{m}}{\text{s}}$
$v_f = 0\ \frac{\text{m}}{\text{s}}$
$t = 10.0$ s
$a = ?$

$$a = \frac{v_f - v_i}{t}$$
$$= \frac{0\ \frac{\text{m}}{\text{s}} - 25.0\ \frac{\text{m}}{\text{s}}}{10.0\ \text{s}}$$
$$= \frac{-25.0}{10.0}\ \frac{\text{m}}{\text{s}} \times \frac{1}{\text{s}}$$
$$= \boxed{-2.50\ \frac{\text{m}}{\text{s}^2}}$$

**Example 2.9, p. 43**

$m = 20$ kg
$F = 40$ N
$a = ?$

$$F = ma \quad \therefore \quad a = \frac{F}{m}$$
$$= \frac{40\ \frac{\text{kg}\cdot\text{m}}{\text{s}^2}}{20\ \text{kg}}$$
$$= \frac{40}{20}\ \frac{\cancel{\text{kg}}\cdot\text{m}}{\text{s}^2} \times \frac{1}{\cancel{\text{kg}}}$$
$$= \boxed{2\ \frac{\text{m}}{\text{s}^2}}$$

**Example 2.11, p. 44**

$m = 60.0$ kg
$w = 100.0$ N
$g = ?$

$$w = mg \quad \therefore \quad g = \frac{w}{m}$$
$$= \frac{100.0\ \frac{\text{kg}\cdot\text{m}}{\text{s}^2}}{60.0\ \text{kg}}$$
$$= \frac{100.0}{60.0}\ \frac{\cancel{\text{kg}}\cdot\text{m}}{\text{s}^2} \times \frac{1}{\cancel{\text{kg}}}$$
$$= \boxed{1.67\ \frac{\text{m}}{\text{s}^2}}$$

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*Physical Science* is accompanied by a variety of multimedia supplementary materials, including a ConnectPlus® online homework site with integrated eBook and a companion website with teacher resources, such as testing software containing multiple-choice test items, and many student self-study resources. The supplements package also includes a laboratory manual, both student and instructor's editions, by the author of the text.

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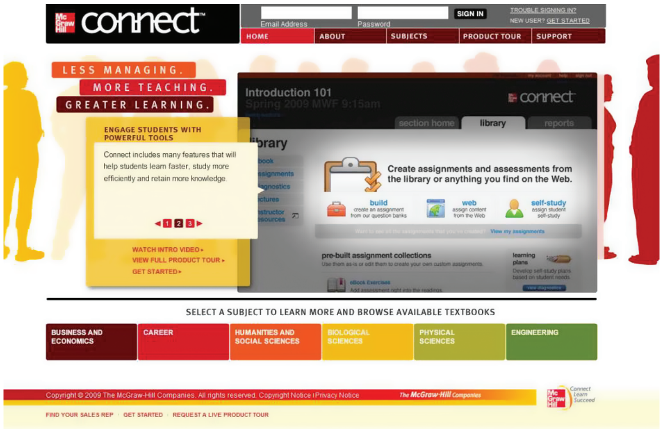

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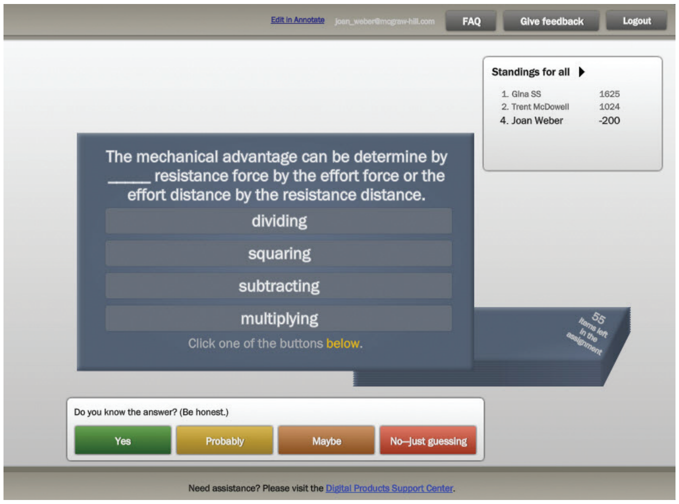

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The mechanical advantage can be determine by _____ resistance force by the effort force or the effort distance by the resistance distance.

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# PRINTED SUPPLEMENTARY MATERIAL

## Laboratory Manual

The *laboratory manual,* written and classroom tested by the author, presents a selection of laboratory exercises specifically written for the interests and abilities of nonscience majors. There are laboratory exercises that require measurement, data analysis, and thinking in a more structured learning environment, while alternative exercises that are open-ended "Invitations to Inquiry" are provided for instructors who would like a less structured approach. When the laboratory manual is used with *Physical Science,* students will have an opportunity to master basic scientific principles and concepts, learn new problem-solving and thinking skills, and understand the nature of scientific inquiry from the perspective of hands-on experiences. The *instructor's edition of the laboratory manual* can be found on the *Physical Science* companion website.

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Bill W. Tillery is professor emeritus of Physics at Arizona State University, where he was a member of the faculty from 1973 to 2006. He earned a bachelor's degree at Northeastern State University and master's and doctorate degrees from the University of Northern Colorado. Before moving to Arizona State University, he served as director of the Science and Mathematics Teaching Center at the University of Wyoming and as an assistant professor at Florida State University. Bill served on numerous councils, boards, and committees, and he was honored as the "Outstanding University Educator" at the University of Wyoming. He was elected the "Outstanding Teacher" in the Department of Physics and Astronomy at Arizona State University.

During his time at Arizona State, Bill taught a variety of courses, including general education courses in science and society, physical science, and introduction to physics. He received more than forty grants from the National Science Foundation, the U.S. Office of Education, private industry (Arizona Public Service), and private foundations (The Flinn Foundation) for science curriculum development and science teacher in-service training. In addition to teaching and grant work, Bill authored or coauthored more than sixty textbooks and many monographs and served as editor of three separate newsletters and journals.

Bill has attempted to present an interesting, helpful program that will be useful to both students and instructors. Comments and suggestions about how to do a better job of reaching this goal are welcome. Any comments about the text or other parts of the program should be addressed to:

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