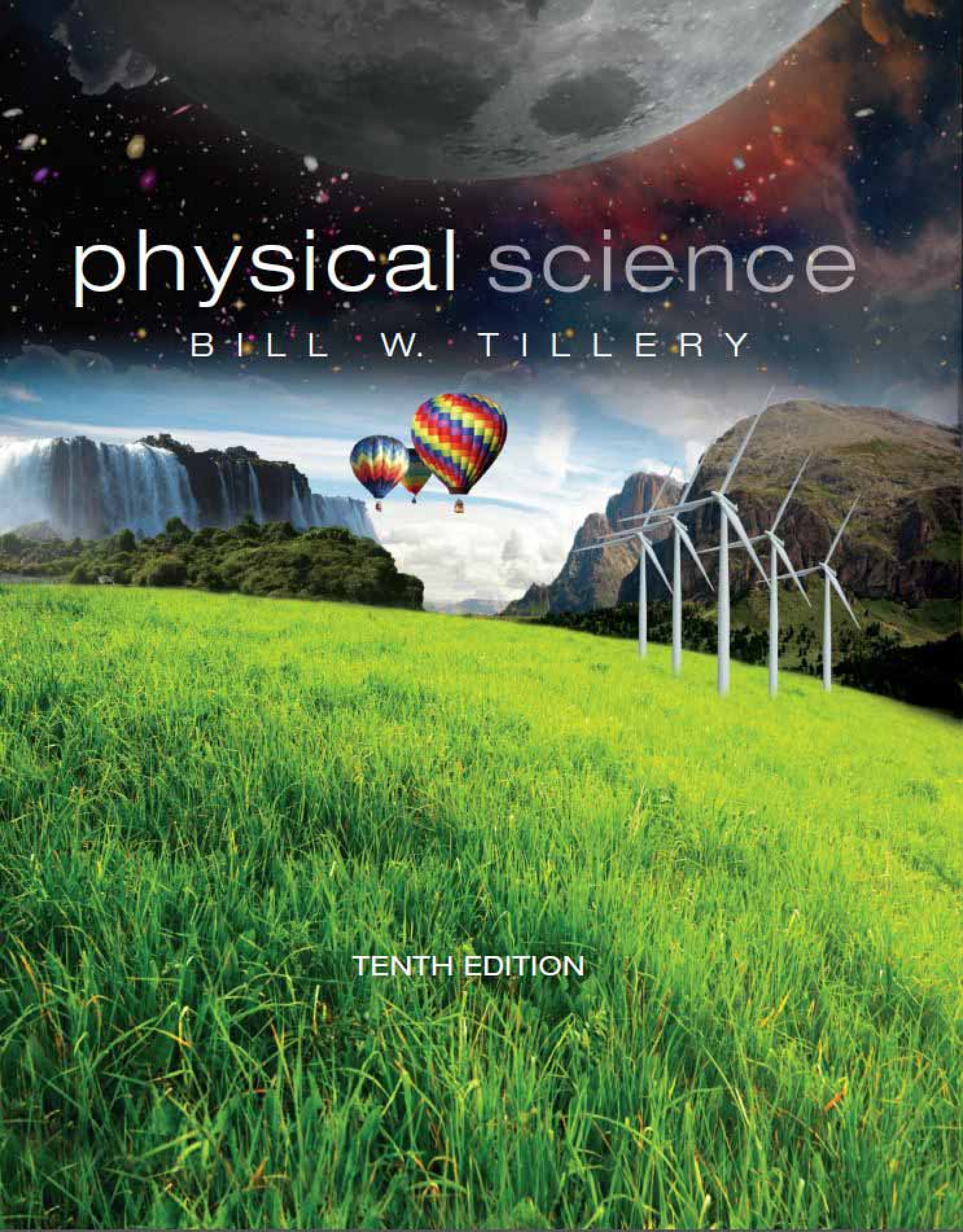
physical science

BILL W. TILLERY



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BILL W. TILLERY

ARIZONA STATE UNIVERSITY

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BRIEF CONTENTS

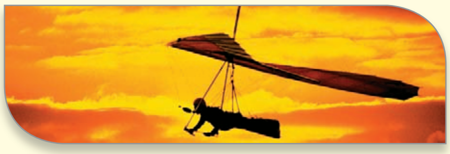
PHYSICS

CHEMISTRY

ASTRONOMY

EARTH SCIENCE

CONTENTS



PHYSICS

4 Heat and Temperature 85

5 Wave Motions and Sound 115

6 Electricity 139

7 Light 177

CHEMISTRY

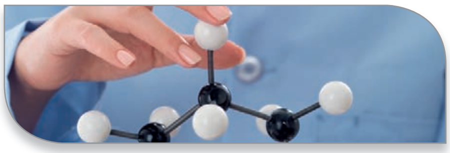
8 Atoms and Periodic Properties 205

9 Chemical Bonds 231

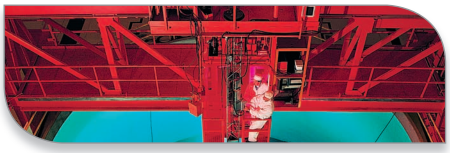
10 Chemical Reactions 253

11 Water and Solutions 277

12 Organic Chemistry 301



13 Nuclear Reactions 325



ASTRONOMY

14 The Universe 353

15 The Solar System 379

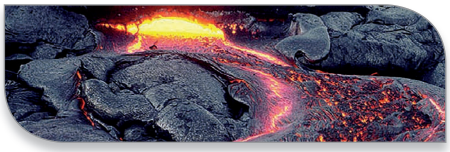
16 Earth in Space 407

EARTH SCIENCE

17 Rocks and Minerals 435

18 Plate Tectonics 457

19 Building Earth's Surface 479



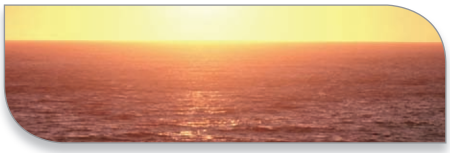
20 Shaping Earth's Surface 503

21 Geologic Time 523

22 The Atmosphere of Earth 543

23 Weather and Climate 567

24 Earth's Waters 599



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

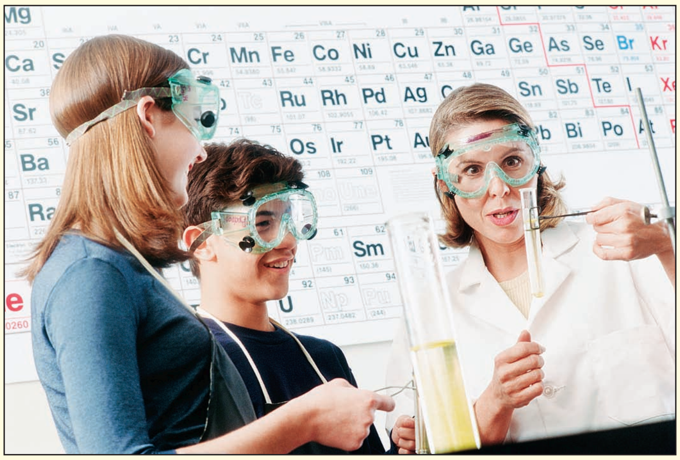
The *Physical Science* sequence of chapters is flexible, and the instructor can determine topic sequence and depth of coverage as needed. The materials are also designed to support a conceptual approach or a combined conceptual and problem-solving approach. With laboratory studies, the text contains 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.

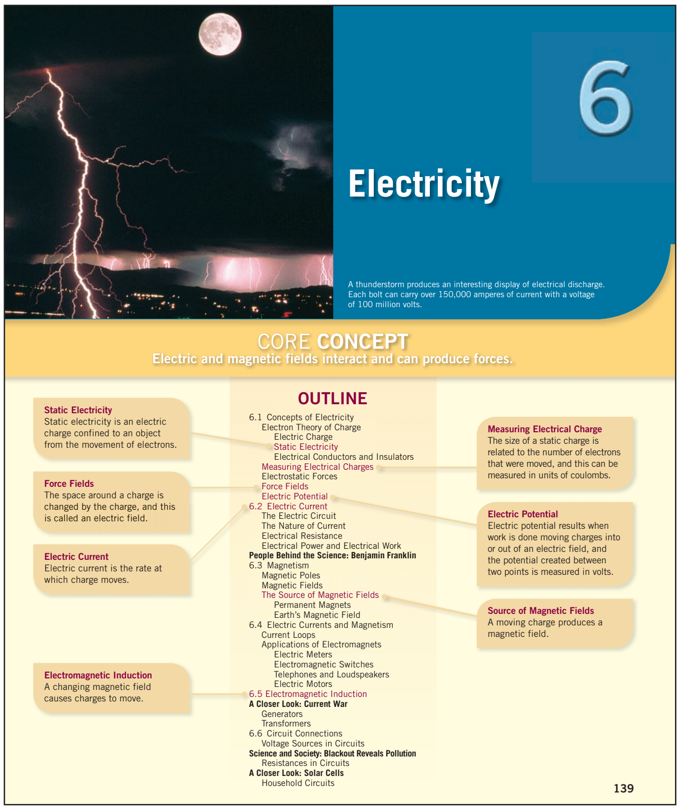
CHAPTER OPENING TOOLS

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.



6

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.

139

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**

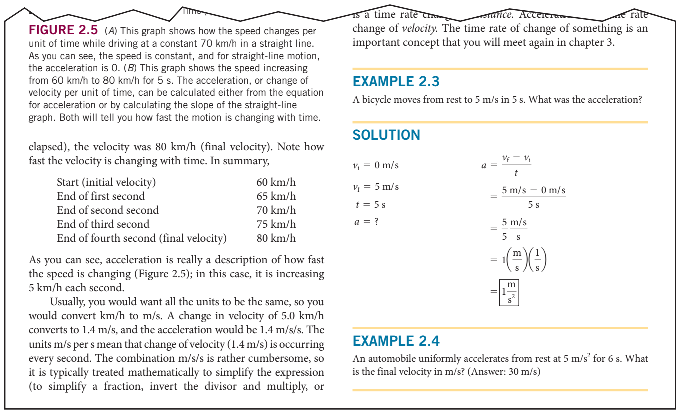


FIGURE 2.5 (*A*) This graph shows how the speed changes per unit of time while driving at a constant 70 km/h in a straight line. As you can see, the speed is constant, and for straight-line motion, the acceleration is 0. (*B*) This graph shows the speed increasing from 60 km/h to 80 km/h for 5 s. The 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

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

$v_i = 0\ \text{m/s}$

$v_f = 5\ \text{m/s}$

$t = 5\ \text{s}$

$a = ?$

$$a = \frac{v_f - v_i}{t} = \frac{5\ \text{m/s} - 0\ \text{m/s}}{5\ \text{s}} = \frac{5}{5}\,\frac{\text{m/s}}{\text{s}} = 1\left(\frac{\text{m}}{\text{s}}\right)\left(\frac{1}{\text{s}}\right) = \boxed{1\frac{\text{m}}{\text{s}^2}}$$

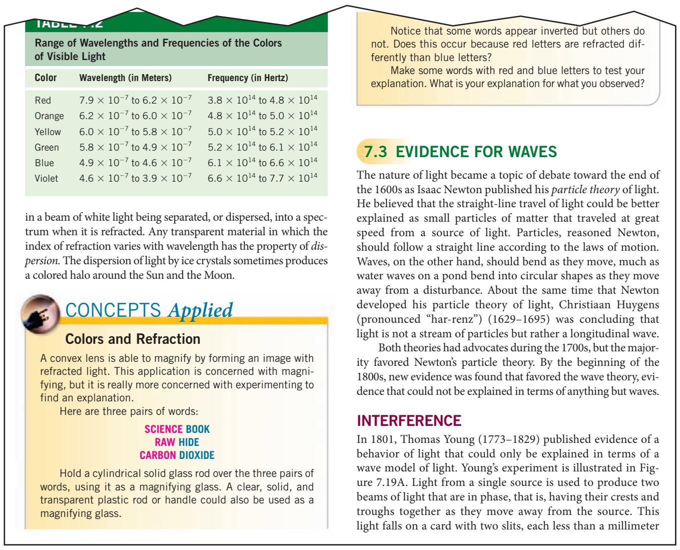
EXAMPLE 2.4

An automobile uniformly accelerates from rest at $5\ \text{m/s}^2$ 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	7.9×10^{-7} to 6.2×10^{-7}	3.8×10^{14} to 4.8×10^{14}
Orange	6.2×10^{-7} to 6.0×10^{-7}	4.8×10^{14} to 5.0×10^{14}
Yellow	6.0×10^{-7} to 5.8×10^{-7}	5.0×10^{14} to 5.2×10^{14}
Green	5.8×10^{-7} to 4.9×10^{-7}	5.2×10^{14} to 6.1×10^{14}
Blue	4.9×10^{-7} to 4.6×10^{-7}	6.1×10^{14} to 6.6×10^{14}
Violet	4.6×10^{-7} to 3.9×10^{-7}	6.6×10^{14} to 7.7×10^{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.

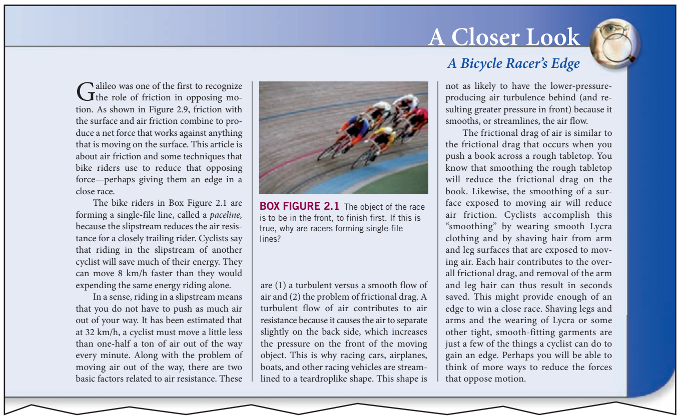
Both theories had advocates during the 1700s, but the majority favored Newton's particle theory. By the beginning of the 1800s, new evidence was found that favored the wave theory, evidence that could not be explained in terms of anything but waves.

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.

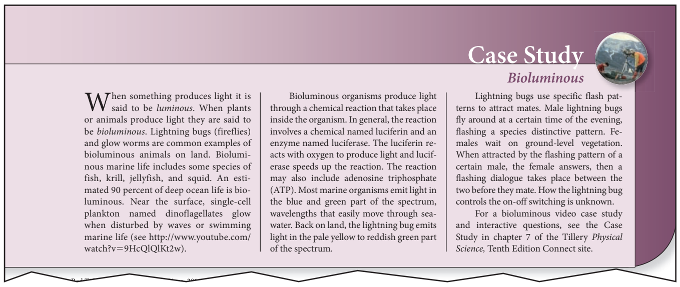
In a sense, riding in a slipstream means that you do not have to push as much air out of your way. It has been estimated that at 32 km/h, a cyclist must move a little less than one-half a ton of air out of the way every minute. Along with the problem of moving air out of the way, there are two basic 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).

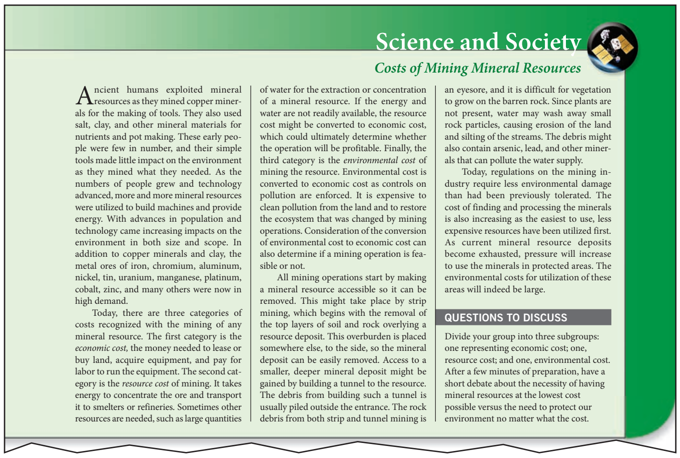
Bioluminous organisms produce light through a chemical reaction that takes place inside the organism. In general, the reaction involves a chemical named luciferin and an enzyme named luciferase. The luciferin reacts with oxygen to produce light and luciferase speeds up the reaction. The reaction may 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.

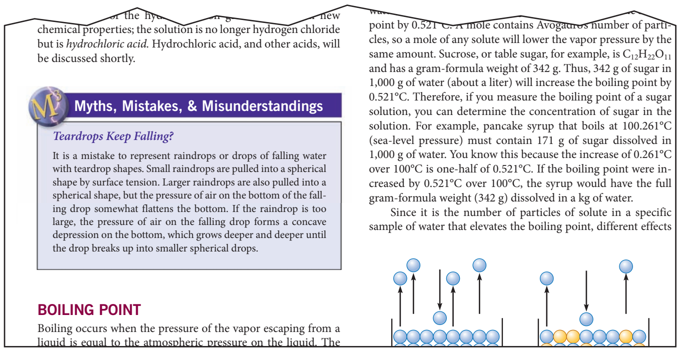
Today, regulations on the mining industry require less environmental damage than had been previously tolerated. The cost of finding and processing the minerals is also increasing as the easiest to use, less expensive resources have been utilized first. As current mineral resource deposits become exhausted, 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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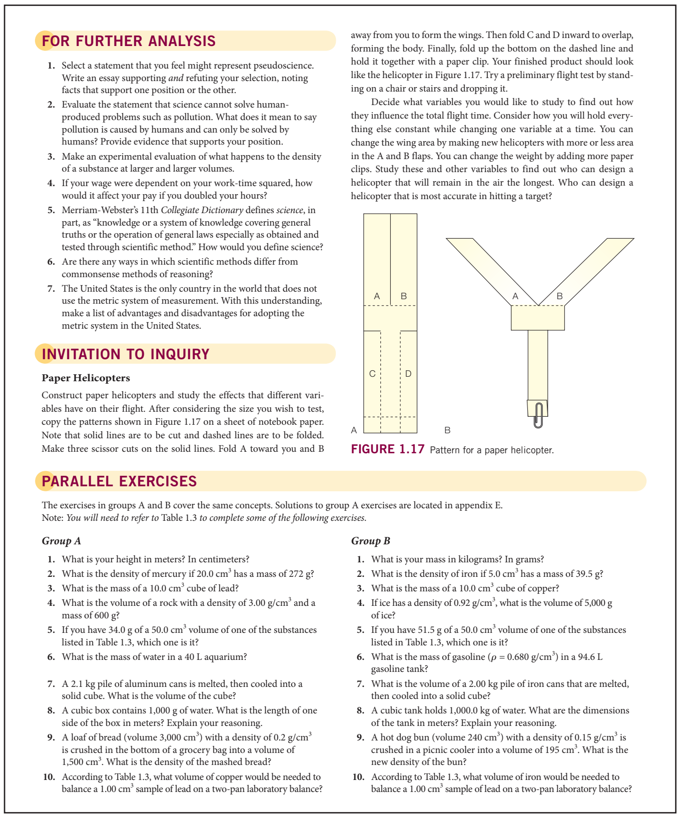
END-OF-CHAPTER FEATURES

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

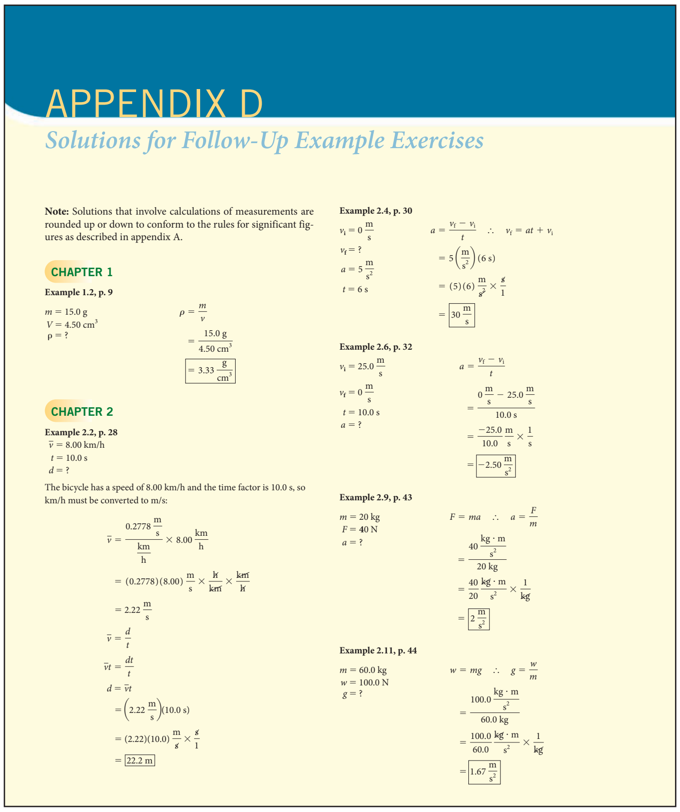
1. What is your height in meters? In centimeters?
2. What is the density of mercury if 20.0 cm^3 has a mass of 272 g?
3. What is the mass of a 10.0 cm^3 cube of lead?
4. What is the volume of a rock with a density of 3.00 g/cm^3 and a mass of 600 g?
5. If you have 34.0 g of a 50.0 cm^3 volume of one 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 cm^3) with a density of 0.2 g/cm^3 is crushed in the bottom of a grocery bag into a volume of 1,500 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 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 cm^3 has a mass of 39.5 g?
3. What is the mass of a 10.0 cm^3 cube of copper?
4. If ice has a density of 0.92 g/cm^3, what is the volume of 5,000 g of ice?
5. If you have 51.5 g of a 50.0 cm^3 volume of one of the substances listed in Table 1.3, which one is it?
6. What is the mass of gasoline ($\rho = 0.680\ g/cm^3$) 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 cm^3) with a density of 0.15 g/cm^3 is crushed in a picnic cooler into a volume of 195 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 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

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

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

CHAPTER 2

Example 2.2, p. 28

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

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

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

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

Example 2.6, p. 32

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

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

Example 2.9, p. 43

$m = 20 \text{ kg}$
$F = 40 \text{ N}$
$a = ?$

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

Example 2.11, p. 44

$m = 60.0 \text{ kg}$
$w = 100.0 \text{ N}$
$g = ?$

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

SUPPLEMENTS

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.

MULTIMEDIA SUPPLEMENTARY MATERIALS

McGraw-Hill ConnectPlus® Physical Science

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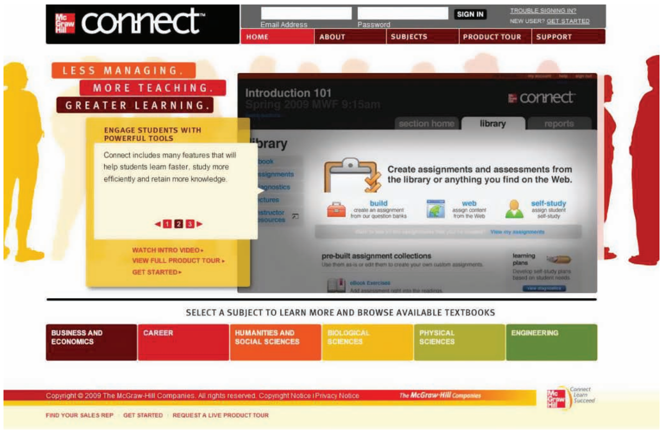

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- Allows for insertion of lecture discussions or instructor-created additional examples using Tegrity™ (see below) to provide additional clarification or varied coverage on a topic.

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With the ConnectPlus companion site, instructors also have access to PowerPoint lecture outlines, the Instructor's Manual, PowerPoint files with electronic images from the text, clicker questions, quizzes, animations, and many other resources directly tied to text-specific materials in *Physical Science.*

Students have access to a variety of self-quizzes (multiple-choice, true/false, tutorial tests, key terms, conversion exercises), animations, videos, and expansions of some topics treated only briefly in the text.

See www.mhhe.com/tillery to learn more and register.

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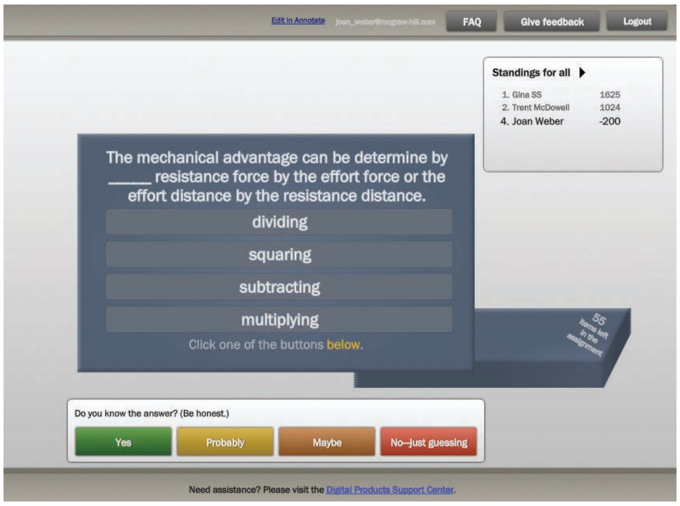

Standings for all

1. Gina SS	1625
2. Trent McDowell	1024
4. Joan Weber	-200

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

dividing
squaring
subtracting
multiplying

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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 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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1

What Is Science?

Physical science is concerned with your physical surroundings and your concepts and understanding of these surroundings.

CORE CONCEPT

Science is a way of thinking about and understanding your environment.

OUTLINE

Objects and Properties
Properties are qualities or attributes that can be used to describe an object or event.

Data
Data is measurement information that can be used to describe objects, conditions, events, or changes.

Scientific Method
Science investigations include collecting observations, developing explanations, and testing explanations.

Quantifying Properties
Measurement is used to accurately describe properties of objects or events.

Symbols and Equations
An equation is a statement of a relationship between variables.

Laws and Principles
Scientific laws describe relationships between events that happen time after time, describing *what* happens in nature.

Models and Theories
A scientific theory is a broad working hypothesis based on extensive experimental evidence, describing *why* something happens in nature.

OVERVIEW

Have you ever thought about your thinking and what you know? On a very simplified level, you could say that everything you know came to you through your senses. You see, hear, and touch things of your choosing, and you can also smell and taste things in your surroundings. Information is gathered and sent to your brain by your sense organs. Somehow, your brain processes all this information in an attempt to find order and make sense of it all. Finding order helps you understand the world and what may be happening at a particular place and time. Finding order also helps you predict what may happen next, which can be very important in a lot of situations.

This is a book on thinking about and understanding your physical surroundings. These surroundings range from the obvious, such as the landscape (Figure 1.1) and the day-to-day weather, to the not so obvious, such as how atoms are put together. You will learn how to think about your surroundings, whatever your previous experience with thought-demanding situations. This first chapter is about "tools and rules" that you will use in the thinking process.

1.1 OBJECTS AND PROPERTIES

Physical science is concerned with making sense out of the physical environment. The early stages of this "search for sense" usually involve *objects* in the environment, things that can be seen or touched. These could be objects you see every day, such as a glass of water, a moving automobile, or a blowing flag. They could be quite large, such as the Sun, the Moon, or even the solar system, or invisible to the unaided human eye. Objects can be any size, but people are usually concerned with objects that are larger than a pinhead and smaller than a house. Outside these limits, the actual size of an object is difficult for most people to comprehend.

As you were growing up, you learned to form a generalized mental image of objects called a *concept*. Your concept of an object is an idea of what it is, in general, or what it should be according to your idea. You usually have a word stored away in your mind that represents a concept. The word *chair*, for example, probably evokes an idea of "something to sit on." Your generalized mental image for the concept that goes with the word *chair* probably includes a four-legged object with a backrest. Upon close inspection, most of your (and everyone else's) concepts are found to be somewhat vague. For example, if the word *chair* brings forth a mental image of something with four legs and a backrest (the concept), what is the difference between a "high chair" and a "bar stool"? When is a chair a chair and not a stool (Figure 1.2)? These kinds of questions can be troublesome for many people.

Not all of your concepts are about material objects. You also have concepts about intangibles such as time, motion, and relationships between events. As was the case with concepts of material objects, words represent the existence of intangible concepts. For example, the words *second, hour, day,* and *month* represent concepts of time. A concept of the pushes and pulls that come with changes of motion during an airplane flight might be represented with such words as *accelerate* and *falling*. Intangible concepts might seem to be more abstract since they do not represent material objects.

By the time you reach adulthood, you have literally thousands of words to represent thousands of concepts. But most, you would find on inspection, are somewhat ambiguous and not at all clear-cut. That is why you find it necessary to talk about certain concepts for a minute or two to see if the other

FIGURE 1.1 Your physical surroundings include naturally occurring things in the landscape as well as things people have made.

FIGURE 1.2 What is your concept of a chair? Is this a picture of a chair or is it a stool? Most people have concepts, or ideas of what things in general should be, that are loosely defined. The concept of a chair is one example, and this is a picture of a swivel office chair with arms.

FIGURE 1.3 Could you describe this rock to another person over the telephone so that the other person would know *exactly* what you see? This is not likely with everyday language, which is full of implied comparisons, assumptions, and inaccurate descriptions.

person has the same "concept" for words as you do. That is why when one person says, "Boy, was it hot!" the other person may respond, "How hot was it?" The meaning of *hot* can be quite different for two people, especially if one is from Arizona and the other from Alaska!

The problem with words, concepts, and mental images can be illustrated by imagining a situation involving you and another person. Suppose that you have found a rock that you believe would make a great bookend. Suppose further that you are talking to the other person on the telephone, and you want to discuss the suitability of the rock as a bookend, but you do not know the name of the rock. If you knew the name, you would simply state that you found a "______." Then you would probably discuss the rock for a minute or so to see if the other person really understood what you were talking about. But not knowing the name of the rock and wanting to communicate about the suitability of the object as a bookend, what would you do? You would probably describe the characteristics, or **properties,** of the rock. Properties are the qualities or attributes that, taken together, are usually peculiar to an object. Since you commonly determine properties with your senses (smell, sight, hearing, touch, and taste), you could say that the properties of an object are the effect the object has on your senses. For example, you might say that the rock is a "big, yellow, smooth rock with shiny gold cubes on one side." But consider the mental image that the other person on the telephone forms when you describe these properties. It is entirely possible that the other person is thinking of something very different from what you are describing (Figure 1.3)!

As you can see, the example of describing a proposed bookend by listing its properties in everyday language leaves much to be desired. The description does not really help the other person form an accurate mental image of the rock. One problem with the attempted communication is that the description of any property implies some kind of *referent.* The word **referent** means that you *refer to,* or think of, a given property in terms of another, more familiar object. Colors, for example, are sometimes stated with a referent. Examples are "sky blue," "grass green," or "lemon yellow." The referents for the colors blue, green, and yellow are, respectively, the sky, living grass, and a ripe lemon.

Referents for properties are not always as explicit as they are for colors, but a comparison is always implied. Since the comparison is implied, it often goes unspoken and leads to assumptions in communications. For example, when you stated that the rock was "big," you assumed that the other person knew that you did not mean as big as a house or even as big as a bicycle. You assumed that the other person knew that you meant that the rock was about as large as a book, perhaps a bit larger.

Another problem with the listed properties of the rock is the use of the word *smooth*. The other person would not know if you meant that the rock *looked* smooth or *felt* smooth. After all, some objects can look smooth and feel rough. Other objects can look rough and feel smooth. Thus, here is another assumption, and probably all of the properties lead to implied comparisons, assumptions, and a not-very-accurate communication. This is the nature of your everyday language and the nature of most attempts at communication.

1.2 QUANTIFYING PROPERTIES

Typical day-to-day communications are often vague and leave much to be assumed. A communication between two people, for example, could involve one person describing some person, object, or event to a second person. The description is made by using referents and comparisons that the second person may or may not have in mind. Thus, such attributes as "long" fingernails or "short" hair may have entirely different meanings to different people involved in a conversation. Assumptions and vagueness can be avoided by using **measurement** in a description. Measurement is a process of comparing a property to a well-defined and agreed-upon referent. The well-defined and agreed-upon referent is used as a standard called a **unit**. The measurement process involves three steps: (1) *comparing* the referent unit to the property being described, (2) following a *procedure,* or operation, that specifies how the comparison is made, and (3) *counting* how many standard units describe the property being considered.

The measurement process uses a defined referent unit, which is compared to a property being measured. The *value* of the property is determined by counting the number of referent units. The name of the unit implies the procedure that results in the number. A measurement statement always contains a *number* and *name* for the referent unit. The number answers the question "How much?" and the name answers the question "Of what?" Thus, a measurement always tells you "how much of what." You will find that using measurements will sharpen your communications. You will also find that using measurements is one of the first steps in understanding your physical environment.

1.3 MEASUREMENT SYSTEMS

Measurement is a process that brings precision to a description by specifying the "how much" and "of what" of a property in a particular situation. A number expresses the value of the property, and the name of a unit tells you what the referent is as well as implies the procedure for obtaining the number. Referent units must be defined and established, however, if others are to understand and reproduce a measurement. When standards are established, the referent unit is called a **standard unit** (Figure 1.4). The use of standard units makes it possible to communicate and duplicate measurements. Standard units are usually defined and established by governments and their agencies that are created for that purpose. In the United States, the agency concerned with measurement standards is the National Institute of Standards and Technology. In Canada, the Standards Council of Canada oversees the National Standard System.

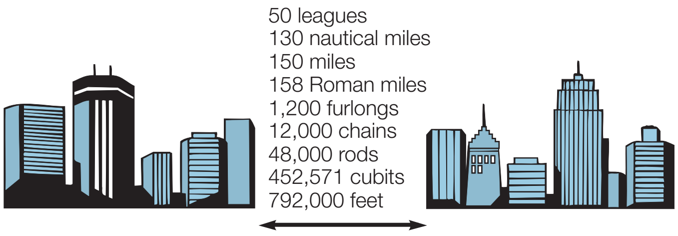


FIGURE 1.4 Which of the listed units should be used to describe the distance between these hypothetical towns? Is there an advantage to using any of the units? Any could be used, and when one particular unit is officially adopted, it becomes known as the *standard unit*.

There are two major *systems* of standard units in use today, the *English system* and the *metric system.* The metric system is used throughout the world except in the United States, where both systems are in use. The continued use of the English system in the United States presents problems in international trade, so there is pressure for a complete conversion to the metric system. More and more metric units are being used in everyday measurements, but a complete conversion will involve an enormous cost. Appendix A contains a method for converting from one system to the other easily. Consult this section if you need to convert from one metric unit to another metric unit or to convert from English to metric units or vice versa. Conversion factors are listed inside the front cover.

People have used referents to communicate about properties of things throughout human history. The ancient Greek civilization, for example, used units of *stadia* to communicate about distances and elevations. The *stadium* was a unit of length of the racetrack at the local stadium (*stadia* is the plural of *stadium*), based on a length of 125 paces. Later civilizations, such as the ancient Romans, adopted the stadia and other referent units from the ancient Greeks. Some of these same referent units were later adopted by the early English civilization, which eventually led to the **English system** of measurement. Some adopted units of the English system were originally based on parts of the human body, presumably because you always had these referents with you (Figure 1.5). The inch, for example, used the end joint of the thumb for a referent. A foot,

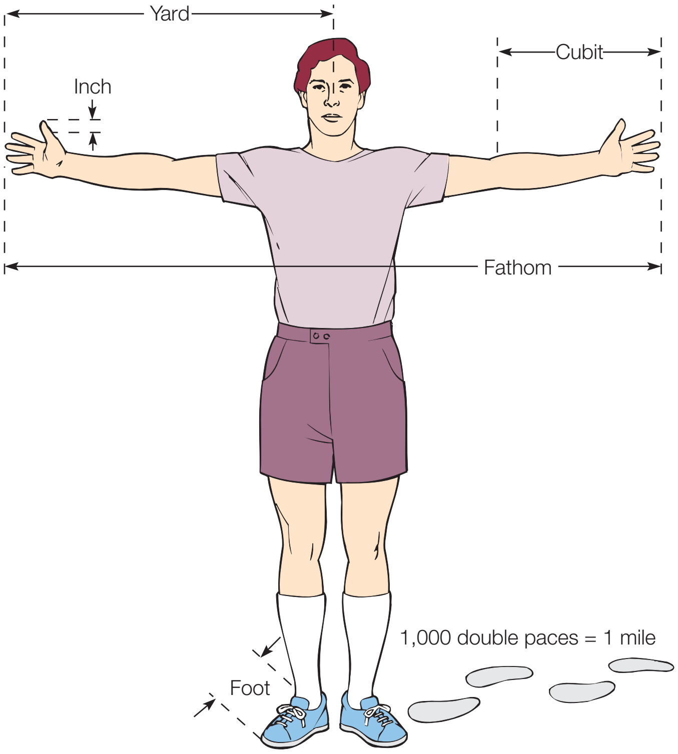


FIGURE 1.5 Many early units for measurement were originally based on the human body. Some of the units were later standardized by governments to become the basis of the English system of measurement.

TABLE 1.1

The SI Base Units

Property	Unit	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Temperature	kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

naturally, was the length of a foot, and a yard was the distance from the tip of the nose to the end of the fingers on an arm held straight out. A cubit was the distance from the end of an elbow to the fingertip, and a fathom was the distance between the fingertips of two arms held straight out. As you can imagine, there were problems with these early units because everyone had different-sized body parts. Beginning in the 1300s, the sizes of the various units were gradually standardized by English kings.

The **metric system** was established by the French Academy of Sciences in 1791. The academy created a measurement system that was based on invariable referents in nature, not human body parts. These referents have been redefined over time to make the standard units more reproducible. The *International System of Units,* abbreviated *SI,* is a modernized version of the metric system. Today, the SI system has seven base units that define standards for the properties of length, mass, time, electric current, temperature, amount of substance, and light intensity (Table 1.1). All units other than the seven basic ones are *derived* units. Area, volume, and speed, for example, are all expressed with derived units. Units for the properties of length, mass, and time are introduced in this chapter. The remaining units will be introduced in later chapters as the properties they measure are discussed.

1.4 STANDARD UNITS FOR THE METRIC SYSTEM

If you consider all the properties of all the objects and events in your surroundings, the number seems overwhelming. Yet, close inspection of how properties are measured reveals that some properties are combinations of other properties (Figure 1.6). Volume, for example, is described by the three length measurements of length, width, and height. Area, on the other hand, is described by just the two length measurements of length and width. Length, however, cannot be defined in simpler terms of any other property. There are four properties that cannot be described in simpler terms, and all other properties are combinations of these four. For this reason, they are called the **fundamental properties**. A fundamental property cannot be defined in simpler terms other than to describe how it is measured.

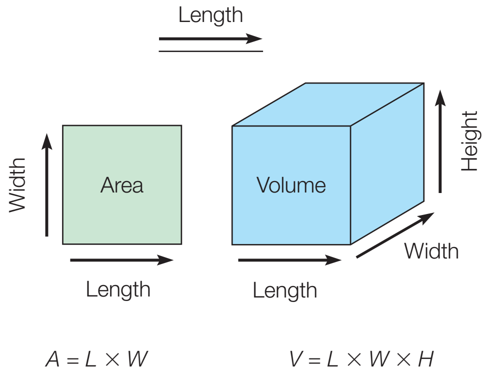


FIGURE 1.6 Area, or the extent of a surface, can be described by two length measurements. Volume, or the space that an object occupies, can be described by three length measurements. Length, however, can be described only in terms of how it is measured, so it is called a *fundamental property*.

These four fundamental properties are (1) *length,* (2) *mass,* (3) *time,* and (4) *charge.* Used individually or in combinations, these four properties will describe or measure what you observe in nature. Metric units for measuring the fundamental properties of length, mass, and time will be described next. The fourth fundamental property, charge, is associated with electricity, and a unit for this property will be discussed in chapter 6.

LENGTH

The standard unit for length in the metric system is the **meter** (the symbol or abbreviation is m). The meter is defined as the distance that light travels in a vacuum during a certain time period, 1/299,792,458 second. The important thing to remember, however, is that the meter is the metric *standard unit* for length. A meter is slightly longer than a yard, 39.3 inches. It is approximately the distance from your left shoulder to the tip of your right hand when your arm is held straight out. Many doorknobs are about 1 meter above the floor. Think about these distances when you are trying to visualize a meter length.

MASS

The standard unit for mass in the metric system is the **kilogram** (kg). The kilogram is defined as the mass of a certain metal cylinder kept by the International Bureau of Weights and Measures in France. This is the only standard unit that is still defined in terms of an object. The property of mass is sometimes confused with the property of weight since they are directly proportional to each other at a given location on the surface of Earth. They are, however, two completely different properties and are measured with different units. All objects tend to maintain their state of rest or straight-line motion, and this property is called "inertia." The *mass* of an object is a measure of the inertia of an object. The *weight* of the object is a measure of the force of gravity on it. This distinction between weight and mass will be discussed in detail in chapter 2. For now, remember that weight and mass are not the same property.

TIME

The standard unit for time is the **second** (s). The second was originally defined as 1/86,400 of a solar day (1/60 × 1/60 × 1/24). Earth's spin was found not to be as constant as thought, so this old definition of one second had to be revised. Adopted in 1967, the new definition is based on a high-precision device known as an *atomic clock*. An atomic clock has a referent for a second that is provided by the characteristic vibrations of the cesium-133 atom. The atomic clock that was built at the National Institute of Standards and Technology in Boulder, Colorado, will neither gain nor lose a second in 20 million years!

1.5 METRIC PREFIXES

The metric system uses prefixes to represent larger or smaller amounts by factors of 10. Some of the more commonly used prefixes, their abbreviations, and their meanings are listed in Table 1.2. Suppose you wish to measure something smaller than the standard unit of length, the meter. The meter is subdivided into 10 equal-sized subunits called *decimeters*. The prefix *deci-* has a meaning of "one-tenth of," and it takes 10 decimeters (dm) to equal the length of 1 meter. For even smaller measurements, each decimeter is divided into 10 equal-sized subunits called *centimeters*. It takes 10 centimeters (cm) to equal 1 decimeter and 100 centimeters to equal 1 meter. In a similar fashion, each prefix up or down the metric ladder represents a simple increase or decrease by a factor of 10 (Figure 1.7).

When the metric system was established in 1791, the standard unit of mass was defined in terms of the mass of a certain volume of water. One cubic decimeter (1 dm^3) of pure water at 4°C was *defined* to have a mass of 1 kilogram (kg). This definition was convenient because it created a relationship between length, mass, and volume. As illustrated in Figure 1.8, a cubic decimeter is 10 cm on each side. The volume of this cube is therefore 10 cm × 10 cm × 10 cm, or 1,000 cubic centimeters (abbreviated as cc or cm^3). Thus, a volume of 1,000 cm^3 of water has a mass of 1 kg. Since 1 kg is 1,000 g, 1 cm^3 of water has a mass of 1 g.

The volume of 1,000 cm^3 also defines a metric unit that is commonly used to measure liquid volume, the **liter** (L). For smaller amounts of liquid volume, the milliliter (mL) is used. The relationship between liquid volume, volume, and mass of water is therefore

$$1.0\ \text{L} \Rightarrow 1.0\ \text{dm}^3 \text{ and has a mass of } 1.0\ \text{kg}$$

or, for smaller amounts,

$$1.0\ \text{mL} \Rightarrow 1.0\ \text{cm}^3 \text{ and has a mass of } 1.0\ \text{g}$$

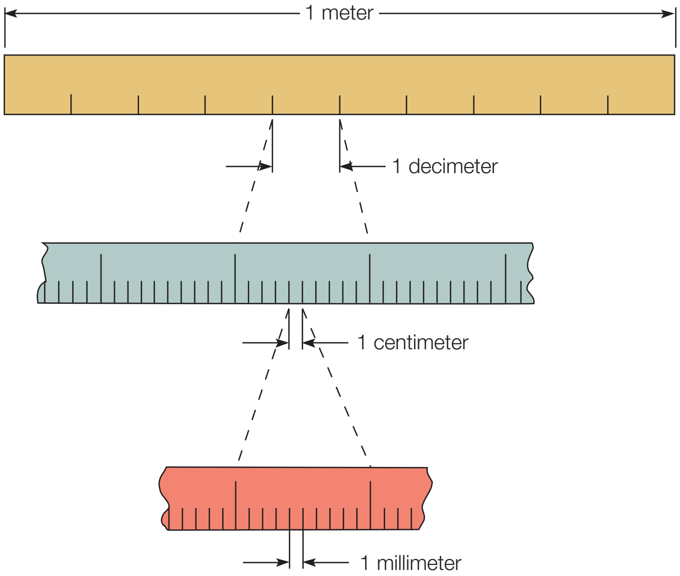


FIGURE 1.7 Compare the units shown here. How many millimeters fit into the space occupied by 1 centimeter? How many millimeters fit into the space of 1 decimeter? How many millimeters fit into the space of 1 meter? Can you express all these as multiples of 10?

TABLE 1.2

Some Metric Prefixes

Prefix	Symbol	Meaning	Unit Multiplier
exa-	E	quintillion	10^{18}
peta-	P	quadrillion	10^{15}
tera-	T	trillion	10^{12}
giga-	G	billion	10^{9}
mega-	M	million	10^{6}
kilo-	k	thousand	10^{3}
hecto-	h	hundred	10^{2}
deka-	da	ten	10^{1}
unit			
deci-	d	one-tenth	10^{-1}
centi-	c	one-hundredth	10^{-2}
milli-	m	one-thousandth	10^{-3}
micro-	μ	one-millionth	10^{-6}
nano-	n	one-billionth	10^{-9}
pico-	p	one-trillionth	10^{-12}
femto-	f	one-quadrillionth	10^{-15}
atto-	a	one-quintillionth	10^{-18}

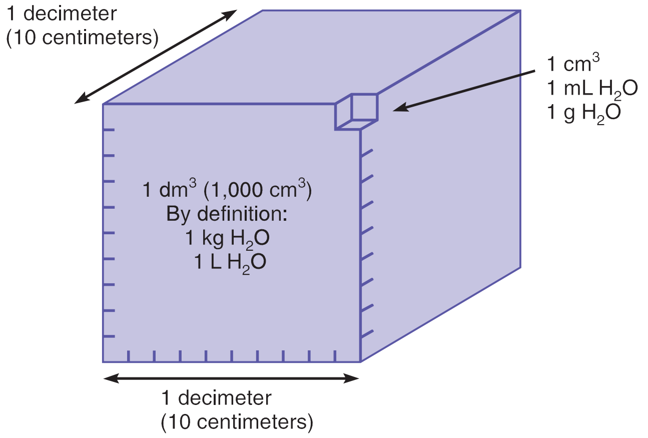


FIGURE 1.8 A cubic decimeter of water (1,000 cm^3) has a liquid volume of 1 L (1,000 mL) and a mass of 1 kg (1,000 g). Therefore, 1 cm^3 of water has a liquid volume of 1 mL and a mass of 1 g.

1.6 UNDERSTANDINGS FROM MEASUREMENTS

One of the more basic uses of measurement is to *describe* something in an exact way that everyone can understand. For example, if a friend in another city tells you that the weather has been "warm," you might not understand what temperature is being described. A statement that the air temperature is 70°F carries more exact information than a statement about "warm weather." The statement that the air temperature is 70°F contains two important concepts: (1) the numerical value of 70 and (2) the referent unit of degrees Fahrenheit. Note that both a numerical value and a unit are necessary to communicate a measurement correctly. Thus, weather reports describe weather conditions with numerically specified units; for example, 70° Fahrenheit for air temperature, 5 miles per hour for wind speed, and 0.5 inch for rainfall (Figure 1.9). When such numerically specified units are used in a description, or a weather report, everyone understands *exactly* the condition being described.

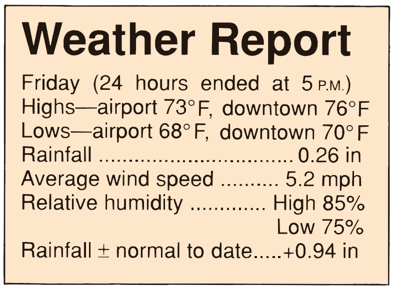
DATA

Measurement information used to describe something is called **data**. Data can be used to describe objects, conditions, events, or changes that might be occurring. You really do not know if the weather is changing much from year to year until you compare the yearly weather data. The data will tell you, for example, if the weather is becoming hotter or dryer or is staying about the same from year to year.

Let's see how data can be used to describe something and how the data can be analyzed for further understanding. The cubes illustrated in Figure 1.10 will serve as an example. Each cube can be described by measuring the properties of size and surface area.

First, consider the size of each cube. Size can be described by **volume,** which means *how much space something occupies.* The volume of a cube can be obtained by measuring and multiplying the length, width, and height. The data is

volume of cube *a*	1 cm^3
volume of cube *b*	8 cm^3
volume of cube *c*	27 cm^3



Weather Report

Friday (24 hours ended at 5 P.M.)
Highs—airport 73°F, downtown 76°F
Lows—airport 68°F, downtown 70°F
Rainfall .... 0.26 in
Average wind speed .... 5.2 mph
Relative humidity .... High 85%
Low 75%
Rainfall ± normal to date.....+0.94 in

FIGURE 1.9 A weather report gives exact information, data that describes the weather by reporting numerically specified units for each condition being described.

Now consider the surface area of each cube. **Area** means *the extent of a surface,* and each cube has six surfaces, or faces (top, bottom, and four sides). The area of any face can be obtained by measuring and multiplying length and width. The data for the three cubes describes them as follows:

	Volume	Surface Area
cube *a*	1 cm^3	6 cm^2
cube *b*	8 cm^3	24 cm^2
cube *c*	27 cm^3	54 cm^2

RATIOS AND GENERALIZATIONS

Data on the volume and surface area of the three cubes in Figure 1.10 describes the cubes, but whether it says anything about a relationship between the volume and surface area of a cube is difficult to tell. Nature seems to have a tendency to camouflage relationships, making it difficult to extract meaning from raw data. Seeing through the camouflage requires the use of mathematical techniques to expose patterns. Let's see how such techniques can be applied to the data on the three cubes and what the pattern means.

One mathematical technique for reducing data to a more manageable form is to expose patterns through a **ratio.** A ratio is a relationship between two numbers that is obtained when one number is divided by another number. Suppose, for example, that an instructor has 50 sheets of graph paper for a laboratory group of 25 students. The relationship, or ratio, between the number of sheets and the number of students is 50 papers to 25 students, and this can be written as 50 papers/25 students. This ratio is *simplified* by dividing 25 into 50, and the ratio becomes 2 papers/1 student. The 1 is usually understood (not stated), and the ratio is written as simply 2 papers/student. It is read as 2 papers "for each" student, or 2 papers "per" student. The concept of simplifying with a ratio is an important one, and you will see it time and again throughout science. It is important that you understand the meaning of *per* and *for each* when used with numbers and units.

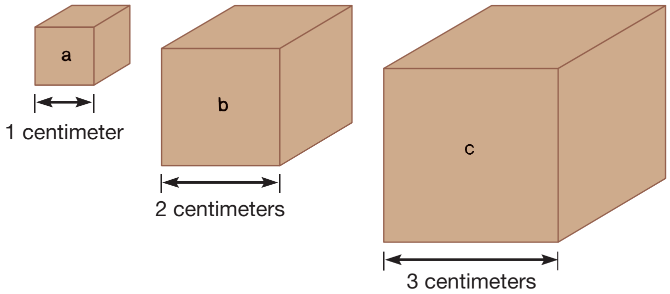


FIGURE 1.10 Cube *a* is 1 centimeter on each side, cube *b* is 2 centimeters on each side, and cube *c* is 3 centimeters on each side. These three cubes can be described and compared with data, or measurement information, but some form of analysis is needed to find patterns or meaning in the data.

Applying the ratio concept to the three cubes in Figure 1.10, the ratio of surface area to volume for the smallest cube, cube *a*, is 6 cm^2 to 1 cm^3, or

$$\frac{6\ \text{cm}^2}{1\ \text{cm}^3} = 6\frac{\text{cm}^2}{\text{cm}^3}$$

meaning there are 6 square centimeters of area *for each* cubic centimeter of volume.

The middle-sized cube, cube *b*, had a surface area of 24 cm^2 and a volume of 8 cm^3. The ratio of surface area to volume for this cube is therefore

$$\frac{24\ \text{cm}^2}{8\ \text{cm}^3} = 3\frac{\text{cm}^2}{\text{cm}^3}$$

meaning there are 3 square centimeters of area *for each* cubic centimeter of volume.

The largest cube, cube *c*, had a surface area of 54 cm^2 and a volume of 27 cm^3. The ratio is

$$\frac{54\ \text{cm}^2}{27\ \text{cm}^3} = 2\frac{\text{cm}^2}{\text{cm}^3}$$

or 2 square centimeters of area *for each* cubic centimeter of volume. Summarizing the ratio of surface area to volume for all three cubes, you have

small cube a — 6:1
middle cube b — 3:1
large cube c — 2:1

Now that you have simplified the data through ratios, you are ready to generalize about what the information means. You can generalize that the surface-area-to-volume ratio of a cube *decreases* as the volume of a cube becomes larger. Reasoning from this generalization will provide an explanation for a number of related observations. For example, why does crushed ice melt faster than a single large block of ice with the same volume? The explanation is that the crushed ice has a larger surface-area-to-volume ratio than the large block, so more surface is exposed to warm air. If the generalization is found to be true for shapes other than cubes, you could explain why a log chopped into small chunks burns faster than the whole log. Further generalizing might enable you to predict if large potatoes would require more or less peeling than the same weight of small potatoes. When generalized explanations result in predictions that can be verified by experience, you gain confidence in the explanation. Finding patterns of relationships is a satisfying intellectual adventure that leads to understanding and generalizations that are frequently practical.

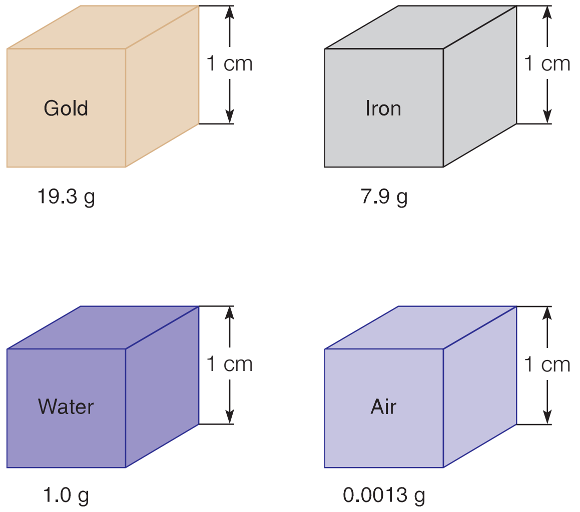


FIGURE 1.11 Equal volumes of different substances do not have the same mass, as these cube units show. Calculate the densities in g/cm^3. Do equal volumes of different substances have the same density? Explain.

THE DENSITY RATIO

The power of using a ratio to simplify things, making explanations more accessible, is evident when you compare the simplified ratio 6 to 3 to 2 with the hodgepodge of numbers that you would have to consider without using ratios. The power of using the ratio technique is also evident when considering other properties of matter. Volume is a property that is sometimes confused with mass. Larger objects do not necessarily contain more matter than smaller objects. A large balloon, for example, is much larger than this book, but the book is much more massive than the balloon. The simplified way of comparing the mass of a particular volume is to find the ratio of mass to volume. This ratio is called **density,** which is defined as *mass per unit volume.* The *per* means "for each" as previously discussed, and *unit* means one, or each. Thus, "mass per unit volume" literally means the "mass of one volume" (Figure 1.11). The relationship can be written as

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

or

$$\rho = \frac{m}{V}$$

(ρ is the symbol for the Greek letter rho.)

equation 1.1

As with other ratios, density is obtained by dividing one number and unit by another number and unit. Thus, the density of an object with a volume of 5 cm^3 and a mass of 10 g is

$$\text{density} = \frac{10\ \text{g}}{5\ \text{cm}^3} = 2\frac{\text{g}}{\text{cm}^3}$$

The density in this example is the ratio of 10 g to 5 cm^3, or 10 g/5 cm^3, or 2 g to 1 cm^3. Thus, the density of the example object is the mass of *one* volume (a unit volume), or 2 g *for each* cm^3.

Any unit of mass and any unit of volume may be used to express density. The densities of solids, liquids, and gases are usually expressed in grams per cubic centimeter (g/cm^3), but the densities of liquids are sometimes expressed in grams per milliliter (g/mL). Using SI standard units, densities are expressed as kg/m^3. Densities of some common substances are shown in Table 1.3.

TABLE 1.3

Densities (ρ) of Some Common Substances

	g/cm^3
Aluminum	2.70
Copper	8.96
Iron	7.87
Lead	11.4
Water	1.00
Seawater	1.03
Mercury	13.6
Gasoline	0.680

If matter is distributed the same throughout a volume, the *ratio* of mass to volume will remain the same no matter what mass and volume are being measured. Thus, a teaspoonful, a cup, and a lake full of freshwater at the same temperature will all have a density of about 1 g/cm^3 or 1 kg/L. A given material will have its own unique density; example 1.1 shows how density can be used to identify an unknown substance. For help with significant figures, see appendix A (p. A3).

CONCEPTS *Applied*

Density Matters—Sharks and Cola Cans

What do a shark and a can of cola have in common? Sharks are marine animals that have an internal skeleton made entirely of cartilage. These animals have no swim bladder to adjust their body density in order to maintain their position in the water; therefore, they must constantly swim or they will sink. The bony fish, on the other hand, have a skeleton composed of bone, and most also have a swim bladder. These fish can regulate the amount of gas in the bladder to control their density. Thus, the fish can remain at a given level in the water without expending large amounts of energy.

Have you ever noticed the different floating characteristics of cans of the normal version of a carbonated cola beverage and a diet version? The surprising result is that the normal version usually sinks and the diet version usually floats. This has nothing to do with the amount of carbon dioxide in the two drinks. It is a result of the increase in density from the sugar added to the normal version, while the diet version has much less of an artificial sweetener that is much sweeter than sugar. So, the answer is that sharks and regular cans of cola both sink in water.

EXAMPLE 1.1

Two blocks are on a table. Block A has a volume of 30.0 cm^3 and a mass of 81.0 g. Block B has a volume of 50.0 cm^3 and a mass of 135 g. Which block has the greater density? If the two blocks have the same density, what material are they? (See Table 1.3.)

SOLUTION

Density is defined as the ratio of the mass of a substance per unit volume. Assuming the mass is distributed equally throughout the volume, you could assume that the ratio of mass to volume is the same no matter what quantities of mass and volume are measured. If you can accept this assumption, you can use equation 1.1 to determine the density.

Block A

mass (m) = 81.0 g
volume (V) = 30.0 cm^3
density = ?

$$\rho = \frac{m}{V}$$

$$= \frac{81.0 \text{ g}}{30.0 \text{ cm}^3}$$

$$= 2.70 \frac{\text{g}}{\text{cm}^3}$$

Block B

mass (m) = 135 g
volume (V) = 50.0 cm^3
density = ?

$$\rho = \frac{m}{V}$$

$$= \frac{135 \text{ g}}{50.0 \text{ cm}^3}$$

$$= 2.70 \frac{\text{g}}{\text{cm}^3}$$

As you can see, both blocks have the same density. Inspecting Table 1.3, you can see that aluminum has a density of 2.70 g/cm^3, so both blocks must be aluminum.

EXAMPLE 1.2

A rock with a volume of 4.50 cm^3 has a mass of 15.0 g. What is the density of the rock? (Answer: 3.33 g/cm^3)

CONCEPTS *Applied*

A Dense Textbook?

What is the density of this book? Measure the length, width, and height of this book in cm, then multiply to find the volume in cm^3. Use a scale to find the mass of this book in grams. Compute the density of the book by dividing the mass by the volume. Compare the density in g/cm^3 with other substances listed in Table 1.3.

Myths, Mistakes, & Misunderstandings

Tap a Can?

Some people believe that tapping on the side of a can of carbonated beverage will prevent it from foaming over when the can is opened. Is this true or a myth? Set up a controlled experiment (see p. 15) to compare opening cold cans of carbonated beverage that have been tapped with cans that have not been tapped. Are you sure you have controlled all the other variables?