Seventh Edition

INTEGRATED SCIENCE

Tillery | Enger | Ross

McGraw Hill Education

Conversion Factors

Length
1 in = 2.54 cm
1 cm = 0.394 in
1 ft = 30.5 cm
1 m = 39.4 in = 3.281 ft
1 km = 0.621 mi
1 mi = 5,280 ft = 1.609 km
1 light-year = 9.461×10^{15} m

Mass
1 lb = 453.6 g (where $g = 9.8$ m/s^2)
1 kg = 2.205 lb (where $g = 9.8$ m/s^2)
1 atomic mass unit u = 1.66061×10^{-27} kg

Volume
1 liter = 1.057 quarts
1 in^3 = 16.39 cm^3
1 gallon = 3.786 liters
1 ft^3 = 0.02832 m^3

Energy
1 cal = 4.184 J
1 J = 0.738 ft·lb = 0.0239 cal
1 ft·lb = 1.356 J
1 Btu = 252 cal = 778 ft·lb
1 kWh = 3.60×10^6 J = 860 kcal
1 hp = 550 ft·lb/s = 746 W
1 W = 0.738 ft·lb/s
1 Btu/h = 0.293 W
Absolute zero (0K) = –273.15°C
1 J = 6.24×10^{18} eV
1 eV = 1.6022×10^{-19} J

Speed
1 km/h = 0.2778 m/s = 0.6214 mi/h
1 m/s = 3.60 km/h = 2.237 mi/h = 3.281 ft/s
1 mi/h = 1.61 km/h = 0.447 m/s = 1.47 ft/s
1 ft/s = 0.3048 m/s = 0.6818 mi/h

Force
1 N = 0.2248 lb
1 lb = 4.448 N

Pressure
1 atm = 1.013 bar = 1.013×10^5 N/m^2 = 14.7 lb/in^2
1 lb/in^2 = 6.90×10^3 N/m^2

Powers of Ten

10^{-10} = 0.000.000.000.1	10^0 = 1
10^{-9} = 0.000.000.001	10^1 = 10
10^{-8} = 0.000.000.01	10^2 = 100
10^{-7} = 0.000.000.1	10^3 = 1,000
10^{-6} = 0.000.001	10^4 = 10,000
10^{-5} = 0.000.01	10^5 = 100,000
10^{-4} = 0.000.1	10^6 = 1,000,000
10^{-3} = 0.001	10^7 = 10,000,000
10^{-2} = 0.01	10^8 = 100,000,000
10^{-1} = 0.1	10^9 = 1,000,000,000
10^0 = 1	10^{10} = 10,000,000,000

Multipliers for Metric Units

a	atto-	10^{-18}	da	deka-	10^1
f	femto-	10^{-15}	h	hecto-	10^2
p	pico-	10^{-12}	k	kilo-	10^3
n	nano-	10^{-9}	M	mega-	10^6
μ	micro-	10^{-6}	G	giga-	10^9
m	milli-	10^{-3}	T	tera-	10^{12}
c	centi-	10^{-2}	P	peta-	10^{15}
d	deci-	10^{-1}	E	exa-	10^{18}

Physical Constants

Quantity	Approximate Value
Gravity (Earth)	$g = 9.8$ m/s^2
Gravitational law constant	G = 6.67×10^{-11} N·m^2/kg^2
Earth radius (mean)	6.38×10^6 m
Earth mass	5.98×10^{24} kg
Earth-Sun distance (mean)	1.50×10^{11} m
Earth-Moon distance (mean)	3.84×10^8 m
Fundamental charge	1.60×10^{-19} C
Coulomb law constant	$k = 9.00 \times 10^9$ N·m^2/C^2
Electron rest mass	9.11×10^{-31} kg
Proton rest mass	1.6726×10^{-27} kg
Neutron rest mass	1.6750×10^{-27} kg
Bohr radius	5.29×10^{-11} m
Avogadro's number	6.02×10^{23}/mol
Planck's constant	6.62×10^{-34} J·s
Speed of light (vacuum)	3.00×10^8 m/s
Pi	$\pi = 3.1415926536$

Integrated SCIENCE

Seventh Edition

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INTEGRATED SCIENCE, SEVENTH EDITION

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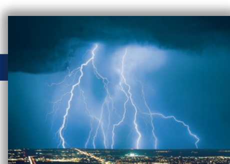

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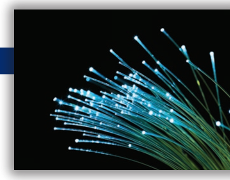

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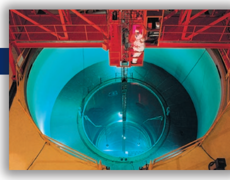

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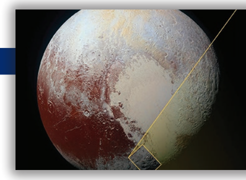

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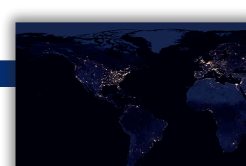

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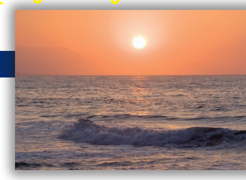

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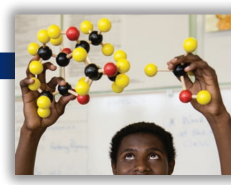

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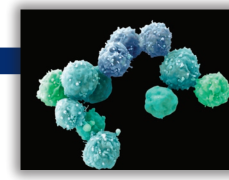

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PREFACE

WHAT SETS THIS BOOK APART?

CREATING INFORMED CITIZENS

Integrated Science is a straightforward, easy-to-read, but substantial introduction to the fundamental behavior of matter and energy in living and nonliving systems. It is intended to serve the needs of nonscience majors who must complete one or more science courses as part of a general or basic studies requirement.

Integrated Science provides an introduction to a scientific way of thinking as it introduces fundamental scientific concepts, often in historical context. Several features of the text provide opportunities for students to experience the methods of science by evaluating situations from a scientific point of view. While technical language and mathematics are important in developing an understanding of science, only the language and mathematics needed to develop central concepts are used. No prior work in science is assumed.

Many features, such as Science and Society readings, as well as basic discussions of the different branches of science help students understand how the branches relate. This allows students to develop an appreciation of the major developments in science and an ability to act as informed citizens on matters that involve science and public policy.

FLEXIBLE ORGANIZATION

The *Integrated 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. The *Integrated Science* Online Learning Center's Instructor's Resources offer suggestions for integrating the text's topics around theme options. With laboratory studies, the text contains enough material for the instructor to select a sequence for a one- or two-semester course.

THE GOALS OF *INTEGRATED SCIENCE*

1. **Create an introductory science course aimed at the nonscience major.** The origin of this book is rooted in our concern for the education of introductory-level students in the field of science. Historically, nonscience majors had to enroll in courses intended for science or science-related majors such as premeds, architects, or engineers. Such courses are important for these majors but are mostly inappropriate for introductory-level nonscience students. To put a nonscience student in such a course is a mistake. Few students will have the time or background to move through the facts, equations, and specialized language to gain any significant insights into the logic or fundamental understandings; instead, they will leave the course with a distaste for science. Today, society has a great need for a few technically trained people but a much larger need for individuals who understand the process of science and its core concepts.
2. **Introduce a course that presents a coherent and clear picture of all science disciplines through an interdisciplinary approach.** Recent studies and position papers have called for an interdisciplinary approach to teaching science to nonmajors. For example, the need is discussed in the American Association for the Advancement of Science's book, *Science for All Americans,* and the National Research Council's book, *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas,* both of which were used in the creation of the most recent version of the U.S. Next Generation Science Standards. Interdisciplinary science is an attempt to broaden and humanize science education by reducing and breaking down the barriers that enclose traditional science disciplines as distinct subjects.
3. **Help instructors build their own mix of descriptive and analytical aspects of science, arousing student interest and feelings as they help students reach the educational goals of their particular course.** The spirit of interdisciplinary science is sometimes found in courses called "General Science," "Combined Science," or "Integrated Science." These courses draw concepts from a wide range of the traditional fields of science but are not concentrated around certain problems or questions. For example, rather than just dealing with the physics of energy, an interdisciplinary approach might consider broad aspects of energy—dealing with potential problems of an energy crisis—including social and ethical issues. A number of approaches can be used in interdisciplinary science, including the teaching of science in a *social, historical, philosophical,* or *problem-solving* context, but there is no single best approach. One of the characteristics of interdisciplinary science is that it is not constrained by the necessity of teaching certain facts or by traditions. It likewise cannot be imposed as a formal discipline, with certain facts to be learned. It is justified by its success in attracting and holding the attention and interest of students, making them a little wiser as they make their way toward various careers and callings.
4. **Humanize science for nonscience majors.** Each chapter presents historical background where appropriate, uses everyday examples in developing concepts, and follows a logical flow of presentation. A discussion of the people and events involved in the development of scientific concepts

puts a human face on the process of science. 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 sciences.

VALUED INPUT WENT INTO STRIVING TO MEET YOUR NEEDS

Text development today involves a team that includes authors and publishers and valuable input from instructors who share their knowledge and experience with publishers and authors through reviews and focus groups. Such feedback has shaped this edition, resulting in reorganization of existing content and expanded coverage in key areas. This text has continued to evolve as a result of feedback from instructors actually teaching integrated science courses in the classroom. Reviewers point out that current and accurate content, a clear writing style with concise explanations, quality illustrations, and dynamic presentation materials are important factors considered when evaluating textbooks. Those criteria have guided the revision of the *Integrated Science* text and the development of its ancillary resources.

NEW TO THIS EDITION

- Many new worked Examples and end-of-chapter Parallel Exercises have been added, especially in chapters 10 and 12–26, to assist students in exploring the computational aspects of the chapters. The Examples should aid students in working the end-of-chapter Parallel Exercises.
- A new feature, Science Sketch, engages students in creating their own explanations and analogies by challenging them to create visual representations of concepts.
- A new feature, Self Checks, allows students to check their understanding of concepts as they progress through the chapter.
- The illustrations within the biological content have been revised to reduce their complexity and to better correlate them to the coverage within the text.
- The revised chapter 13 includes many new images and updated information from the latest space missions. There are also many new worked Examples to assist students in exploring the computational aspects of the chapter and in working the end-of-chapter Parallel Exercises.
- The revised chapter 16 contains additional information on distances in space, with accompanying new worked Examples and end-of-chapter Parallel Exercises. This revised chapter also includes updated information on the future of our universe.
- Chapter 17 includes the most recent information on climate change, causes of global climate change, and global warming.

THE LEARNING SYSTEM

To achieve the goals stated, this text includes a variety of features that should make students' study of *Integrated Science* more effective and enjoyable. These aids are included to help you clearly understand the concepts and principles that serve as the foundation of the integrated sciences.

OVERVIEW TO INTEGRATED SCIENCE

Chapter 1 provides an overview or orientation to integrated science in general and this text in particular. It also describes the fundamental methods and techniques used by scientists to study and understand the world around us.

MULTIDISCIPLINARY APPROACH

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 supporting concepts list is designed to help students focus their studies by identifying the most important topics in the chapter outline.

CONNECTIONS

The relationship of other science disciplines throughout the text are related to the chapter's contents. The core concept map, integrated with the chapter outline and supporting concepts list, the connections list, and overview, help students to see the big picture of the chapter content and the even bigger picture of how that content relates to other science discipline areas.

CHAPTER OVERVIEWS

Each chapter begins with an introductory overview. The overview previews the chapter's contents and what students can expect to learn from reading the chapter. It adds to the general outline of the chapter by introducing students to the concepts to be covered. It also expands upon the core concept map, facilitating in the integration of topics. Finally, the overview will help students to stay focused and organized while reading the chapter for the first time. After reading this introduction, students should browse through the chapter, paying particular attention to the topic headings and illustrations so that they get a feel for the kinds of ideas included within the chapter.

APPLYING SCIENCE TO THE REAL WORLD

CONCEPTS APPLIED

As students look through each chapter, they will find one or more Concepts Applied boxes. These activities are simple exercises that students can perform at home or in the classroom to demonstrate important concepts and reinforce their understanding of them. This feature also describes the application of those concepts to their everyday lives.

EXAMPLES

Many of the more computational topics discussed within the chapters contain 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 sciences. Follow-up Examples (with their solutions found in appendix E) allow students to practice their problem-solving skills. The Examples have been marked as "optional" to allow instructors to place as much emphasis (or not) on problem solving as deemed necessary for their courses.

NEW! SCIENCE SKETCHES

The new feature, Science Sketch, found in each chapter, engages students in creating their own explanations and analogies by challenging them to create visual representations of concepts.

NEW! SELF CHECKS

The new feature, Self Check, allows students to check their understanding of concepts as they progress through the chapter.

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 students an opportunity to discuss issues with their peers.

MYTHS, MISTAKES, AND MISUNDERSTANDINGS

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

PEOPLE BEHIND THE SCIENCE

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

CLOSER LOOK AND CONNECTIONS

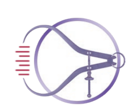
Each chapter of *Integrated Science* also includes one or more **Closer Look** readings that discuss topics of special human or environmental concern, topics concerning interesting technological applications, or topics on the cutting edge of scientific research. These readings enhance the learning experience by taking a more detailed look at related topics and adding concrete examples to help students better appreciate the real-world applications of science.

In addition to the **Closer Look** readings, each chapter contains concrete interdisciplinary **Connections** that are highlighted. **Connections** will help students better appreciate the interdisciplinary nature of the sciences. The **Closer Look** and **Connections** readings are informative materials that are supplementary in nature. These boxed features highlight valuable information beyond the scope of the text and relate intrinsic concepts discussed to real-world issues, underscoring the relevance of integrated science in confronting the many issues we face in our day-to-day lives. They are identified with the following icons:

General: This icon identifies interdisciplinary topics that cross over several categories; for example, life sciences and technology.

Life: This icon identifies interdisciplinary life science topics, meaning connections concerning all living organisms collectively: plant life, animal life, marine life, and any other classification of life.

Technology: This icon identifies interdisciplinary technology topics, that is, connections concerned with the application of science for the comfort and well-being of people, especially through industrial and commercial means.



Measurement, Thinking, Scientific Methods: This icon identifies interdisciplinary concepts and understandings concerned with people trying to make sense out of their surroundings by making observations, measuring, thinking, developing explanations for what is observed, and experimenting to test those explanations.

Environmental Science: This icon identifies interdisciplinary concepts and understandings about the problems caused by human use of the natural world and remedies for those problems.

END-OF-CHAPTER FEATURES

At the end of each chapter are the following materials:

- *Summary:* highlights the key elements of the chapter
- *Summary of Equations:* highlights the key equations to reinforce retention of them
- *Key Terms:* page-referenced where students will find the terms defined in context
- *Concept Questions:* designed to challenge students to demonstrate their understandings of the topic. Some exercises include analysis or discussion questions, independent investigations, and activities intended to emphasize critical thinking skills and societal issues, and develop a deeper understanding of the chapter content.

- *Self-Guided Labs:* exercises that consist of short, open-ended activities that allow students to apply investigative skills to the material in the chapter
- *Parallel Exercises:* 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. 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 provided solutions, students will gain confidence in tackling the parallel exercises in Group B and thus reinforce their problem-solving skills.

END-OF-TEXT MATERIAL

At the back of the text are appendices that give additional background details, charts, and answers to chapter exercises. Appendix E provides solutions for each chapter's follow-up Example exercises. There is also an index organized alphabetically by subject matter, and special tables are printed on the pages just inside the covers for reference use.

SUPPLEMENTARY MATERIALS

PRESENTATION TOOLS

Complete set of electronic book images and assets for instructors. Build instructional materials wherever, whenever, and however you want!

Accessed from your textbook's Connect Instructor's Resources, **Presentation Tools** is an online digital library containing photos, artwork, animations, and other media types that can be used to create customized lectures, visually enhanced tests and quizzes, compelling course websites, or attractive printed support materials. All assets are copyrighted by McGraw-Hill Higher Education but can be used by instructors for classroom purposes. The visual resources in this collection include:

- **Art, Photo, and Table Library:** Full-color digital files of all of the illustrations and tables and many of the photos in the text can be readily incorporated into lecture presentations, exams, or custom-made classroom materials.
- **Animations Library:** Files of animations and videos covering the many topics in *Integrated Science* are included so that you can easily make use of these animations in a lecture or classroom setting.

Also residing on your textbook's Connect Instructor's Resources site are:

- **PowerPoint Slides:** For instructors who prefer to create their lectures from scratch, all illustrations, photos, and tables are pre-inserted by chapter into PowerPoint slides.
- **Lecture Outlines:** Lecture notes, incorporating illustrations, have been written to the seventh edition text. They are provided in PowerPoint format so that you may use these lectures as written or customize them to fit your lecture.

LABORATORY MANUAL

The laboratory manual, written and classroom-tested by the authors, presents a selection of laboratory exercises specifically written for the interest and abilities of nonscience majors. Each lab begins with an open-ended ***Invitations to Inquiry,*** designed to pique student interest in the lab concept. This is followed by laboratory exercises that require measurement and data analysis for work in a more structured learning environment. When the laboratory manual is used with *Integrated 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.

McGraw-Hill Connect® is a highly reliable, easy-to-use homework and learning management solution that utilizes learning science and award-winning adaptive tools to improve student results.

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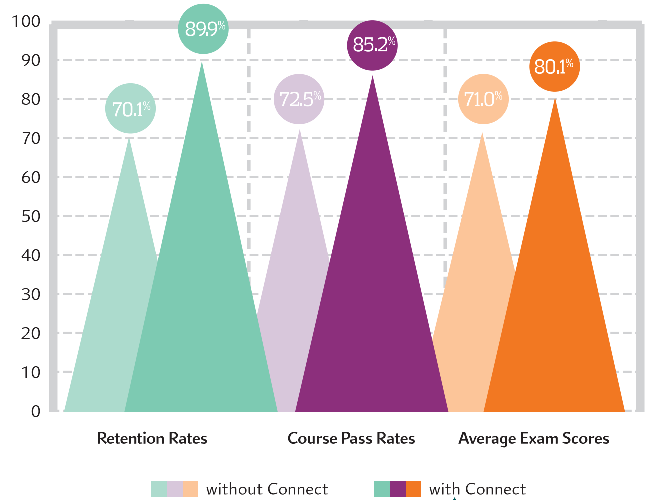

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- Connect automatically grades assignments and quizzes, providing easy-to-read reports on individual and class performance.

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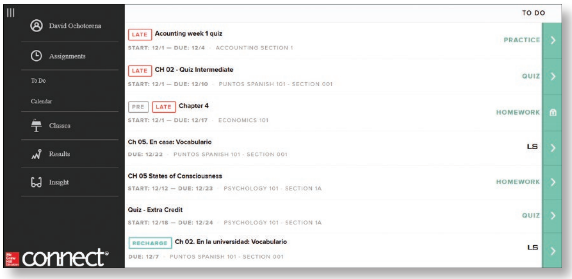

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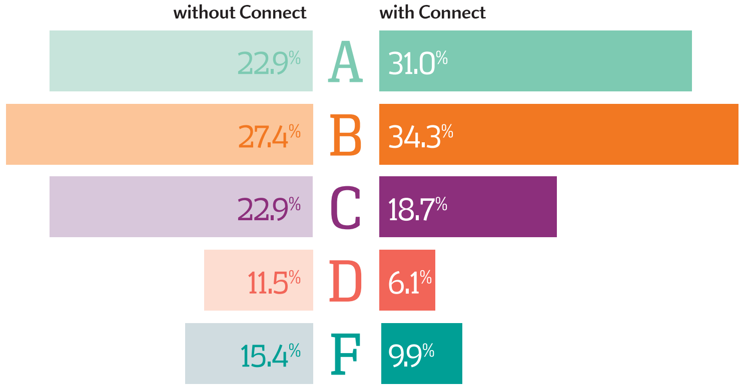

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BILL W. TILLERY

Bill W. Tillery is professor emeritus of physics at Arizona State University. He earned a bachelor's degree at Northeastern State University (1960) and master's and doctorate degrees from the University of Northern Colorado (1967). Before moving to Arizona State University, he served as director of the Science and Mathematics Teaching Center at the University of Wyoming (1969–1973) and as an assistant professor at Florida State University (1967–1969). Bill has served on numerous councils, boards, and committees and was honored as the "Outstanding University Educator" at the University of Wyoming in 1972. He was elected the "Outstanding Teacher" in the Department of Physics and Astronomy at Arizona State University in 1995.

During his time at Arizona State, Bill has taught a variety of courses, including general education courses in science and society, physical science, and introduction to physics. He has received more than forty grants from the National Science Foundation, the U.S. Office of Education, private industry (Arizona Public Service), and private foundations (Flinn Foundation) for science curriculum development and science teacher in-service training. In addition to teaching and grant work, Bill has authored or co-authored more than sixty textbooks and many monographs, and has served as editor of three newsletters and journals between 1977 and 1996.

ELDON D. ENGER

Eldon D. Enger is professor emeritus of biology at Delta College, a community college near Saginaw, Michigan. He received his B.A. and M.S. degrees from the University of Michigan. Professor Enger has over thirty years of teaching experience, during which he has taught biology, zoology, environmental science, and several other courses. He has been very active in curriculum and course development.

Professor Enger is an advocate for variety in teaching methodology. He feels that if students are provided with varied experiences, they are more likely to learn. In addition to the standard textbook assignments, lectures, and laboratory activities, his classes are likely to include writing assignments, student presentation of lecture material, debates by students on controversial issues, field experiences, individual student projects, and discussions of local examples and relevant current events. Textbooks are very valuable for presenting content, especially if they contain accurate, informative drawings and visual examples. Lectures are best used to help students see themes and make connections, and laboratory activities provide important hands-on activities.

Professor Enger has been a Fulbright Exchange Teacher to Australia and Scotland, received the Bergstein Award for Teaching Excellence and the Scholarly Achievement Award from Delta College, and participated as a volunteer in Earthwatch Research Programs in Costa Rica, the Virgin Islands, and Australia. During 2001, he was a member of a People to People delegation to South Africa.

Professor Enger is married, has two adult sons, and enjoys a variety of outdoor pursuits such as cross-country skiing, hiking, hunting, kayaking, fishing, camping, and gardening. Other interests include reading a wide variety of periodicals, beekeeping, singing in a church choir, and preserving garden produce.

FREDERICK C. ROSS

Fred Ross is professor emeritus of biology at Delta College, a community college near Saginaw, Michigan. He received his B.S. and M.S. from Wayne State University, Detroit, Michigan, and has attended several other universities and institutions. Professor Ross has thirty years' teaching experience, including junior and senior high school, during which he has taught biology, cell biology and biological chemistry, microbiology, environmental science, and zoology. He has been very active in curriculum and course development. These activities included the development of courses in infection control and microbiology, and AIDS and infectious diseases, and a PBS ScienceLine course for elementary and secondary education majors in cooperation with Central Michigan University. In addition, he was involved in the development of the wastewater microbiology technician curriculum offered by Delta College.

He was also actively involved in the National Task Force of Two Year College Biologists (American Institute of Biological Sciences) and in the National Science Foundation College Science Improvement Program, and has been an evaluator for science and engineering fairs, Michigan Community College

Biologists, a judge for the Michigan Science Olympiad and the Science Bowl, a member of a committee to develop and update blood-borne pathogen standards protocol, and a member of Topic Outlines in Introductory Microbiology Study Group of the American Society for Microbiology.

Professor Ross involves his students in a variety of learning techniques and has been a prime advocate of the writing-to-learn approach. Besides writing, his students are typically engaged in active learning techniques including use of inquiry-based learning, the Internet, e-mail communications, field experiences, classroom presentation, as well as lab work. The goal of his classroom presentations and teaching is to actively engage the minds of his students in understanding the material, not just memorization of "scientific facts." Professor Ross is married and recently a grandfather. He enjoys sailing, horseback riding, and cross-country skiing.

STEPHANIE J. SLATER

Stephanie Slater is the Director of the CAPER Center for Astronomy & Physics Education Research. After undergraduate studies at Massachusetts Institute of Technology and graduate work at Montana State University, Dr. Slater earned her Ph.D. from the University of Arizona in the Department of Teaching, Learning and Sociocultural Studies studying how undergraduate research experiences influence the professional career pathways of women scientists. Dr. Slater was selected as the American Physical Society's Woman Physicist of the Month in December 2013 and received both NASA Top Star and NASA Gold Star Education awards.

With more than twenty years of teaching experience, Dr. Slater has written science textbooks for undergraduate classes and books on education research design and methods for graduate courses. Her work on educational innovations has been funded by the National Science Foundation and NASA, and she serves on numerous science education and outreach committees for the American Association of Physics Teachers, the American Physical Society, the American Geophysical Union, and the American Institute of Physics, among others. She is also a frequent lecturer at science fiction conventions, illustrating how science fiction books, television series, and movies describe how humans interact at the intersection of science and culture.

TIMOTHY F. SLATER

Tim Slater has been the University of Wyoming Excellence in Higher Education Endowed Professor of Science Education since 2008. Prior to joining the faculty at the University of Wyoming, he was an astronomer at the University of Arizona from 2001–2008 where he was the first professor in the United States to earn tenure in a top-ranked Astronomy Department on the basis of his scholarly publication and grant award record in astronomy education research. From 1996–2001, he was a research professor of physics at Montana State University.

Dr. Slater earned a Ph.D. at the University of South Carolina, an M.S. at Clemson University, and two bachelor's degrees at Kansas State University. He is widely known as the "professor's professor" because of the hundreds of college teaching talks and workshops he has given to thousands of professors on innovative teaching methods. Dr. Slater serves as the Editor-in-Chief of the *Journal of Astronomy & Earth Sciences Education* and was the initial U.S. Chairman of the International Year of Astronomy. An avid motorcycle rider, he is the author of 13 books, has written more than 100 peer-reviewed journal articles, and been the recipient of numerous teaching awards.

1 What Is Science?

Science is concerned with your surroundings and your concepts and understanding of these surroundings.
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CORE CONCEPT

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

OUTLINE

Measurement is used to accurately describe properties and events. ***Pg. 4***

An equation is a statement of a relationship between variables. ***Pg. 11***

Science investigations include collecting observations, developing explanations, and testing explanations. ***Pg. 13***

Scientific laws describe relationships between events that happen time after time. ***Pg. 15***

CONNECTIONS

Physics

- Energy flows in and out of your surroundings (Ch. 2–7).

Chemistry

- Matter is composed of atoms that interact on several different levels (Ch. 8–11).

Earth Science

- Earth is matter and energy that interact through cycles of change (Ch. 14–18).

Astronomy

- The stars and solar system are matter and energy that interact through cycles of change (Ch. 12–13).

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 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.

This is a book on thinking about and understanding your surroundings. These surroundings range from the obvious, such as the landscape and the day-to-day weather, to the not so obvious, such as how atoms are put together. Your surroundings include natural things as well as things that people have made and used (figure 1.1). 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. We will focus on describing your world in terms of how many, how big, how far, and how things change.

1.1 OBJECTS AND PROPERTIES

Science is concerned with making sense out of the 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 running dog. 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 (figure 1.2). 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? 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 person has the same "concept" for words as you do. That is why when

FIGURE 1.1 Your surroundings include naturally occurring objects and manufactured objects such as sidewalks and walls. ©Photodisc/Getty Images RF

FIGURE 1.2 What is your concept of a chair? Is this a picture of a row of chairs, or are they something else? 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 row of beach chairs. ©rolfo/Getty Images RF

one person says, "Wow, was it hot today!" 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 the deserts of Arizona and the other from snow-covered 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 in figure 1.3 is "big, yellow, and smooth, with shiny gold cubes on

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. ©Bill W. Tillery

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!

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 with 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.

SELF CHECK

1.1 The process of comparing a property of an object to a well-defined and agreed-upon referent is called the process of

a. generalizing.
b. measurement.
c. graphing.
d. scientific investigation.

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.

CONCEPTS APPLIED

Communication Without Measurement

1. Find out how people communicate about the properties of objects. Ask several friends to describe a paper clip while their hands are behind their backs. Perhaps they can do better describing a goatee? Try to make a sketch that represents each description.
2. Ask two classmates to sit back to back. Give one of them a sketch or photograph that shows an object in some detail, perhaps a guitar or airplane. This person is to describe the properties of the object *without naming it*. The other person is to make a scaled sketch from the description. Compare the sketch to the description; then see how the use of measurement would improve the 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.

SCIENCE SKETCH

On a piece of paper with two outlines of your hand traced on it with a pencil, illustrate and label what is meant by the referents "short" and "long" fingernails.

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, which specifies how the comparison is made, and (3) *counting* how many standard units describe the property being considered.

The measurement process thus 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 implying the procedure for obtaining the number. Referent units must be defined and established, however, if others are to understand and reproduce a measurement. It would be meaningless, for example, for you to talk about a length in "clips" if other people did not know what you meant by a "clip" unit. When

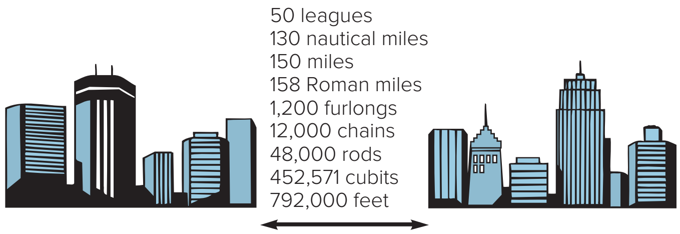

FIGURE 1.4 Any of these units and values could have been used at some time or another to describe the same distance between these hypothetical towns. Any unit could be used for this purpose, but when one particular unit is officially adopted, it becomes known as the *standard unit.*

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.

There are two major *systems* of standard units in use today, the English system and the metric system. The metric system is used in all industrialized countries except 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.

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, 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 was not the same size. Beginning in the 1300s, the sizes of the units were gradually standardized by various English kings. In 1879, the United States, along with sixteen other countries, signed the

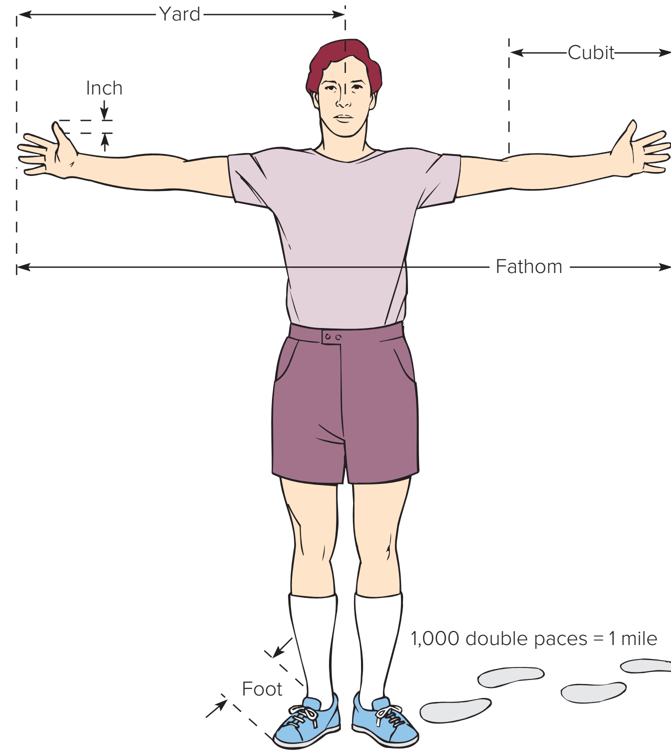

FIGURE 1.5 Many early units for measurement were originally based on the human body. Some of the units were later standardized by governments to become the basis of the English system of measurement.

Treaty of the Meter, defining the English units in terms of the metric system. The United States thus became officially metric but not entirely metric in everyday practice.

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. In 1960, six standard metric units were established by international agreement. The *International System of Units,* abbreviated *SI,* is a modernized version of the metric system. Today, the SI system has seven units that define standards for the properties of length, mass, time, electric current, temperature, amount of substance, and light intensity (table 1.1). The standard units for the properties of

TABLE 1.1

The SI Standard 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

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. 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). A meter is defined in terms of 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*

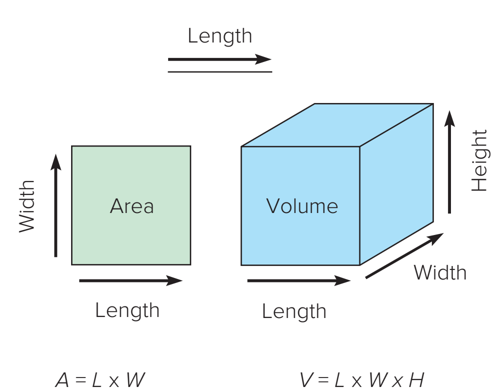

FIGURE 1.6 Area, or the extent of a surface, can be described by two length measurements. Volume, or the space that an object occupies, can be described by three length measurements. Length, however, can be described only in terms of how it is measured, so it is called a *fundamental property.*

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.

SELF CHECK

1.2 The height of an average person is closest to
a. 1.0 m.
b. 1.5 m.
c. 2.5 m.
d. 3.5 m.

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 the 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 originally thought, so the second was redefined to be the duration required for a certain number of vibrations of a specific type of cesium atom. A special spectrometer called an "atomic clock" measures these vibrations and keeps time with an accuracy of several millionths of a second per year.

SELF CHECK

1.3 Which of the following standard units is defined in terms of an object as opposed to an event?
a. kilogram
b. meter
c. second
d. none of the above

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 ten equal-sized subunits called *decimeters*. The prefix *deci-* has a meaning of "one-tenth of," and it takes 10 decimeters to equal the length of 1 meter. For even smaller measurements, each decimeter is divided into ten equal-sized subunits called *centimeters*. It takes 10 centimeters 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. A cubic decimeter (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,

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

TABLE 1.2

Some Metric Prefixes

Prefix	Symbol	Meaning
tera-	T	10^{12} (1,000,000,000,000 times the unit)
giga-	G	10^{9} (1,000,000,000 times the unit)
mega-	M	10^{6} (1,000,000 times the unit)
kilo-	k	10^{3} (1,000 times the unit)
hecto-	h	10^{2} (100 times the unit)
deka-	da	10^{1} (10 times the unit)
Unit		
deci-	d	10^{-1} (0.1 of the unit)
centi-	c	10^{-2} (0.01 of the unit)
milli-	m	10^{-3} (0.001 of the unit)
micro-	µ	10^{-6} (0.000001 of the unit)
nano-	n	10^{-9} (0.000000001 of the unit)
pico-	p	10^{-12} (0.000000000001 of the unit)

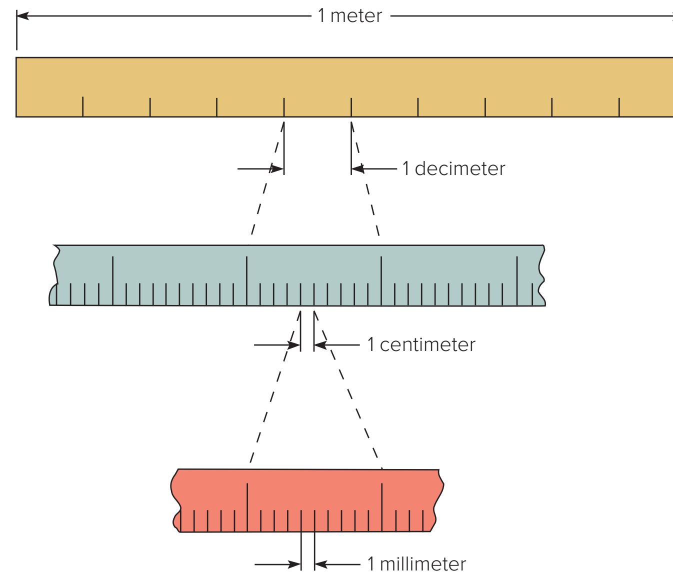

FIGURE 1.7 Compare the units shown above. How many millimeters fit into the space occupied by 1 centimeter? How many millimeters fit into the space of 1 decimeter? Can you express this as multiples of ten?

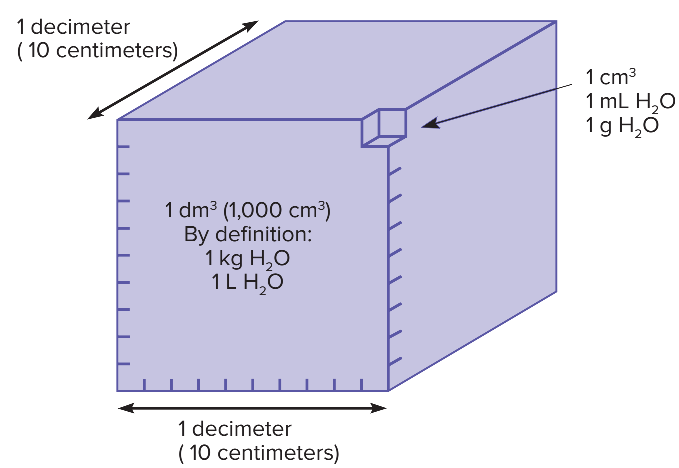

FIGURE 1.8 A cubic decimeter of water (1,000 cm^3) has a liquid volume of 1 L (1,000 mL) and a mass of 1 kg (1,000 g). Therefore, 1 cm^3 of water has a liquid volume of 1 mL and a mass of 1 g.

SELF CHECK

1.4 One-half liter of water has a mass of
- **a.** 0.5 g.
- **b.** 5 g.
- **c.** 50 g.
- **d.** 500 g.

1.5 A cubic centimeter (cm^3) of water has a mass of about 1
- **a.** mL.
- **b.** kg.
- **c.** g.
- **d.** dm.

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 drier 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 describe the weather by reporting numerically specified units for each condition.

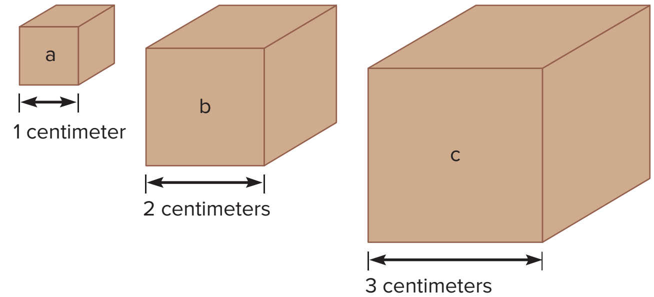

FIGURE 1.10 Cube *a* is 1 centimeter on each side, cube *b* is 2 centimeters on each side, and cube *c* is 3 centimeters on each side. These three cubes can be described and compared with data, or measurement information, but some form of analysis is needed to find patterns or meaning in the data.

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 thus 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

SELF CHECK

1.6 The property of volume is a measure of
- **a.** how much matter an object contains.
- **b.** how much space an object occupies.
- **c.** the compactness of matter in a certain size.
- **d.** the area on the outside surface.

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 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 time again throughout science. It is important that you understand the meaning of *per* and *for each* when used with numbers and units.

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.

SELF CHECK

1.7 As the volume of a cube becomes larger and larger, the surface-area-to-volume ratio

a. increases.
b. decreases.
c. remains the same.
d. sometimes increases and sometimes decreases.

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

$$\rho = \frac{m}{V} \qquad \textbf{equation 1.1}$$

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

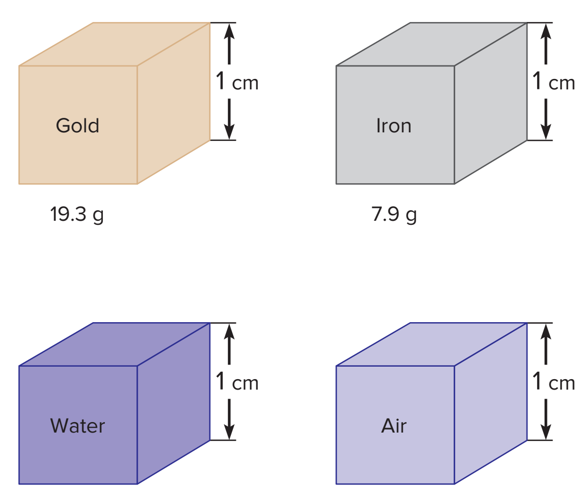

FIGURE 1.11 Equal volumes of different substances do not have the same mass, as these cube units show. Calculate the densities in g/m^3. Do equal volumes of different substances have the same density? Explain.