1.1 What Is Science?

Key Concepts
- How does the process of science start and end?
- What is the relationship between science and technology?
- What are the branches of natural science?

Vocabulary
- science
- technology
- chemistry
- physics
- geology
- astronomy
- biology

Reading Focus

Build Vocabulary
Word-Part Analysis Tell students that many words in science consist of roots to which prefixes and/or suffixes are added. Explain that the root is the key to a word’s meaning. Ask students to identify the roots in the vocabulary words and to name other words with the same root. Students may suggest sci-, conscience; tech-, technique; phys-, physical; geog-, geography; astro-, astronaut; and bio-, biography.

Reading Strategy
L2
- a. Earth and space
- b. Life
- c. The study of nonliving things
- d. The study of Earth and the universe beyond Earth

Science From Curiosity

Predicting Tell students that it can be difficult to prove the existence of something invisible. Place a large candle in a jar and light it. Ask, What do you predict will happen if the jar is covered? Explain your prediction. (The candle will go out once the oxygen in the jar is used up.) Cover the jar with aluminum foil so students can check their prediction. Ask, What invisible substances did you assume in your explanation? (Oxygen, carbon dioxide)
Visual, Group

Section Resources
Print
- Reading and Study Workbook With Math Support, Section 1.1
- Transparencies, Chapter Pretest and Section 1.1

Technology
- Interactive Textbook, Section 1.1
- Presentation Pro CD-ROM, Section 1.1
- Go Online, NSTA SciLinks, Motion

Suppose you could send a robot to another planet. What kinds of experiments would you program the robot to carry out? Before you programmed the robot, you would need to figure out what information you wanted it to gather. Scientists are currently developing robots, like the one in Figure 1, that they plan to send to Mars. These robots are being designed to examine the atmosphere, rocks, gravity, and magnetic fields of the planet.

Science involves asking questions about nature and then finding ways to answer them. This process doesn’t happen by itself—it is driven by the curiosity of scientists.

Science From Curiosity

Throughout history, human beings have had a strong sense of curiosity. Human curiosity led to the use of fire, the building of tools, and the development of languages. Have you ever checked what was living at the bottom of a pond? Taken off the cover of a baseball to see what was inside? Tried putting more chocolate or less in your milk to find out how much would give the best flavor? These are all examples of curiosity, and curiosity is the basis of science.
Science is a system of knowledge and the methods you use to find that knowledge. Part of the excitement of science is that you never know what you will find. For instance, when you flip over a rock, will you see crawling insects, a snake, or nothing at all? You won’t know until you look. Science begins with curiosity and often ends with discovery.

Curiosity provides questions but is seldom enough to achieve scientific results. Methods such as observing and measuring provide ways to find the answers. In some experiments, observations are qualitative, or descriptive. In others, they are quantitative, or numerical. Some experiments are impossible to do, such as observing what happened at the start of the universe. Scientists cannot go back in time to observe the creation of the universe. However, they can use the evidence of the universe around them to envision how this event occurred.

Science and Technology

As scientific knowledge is discovered, it can be applied in ways that improve the lives of people. Technology is the use of knowledge to solve practical problems. While the goal of science is to expand knowledge, the goal of technology is to apply that knowledge. Imagine living in the late 1700s, when there were no televisions, cars, antibiotics, or electricity. In a relatively small amount of time, people’s lives changed dramatically. Perhaps your grandparents were born at a time when there were no televisions, and your parents were born at a time when there were no personal computers. Technology will have also changed your world dramatically by the time the generation following yours comes along.

Figure 2 illustrates the rapid evolution of the telephone, a technology invented in 1876. Within two years, the first telephone operators were connecting calls by hand. The first coin-operated phones appeared in 1889. By 1927, it was possible to make a phone call from New York to London. World War II saw the development of the first mobile telephones, which paved the way for modern cellular phones. Today, you can communicate by telephone between almost any two places in the world.

Science and technology are interdependent. Advances in one lead to advances in the other. For example, advances in the study of physics led to the invention of the transistor. The use of transistors, in turn, led to advances in various other scientific fields, such as computer science and space science.

Customize for Inclusion Students

Learning Disabled

Reinforce the idea that technology plays an important role in the students’ daily lives. Ask students to list several things they experience every day that depend on modern technology. Have students share their lists. Discuss each item and technology’s role in it. Next, have students describe how modern technology affects them in the classroom. For example, students may mention that calculators and computers help them find and learn new information. Some students may point to the write-on boards that have replaced chalkboards, and other students may point out insulated glass, durable carpeting, an intercom system, or other parts of the classroom building as examples of technology at school. Students may also note that ballpoint pens and other writing instruments make writing much easier and much less messy than the quill pens used before the American Revolution.

The Compass

Purpose Students observe that a compass needle does not always point north.

Materials compass, magnet, chalk

Procedure Tell students that a compass is an instrument that is used to locate north. Show students where north is on the compass. Move around the room and show students that the compass needle continues to point toward north. Place the chalk near the east edge of the compass and ask students what happens. Replace the chalk with the magnet and show students that the needle has been deflected toward the east or west. Move the compass around the magnet to show that the compass needle continues to point toward or away from the magnet.

Expected Outcome The chalk has no effect on the compass, but the magnet deflects the compass needle toward the magnet. Visual, Logical

Science and Technology

Use Visuals

Example 2 Telephones have quickly evolved from cumbersome, expensive machines to practical, cheap tools for communicating. Classifying How is a telephone an example of both science and technology?

Answer to . . .

Figure 2 Technology: It is an application of knowledge to solve the problem of long-distance communication. Science: It can be used to demonstrate various areas of study, including the physics of sound and of electricity, and the properties of materials.

Science is a system of knowledge and the methods used to find that knowledge.
Branches of Science

Integrate Biology

The area of science that deals with the connections between biology and physics is biophysics. It is a very broad area that includes biomolecular systems, neural networks, immunology, evolution, and population biology. Each of these components of biophysics, as well as many others, studies how a biological response (from an organism or an ecosystem, for example) is determined by the laws of physics. Encourage students to learn about one of the areas of study within biophysics. Have students make a poster that shows how physics and biology contribute to understanding in that specialty.

Visual, Portfolio

Figure 3 Natural science covers a very broad range of knowledge. Interpreting Diagrams How could you change this diagram to show how the branches of science can overlap?

Branches of Science

The study of science is divided into social science and natural science. Natural science is generally divided into three branches: physical science, Earth and space science, and life science. Each of these branches can be further divided, as shown in Figure 3.

Physical science covers a broad range of study that focuses on nonliving things. The two main areas of physical science are chemistry and physics. Chemistry is the study of the composition, structure, properties, and reactions of matter. Physics is the study of matter and energy and the interactions between the two through forces and motion.

The application of physics and chemistry to the study of Earth is called Earth science. The foundation of Earth science is geology, the study of the origin, history, and structure of Earth. Geology has traditionally focused on the study of Earth’s rocks. However, modern Earth science also involves the study of systems that may include living organisms. The foundation of space science is astronomy, the study of the universe beyond Earth, including the sun, moon, planets, and stars.

The study of living things is known as biology, or life science. Biology is not only the physics and chemistry of living things, but the study of the origin and behavior of living things. Biologists study the different ways that organisms grow, survive, and reproduce.

The problem with subdividing science into different areas is that there is often overlap between them. The boundary around each area of science is not always clear. For instance, much of biology is also chemistry, while much of chemistry is also physics. And a rapidly growing area of physics is biophysics, the application of physics to biology.

What is physical science?

Facts and Figures

Technological Advances During the twentieth century, rapid technological changes have occurred in areas other than communications. For example, advances in transportation, especially air travel, dramatically changed society. At the beginning of the century, the Wright brothers flew a propeller-powered airplane 120 feet in 12 seconds.

On October 4, 1957, the Soviet Union launched a basketball-sized satellite called Sputnik 1 into Earth’s orbit, making it the first satellite. Another milestone occurred on July 20, 1969, when Neil Armstrong and his crew flew to the moon. Armstrong was the first person to walk on the moon.
The Big Ideas of Physical Science

What are the basic rules of nature? You can read this book to find out. As a sneak preview, some of these rules are summarized here. You can think of them as the big ideas of physical science. Keep in mind that there are also unknown rules of nature that are waiting to be discovered.

In fact, you can take part in the search for these unknown laws if you become a scientist. Even though scientists have already discovered a great deal about the universe, there is still much to learn.

Space and Time The universe is both very old and very big. The age of the universe is about 13,700,000,000 (13.7 billion) years. The observable universe is about \(700,000,000,000,000,000,000,000,000,000,000\) (700 million billion billion) meters in diameter. The diameter of Earth is “only” 12,700,000 meters. To get an idea of how big this distance is, the diameter of a giant beach ball is about 1 meter.

Matter and Change A very small amount of the universe is matter. Matter has volume and mass, and on Earth usually takes the form of a solid, liquid, or gas. All matter that you are familiar with, from plants to stars to animals to humans, is made up of building blocks called atoms. Atoms consist of even smaller building blocks called electrons, protons, and neutrons.

Forces and Motion If you push on something that is sitting still, it starts to move. If you push on something that is already moving, you will change its motion. Forces cause changes in motion. As Figure 4 shows, your world is filled with motion and forces. Calculating these forces can sometimes be very challenging. For example, on a NASA mission to Mars, the Mars Exploration Rover must blast off from Earth with enough speed to escape Earth’s gravity. The rocket must then travel a great distance through space and land delicately on a planet that is moving very rapidly around the Sun. The laws of physics allow these movements to be calculated exactly so that the NASA robots get to where scientists want them to go.

Answer to . . .

**Figure 3** By drawing dotted lines to connect related areas of science, you could show how the branches of science overlap. Another way to illustrate these overlapping relationships would be to reconfigure the branched diagram as a Venn diagram.

Physical science is a branch of natural science that focuses on nonliving things. The two main areas of physical science are physics and chemistry.
Science and Your Perspective

6 Chapter 1

Section 1.1 Assessment

1. The scientific process begins with curiosity and often ends with discovery.
2. Science and technology are interdependent. Advances in one lead to advances in the other.
3. Natural science is divided into physical science, Earth and space science, and life science.
4. Dividing science into branches makes it easier to understand such a broad subject. However, dividing science into "strict" branches neglects the fact that different areas of science frequently overlap.
5. Scientists seek to discover new laws of the universe because they are curious and wish to understand how the natural world is governed.
6. Scientific investigations are often initiated by curiosity. For example, an observed event might prompt you to ask a question. To answer that question, however, you need to use a systematic method that can provide evidence such as experimental or observational data.

7. Even if a scientific discovery does not immediately lead to advances in technology, that discovery is still useful because it adds to the overall body of scientific knowledge.
8. Both. Because muscle movements involve motion and forces, they fall under the study of physics. However, because muscle movements are specific to living things, they also fall under the study of biology.
If you've ever been caught in the rain without an umbrella, your first instinct was probably to start running. After all, the less time you spend in the rain, the less water there is falling down on you. So you might think that running in the rain keeps you drier than walking in the rain over a given distance. However, by running in the rain you run into more raindrops than by walking, thereby wetting more of your face, chest, and legs. Have your instincts been getting you wetter instead of keeping you drier?

You now have a question that you can try to answer with a scientific approach. Which keeps you drier—walking or running?

**Scientific Methods**

In order to answer questions about the world around them, scientists need to gather information. An organized plan for gathering, organizing, and communicating information is called a **scientific method**. Despite the name, a scientific method can be used by anyone, including yourself. All you need is a reason to use it. The goal of any scientific method is to solve a problem or to better understand an observed event.

**Reading Strategy**

**Using Prior Knowledge**

Before you read, copy the web diagram below. Add to the web diagram what you already know about scientific methods. After you read, revise the diagram based on what you have learned.

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**Vocabulary**
- **scientific method**
- **observation**
- **hypothesis**
- **manipulated variable**
- **responding variable**
- **controlled experiment**
- **scientific theory**
- **scientific law**

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**Key Concepts**
- What is the goal of a scientific method?
- How does a scientific law differ from a scientific theory?
- Why are scientific models useful?

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**Figure 6** To run, or not to run: that is the question. Designing Experiments How can you test if running in the rain keeps you drier than walking in the rain over the same distance?

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**Section Resources**
- **Print**
  - Reading and Study Workbook With Math Support, Section 1.2
  - Transparencies, Section 1.2
- **Technology**
  - Interactive Textbook, Section 1.2
  - Presentation Pro CD-ROM, Section 1.2
  - GoOnline, Science News, Nature of science

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**Answers to . . .**

**Figure 6** Possible answer: Take two identical pieces of absorbent cloth and measure the mass of each. Give the cloths to two people to hold at arm’s length during a rain storm. One person should walk a fixed distance, and the other should run the same distance. Compare the masses of the wet pieces of cloth.
**Section 1.2 (continued)**

**Build Science Skills**

**Observing**

**Purpose** Students observe that as the distance from a light source increases, the brightness decreases.

**Materials** low-wattage incandescent bulb, power source for the bulb

**Class Time** 10 minutes

**Procedure** Darken the room and turn on the bulb. Tell students that its light can be considered to be coming from a single point (a point source). Ask two or three volunteers to walk around the room and observe whether the light from the bulb is visible in all parts of the room. Be sure that volunteers observe the light’s brightness at various distances from the bulb.

**Expected Outcome** Students will see that the bulb radiates light in all directions and that as distance from the bulb increases, the bulb’s brightness decreases. Kinesthetic, Visual, Group

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The scientific method is a proposed approach for solving problems. Each step in the method shown involves specific skills, some of which you will be learning as you read this book. It is important to note that scientific methods can vary from case to case. For example, one scientist might follow the steps shown in Figure 7 in a different order, or another might choose to skip one or more steps.

**Making Observations** Scientific investigations often begin with observations. An observation is information that you obtain through your senses. Repeatable observations are known as facts. For example, when you walk or run in the rain, you get wet. Standing in the rain leaves you much wetter than walking or running in the rain. You might combine these observations into a question: How does your speed affect how wet you get when you are caught in the rain?

**Forming a Hypothesis** A hypothesis is a proposed answer to a question. To answer the question raised by your observations about traveling in the rain, you might guess that the faster your speed, the drier you will stay in the rain. What can you do with your hypothesis? For a hypothesis to be useful, it must be testable.

**Testing a Hypothesis** Scientists perform experiments to test their hypotheses. In an experiment, any factor that can change is called a variable. Suppose you do an experiment to test if speed affects how wet you get in the rain. The variables will include your speed, your size, the rate of rainfall, and the amount of water that hits you.

Your hypothesis states that one variable, speed, causes a change in another variable, the amount of water that hits you. The speed with which you walk or run is the manipulated variable, or the variable that causes a change in another. The amount of water that you accumulate is the responding variable, or the variable that changes in response to the manipulated variable. To examine the relationship between a manipulated variable and a responding variable, scientists use controlled experiments. A controlled experiment is an experiment in which only one variable, the manipulated variable, is deliberately changed at a time. While the responding variable is observed for changes, all other variables are kept constant, or controlled.

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**Customize for English Language Learners**

**Increase Word Exposure**

Ask students who are learning English to make flashcards for each step of the scientific method shown in Figure 7. Tell students to write the English words describing the steps on an index card. They should also write a brief definition in their first language on the back of each card. Students can make the flashcards as they read the section. Then, have students shuffle their cards and place the steps of the scientific method in the correct order. Students may refer to the definition on the back of the card if they need help. Reinforce that the scientific method shown in Figure 7 is only one of many possible methods.
In 1997, two meteorologists conducted a controlled experiment to determine if moving faster keeps you drier in the rain. In the experiment, both scientists traveled 100 yards by foot in the rain. One of them walked; the other ran. By measuring the mass of their clothes before and after traveling in the rain, the scientists were able to measure how much water each had accumulated. One of the controlled variables was size—the two scientists were about the same height and build. Another was the rate of rainfall—the scientists began traveling at the same time during the same rainstorm on the same path. A third was the ability to absorb water—the scientists wore identical sets of clothes.

**Drawing Conclusions** The scientists’ rainy-day experiment produced some convincing data. The clothes of the walking scientist accumulated 217 grams of water, while the clothes of the running scientists accumulated 130 grams of water. Based on their data, the scientists concluded that running in the rain keeps you drier than walking—about 40 percent drier, in fact. Now you have scientific evidence to support the hypothesis stated earlier.

What happens if the data do not support the hypothesis? In such a case, a scientist can revise the hypothesis or propose a new one, based on the data from the experiment. A new experiment must then be designed to test the revised or new hypothesis.

**Developing a Theory** Once a hypothesis has been supported in repeated experiments, scientists can begin to develop a theory. A *scientific theory* is a well-tested explanation for a set of observations or experimental results. For example, according to the kinetic theory of matter, all particles of matter are in constant motion. Kinetic theory explains a wide range of observations, such as ice melting or the pressure of a gas.

Theories are never proved. Instead, they become stronger if the facts continue to support them. However, if an existing theory fails to explain new facts and discoveries, the theory may be revised or a new theory may replace it.

**Scientific Laws** After repeated observations or experiments, scientists may arrive at a scientific law. A *scientific law* is a statement that summarizes a pattern found in nature. For example, Newton’s law of gravity describes how two objects attract each other by means of a gravitational force. This law has been verified over and over. However, scientists have yet to agree on a theory that explains how gravity works. A scientific law describes an observed pattern in nature without attempting to explain it. The explanation of such a pattern is provided by a scientific theory.
Scientific Models

Flaps on an Airplane

Purpose  Students observe how models can be used.
Material  sheet of paper
Procedure  Tell students that the flaps on airplane wings help control how the plane flies. Point out that because you do not have an airplane in the class, you will use a model to observe how wing flaps can affect an airplane’s flight. Fold the sheet of paper into a paper airplane. Throw the plane so the class sees how the plane flies without flaps. On the trailing edge of each wing, cut a flap. Bend the flaps into different positions such as both up, both down, or one up and one down. Throw the plane with different flap positions and observe how the plane flies. Ask students if they think the wing flaps on a real airplane would have the same effect.
Expected Outcome  Students should see that using the paper airplane as a model for a real airplane is appropriate. With both flaps down, the plane descends; with both up, it ascends. With one flap up and the other down, the plane turns in the direction of the flap that is up.
Visual, Logical

Figure 9 Two engineers discuss a computer-aided design, or CAD, of an aircraft component.

Scientific Models

If you have ever been lost in a city, you know that a street map can help you find your location. A street map is a type of model, or representation, of an object or event. Scientific models make it easier to understand things that might be too difficult to observe directly. For example, to understand how Earth rotates on its axis, you could look at a globe, which is a small-scale model of Earth. The computer model in Figure 9 represents the interior of an airplane. Other models help you visualize things that are too small to see, such as atoms. As long as a model lets you mentally picture what is supposed to be represented, then the model has done its job.

An example of a mental, rather than physical, model might be that comets are like giant snowballs, primarily made of ice. Scientists would test this model through observations, experiments, and calculations. Possibly they would even send a space probe—a visit to a comet really is planned! If all of these tests support the idea that comets are made of ice, then the model of icy comets will continue to be believed.

However, if the data show that this model is wrong, then it must either be changed or be replaced by a new model. If scientists never challenged old models, then nothing new would be learned, and we would still believe what we believed hundreds of years ago. Science works by making mistakes. The fact that newer models are continually replacing old models is a sign that new discoveries are continually occurring. As the knowledge that makes up science keeps changing, scientists develop a better and better understanding of the universe.

What is a model?
Working Safely in Science

Scientists working in the field, or in a laboratory, like those in Figure 10, are trained to use safe procedures when carrying out investigations. Laboratory work may involve flames or hot plates, electricity, chemicals, hot liquids, sharp instruments, and breakable glassware.

Whenever you work in your science laboratory, it’s important for you to follow safety precautions at all times. Before performing any activity in this course, study the rules in the Science Safety section of the Skills Handbook. Before you start any activity, read all the steps. Make sure that you understand the entire procedure, especially any safety precautions that must be followed.

The single most important rule for your safety is simple: Always follow your teacher’s instructions and the textbook directions exactly. If you are in doubt about any step in an activity, always ask your teacher for an explanation. Because you may be in contact with chemicals you cannot see, it is essential that you wash your hands thoroughly after every scientific activity. Remember, you share responsibility for your own safety and that of your teacher and classmates.

Section 1.2 Assessment

Reviewing Concepts
1. ☐ What is the goal of scientific methods?
2. ☐ How does a scientific law differ from a scientific theory?
3. ☐ Why are scientific models useful?
4. What are three types of variables in a controlled experiment?

Critical Thinking
6. Classifying The scientists who tested the hypothesis on running in the rain performed only one controlled experiment that supported their hypothesis. Can their supported hypothesis be called a theory? Explain.
7. Designing Experiments Suppose you wanted to find out how running affects your pulse rate. What would your hypothesis be? Explain how you could test your hypothesis.
8. Using Models A scientific model can take the form of a physical object or a concept. List one example of each type of model. How does each one resemble what it is supposed to model?

Writing in Science

Descriptive Paragraph Write a paragraph describing the steps of a scientific method. (Hint: Before you write, use a flowchart to arrange your steps in a particular order.)

Answer to . . .

Science Skills 11

Section 1.2 Assessment
1. The goal of scientific methods is to solve a problem or to better understand an observed event.
2. A scientific law describes an observed pattern in nature without attempting to explain it. The explanation of such a pattern is provided by a scientific theory.
3. Scientific models make it easier to understand things that might be too difficult to observe directly.
4. Three types of variables in a controlled experiment are manipulated variables, responding variables, and controlled variables.
5. No. The order of the steps within a scientific method can vary from case to case.
6. Although the data from the meteorologists’ experiment supported their hypothesis, the scope of their investigation is too narrow to be considered a theory. A scientific theory explains a broad set of observations and/or supported hypotheses—not just a single hypothesis.
7. Students will likely hypothesize that running increases one’s pulse rate. Students can test their hypotheses by performing a controlled experiment in which the manipulated variable is speed (e.g., running, walking, or standing still) and the responding variable is pulse rate.

Possible answer: A globe, a physical model of Earth, has the same shape as Earth. The quantum mechanical model of the atom describes the behavior of electrons around the nucleus.
Forensic Science

Background

Forensic science is any aspect of science that relates to law. It includes methods for identifying, collecting, and analyzing evidence that may be related to a crime. At a crime scene, data is often identified and collected. Data collection may include taking fingerprints; collecting hair, blood, or tissue samples; or making plaster casts of tire prints or footprints. Depending on the nature of the crime and the crime scene, investigators may also collect samples of soil, pollen, fibers from clothing, or other materials at the crime scene. In the laboratory, technicians study and analyze the samples so that they can provide investigators with accurate information. Data analysis can shed light on what happened, where it happened, and even who might have committed the crime.

Build Science Skills

Analyzing Data

**Purpose** Students compare tire tracks to determine which ones were made by the same toy car.

**Materials** modeling clay, at least 5 different toy cars with similar-sized tires that have different tread, cooking oil, magnifying glass

**Class Time** 30 minutes

**Preparation** Flatten a piece of clay for each group of students. Lightly oil the tread of all the tires on the toy cars. Choose a car and roll the tire across each piece of clay to make an impression.

**Safety** Students who are allergic to corn or olives should wear plastic gloves and dispose of them carefully.

**Procedure** Tell students that they are forensic scientists and they must find out which car was at the scene of a crime based on a tire track from the scene. Give students a piece of clay with a tire track and another piece of unmarked clay. Have students use the clay to test each car’s tires and, as needed, use the magnifying glass to find a match. Ask each group to write a short paragraph stating what they did and why they think they have identified the car that made the tracks.

**Expected Outcome** Students should correctly identify the car by the similar tire patterns. Logical, Visual, Group

**L2**

The first job of police officers at a crime scene is to seal off the area so that potential evidence is not disturbed. Such evidence will be sent to a forensic science laboratory for examination.

Forensic science is the use of scientific methods, such as fingerprint matching or the analysis of clothing fibers, to solve crimes. As techniques in analytical chemistry have become more advanced, the amount of information that can be gleaned from tiny crime-scene samples has grown. Forensic science is becoming ever more powerful as a crime-solving tool.

Criminal investigators need to use several scientific techniques. They include making observations, establishing the problem to be solved, collecting evidence and gathering information, formulating hypotheses, analyzing evidence, testing hypotheses, and drawing conclusions.

**L2**

**Activity**

**The crime scene** At the scene, the investigators make observations that may shed light on the nature of the crime. The investigators establish the problem to be solved—in this case, who committed the murder?

**Collecting evidence and forming a hypothesis** Forensic scientists take photographs and collect materials from the crime scene. Investigators use all of the information gathered to formulate hypotheses about how and why the crime took place.

DNA evidence can be obtained from blood stains.
Analyzing the evidence
Much of the physical evidence must be analyzed in a laboratory. With a blood sample, for example, DNA is extracted and analyzed and the blood type is established.

Forensic blood sampling Articles from a crime scene, such as the blood-stained clothing and the hatchet shown here, may match DNA to a suspect.

Testing hypotheses against the evidence
Investigators now test hypotheses on who committed the crime—looking for matches in DNA, fingerprints, or clothing fibers, for example. In some cases, this testing excludes a suspect. In other cases it strengthens the case against a particular person.

Drawing conclusions
To build a convincing case against a suspect, various pieces and types of evidence may be needed. Evidence might include a fingerprint match, a piece of clothing left at the crime scene, or a connection to the murder weapon.

Documents may provide evidence for a motive.

Fibers can link a suspect to a crime scene.

**Going Further**
- Describe how criminal investigators use scientific methods to solve their cases. (Hint: start by creating a flowchart of a scientific method. Then identify how criminal investigators carry out each step.)
- Take a Discovery Channel Video Field Trip by watching "Cracking the Case."

**Science Skills 13**

**Video Field Trip**

**Cracking the Case**

After students have viewed the Video Field Trip, ask them the following questions: What is the main goal of forensic science? (To analyze clues to reconstruct past events) What discovery led to the use of fingerprinting in forensic science? (The discovery that no two people had the same fingerprints) What do forensic scientists look for in the pattern of a fingerprint so that they can identify who the fingerprint belongs to? (The tiny imperfections such as ridges that end abruptly, ridges that split, and ridges that form little dots; also where these are located with respect to one another)

How do detectives find fingerprints on an object? (The old method involved spreading powder on the area. The powder adhered to traces of sweat left behind by contact with the fingers. The powder was then lifted off with transparent tape, showing the pattern. Newer methods use fluorescent powder and high intensity lasers to find prints that could otherwise be missed.)

Name two things police detectives and forensic scientists might do to track down the identity of a car that left a suspicious tire track at a crime scene. (Student answers may include measure and photograph the area, make a mold of the tire track, and look for irregularities in the mold of the tire tread that are unique to that tire.)
Section 1.3

1 FOCUS

Objectives
1.3.1 Perform calculations involving scientific notation and conversion factors.
1.3.2 Identify the metric and SI units used in science and convert between common metric prefixes.
1.3.3 Compare and contrast accuracy and precision.
1.3.4 Relate the Celsius, Kelvin, and Fahrenheit temperature scales.

Reading Focus

Build Vocabulary
LINCS Use LINCS to help students learn and review section vocabulary, including scientific notation: List parts that they know (Scientific means “related to science,” and notation means “a system of symbols.”); Imagine a picture (Students might visualize a series of symbols written in a table.); Note a sound-alike word (Notation is similar to note.); Connect the terms in a sentence (The scientist used scientific notation to communicate her results.); Self-test (quiz themselves).

Reading Strategy
Possible answers may include:
a. What is SI? SI is a set of metric measuring units used by scientists.
b. What are base units? Base units are the fundamental units of SI. There are seven SI base units, including the meter, the kilogram, the kelvin, and the second.

2 INSTRUCT

Using Scientific Notation

Use Visuals
Figure 11 Ask, Would it be easy to count the number of stars shown in the photo? (No) Why might using scientific notation be appropriate when counting the number of stars? (The number of stars could be very large.) Visual, Logical

Key Concepts

Why is scientific notation useful?
What units do scientists use for their measurements?
How does the precision of measurements affect the precision of scientific calculations?

Vocabulary
- scientific notation
- length
- mass
- volume
- density
- conversion factor
- significant figures
- precision
- accuracy
- precision
- thermometer

Reading Strategy
Previewing Make a table like the one below. Before you read the section, rewrite the green and blue topic headings as questions. As you read, write answers to the questions.

How old are you? How tall are you? The answers to these questions are measurements. Measurements are important in both science and everyday life. Hardly a day passes without the need for you to measure amounts of money or the passage of time. It would be difficult to imagine doing science without any measurements.

Using Scientific Notation

How many stars do you see in Figure 11? There are too many to count. Scientists often work with very large or very small numbers. For example, the speed of light is about 300,000,000 meters per second. On the other hand, an average snail has been clocked at a speed of only 0.000086 meter per second.

Instead of having to write out all the zeroes in these numbers, you can use a shortcut called scientific notation. Scientific notation is a way of expressing a value as the product of a number between 1 and 10 and a power of 10. For example, the number 300,000,000 written in scientific notation is $3.0 \times 10^8$. The exponent, 8, tells you that the decimal point is really 8 places to the right of the 3.

For numbers less than 1 that are written in scientific notation, the exponent is negative. For example, the number 0.000086 written in scientific notation is $8.6 \times 10^{-5}$. The negative exponent tells you how many decimals places there are to the left of the 8.6. Scientific notation makes very large or very small numbers easier to work with.
When multiplying numbers written in scientific notation, you multiply the numbers that appear before the multiplication signs and add the exponents. For example, to calculate how far light travels in 500 seconds, you multiply the speed of light by the number of seconds.

\[
(3.0 \times 10^8 \text{ m/s}) \times (5.0 \times 10^2 \text{ s}) = 15 \times 10^{10} \text{ m} = 1.5 \times 10^{11} \text{ m}
\]

This distance is about how far the sun is from Earth.

When dividing numbers written in scientific notation, you divide the numbers that appear before the exponential terms and subtract the exponents. For example, to calculate how long it takes for light from a given star to reach Earth, you would perform a division.

\[
\frac{1.5 \times 10^{11} \text{ m}}{3.0 \times 10^8 \text{ m/s}} = \frac{1.5}{3.0} \times 10^{11-8} \text{ s} = 0.50 \times 10^3 \text{ s} = 5.0 \times 10^2 \text{ s}
\]

Using Scientific Notation
A rectangular parking lot has a length of 1.1 \times 10^3 meters and a width of 2.4 \times 10^3 meters. What is the area of the parking lot?

1. **Read and Understand**
   What information are you given?
   - Length (l) = 1.1 \times 10^3 \text{ m}
   - Width (w) = 2.4 \times 10^3 \text{ m}

2. **Plan and Solve**
   What unknown are you trying to calculate?
   - Area (A) = ?
   - What formula contains the given quantities and the unknown?
     \[ A = l \times w \]
   - Replace each variable with its known value:
     \[ A = (1.1 \times 10^3 \text{ m})(2.4 \times 10^3 \text{ m}) \]
     \[ = (1.1 \times 2.4) (10^3 \times 10^3)(\text{m} \times \text{m}) \]
     \[ = 2.6 \times 10^6 \text{ m}^2 \]

3. **Look Back and Check**
   Is your answer reasonable?
   - Yes, the number calculated is the product of the numbers given, and the units (m^2) indicate area.

**Solutions**
1. a. \((7.6 \times 10^{-4} \text{ m})(1.5 \times 10^7 \text{ m}) = (7.6 \times 1.5)(10^{-4+7}) \text{ m} \times \text{m} = 11 \times 10^3 \text{ m}^2 = 1.1 \times 10^4 \text{ m}^2\)
   b. \((5.3 \times 10^{-4})/(2.9 \times 10^1) \approx (5.3/2.9) \times 10^{-4-1} = 1.8 \times 10^{-5}\)
   2. \((3.0 \times 10^8 \text{ m/s})(8.64 \times 10^4 \text{ s}) = (3.0 \times 8.64)(10^8 \times 10^4) \text{ m} = 26 \times 10^{12} = 2.6 \times 10^{13} \text{ m}\)
   (Note: This is how far light travels in one day.)

**Additional Problems**
1. Perform the following calculations. Express your answers in scientific notation.
   a. \((7.6 \times 10^{-4} \text{ m}) \times (1.5 \times 10^7 \text{ m})\)
   b. \(0.00053 \div 29\)
   2. Calculate how far light travels in 8.64 \times 10^4 \text{ seconds}. (Hint: The speed of light is about 3.0 \times 10^8 \text{ m/s}.)

**For Extra Help**
Reinforce the concepts of adding exponents when numbers in scientific notation are multiplied and subtracting exponents when numbers in scientific notation are divided.

Logical
Direct students to the Math Skills in the Skills and Reference Handbook at the end of the student text for additional help.

**Customize for Inclusion Students**

**Visually Impaired**
To help visually impaired students understand the concepts of length, mass, and volume, give students common objects. Ask students to describe the objects in regard to their lengths, masses, and volumes. Help students to understand the definitions of these terms during the exercise.

**Answer to . . .**

**Figure 11** \(2 \times 10^{11}\)
SI Units of Measurement

Some students may incorrectly think that scientists use the metric system because it is more accurate than other measurement systems. Point out to students that the units of the measurement system have little to do with accuracy. Help students overcome this misconception by measuring one object with several different centimeter- and inch-rulers. Have students record the measurements. List the metric measurements in one column on the board and the English measurements in another column. Point out that all the measurements in the metric column are similar to one another and that the measurements in the English column are also similar to one another.

SI Base Units

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Unit</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>meter</td>
<td>m</td>
</tr>
<tr>
<td>Mass</td>
<td>kilogram</td>
<td>kg</td>
</tr>
<tr>
<td>Temperature</td>
<td>kelvin</td>
<td>K</td>
</tr>
<tr>
<td>Time</td>
<td>second</td>
<td>s</td>
</tr>
<tr>
<td>Amount of substance</td>
<td>mole</td>
<td>mol</td>
</tr>
<tr>
<td>Electric current</td>
<td>ampere</td>
<td>A</td>
</tr>
<tr>
<td>Luminous intensity</td>
<td>candela</td>
<td>cd</td>
</tr>
</tbody>
</table>

SI Derived Units

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Unit</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>square meter</td>
<td>m²</td>
</tr>
<tr>
<td>Volume</td>
<td>cubic meter</td>
<td>m³</td>
</tr>
<tr>
<td>Density</td>
<td>kilograms per cubic meter</td>
<td>kg/m³</td>
</tr>
<tr>
<td>Pressure</td>
<td>pascal (kg m⁻²s⁻²)</td>
<td>Pa</td>
</tr>
<tr>
<td>Energy</td>
<td>joule (J)</td>
<td>J</td>
</tr>
<tr>
<td>Frequency</td>
<td>hertz (Hz)</td>
<td>Hz</td>
</tr>
<tr>
<td>Electric charge</td>
<td>coulomb (C)</td>
<td>C</td>
</tr>
</tbody>
</table>

Figure 12: A measurement consists of a number and a unit. One of the units used to measure temperature is the degree Celsius.

Figure 13: Seven metric base units make up the foundation of SI.

Figure 14: Specific combinations of SI base units yield derived units.

Facts and Figures

The Meter: The meter was originally defined by the French Academy of Science in 1791. At that time, a meter was intended to be one ten-millionth part of the quadrant of Earth. This length was transferred to a platinum bar with polished ends. The bar could be measured at a specific temperature to define the length of a meter. Later measurements of Earth showed that the length of the bar was not one ten-millionth of the quadrant.

However, the meter’s length was not changed. It was redefined to be the length on the bar. In 1960, the length of a meter was more precisely defined by the number of wave-lengths of light, of a very precise color, emitted by krypton-86. This method was difficult to perform and was quickly replaced with the current method. Currently, a meter is defined as the distance light travels in a vacuum in 1/299,792,458 second.
A kiloton is a unit of explosive force equal to 1,000 tons of TNT. A digital camera, you may know that a megapixel is 1,000,000 pixels. Of 12,000 meters can also be written as 12 kilometers. The metric unit for a given quantity is not always Metric prefixes can also make a unit larger. For example, a distance of 12,000 meters can also be written as 12 kilometers. Metric prefixes turn up in non-metric units as well. If you have used a digital camera, you may know that a megapixel is 1,000,000 pixels. A kiloton is a unit of explosive force equal to 1,000 tons of TNT.

**Metric Prefixes** The metric unit for a given quantity is not always a convenient one to use. For example, the time it takes for a computer hard drive to read or write data—also known as the seek time—is in the range of thousandths of a second. A typical seek time might be 0.009 second. This can be written in a more compact way by using a metric prefix. A metric prefix indicates how many times a unit should be multiplied or divided by 10. Figure 15 shows some common metric prefixes. Using the prefix milli-(m), you can write 0.009 second as 9 milliseconds, or 9 ms.

9 ms = \frac{9}{1000} s = 0.009 s

Note that dividing by 1000 is the same as multiplying by 0.001. Metric prefixes can also make a unit larger. For example, a distance of 12,000 meters can also be written as 12 kilometers.

12 km = 12 \times 1000 m = 12,000 m

Metric prefixes turn up in non-metric units as well. If you have used a digital camera, you may know that a megapixel is 1,000,000 pixels. A kiloton is a unit of explosive force equal to 1,000 tons of TNT.

**Table 15. Metric prefixes allow for more convenient ways to express SI base and derived units.**

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Symbol</th>
<th>Meaning</th>
<th>Multiply Unit by</th>
</tr>
</thead>
<tbody>
<tr>
<td>giga-</td>
<td>G</td>
<td>billion (10^9)</td>
<td>1,000,000,000</td>
</tr>
<tr>
<td>mega-</td>
<td>M</td>
<td>million (10^6)</td>
<td>1,000,000</td>
</tr>
<tr>
<td>kilo-</td>
<td>k</td>
<td>thousand (10^3)</td>
<td>1000</td>
</tr>
<tr>
<td>deci-</td>
<td>d</td>
<td>tenth (10^{-1})</td>
<td>0.1</td>
</tr>
<tr>
<td>centi-</td>
<td>c</td>
<td>hundredth (10^{-2})</td>
<td>0.01</td>
</tr>
<tr>
<td>milli-</td>
<td>m</td>
<td>thousandth (10^{-3})</td>
<td>0.001</td>
</tr>
<tr>
<td>micro-</td>
<td>(\mu)</td>
<td>millionth (10^{-6})</td>
<td>0.000001</td>
</tr>
<tr>
<td>nano-</td>
<td>n</td>
<td>billionth (10^{-9})</td>
<td>0.000000001</td>
</tr>
</tbody>
</table>

Another quantity that requires a derived unit is density. Density is the ratio of an object’s mass to its volume.

\[
\text{Density} = \frac{\text{Mass}}{\text{Volume}}
\]

To derive the SI unit for density, you can divide the base unit for mass by the derived unit for volume. Dividing kilograms by cubic meters yields the SI unit for density, kilograms per cubic meter \((\text{kg}/\text{m}^3)\).

What is the SI derived unit for density?

**Metric Prefixes**

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**Figure 15** Metric prefixes allow for more convenient ways to express SI base and derived units.

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**Science Skills 17**

**Build Science Skills**

**Inferring** Have students look at Figure 15. Ask, What factor are the metric prefixes based on? (10) How does that make it convenient for converting between units? (The numbers stay the same but the decimal point moves.) Logical, Visual

**Build Math Skills**

**Conversion Factors** Give students the conversion factors 1 in = 2.54 cm and 1 ft = 30.48 cm. Divide students into pairs, and have each pair measure the lengths of at least three different objects of various sizes, such as a pencil, a desktop, and the floor of a room. Direct the pairs to calculate the measurements of each object in inches, feet, centimeters, meters, and kilometers. (Answers will vary depending upon the objects measured.) Ask students which conversion factors they used to make their calculations. Kinesthetic, Logical

Direct students to the Math Skills in the Skills and Reference Handbook at the end of the student text for additional help.

**Figure 16** A bar of gold has more mass per unit volume than a feather. Inferring Which takes up more space—one kilogram of gold or one kilogram of feathers?

**Answer to . . .**

**Figure 16** Because feathers are less dense than gold, one kilogram of feathers takes up more space than one kilogram of gold.

The SI derived unit for density is the kilogram per cubic meter \((\text{kg}/\text{m}^3)\).
The easiest way to convert from one unit of measurement to another is to use conversion factors. A conversion factor is a ratio of equivalent measurements that is used to convert a quantity expressed in one unit to another unit. Suppose you want to convert the height of Mount Everest, 8848 meters, into kilometers. Based on the prefix kilo-, you know that 1 kilometer is 1000 meters. This ratio gives you two possible conversion factors.

\[
\frac{1 \text{ km}}{1000 \text{ m}} = 0.001 \text{ km/m} \quad \text{and} \quad \frac{1000 \text{ m}}{1 \text{ km}} = 1000 \text{ m/km}
\]

Since you are converting from meters to kilometers, the number should get smaller. Multiplying by the conversion factor on the right. Since you are converting from kilometers to meters, the number should get larger.

\[
8848 \text{ m} \times \frac{1000 \text{ m}}{1 \text{ km}} = 8848 \text{ m}
\]

In this case, the kilometer units cancel, leaving you with meters.

### Section 1.3 (continued)

**Conversion Factor**

**Purpose** Students observe how conversion factors work.

**Materials** 12-in. object, 3-in. object, metric ruler

**Procedure** Give students the conversion factor 1 in. = 2.54 in. Measure the 12-in. object and report its length in centimeters. Tell the students the length in inches of the 3-in. object. Ask them to use the conversion factor to calculate its length in centimeters. (7.6 cm) Measure the object and report the length in centimeters.

**Expected Outcome** Students see how conversion factors convert between units of different measure. Visual, Logical

### Comparing Precision

**Objective** After completing this lab, students will be able to

- describe and distinguish accuracy and precision.
- compare the precision of measuring devices.

**Skills Focus** Measuring, Comparing

**Prep Time** 10 minutes

**Class Time** 15 minutes

**Safety** Caution students to handle glassware carefully.

**Teaching Tips**

- Provide 3 different plastic bottles with labels removed, and a beaker and graduated cylinder large enough to contain the volume of each bottle.
- If necessary, use paper cups instead of plastic bottles.

**Expected Outcome** The graduated cylinder will provide a more precise measurement than the beaker.

### Comparing Lab

**Materials**

- 3 plastic bottles of different sizes, beaker, graduated cylinder

**Procedure**

1. Draw a data table with three rows and three columns. Label the columns Estimate, Beaker, and Graduated Cylinder.
2. Record your estimate of the volume of a plastic bottle in your data table. Then, fill the bottle with water and pour the water into the beaker. Read and record the volume of the water.
3. Pour the water from the beaker into the graduated cylinder. Read and record the volume of water.
4. Repeat Steps 2 and 3 with two other plastic bottles.

**Analyze and Conclude**

1. **Analyzing Data** Review your volume measurements for one of the bottles. How many significant figures does the volume measured with the beaker have? How many significant figures does the volume measured with the graduated cylinder have?
2. **Comparing and Contrasting** Which provided a more precise measurement—the beaker or the graduated cylinder?
3. **Inferring** How could you determine the accuracy of your measurements?
**Limits of Measurement**

Suppose you wanted to measure how much time it takes for you to eat your breakfast. Figure 18 shows two clocks you could use—an analog clock and a digital clock. The analog clock displays time to the nearest second (or one sixtieth of a minute). Which clock would you choose?

**Precision** The digital clock offers more precision. Precision is a gauge of how exact a measurement is. According to the analog clock, it might take you 5 minutes to eat your breakfast. Using the digital clock, however, you might measure 5 minutes and 15 seconds, or 5.25 minutes. The second measurement has more significant figures. Significant figures are all the digits that are known in a measurement, plus the last digit that is estimated. The time recorded as 5.25 minutes has three significant figures. The time recorded as 5 minutes has one significant figure. The fewer the significant figures, the less precise the measurement is.

When you make calculations with measurements, the uncertainty of the separate measurements must be correctly reflected in the final result. The precision of a calculated answer is limited by the least precise measurement used in the calculation. So if the least precise measurement in your calculation has two significant figures, then your calculated answer can have at most two significant figures.

Suppose you measure the mass of a piece of iron to be 34.73 grams on an electronic balance. You then measure the volume to be 4.42 cubic centimeters. What is the density of the iron?

\[
\text{Density} = \frac{34.73 \text{ g}}{4.42 \text{ cm}^3} = 7.857466 \text{ g/cm}^3
\]

Your answer should have only three significant figures because the least precise measurement, the volume, has three significant figures. Rounding your answer to three significant figures gives you a density of 7.86 grams per cubic centimeter.

**Accuracy** Another important quality in a measurement is its accuracy. Accuracy is the closeness of a measurement to the actual value of what is being measured. For example, suppose the digital clock in Figure 18 is running 15 minutes slow. Although the clock would remain precise to the nearest second, the time displayed would not be accurate.

What is accuracy?

---

**Facts and Figures**

**Measuring Time Precisely** As scientific knowledge increases, so does the accuracy and precision of time measurements. In the seventeenth century, Robert Hooke developed a mechanically powered clock. It was based on Galileo’s 1583 observation that each swing of a pendulum takes the same amount of time. Early pendulum clocks were much more accurate and precise than hourglasses, which may have been precise to within an hour or two.

Quartz clocks, developed in 1929, are more precise. They generally lose only one five-hundredths of a second per year. Atomic clocks measure time using the frequencies at which atoms absorb or emit light. They are the most precise clocks today. Today’s cesium atomic clocks are projected to neither lose nor gain a second in 1,000,000 years. Even more precise time measurements are based on pulsars, radio pulsations from collapsed stars.

---

**Limits of Measurement**

**Build Reading Literacy**

**Use Prior Knowledge** Refer to page 2D in this chapter, which provides the guidelines for using prior knowledge. Have students make a three-column chart with columns headed Term, Prior Knowledge, and New Knowledge. Tell students to write accuracy and precision in the first column and then fill in the Prior Knowledge column. Discuss students’ responses and determine whether they have misconceptions about these terms. If so, begin to address those misconceptions directly in discussion. After students finish reading, have them complete the third column, correcting or revising their prior knowledge as needed.

**Verbal**

**Use Visuals**

**Figure 18** Have students look at the figure and read the caption. Ask, How precisely does this digital clock measure time? (It measures time to the second.) Ask, How precisely does the analog clock measure time? (It is divided into five-minute intervals, so time to the nearest minute can be estimated.) What would make the analog clock more precise? (The clock would be more precise if it had tick marks for minutes, and a second hand.)

**Visual**

---

**Answer to . . .**

**Figure 17** The measurement 160 milligrams is equivalent to 0.160 gram. Accuracy is the closeness of a measurement to the actual value of what is being measured.
Measuring Temperature

Use Visuals

Figure 19 Have students look at the figure. Ask, Is any one of the three scales more accurate than the others? (No, they all can be used to measure temperature accurately.) Why do you think scientists use degrees Celsius for measuring temperature? (Some students may note that the range between the freezing and boiling points is 100 degrees and that like other SI units of measure, it can easily be divided into hundreds. Other students may say that it is just an agreed-upon standard.)

Visual, Logical

3. ASSESS

Evaluate Understanding

Ask students to write three conversion problems (with solutions) based on the prefixes used in the metric system. Have students take turns analyzing and solving the problems in class. Note that even incorrectly worded problems are useful, as students can be asked to identify and correct the errors.

Reteach

Use Figure 15 to help students understand how prefixes modify units of measurement. Give students examples such as kilogram, milliliter, and microsecond and ask students to name units that are larger and smaller.

Math Practice

Solutions

7. a. \(3.72 \times 10^{-11}\) g
b. \(3.72 \times 10^{-14}\) kg

b. \(4.5 \times 10^{10}\) km
4. \(4.5 \times 10^{10}\) km \(\times (\frac{1000\, \text{m}}{1\, \text{km}}) = 4.5 \times 10^{13}\) m

8. \(V = (\pi r^2 l) = (3.14) (6.5 \times 10^{-3}\, \text{cm})^2 (1.1\, \text{cm}) = (3.14) (6.5 \times 6.5) (10^{-3} \times 3) (1.1) (\text{cm} \times \text{cm} \times \text{cm}) = 145.9 \times 10^{-6}\, \text{cm}^3 = 1.5 \times 10^{-4}\, \text{cm}^3

Section 1.3 Assessment

Reviewing Concepts

1. Why do scientists use scientific notation?
2. What system of units do scientists use for measurements?
3. How does the precision of measurements affect the precision of scientific calculations?
4. List the SI units for mass, length, and temperature.

Critical Thinking

5. Applying Concepts: A bulb thermometer gives an indoor temperature reading of 21°C. A digital thermometer in the same room gives a reading of 20.7°C. Which device is more precise? Explain.

6. Calculating: Convert –11°F into degrees Celsius, and then into kelvins.

7. Write the following measurements in scientific notation. Then convert each measurement into SI base units.
   a. 0.0000000000372 g
   b. 45,000,000,000 km
8. The liquid in a bulb thermometer falls 1.1 cm. Calculate the liquid’s change in volume if the inner radius of the tube is 6.5 \(\times\) 10^{-4} cm.
**Thermometer**

A bulb thermometer consists of a sealed, narrow glass tube, called a capillary tube. It has a glass bulb at one end and is filled with colored alcohol or mercury. The thermometer works on the principle that the volume of a liquid changes when the temperature changes. When warmed, the liquid in the bulb takes up more space and moves up the capillary tube.

**Interpreting Diagrams** Why is a thermometer with a narrow tube easier to read than a thermometer with a wide tube?

**Measuring Temperature** Thermometers are useful scientific instruments. They can be used to measure the static temperature of a material, or to record the change in temperature of a substance being heated, as shown above.

**Scale** The scale indicates the temperature according to how far up or down the capillary tube the liquid has moved.

**Wide or narrow?** The volume of a tube is calculated using the formula \( V = \pi r^2 l \), where \( r \) is the radius and \( l \) is the length. For a given volume, if the radius of a tube is decreased (as in a capillary tube), the length of the liquid column increases. Any change in volume is then easier to see.

**Logical**

**For Enrichment** Tell students that in the early 1600s, Galileo created a thermometer based on density. Interested students can find out more about Galileo’s thermometer and create a brief report and illustration.
### Section 1.4

#### FOCUS

**Objectives**

1.4.1 Organize and analyze data using tables and graphs.
1.4.2 Identify the relationship between a manipulated variable and a responding variable.
1.4.3 Explain the importance of communicating data.
1.4.4 Discuss the process of peer review.

#### Reading Focus

**Build Vocabulary**

*Paraphrase* Tell students to write the vocabulary terms on a sheet of paper, leaving enough space beside each to write a definition and a mathematical formula. As students read the section, they should look for these terms. When they encounter one, they should write their own definition and a formula that illustrates the term.

**Reading Strategy**

a. A line represents variable y plotted vs. variable x. b. Showing how one variable responds to changes in another c. Scaled bars are used to represent various measurements. d. Comparing two sets of similar data e. A divided circle, with each “slice” representing a fractional portion f. Showing how a part relates to the whole

#### INSTRUCT

**Organizing Data**

**Build Reading Literacy**

*Preview* Refer to page 36D in Chapter 2, which provides the guidelines for a preview.

Ask students to skim Organizing Data. Tell them to pay particular attention to the figures. Ask, *Where else have you seen graphs?* (Newspapers, television, news, magazines, books, and so on) Ask, *Why is data presented in graphs instead of in text?* (Graphs make the data easier to read and understand.) Visual, Logical

#### Key Concepts

- How do scientists organize data?
- How can scientists communicate experimental data?

**Vocabulary**

- slope
- direct proportion
- inverse proportion

<table>
<thead>
<tr>
<th>Type of Graph</th>
<th>Description</th>
<th>Used For</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line</td>
<td>a. 1</td>
<td>b. 2</td>
</tr>
<tr>
<td>Bar</td>
<td>c. 3</td>
<td>d. 4</td>
</tr>
<tr>
<td>Circle</td>
<td>e. 5</td>
<td>f. 6</td>
</tr>
</tbody>
</table>

### Organizing Data

Much of the information you get every day comes from the news media. Newspapers, television, radio, and the Internet let you access a wealth of information about events going on in the world. But in order for news to be useful, it must be communicated. If a news reporter witnesses an event but doesn’t report it, then he might as well not have seen it. If the event is reported, then it must be described in a clear, organized manner for it to be understood and appreciated. Like the news, scientific data become meaningful only when they are organized and communicated.

**Data Tables** The simplest way to organize data is to present them in a table. Figure 20 is a data table that shows the average annual precipitation for seven U.S. cities. The table relates two variables—a manipulated variable (location) and a responding variable (average annual precipitation).

<table>
<thead>
<tr>
<th>City</th>
<th>Average Annual Precipitation (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buffalo, N.Y.</td>
<td>98.0</td>
</tr>
<tr>
<td>Chicago, Ill.</td>
<td>91.0</td>
</tr>
<tr>
<td>Colorado Springs, Colo.</td>
<td>41.2</td>
</tr>
<tr>
<td>Houston, Tex.</td>
<td>117.0</td>
</tr>
<tr>
<td>San Diego, Calif.</td>
<td>25.1</td>
</tr>
<tr>
<td>Tallahassee, Fla.</td>
<td>166.9</td>
</tr>
<tr>
<td>Tucson, Ariz.</td>
<td>30.5</td>
</tr>
</tbody>
</table>

#### Section Resources

**Print**

- *Reading and Study Workbook With Math Support*, Section 1.4
- *Math Skills and Problem Solving Workbook*, Section 1.4
- *Transparencies*, Section 1.4

**Technology**

- *Interactive Textbook*, Section 1.4
- *Presentation Pro CD-ROM*, Section 1.4
- *Go Online*, NSTA SciLinks, Graphing
**Line Graphs** A line graph is useful for showing changes that occur in related variables. In a line graph, the manipulated variable is generally plotted on the horizontal axis, or x-axis. The responding variable is plotted on the vertical axis, or y-axis, of the graph.

Figure 21 is a line graph that shows how the mass of water increases with volume. The data points yield a straight line. The steepness, or slope, of this line is the ratio of a vertical change to the corresponding horizontal change. The formula for the slope of a line is

\[ \text{Slope} = \frac{\text{Rise}}{\text{Run}} \]

“Rise” represents the change in the y-variable, “Run” represents the corresponding change in the x-variable. Note that in Figure 21, because mass per unit volume is density, the slope represents the density of water.

The relationship between the mass and volume of water is an example of a direct proportion. A direct proportion is a relationship in which the ratio of two variables is constant. For example, suppose you have a 3-cubic-centimeter sample of water that has a mass of 3 grams. Doubling the volume of the sample to 6 cubic centimeters results in doubling the mass of the sample to 6 grams. Tripling the volume to 9 cubic centimeters results in tripling the mass to 9 grams.

Figure 22 shows how the flow rate of a water faucet affects the time required to fill a 1-gallon pot. Figure 22 illustrates an inverse proportion, a relationship in which the product of two variables is a constant. If you start with a flow rate of 0.5 gallon per minute, you will fill the pot in 2 minutes. If you double the flow rate to 1.0 gallon per minute, you reduce the time required to fill the pot to 1 minute, or one half of the original time.
Section 1.4 (continued)

Data Analysis

Faster Than Speeding Data

Answers

1. The greater the modem speed is, the shorter the upload time.

2. Doubling the data transfer rate would halve the upload time.

For Extra Help

Explain that modem speeds are similar to speed measurements for vehicles. For example, a car moving at 50 km/h will travel 50 km in one hour. The speed of the modems is measured in kilobits per second. If students need help constructing a line graph, refer them to the Math Skills in the Skills and Reference Handbook at the end of the student text. Logical

Address Misconceptions

Some students may mistakenly think that graphs validate data. Point out to students that graphs are merely a method of presenting data. If necessary, work with students to graph a set of inaccurate data. For example, estimate the average daily temperatures for the past week, double them, and graph the results. Tell students that this graph is inaccurate because it is based on flawed data. Tell students that one way to validate data is to make multiple measurements. Logical

Use Visuals

Figure 23 Ask: On the bar graph, which pairs of cities have similar annual precipitation? (Buffalo and Chicago; San Diego and Tucson) Visual

Faster Than Speeding Data

A modem is a device used to send and receive data. For example, if you upload an image to a Web site, the modem in your computer converts the data of the image into a different format. The converted data are then sent through a telephone line or cable TV line. The smallest unit of data that can be read by a computer is a binary digit, or “bit.” A bit is either a 0 or a 1. Computers process bits in larger units called bytes, a byte is a group of eight bits.

The table shows the data transfer rates for modems used in home computers. Data transfer rates are often measured in kilobits per second, or kbps. The time required to upload a 1-megabyte (MB) file is given for each rate listed.

1. Using Graphs Use the data in the table to create a line graph. Describe the relationship between data transfer rate and upload time.

2. Inferring How would doubling the data transfer rate affect the upload time?

Bar Graphs

A bar graph is often used to compare a set of measurements, amounts, or changes. Figure 23 is a bar graph of the data from Figure 20. The bar graph makes it easy to see how the data for one city compare with the data for another.

Circle Graphs

If you think of a pie cut into pieces, you have a mental model of a circle graph. A circle graph is a divided circle that shows how a part or share of something relates to the whole. Figure 24 is a circle graph that describes the composition of Earth’s crust. The entire circle represents the mass of Earth’s crust. Each “slice” of the circle represents a percentage of that mass corresponding to a specific substance.

Facts and Figures

Scientific Journals

Thousands of scientific journals are published around the world. Some of them include articles on a broad range of topics, while others are narrowly focused. The decision that scientists make about where to publish their research depends on the nature of their results. Publishing in a well-known journal makes the research available to scientists in many different areas. Publishing in a narrowly focused journal means that the information will reach a smaller group of scientists. However, this small group includes scientists who are likely to need the information for their own research. Because it is not possible for scientists to read all the journals—or even all the journals in a single field—they must carefully choose the journals they read and the journals in which they publish their research.
Communicating Data

A crucial part of any scientific investigation is reporting the results. Scientists can communicate results by writing in scientific journals or speaking at conferences. Scientists also exchange information through conversations, e-mails, and Web sites. Young scientists often present their research at science fairs like the one in Figure 25.

Different scientists may interpret the same data differently. This important notion is the basis for peer review, a process in which scientists examine other scientists’ work. Not only do scientists share research with their peers, but they also invite feedback from those peers. Peer review encourages comments, suggestions, questions, and criticism from other scientists. Peer review can also help determine if data were reported accurately and honestly. Based on their peers’ responses, the scientists who submitted their work for review can then reevaluate how to best interpret their data.

Figure 25 At a science fair, students communicate what knowledge they have gained by using scientific methods.

Section 1.4 Assessment

Reviewing Concepts

1. How do scientists organize data?
2. How can scientists communicate experimental results?
3. What does a given point represent on a line graph?
4. The density of copper is 8.92 g/cm³. If you plotted the mass of copper in grams versus the volume in cubic centimeters, what would the slope of the line be?

Critical Thinking

5. Comparing and Contrasting When would you choose a line graph to present data? When would you choose a bar graph?

6. Using Tables and Graphs Count the number of students in your class with blue eyes, brown eyes, and green eyes. Display these data in a table and bar graph.

Scientific Methods Reread the description of scientific methods in Section 1.2. Then write a paragraph explaining which steps in a scientific method might require data to be organized. (Hint: You might use information diagrammed in Figure 3.)

Section 1.4 Assessment

1. Scientists can organize their data by using tables and graphs.
2. Scientists can communicate results by writing in scientific journals and speaking at conferences.
3. A given point on a line graph generally represents two measurements corresponding to two related variables, one plotted on the horizontal axis and the other plotted on the vertical axis.
4. The slope would be 1.
5. A line graph is useful for showing how one variable changes with respect to another (for example, how one’s distance changes with respect to time). A bar graph is useful for comparing a set of measurements (for example, how the average temperatures of various U.S. cities compare).
6. Students’ graphs should show three bars representing three different groups of classmates (blue-eyed, brown-eyed, and green-eyed).

Go Online Download a worksheet on graphing for students to complete, and find additional teacher support from NSTA SciLinks.