SECTION 4

Tools, Measurement, and Safety

Would you use a hammer to tighten a bolt on a bicycle? No, you wouldn't. You need the right tools to fix a bike.

Scientists use a variety of tools in their experiments. A tool is anything that helps you do a task.

READING WARM-UP

Objectives

- Collect, record, and analyze information by using various tools.
- Explain the importance of the International System of Units.
- Calculate area and density.
- Identify lab safety symbols, and demonstrate safe practices during lab investigations.

Terms to Learn

meter	volume
area	temperature
mass	density

READING STRATEGY

Reading Organizer As you read this section, make a concept map by using the terms above.

Tools for Measuring

You might remember that one way to collect data is to take measurements. To get the best measurements, you need the proper tools. Stopwatches, metersticks, and balances are tools that you can use to make measurements. Thermometers, spring scales, and graduated cylinders are also helpful tools. Some of the uses of these tools are shown in **Figure 1.**

Reading Check **Name six tools used for taking measurements.** *(See the Appendix for answers to Reading Checks.)*

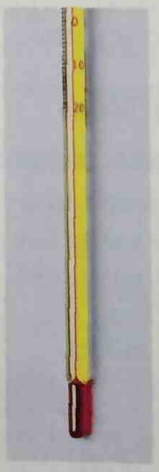
Tools for Analyzing

After you collect data, you need to analyze them. Perhaps you need to find the average of your data. Calculators are handy tools to help you do calculations quickly. Or you might show your data in a graph or a figure. A computer that has the correct software can help you make neat, colorful figures. Of course, even a pencil and graph paper are tools that you can use to graph your data.

Figure 1 **Measurement Tools**

You can use a **graduated cylinder** to measure volume.

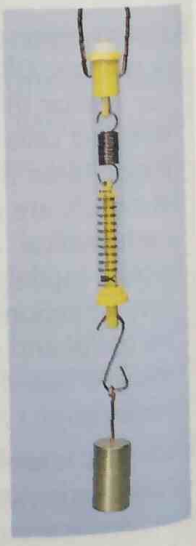
You can use a **thermometer** to measure temperature.



You can use a **stopwatch** to measure time.

You can use a **meterstick** to measure length.

You can use a **balance** to measure mass.



You can use a **spring scale** to measure force.

Units of Measurement

The ability to make accurate and reliable measurements is an important skill in science. Many systems of measurement are used throughout the world. At one time in England, the standard for an inch was three grains of barley placed end to end. Other modern standardized units were originally based on parts of the body, such as the foot. Such systems were not very reliable. Their units were based on objects that had different sizes.

The International System of Units

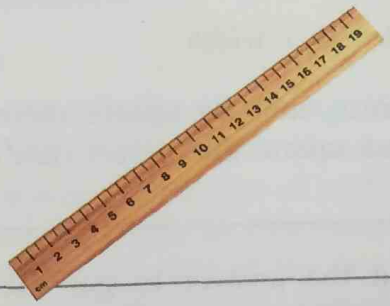
In the late 1700s, the French Academy of Sciences began to form a global measurement system now known as the *International System of Units*, or SI. Today, most scientists and almost all countries use this system. One advantage of using SI measurements is that doing so helps scientists share and compare their observations and results.

Another advantage of SI units is that all units are based on the number 10, which makes conversions from one unit to another easy. The table in **Table 1** contains commonly used SI units for length, volume, mass, and temperature.

No Rulers Allowed

1. Measure the width of your desk, but don't use a ruler.
2. Select another object to use as your unit of measurement.
3. Compare your measurement with those of your classmates.
4. Explain why it is important to use standard units of measurement.

Table 1 **Common SI Units and Conversions**

Length 	**meter (m)** kilometer (km) decimeter (dm) centimeter (cm) millimeter (mm) micrometer (μm) nanometer (nm)	1 km = 1,000 m 1 dm = 0.1 m 1 cm = 0.01 m 1 mm = 0.001 m 1 μm = 0.000001 m 1 nm = 0.000000001 m
Volume 	**cubic meter (m^3)** cubic centimeter (cm^3) liter (L) milliliter (mL)	1 cm^3 = 0.000001 m^3 1 L = 1 dm^3 = 0.001 m^3 1 mL = 0.001 L = 1 cm^3
Mass 	**kilogram (kg)** gram (g) milligram (mg)	1 g = 0.001 kg 1 mg = 0.000001 kg
Temperature 	**Kelvin (K)** **Celsius (°C)**	0°C = 273 K 100°C = 373 K

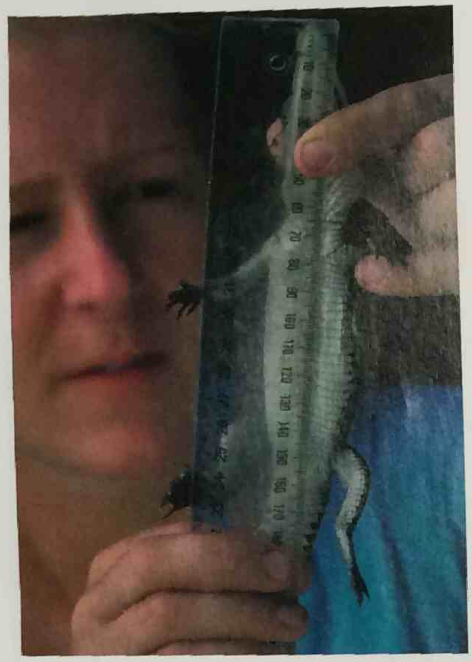


Figure 2 *This scientist is using a metric ruler to measure a lizard's length. The unit chosen to describe an object, such as this lizard, depends on the size of the object being measured.*

meter the basic unit of length in the SI (symbol, m)

area a measure of the size of a surface or a region

Measurement

Scientists report measured quantities in a way that shows the precision of the measurement. To do so, they use significant figures. *Significant figures* are the digits in a measurement that are known with certainty. The MathFocus below will help you understand significant figures and will teach you how to use the correct number of digits. Now that you have a standardized system of units for measuring things, you can use the system to measure length, area, mass, volume, and temperature.

Length

How long is a lizard? Well, a **meter** (m) is the basic SI unit of length. However, a scientist, such as the one in **Figure 2,** would use centimeters (cm) to describe a small lizard's length. If you divide 1 m into 100 parts, each part equals 1 cm. So, 1 cm is one-hundredth of a meter. Even though 1 cm seems small, some things are even smaller. Scientists describe the length of very small objects in micrometers (μm) or nanometers (nm). To see these small objects, scientists use powerful microscopes.

Area

How much paper would you need to cover the top of your desk? To answer this question, you must find the area of the desk. **Area** is a measure of the size of the surface of an object. To calculate the area of a square or a rectangle, measure the length and width. Then, use the following equation:

$$area = length \times width$$

Units for area are square units, such as square meters (m^2), square centimeters (cm^2), and square kilometers (km^2).

MATH FOCUS

Significant Figures Calculate the area of a carpet that is 3.145 m long (four significant figures) and 5.75 m (three significant figures) wide. (Hint: In multiplication and division problems, the answer cannot have more significant figures than the measurement that has the smallest number of significant figures does.)

Step 1: Write the equation for area.

$$area = length \times width$$

Step 2: Replace *length* and *width* with the measurements given, and solve.

$$area = 3.125 \text{ m} \times 5.75 \text{ m} = 18.08375 \text{ m}^2$$

Step 3: Round the answer to get the correct number of significant figures. Here, the correct number of significant figures is three, because the value with the smallest number of significant figures has three significant figures.

$$area = 18.1 \text{ m}^2$$

Now Its Your Turn

1. Use a calculator to perform the following calculation: 125.5 km × 8.225 km. Write the answer with the correct number of significant figures.

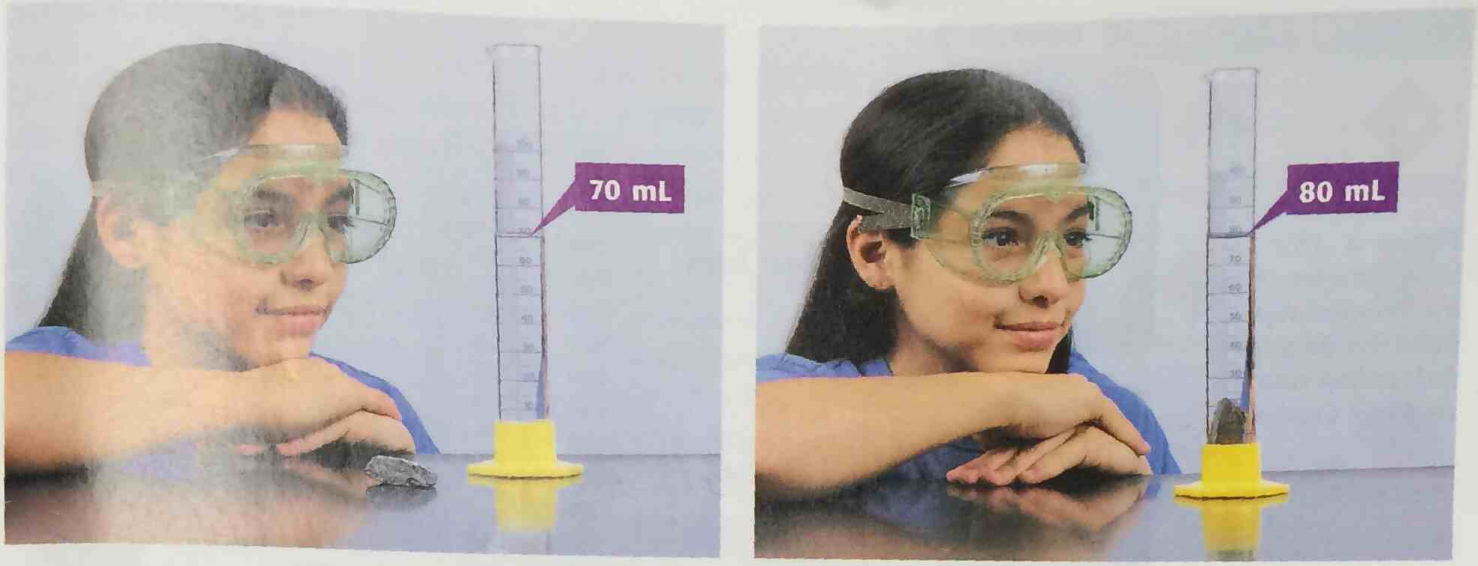


Figure 3 *Adding the rock changes the water level from 70 mL to 80 mL. So, the rock displaces 10 mL of water. Because 1 mL = 1 cm^3, the volume of the rock is 10 cm^3.*

Mass

How large a rock can a rushing stream move? The answer depends on the energy of the stream and the mass of the rock. **Mass** is a measure of the amount of matter in an object. The kilogram (kg) is the basic unit for mass in the SI. Kilograms are used to describe the mass of a large rock. Grams are used to measure the mass of smaller objects. One thousand grams equals 1 kg. For example, a medium-sized apple has a mass of about 100 g. Masses of very large objects are given in metric tons. A metric ton equals 1,000 kg.

Reading Check **What is the basic SI unit for mass?**

Volume

Think about moving some magnets to a laboratory. How many magnets will fit into a box? The answer depends on the volume of the box and the volume of each magnet. **Volume** is a measure of the size of a body in three-dimensional space. In this case, you need the volumes of the box and of the magnets.

The volume of a liquid is often given in liters (L). Liters are based on the meter. A cubic meter (1 m^3) is equal to 1,000 L. So, 1,000 L will fit into a box measuring 1 m on each side. A milliliter (mL) will fit into a box measuring 1 cm on each side. So, 1 mL = 1 cm^3. Graduated cylinders are used to measure the volume of liquids.

The volume of a large, solid object is given in cubic meters (m^3). The volumes of smaller objects can be given in cubic centimeters (cm^3) or cubic millimeters (mm^3). The volume of a box can be calculated by multiplying the object's length, width, and height. The volume of an irregularly shaped object can be found by measuring the volume of liquid that the object displaces. You can see how this works in **Figure 3.**

mass a measure of the amount of matter in an object

volume a measure of the size of a body or region in three-dimensional space

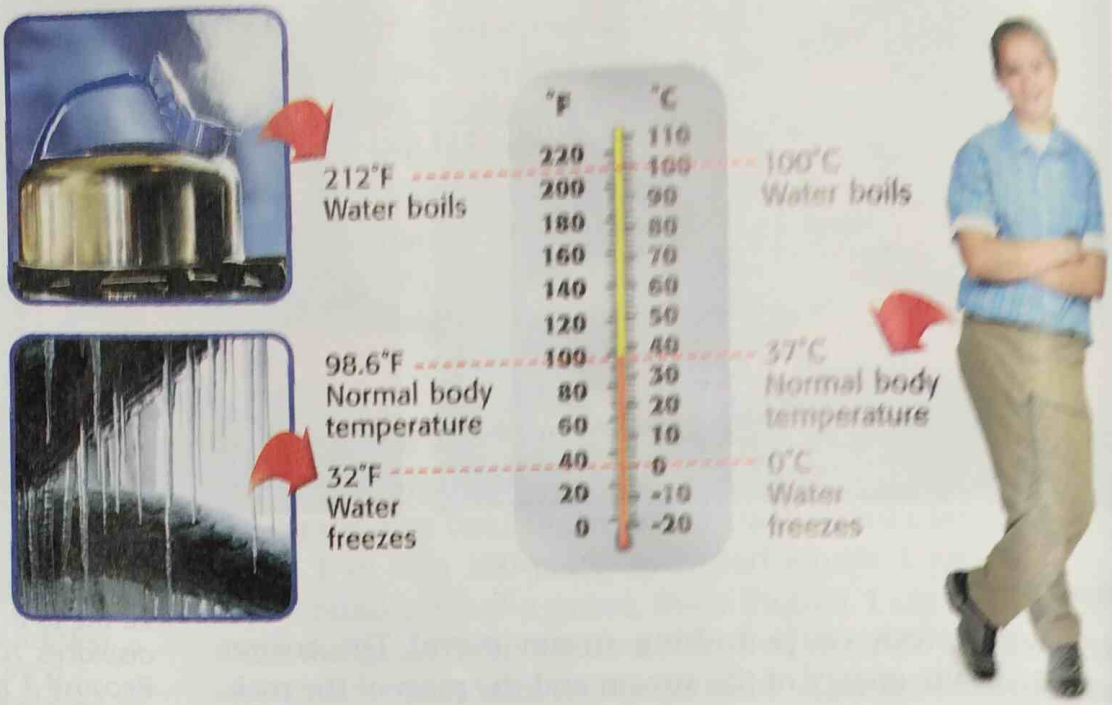


Figure 4 *This thermometer shows the relationship between degrees Fahrenheit and degrees Celsius.*

temperature the measure of how hot (or cold) something is

density the ratio of the mass of a substance to the volume of the substance

Temperature

How hot is melted iron? To answer this question, a scientist would measure the temperature of the liquid metal. **Temperature** is a measure of how hot or cold something is. You probably use degrees Fahrenheit (°F) to describe temperature. Scientists commonly use degrees Celsius (°C), although the kelvin (K) is the official SI base unit for temperature. You will use degrees Celsius in this book. The thermometer in **Figure 4** compares the Fahrenheit and Celsius scales.

Density

If you measure the mass and volume of an object, you have the measurements that you need to find the density of the object. **Density** is the amount of matter in a given volume. You cannot measure density directly. But after you have measured the mass and the volume, you can use the following equation to calculate density:

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

Density is the ratio of mass to volume, so units often used for density are grams per milliliter (g/mL) and grams per cubic centimeter (g/cm^3). Density may be difficult to understand. Think of a table-tennis ball and a golf ball. They have similar volumes. But a golf ball has more mass than a table-tennis ball does. So the golf ball has a greater density.

CONNECTION TO Social Studies

Archimedes (287 BCE–212 BCE) Archimedes was a Greek mathematician. He was probably the greatest mathematician and scientist that classical Greek civilization produced and is considered to be one of the greatest mathematicians of all time. Archimedes was very interested in putting his theoretical discoveries to practical use. Use the library or Internet to research Archimedes. Make a poster that illustrates one of his scientific or mathematical discoveries.

Safety Rules!

Science is exciting and fun, but it can also be dangerous. Don't take any chances! Always follow your teacher's instructions. Don't take shortcuts—even when you think there is no danger. Before starting an experiment, get your teacher's permission. Read the lab procedures carefully. Pay special attention to safety information and caution statements. **Figure 5** shows the safety symbols used in this book. Get to know these symbols and their meanings. Do so by reading the safety information in the front of this book. **This is important!** If you are still unsure about what a safety symbol means, ask your teacher.

Reading Check Why are safety symbols important?

Figure 5 Safety Symbols

SECTION Review

Summary

- Scientists use a variety of tools to measure and analyze the world around them.
- The International System of Units (SI) is a simple, reliable, and uniform system of measurement that is used by most scientists.
- The basic units of measurement in the SI are the meter (for length), the kilogram (for mass), and the Kelvin (for temperature).
- Before starting any science activity or science lab, review the safety symbols and the safety rules for that activity or lab. Don't take chances with your health and safety.

Using Key Terms

Complete each of the following sentences by choosing the correct term from the word bank.

mass area
volume temperature

1. A measure of the size of a surface or a region is called ___.
2. Scientists use kilograms when measuring an object's ___.
3. The ___ of a liquid is usually described in liters.

Understanding Key Ideas

4. SI units are
   a. based on standardized measurements of body parts.
   b. almost always based on the number 10.
   c. used to measure only length.
   d. used only in France.
5. What is temperature?
6. If you wanted to measure the mass of a fly, which SI unit would be most appropriate?

Math Skills

7. What is the area of a soccer field that is 110 m long and 85 m wide?
8. What is the density of silver if a 6 cm^3 piece of silver has a mass of 63 g?

Critical Thinking

9. **Applying Concepts** Some people are thinking about sending humans to the moon and then to the planet Mars. Why is it important for scientists around the world to use the International System of Units as they make these plans?
10. **Making Inferences** Give an example of something that can happen if you do not follow safety rules.
11. **Applying Concepts** What tool would you use to measure the mass of the air in a basketball?