# Section 2

**Reading Preview**

### Essential Questions

- What is a standard of measurement?
- What multiple of ten does each SI prefix represent?
- What are the SI units and symbols for length, volume, mass, density, time, and temperature?
- How can related SI units be converted?

### Review Vocabulary

**measurement:** the dimensions, capacity, or amount of something

### New Vocabulary

standard
SI
volume
matter
mass
density

Multilingual eGlossary

## Standards of Measurement

**MAIN Idea** **Standard measurement units, such as centimeters and seconds, are exact quantities used to compare measurements.**

**Real-World Reading Link** You know what time to go to school because you use seconds, minutes, and hours to tell time. The bus driver knows what speed to drive because the speedometer measures the speed of the bus. What if we all used different types of measurement?

### Units and Standards

Suppose you and a friend want to find out whether a desk will fit through a doorway. You have no ruler, so you decide to use your hands as measuring tools. Using the width of his hands, your friend measures the doorway and says it is eight hands wide. Using the width of your hands, you measure the desk and find it is $7\frac{3}{4}$ hands wide. Will the desk fit through the doorway? You can't be sure. Even though you both used hands to measure, you didn't check to see whether your hands were the same width as your friend's hands. In other words, because you didn't use a measurement standard, you can't compare the measurements. A **standard** is an exact quantity that people agree to use to compare measurements.

### Measurement Systems

Suppose the label on a ball of string says that the length of the string is 1. Is the length 1 meter (m), 1 foot (ft), or 1 centimeter (cm)? For a measurement to make sense, it must include a number and a unit, as shown in **Figure 9.**

Your family might buy lumber by the foot, milk by the gallon, and potatoes by the pound. These measurement units are part of the English system of measurement, which is commonly used in the United States. Most other nations use the metric system, a system of measurement based on multiples of ten.


**Figure 9** For data collected in an investigation or experiment, you need appropriate and consistent standards of measurement. It is important that you always use a number and a unit when describing length.



**International System of Units** In 1960, an improved version of the metric system was devised. Known as the International System of Units, this system is often abbreviated **SI,** from the French *Le Systeme Internationale d'Unites.* All SI standards are universally accepted and understood by scientists throughout the world.

For example, the standard kilogram is kept in Sevres, France, and the standard meter equals the exact distance that light travels through a vacuum in 1/299,792,458 seconds. All kilograms and meters used throughout the world match these standards.

The kilogram is an example of a base unit. A base unit in SI is one that is based on an object or event in the physical world. The meter is the base unit of length. There are seven base units in SI. Each has its own symbol. These names and symbols for the seven base units are shown in **Table 2.** All other SI units are obtained from these seven units.

**SI prefixes** The SI system is easy to use because it is based on multiples of ten. Prefixes are used with the names of the units to indicate what multiple of ten should be used with the units. For example, the prefix *kilo–* means "1,000," which means that one kilometer equals 1,000 meters. Likewise, one kilogram equals 1,000 grams. Because *deci–* means "one-tenth," one decimeter equals one tenth of a meter. A decigram equals one tenth of a gram. The most frequently used prefixes are shown in **Table 3.**

**Reading Check** **Calculate** How many meters is 1 km? How many grams is 1 dg?

**Converting between SI units** Sometimes, quantities are measured using different units. A conversion factor is a ratio that is equal to one. It is used to change one unit to another. For example, there are 1,000 mL in 1 L, so 1,000 mL = 1 L. If both sides in this equation are divided by 1 L, the equation becomes:

$$\frac{1{,}000 \text{ mL}}{1 \text{ L}} = 1$$

To convert units, multiply by the appropriate conversion factor. For example, to convert 1.255 L to mL, multiply 1.255 L by a conversion factor. Use the conversion factor with new units (mL) in the numerator and the old units (L) in the denominator.

$$1.255 \text{ L} \times \frac{1{,}000 \text{ mL}}{1 \text{ L}} = 1{,}255 \text{ mL}$$

**Table 2 SI Base Units**

| Quantity Measured | Unit | Symbol |
|---|---|---|
| Length | meter | m |
| Mass | kilogram | kg |
| Time | second | s |
| Electric current | ampere | A |
| Temperature | kelvin | K |
| Amount of substance | mole | mol |
| Intensity of light | candela | cd |

Concepts in Motion
Interactive Table

Concepts in Motion
Interactive Table

**Table 3 Common SI Prefixes**

| Prefix | Symbol | Multiplying Factor |
|---|---|---|
| Kilo– | k | 1,000 |
| Deci– | d | 0.1 |
| Centi– | c | 0.01 |
| Milli– | m | 0.001 |
| Micro– | μ | 0.000 001 |
| Nano– | n | 0.000 000 0 |

## EXAMPLE Problem 1

**Convert Units** How long, in centimeters, is a 3,075-mm rope?

**Identify the Unknown:** rope length in cm

**List the Knowns:** rope length in mm = 3,075 mm

1 m = 100 cm = 1,000 mm

**Set Up the Problem:** $\text{length in cm} = \text{length in mm} \times \frac{100\ \text{cm}}{1{,}000\ \text{mm}}$

**Solve the Problem:** $\text{length in cm} = 3{,}075\ \text{mm} \times \frac{100\ \text{cm}}{1{,}000\ \text{mm}} = 307.5\ \text{cm}$

**Check the Answer:** Millimeters are smaller than centimeters, so make sure your answer in mm is larger than the measurement in cm. Because SI is based on tens, the answer in mm should differ from the length in cm by a factor of ten.

## PRACTICE Problems

Find Additional Practice Problems in the back of your book.

5. If your pencil is 11 cm long, how long is it in millimeters?
6. **Challenge** Some birds migrate 20,000 miles. If 1 mile equals 1.6 kilometers, calculate the distance these birds fly in kilometers.

Review
Additional Practice Problems

## Measuring Length

The word *length* is used in many ways. For example, the length of a novel is the number of pages or words it contains. In scientific measurement, however, length is the distance between two points. That distance might be the diameter of a hair or the distance from Earth to the Moon. The SI base unit of length is the meter (m). A baseball bat is about 1 m long. Metric rulers and metersticks are used to measure length. **Figure 10** compares a meter and a yard.

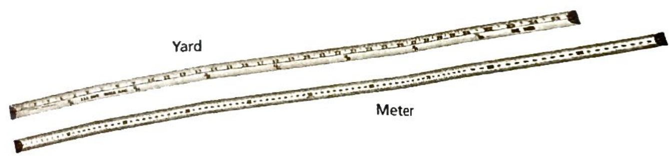


**Figure 10** One meter is slightly longer than 1 yard, and 100 m is slightly longer than a football field.
***Predict** whether your time for a 100-m dash would be slightly more or less than your time for a 100-y dash.*



**Figure 11** The size of the object being measured determines which unit you will use. A tape measure measures in meters. The micrometer measures in small lengths.

**Choosing a unit of length** As shown in **Figure 11**, the unit with which you measure will depend on the size of the object being measured. For example, the diameter of a shirt button is about 1 cm. You would most likely use the centimeter to measure the length of your pencil but the meter to measure the length of your classroom. What unit would you use to measure the distance from your home to school? You would probably want to use a unit larger than a meter. The kilometer (km), which is 1,000 m, is used to measure these kinds of distances.

By choosing an appropriate unit, you avoid large-digit numbers and numbers with many decimal places. Twenty-one kilometers is easier to deal with than 21,000 m. And 13 mm is easier to use than 0.013 m.

## Measuring Volume

The amount of space occupied by an object is called its **volume.** If you want to know the volume of a solid rectangle, such as a brick, you measure its length, width, and height and multiply the three numbers and their units together: $V = l \times w \times h$. For a brick, your length measurements would most likely be in centimeters. The volume would then be expressed in cubic centimeters ($cm^3$) because when you multiply, you add the exponents. To find out how large of a load a moving van can carry, your length measurements would probably be in meters and the volume would be expressed in cubic meters ($m^3$).

Sometimes, liquid volumes, such as doses of medicine, are expressed in cubic centimeters. One cubic centimeter and one milliliter are the same volume.

$$1\ \text{mL} = 1\ \text{cm}^3$$

Suppose you wanted to convert a measurement in liters to cubic centimeters. You use conversion factors to convert L to mL and then mL to $cm^3$.

$$1.5\ \text{L} \times \frac{1{,}000\ \text{mL}}{1\ \text{L}} \times \frac{1\ \text{cm}^3}{1\ \text{mL}} = 1{,}500\ \text{cm}^3$$

**VOCABULARY**
**SCIENCE USAGE V. COMMON USAGE**
**Volume**
***Science usage***
the amount of space occupied by an object
*To measure the volume of the cube, Raul submerged it in a beaker of water.*
***Common usage***
the degree of loudness
*Alisa couldn't hear the radio, so she turned up the volume.*

| Material | Density (g/cm³) | Material | Density (g/cm³) |
|---|---|---|---|
| Hydrogen | 0.00009 | Aluminum | 2.7 |
| Oxygen | 0.0014 | Iron | 7.9 |
| Water | 1.0 | Gold | 19.3 |

**Table 4** Densities of Some Materials at 20°C

## MiniLab

Inquiry MiniLab

### Determine the Density of a Pencil

**Procedure**

1. Read the procedure and safety information, and complete the lab form.
2. Find a **pencil** that will fit entirely in a **100-mL graduated cylinder** below the 90-mL mark.
3. Measure the mass of the pencil in grams with a **balance.**
4. Put 90 mL of **water** (initial volume) into the 100-mL graduated cylinder. Lower the pencil, eraser first, into the cylinder. Push the pencil down until it is just submerged. Hold it there, and record the final volume to the nearest tenth of a milliliter.

**Analysis**

1. **Determine** the water displaced by the pencil by subtracting the initial volume from the final volume.

**Calculate** the pencil's density by dividing its mass by the volume of water displaced.

**Compare** the density of the pencil to the density of water.

Inquiry Video Lab

## Measuring Mass and Density

**Matter** is anything that takes up space and has mass. A table-tennis ball and a golf ball have about the same volume. If you pick them up, you notice a difference. The golf ball has more mass. **Mass** is a measurement of the quantity of matter in an object. The mass of the golf ball is about 45 g. It is almost 18 times the mass of the table-tennis ball, which is about 2.5 g. A bowling ball has a mass of about 5,000 g. This makes its mass roughly 100 times greater than the mass of the golf ball and 2,000 times greater than the table-tennis ball's mass.

**Density** A cube of polished aluminum and a cube of silver that are the same size look similar and have the same volume, but they have different masses. The mass and volume of an object can be used to find the density of the material of which the object is made. **Density** is the mass per unit volume of a material. You find density by dividing an object's mass by the object's volume. For example, the density of an object having a mass of 10 g and a volume of 2 $cm^3$ is 5 $g/cm^3$. **Table 4** lists the densities of some familiar materials.

**Derived units** The measurement unit for density, $g/cm^3$, is a combination of SI units. A unit obtained by combining different SI units is called a derived unit. An SI unit multiplied by itself also is a derived unit. Thus, the liter, which is based on the cubic decimeter, is a derived unit. A cubic meter, $m^3$, is another example of a derived unit.

## Measuring Time and Temperature

It is often necessary to keep track of how long it takes for something to happen. Time is the interval between two events. The SI unit for time is the second. In the laboratory, you will use a stopwatch or a clock with a second hand to measure time.

Another type of measurement common to science is temperature. You will learn the scientific meaning of the word *temperature* in a later chapter, but for now, think of temperature as a measure of how hot or how cold something is. **Table 5** summarizes measurements in SI, including time and temperature.



**Table 5** SI Dimensions

| Unit | Example | |
|---|---|---|
| Millimeters |  | A dime is about 1 mm thick. |
| Meters |  | A football field is about 91 m long. |
| Kilometers |  | The distance from your house to the store can be measured in kilometers. |
| Milliliters |  | A teaspoonful of medicine is about 5 mL. |
| Liters |  | This carton holds 1.89 L of milk. |
| Grams/cm³ |  | This stone sinks because it is denser—has more grams per cubic centimeter—than water. |
| Meters/second |  | The speed of a roller coaster car can be measured in meters per second. |
| Kelvin |  | Water boils at 373 K and freezes at 273 K. |
| Grams |  | The mass of a paper clip can be measured in grams. |

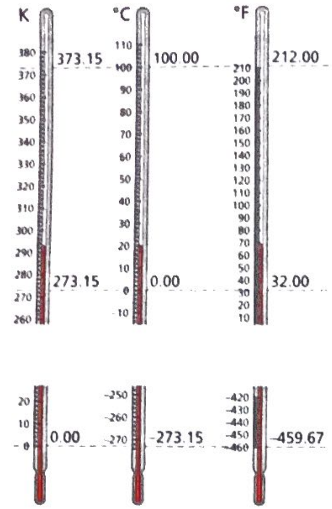


**Figure 12** These three thermometers illustrate the scales of temperature from absolute zero to the boiling point of water.

**Compare** *the boiling points of the three scales.*

**Celsius** Look at **Figure 12.** For much scientific work, temperature is measured on the Celsius (C) scale. On this scale, the freezing point of water is 0°C, and the boiling point of water is 100°C. Between these points, the scale is divided into 100 equal divisions. Each one represents 1°C. On the Celsius scale, average human body temperature is 37°C, and a typical room temperature is between 20°C and 25°C.

**Kelvin and Fahrenheit** The SI unit of temperature is the kelvin (K). Zero on the Kelvin scale (0 K) is the coldest possible temperature, also known as absolute zero. Absolute zero is roughly equal to –273°C, which is 273°C below the freezing point of water.

Most laboratory thermometers are marked only with the Celsius scale. Because the divisions on the Celsius and Kelvin scales are the same size, the Kelvin temperature can be found by adding 273 to the Celsius reading. So, on the Kelvin scale, water freezes at 273 K and boils at 373 K. Notice that degree symbols are not used with the Kelvin scale.

The temperature measurement with which you are probably most familiar is the Fahrenheit scale. On the Fahrenheit scale, the freezing point of water is 32°F and the boiling point is 212°F. A temperature difference of 1° on the Fahrenheit scale is 5/9° on the Celsius scale.

## Section 2 Review

### Section Summary

- The International System of Units, or SI, was established to provide a standard of measurement and to reduce confusion.
- Conversion factors are used to change one unit to another and involve using a ratio equal to 1.
- The size of an object determines which unit you will use to measure it.

7. **MAIN Idea Explain** why it is important to have exact standards of measurement.
8. **Make a Table** Organize the following measurements from smallest to largest and include the multiplying factor for each: kilometer, nanometer, centimeter, meter, and micrometer.
9. **Think Critically** Explain why density is a derived unit.

### Apply Math

10. **Convert Units** Make the following conversions: 27°C to Kelvin, 20 dg to milligrams, and 3 m to decimeters.
11. **Calculate Density** What is the density of an unknown metal that has a mass of 158 g and a volume of 20 mL? Use **Table 4** to identify this metal.



Assessment Online Quiz

## Section 3

### Reading Preview

**Essential Questions**

- What are the three types of graphs, and how are they used?
- How are dependent and independent variables expressed in a graph?
- How can you analyze data using the various types of graphs?

**Review Vocabulary**

**data:** information gathered during an investigation or observation

**New Vocabulary**

graph

Multilingual eGlossary

# Communicating with Graphs

**MAIN Idea Graphs are visual representations of numerical data that help scientists detect patterns.**

**Real-World Reading Link** Just as a carpenter needs a variety of tools depending on the job, a scientist needs different types of graphs to communicate data.

## A Visual Display

Scientists often graph the results of their experiments because they can detect patterns in the data easier in a graph than in a table. A **graph** is a visual display of information or data. **Figure 13** is a graph that shows the time and distance from home as a girl walked her dog. The horizontal axis, called the *x*-axis, measures time. Time is the independent variable because as it changes, it affects the measure of another variable. The distance from home that the girl and the dog walk is the other variable. It is the dependent variable and is measured on the vertical axis, called the *y*-axis.

Graphs are useful for displaying numerical information in business, science, sports, advertising, and many everyday situations. Graphs make it easier to understand patterns by displaying data in a visual manner.

Scientists often graph their data to detect patterns that would not have been evident in a table. Business people may graph sales dollars to determine trends. Different kinds of graphs—line, bar, and circle—are appropriate for displaying different types of information. Additional information on making and using graphs can be found in the Math Skill Handbook in the back of this book.

Concepts in Motion
**Animation**

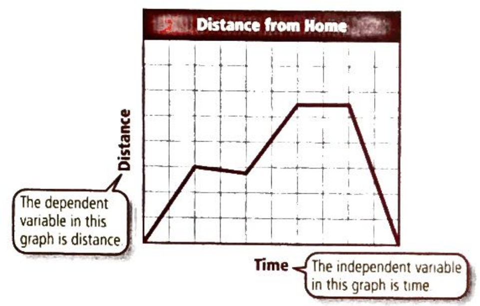


**Figure 13** This graph tells the story of the motion that takes place when a girl takes her dog for a 10-minute walk. The dependent variable is on the *y*-axis, and the independent variable is on the *x*-axis.