You are feeling crowded in. Perhaps it would be a good time to move to a state with more elbow room. But which state? You can look up the population of each state, but that does not take into account the amount of land the population occupies. How is this land measured and how can you use this measure to select a place where wildlife outnumber humans?

In this chapter, we explore ways of measuring things in our English system, as well as in the metric system. We return to finding a state with lots of room to spread out in Example 2 of Section 9.2. Knowing how units of measure are used to describe your world can help you make decisions on issues ranging from where to live to alcohol consumption (see the Blitzer Bonus on page 522).
9.1 Measuring Length: The Metric System

Have you seen either of the *Jurassic Park* films? The popularity of these movies reflects our fascination with dinosaurs and their incredible size. From end to end, the largest dinosaur from the Jurassic period, which lasted from 208 to 146 million years ago, was about 88 feet. To measure an object such as a dinosaur is to assign a number to its size. The number representing its measure from end to end is called its length. Measurements are used to describe properties of length, area, volume, weight, and temperature. Over the centuries, people have developed systems of measurement that are now accepted in most of the world.

**Length**

Every measurement consists of two parts: a number and a unit of measure. For example, if the length of a dinosaur is 88 feet, the number is 88 and the unit of measure is the foot. Many different units are commonly used in measuring length. The foot is from a system of measurement called the **English system**, which is generally used in the United States. In this system of measurement, length is expressed in such units as inches, feet, yards, and miles.

The result obtained from measuring length is called a **linear measurement** and is stated in **linear units**.

**LINEAR UNITS OF MEASURE: THE ENGLISH SYSTEM**

<table>
<thead>
<tr>
<th>Linear Units</th>
<th>Conversion</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 inches (in.)</td>
<td>1 foot (ft)</td>
</tr>
<tr>
<td>3 feet</td>
<td>1 yard (yd)</td>
</tr>
<tr>
<td>36 inches</td>
<td>1 yard</td>
</tr>
<tr>
<td>5280 feet</td>
<td>1 mile (mi)</td>
</tr>
</tbody>
</table>

Because many of us are familiar with the measures in the box, we find it simple to change from one measure to another, say from feet to inches. We know that there are 12 inches in a foot. To convert from 5 feet to a measure in inches, we multiply by 12. Thus, 5 feet = 5 × 12 inches = 60 inches.

Another procedure used to convert from one unit of measurement to another is called **dimensional analysis**. Dimensional analysis uses **unit fractions**. A **unit fraction** has two properties: The numerator and denominator contain different units and the value of the unit fraction is 1. Here are some examples of unit fractions:

\[
\frac{12 \text{ in.}}{1 \text{ ft}}, \frac{1 \text{ ft}}{12 \text{ in.}}, \frac{3 \text{ ft}}{1 \text{ yd}}, \frac{1 \text{ yd}}{3 \text{ ft}}, \frac{1 \text{ mi}}{5280 \text{ ft}}, \frac{5280 \text{ ft}}{1 \text{ mi}}
\]

In each unit fraction, the numerator and denominator are equal measures, making the value of the fraction 1.

Let’s see how to convert 5 feet to inches using dimensional analysis.

\[
5 \text{ ft} = ? \text{ in.}
\]
We need to eliminate feet and introduce inches. The unit we need to introduce, inches, must appear in the numerator of the fraction. The unit we need to eliminate, feet, must appear in the denominator. Therefore, we choose the unit fraction with inches in the numerator and feet in the denominator. The units divide out as follows:

\[
5 \text{ ft} = \frac{5 \text{ ft}}{1} \cdot \frac{12 \text{ in.}}{1 \text{ ft}} = 5 \cdot 12 \text{ in.} = 60 \text{ in.}
\]

**DIMENSIONAL ANALYSIS**

To convert a measurement to a different unit, multiply by a unit fraction (or by unit fractions). The given unit of measurement should appear in the denominator of the unit fraction so that this unit cancels upon multiplication. The unit of measurement that needs to be introduced should appear in the numerator of the fraction so that this unit will be retained upon multiplication.

**EXAMPLE 1 Using Dimensional Analysis to Change Units of Measurement**

Convert:

a. 40 inches to feet  
b. 13,200 feet to miles  
c. 9 inches to yards.

**Solution**

a. Because we want to convert 40 inches to feet, feet should appear in the numerator and inches in the denominator. We use the unit fraction \( \frac{1 \text{ ft}}{12 \text{ in.}} \) and proceed as follows:

\[
40 \text{ in.} = \frac{40 \text{ in.}}{1} \cdot \frac{1 \text{ ft}}{12 \text{ in.}} = \frac{40}{12} \text{ ft} = 3 \frac{1}{3} \text{ ft} \text{ or } 3.3 \text{ ft}. 
\]

b. To convert 13,200 feet to miles, miles should appear in the numerator and feet in the denominator. We use the unit fraction \( \frac{1 \text{ mi}}{5280 \text{ ft}} \) and proceed as follows:

\[
13,200 \text{ ft} = \frac{13,200 \text{ ft}}{1} \cdot \frac{1 \text{ mi}}{5280 \text{ ft}} = \frac{13,200}{5280} \text{ mi} = 2 \frac{1}{2} \text{ mi} \text{ or } 2.5 \text{ mi}. 
\]

c. To convert 9 inches to yards, yards should appear in the numerator and inches in the denominator. We use the unit fraction \( \frac{1 \text{ yd}}{36 \text{ in.}} \) and proceed as follows:

\[
9 \text{ in.} = \frac{9 \text{ in.}}{1} \cdot \frac{1 \text{ yd}}{36 \text{ in.}} = \frac{9}{36} \text{ yd} = \frac{1}{4} \text{ yd} \text{ or } 0.25 \text{ yd}. 
\]

**HOMEWORK**

Convert:

a. 78 inches to feet  
b. 17,160 feet to miles  
c. 3 inches to yards.
Length and the Metric System

Although the English system of measurement is most commonly used in the United States, most industrialized countries use the metric system of measurement. One of the advantages of the metric system is that units are based on powers of ten, making it much easier than the English system to change from one unit of measure to another.

The basic unit for linear measure in the metric system is the meter (m). A meter is slightly longer than a yard, approximately 39 inches. Prefixes are used to denote a multiple or part of a meter. Table 9.1 summarizes the more commonly used metric prefixes and their meanings.

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Symbol</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>kilo</td>
<td>k</td>
<td>$1000 \times$ base unit</td>
</tr>
<tr>
<td>hecto</td>
<td>h</td>
<td>$100 \times$ base unit</td>
</tr>
<tr>
<td>deka</td>
<td>da</td>
<td>$10 \times$ base unit</td>
</tr>
<tr>
<td>deci</td>
<td>d</td>
<td>$\frac{1}{10}$ of base unit</td>
</tr>
<tr>
<td>centi</td>
<td>c</td>
<td>$\frac{1}{100}$ of base unit</td>
</tr>
<tr>
<td>milli</td>
<td>m</td>
<td>$\frac{1}{1000}$ of base unit</td>
</tr>
</tbody>
</table>

The prefixes kilo, centi, and milli are used more frequently than hecto, deka, and deci. Table 9.2 applies all six prefixes to the meter. The first part of the symbol indicates the prefix and the second part (m) indicates meter.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Unit</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>km</td>
<td>kilometer</td>
<td>1000 meters</td>
</tr>
<tr>
<td>hm</td>
<td>hectometer</td>
<td>100 meters</td>
</tr>
<tr>
<td>dam</td>
<td>dekameter</td>
<td>10 meters</td>
</tr>
<tr>
<td>m</td>
<td>meter</td>
<td>1 meter</td>
</tr>
<tr>
<td>dm</td>
<td>decimeter</td>
<td>0.1 meter</td>
</tr>
<tr>
<td>cm</td>
<td>centimeter</td>
<td>0.01 meter</td>
</tr>
<tr>
<td>mm</td>
<td>millimeter</td>
<td>0.001 meter</td>
</tr>
</tbody>
</table>

In the metric system, the kilometer is used to measure distances comparable to those measured in miles in the English system. One kilometer is approximately 0.6 mile, and one mile is approximately 1.6 kilometers.

Metric units of centimeters and millimeters are used to measure what the English system measures in inches. Figure 9.1 shows that a centimeter is less than half an inch; there are 2.54 centimeters in an inch. The smaller markings on the bottom scale are millimeters. A millimeter is approximately the thickness of a dime. The length of a bee or a fly may be measured in millimeters.

![Figure 9.1](image_url)
Those of us born in the United States have a good sense of what a length in
the English system tells us about an object. An 88-foot dinosaur is huge, about
15 times the height of a 6-foot man. But what sense can we make of knowing that a
whale is 25 meters long? The following lengths and the given approximations can
help give you a feel for metric units of linear measure.

<table>
<thead>
<tr>
<th>Item</th>
<th>Approximate Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width of lead in pencil</td>
<td>2 mm or 0.08 in.</td>
</tr>
<tr>
<td>Width of an adult’s thumb</td>
<td>2 cm or 0.8 in.</td>
</tr>
<tr>
<td>Height of adult male</td>
<td>1.8 m or 6 ft</td>
</tr>
<tr>
<td>Typical room height</td>
<td>2.5 m or 8.3 ft</td>
</tr>
<tr>
<td>Length of medium-size car</td>
<td>5 m or 16.7 ft</td>
</tr>
<tr>
<td>Height of Empire State Building</td>
<td>381 m or 1270 ft</td>
</tr>
<tr>
<td>Average depth of ocean</td>
<td>4 km or 2.5 mi</td>
</tr>
<tr>
<td>Length of Manhattan Island</td>
<td>18 km or 11.25 mi</td>
</tr>
<tr>
<td>Distance from New York City to San Francisco</td>
<td>4800 km or 3000 mi</td>
</tr>
<tr>
<td>Radius of Earth</td>
<td>6378 km or 3986 mi</td>
</tr>
<tr>
<td>Distance from Earth to the moon</td>
<td>384,401 km or 240,251 mi</td>
</tr>
</tbody>
</table>

Although dimensional analysis can be used to convert from one unit to another
within the metric system, there is an easier, faster way to accomplish this conversion.
The procedure is based on the observation that successively smaller units involve
division by 10 and successively larger units involve multiplication by 10.

**CHANGING UNITS WITHIN THE METRIC SYSTEM**

Use the following chart to find equivalent measures of length:

Multiply by 10 for each step to the right.

\[
\begin{align*}
\text{km} & \quad \times 10 \quad \text{hm} \\
\text{hm} & \quad \times 10 \quad \text{dam} \\
\text{dam} & \quad \times 10 \quad \text{m} \\
\text{m} & \quad \times 10 \quad \text{dm} \\
\text{dm} & \quad \times 10 \quad \text{cm} \\
\text{cm} & \quad \times 10 \quad \text{mm}
\end{align*}
\]

Divide by 10 for each step to the left.

1. To change from a larger unit to a smaller unit (moving to the right in the
diagram), multiply by 10 for each step to the right. Thus, move the decimal
point in the given quantity one place to the right for each smaller unit until
the desired unit is reached.

2. To change from a smaller unit to a larger unit (moving to the left in the
diagram), divide by 10 for each step to the left. Thus, move the decimal point
in the given quantity one place to the left for each larger unit until the
desired unit is reached.

**STUDY TIP**

The following sentence provides a way to remember the metric units for length from
largest to smallest.

King Henry died Monday drinking chocolate milk.

km  hm  dam  m  dm  cm  mm
EXAMPLE 2  Changing Units within the Metric System

a. Convert 504.7 meters to kilometers.

b. Convert 27 meters to centimeters.

c. Convert 704 mm to hm.

d. Convert 9.71 dam to dm.

**Solution**

a. To convert from meters to kilometers, we start at meters and move three steps to the left to obtain kilometers:

\[ \text{km} \rightarrow \text{hm} \rightarrow \text{dam} \rightarrow \text{m} \rightarrow \text{dm} \rightarrow \text{cm} \rightarrow \text{mm} \]

Hence, we move the decimal point three places to the left:

\[ 504.7 \text{ m} = 0.5047 \text{ km} \]

Thus, 504.7 meters converts to 0.5047 kilometer. Changing from a smaller unit of measurement (meter) to a larger unit of measurement (kilometer) results in an answer with a smaller number of units.

b. To convert from meters to centimeters, we start at meters and move two steps to the right to obtain centimeters:

\[ \text{km} \rightarrow \text{hm} \rightarrow \text{dam} \rightarrow \text{m} \rightarrow \text{dm} \rightarrow \text{cm} \rightarrow \text{mm} \]

Hence, we move the decimal point two places to the right:

\[ 27 \text{ m} = 2700 \text{ cm} \]

Thus, 27 meters converts to 2700 centimeters. Changing from a larger unit of measurement (meter) to a smaller unit of measurement (centimeter) results in an answer with a larger number of units.

c. To convert from mm (millimeters) to hm (hectometers), we start at mm and move five steps to the left to obtain hm:

\[ \text{km} \rightarrow \text{hm} \rightarrow \text{dam} \rightarrow \text{m} \rightarrow \text{dm} \rightarrow \text{cm} \rightarrow \text{mm} \]

Hence, we move the decimal point five places to the left:

\[ 704 \text{ mm} = 0.000704 \text{ hm} \]

d. To convert from dam (dekameters) to dm (decimeters), we start at dam and move two places to the right to obtain dm:

\[ \text{km} \rightarrow \text{hm} \rightarrow \text{dam} \rightarrow \text{m} \rightarrow \text{dm} \rightarrow \text{cm} \rightarrow \text{mm} \]

Hence, we move the decimal point two places to the right:

\[ 9.71 \text{ dam} = 971 \text{ dm} \]

In Example 2(b), we showed that 27 meters converts to 2700 centimeters. This is the average length of the California blue whale, the longest of the great whales. Blue whales can have lengths that exceed 30 meters, making them over 100 feet long.
a. Convert 8000 meters to kilometers.
b. Convert 53 meters to millimeters.
c. Convert 604 cm to m.
d. Convert 6.72 dam to cm.

**BLITZER BONUS**

**VIRUSES AND METRIC PREFIXES**

Viruses are measured in attometers. An attometer is one quintillionth of a meter, or \(10^{-18}\) meter, symbolized \(\text{am}\). If a virus measures 1 am, you can place \(10^{15}\) of them across a penciled 1 millimeter dot. If you were to enlarge each of these viruses to the size of the dot, they would stretch far into space, almost reaching Saturn.

Here is a list of all twenty metric prefixes. When applied to the meter, they range from the yottameter \((10^{24}\) meters) to the yoctometer \((10^{-24}\) meters).

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Symbol</th>
<th>Power of Ten</th>
<th>English Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>yotta-</td>
<td>Y</td>
<td>+24</td>
<td>septillion</td>
</tr>
<tr>
<td>zetta-</td>
<td>Z</td>
<td>+21</td>
<td>sextillion</td>
</tr>
<tr>
<td>exa-</td>
<td>E</td>
<td>+18</td>
<td>quintillion</td>
</tr>
<tr>
<td>peta-</td>
<td>P</td>
<td>+15</td>
<td>quadrillion</td>
</tr>
<tr>
<td>tera-</td>
<td>T</td>
<td>+12</td>
<td>trillion</td>
</tr>
<tr>
<td>giga-</td>
<td>G</td>
<td>+9</td>
<td>billion</td>
</tr>
<tr>
<td>mega-</td>
<td>M</td>
<td>+6</td>
<td>million</td>
</tr>
<tr>
<td>kilo-</td>
<td>k</td>
<td>+3</td>
<td>thousand</td>
</tr>
<tr>
<td>hecto-</td>
<td>h</td>
<td>+2</td>
<td>hundred</td>
</tr>
<tr>
<td>deca-</td>
<td>da</td>
<td>+1</td>
<td>ten</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Symbol</th>
<th>Power of Ten</th>
<th>English Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>deci-</td>
<td>d</td>
<td>−1</td>
<td>tenth</td>
</tr>
<tr>
<td>centi-</td>
<td>c</td>
<td>−2</td>
<td>hundredth</td>
</tr>
<tr>
<td>milli-</td>
<td>m</td>
<td>−3</td>
<td>thousandth</td>
</tr>
<tr>
<td>micro-</td>
<td>µ</td>
<td>−6</td>
<td>millionth</td>
</tr>
<tr>
<td>nano-</td>
<td>n</td>
<td>−9</td>
<td>billionth</td>
</tr>
<tr>
<td>pico-</td>
<td>p</td>
<td>−12</td>
<td>trilionth</td>
</tr>
<tr>
<td>femto-</td>
<td>f</td>
<td>−15</td>
<td>quadrillionth</td>
</tr>
<tr>
<td>atto-</td>
<td>a</td>
<td>−18</td>
<td>quintillionth</td>
</tr>
<tr>
<td>zepto-</td>
<td>z</td>
<td>−21</td>
<td>sextillionth</td>
</tr>
<tr>
<td>yocto-</td>
<td>y</td>
<td>−24</td>
<td>septillionth</td>
</tr>
</tbody>
</table>

Although dimensional analysis is not necessary when changing units within the metric system, it is a useful tool when converting to and from the metric system. Some conversions are given in **Table 9.3**.

**Table 9.3** English and Metric Equivalents

<table>
<thead>
<tr>
<th>Conversion</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 inch (in.)</td>
<td>= 2.54 centimeters (cm)</td>
</tr>
<tr>
<td>1 foot (ft)</td>
<td>= 30.48 centimeters (cm)</td>
</tr>
<tr>
<td>1 yard (yd)</td>
<td>≈ 0.9 meter (m)</td>
</tr>
<tr>
<td>1 mile (mi)</td>
<td>≈ 1.6 kilometers (km)</td>
</tr>
</tbody>
</table>

*These conversions are exact.*

*These conversions are approximate.*
TABLE 9.3 English and Metric Equivalents

1 inch (in.) = 2.54 centimeters (cm)
1 foot (ft) = 0.3048 centimeters (cm)
1 yard (yd) = 0.9 meter (m)
1 mile (mi) = 1.6 kilometers (km)

EXAMPLE 3 Using Dimensional Analysis to Change to and from the Metric System

a. Convert 8 inches to centimeters.

b. Convert 125 miles to kilometers.

c. Convert 26,800 millimeters to inches.

Solution

a. To convert 8 inches to centimeters, we use a unit fraction with centimeters in the numerator and inches in the denominator:

\[
\frac{2.54 \text{ cm}}{1 \text{ in.}}
\]

We proceed as follows.

\[
8 \text{ in.} = \frac{8 \text{ in.}}{1} \cdot \frac{2.54 \text{ cm}}{1 \text{ in.}} = 8(2.54) \text{ cm} = 20.32 \text{ cm}
\]

b. To convert 125 miles to kilometers, we use a unit fraction with kilometers in the numerator and miles in the denominator:

\[
\frac{1.6 \text{ km}}{1 \text{ mi}}
\]

Thus,

\[
125 \text{ mi} \approx \frac{125 \text{ mi}}{1} \cdot \frac{1.6 \text{ km}}{1 \text{ mi}} = 125(1.6) \text{ km} = 200 \text{ km}
\]

c. To convert 26,800 millimeters to inches, we observe that Table 9.3 has only a conversion factor between inches and centimeters. We begin by changing millimeters to centimeters:

\[
26,800 \text{ mm} = 2680 \text{ cm}
\]

Now we need to convert 2680 centimeters to inches. We use a unit fraction with inches in the numerator and centimeters in the denominator:

\[
\frac{1 \text{ in.}}{2.54 \text{ cm}}
\]

Thus,

\[
26,800 \text{ mm} = 2680 \text{ cm} = \frac{2680 \text{ cm}}{1} \cdot \frac{1 \text{ in.}}{2.54 \text{ cm}} = \frac{2680}{2.54} \text{ in.} \approx 1055 \text{ in.}
\]

This measure is equivalent to about 88 feet, the length of the largest dinosaur from the Jurassic period. The diplodocus, a plant eater, was 26.8 meters, approximately 88 feet, long.

a. Convert 8 feet to centimeters.

b. Convert 20 meters to yards.

c. Convert 30 meters to inches.

So far, we have used dimensional analysis to change units of length. Dimensional analysis may also be used to convert other kinds of measures, such as speed.
EXAMPLE 4  Using Dimensional Analysis

a. The speed limit on many highways in the United States is 55 miles per hour (mi/hr). How many kilometers per hour (km/hr) is this?

b. If a high-speed train in Japan is capable of traveling at 200 kilometers per hour, how many miles per hour is this?

Solution

a. To change miles per hour to kilometers per hour, we need to concentrate on changing miles to kilometers, so we need a unit fraction with kilometers in the numerator and miles in the denominator:

\[
\frac{1.6 \text{ km}}{1 \text{ mi}}.
\]

Table 9.3 shows that 1 mi ≈ 1.6 km.

Thus,

\[
\frac{55 \text{ mi}}{\text{hr}} \approx 55 \frac{\text{mi}}{\text{hr}} \cdot \frac{1.6 \text{ km}}{1 \text{ mi}} = 55(1.6) \frac{\text{km}}{\text{hr}} = 88 \text{ km/hr}.
\]

This shows that 55 miles per hour is approximately 88 kilometers per hour.

b. To change 200 kilometers per hour to miles per hour, we must convert kilometers to miles. We need a unit fraction with miles in the numerator and kilometers in the denominator:

\[
\frac{1 \text{ mi}}{1.6 \text{ km}}.
\]

Table 9.3 shows that 1 mi ≈ 1.6 km.

Thus,

\[
\frac{200 \text{ km}}{\text{hr}} \approx 200 \frac{\text{km}}{\text{hr}} \cdot \frac{1 \text{ mi}}{1.6 \text{ km}} = 200 \frac{\text{mi}}{1.6 \text{ hr}} = 125 \text{ mi/hr}.
\]

A train capable of traveling at 200 kilometers per hour can therefore travel at about 125 miles per hour.

A road in Europe has a speed limit of 60 kilometers per hour. Approximately how many miles per hour is this?
37. 14 dm to in. 38. 1.2 dam to in.
39. 160 in. to dam 40. 180 in. to hm
41. 5 ft to m 42. 8 ft to m
43. 5 m to ft 44. 8 m to ft

Use 1 mi ≈ 1.6 km to solve Exercises 45–48.
45. Express 96 kilometers per hour in miles per hour.
46. Express 104 kilometers per hour in miles per hour.
47. Express 45 miles per hour in kilometers per hour.
48. Express 50 miles per hour in kilometers per hour.

Practice Plus
In Exercises 49–52, use the unit fractions
\[ \frac{36 \text{ in.}}{1 \text{ yd}} \text{ and } \frac{2.54 \text{ cm}}{1 \text{ in.}} \]
49. Convert 5 yd to cm.
50. Convert 8 yd to cm.
51. Convert 762 cm to yd.
52. Convert 1016 cm to yd.

In Exercises 53–54, use the unit fractions
\[ \frac{5280 \text{ ft}}{1 \text{ mi}}, \frac{12 \text{ in.}}{1 \text{ ft}}, \text{ and } \frac{2.54 \text{ cm}}{1 \text{ in.}} \]
53. Convert 30 mi to km.
54. Convert 50 mi to km.
55. Use unit fractions to express 120 miles per hour in feet per second.
56. Use unit fractions to express 100 miles per hour in feet per second.

Application Exercises
In Exercises 57–66, selecting from millimeter, meter, and kilometer, determine the best unit of measure to express the given length.
57. A person's height
58. The length of a football field
59. The length of a bee
60. The distance from New York City to Washington, D.C.
61. The distance around a one-acre lot
62. The length of a car
63. The width of a book
64. The altitude of an airplane
65. The diameter of a screw
66. The width of a human foot

In Exercises 67–74, select the best estimate for the measure of the given item.
67. The length of a pen
   a. 30 cm   b. 19 cm   c. 19 mm
68. The length of this page
   a. 2.5 mm   b. 25 mm   c. 250 mm
69. The height of a skyscraper
   a. 325 m   b. 32.5 km   c. 325 km   d. 3250 km

70. The length of a pair of pants
   a. 700 cm   b. 70 cm   c. 7 cm
71. The height of a room
   a. 4 mm   b. 4 cm   c. 4 m   d. 4 dm
72. The length of a rowboat
   a. 4 cm   b. 4 dm   c. 4 m   d. 4 dam
73. The width of an electric cord
   a. 4 mm   b. 4 cm   c. 4 dm   d. 4 m
74. The dimensions of a piece of typing paper
   a. 22 mm by 28 mm   b. 22 cm by 28 cm
   c. 22 dm by 28 cm   d. 22 m by 28 m
75. A baseball diamond measures 27 meters along each side. If a batter scored two home runs in a game, how many kilometers did the batter run?
76. If you jog six times around a track that is 700 meters long, how many kilometers have you covered?
77. The distance from the Earth to the sun is about 93 million miles. What is this distance in kilometers?
78. The distance from New York City to Los Angeles is 4690 kilometers. What is the distance in miles?

Exercises 79–80 give the approximate length of some of the world's longest rivers. In each exercise, determine which is the longer river and by how many kilometers.
79. Nile: 4130 miles; Amazon: 6400 kilometers
80. Yangtze: 3940 miles; Mississippi: 6275 kilometers

Exercises 81–82 give the approximate height of some of the world's tallest mountains. In each exercise, determine which is the taller mountain and by how many meters. Round to the nearest meter.
81. K2: 8611 meters; Everest: 29,035 feet
82. Lhotse: 8516 meters; Kangchenjunga: 28,170 feet

Exercises 83–84 give the average rainfall of some of the world's wettest places. In each exercise, determine which location has the greater average rainfall and by how many inches. Round to the nearest inch.
83. Debundscha (Cameroon): 10,280 millimeters; Waialeale (Hawaii): 451 inches
84. Mawsyaram (India): 11,870 millimeters; Cherrapunji (India): 498 inches
(Source for Exercises 79–84: Russell Ash, The Top 10 of Everything 2009)

Writing in Mathematics
85. Describe the two parts of a measurement.
86. Describe how to use dimensional analysis to convert 20 inches to feet.
87. Describe advantages of the metric system over the English system.
88. Explain how to change units within the metric system.
89. You jog 500 meters in a given period of time. The next day, you jog 500 yards over the same time period. On which day was your speed faster? Explain your answer.
90. What kind of difficulties might arise if the United States immediately eliminated all units of measure in the English system and replaced the system by the metric system?
91. The United States is the only Westernized country that does not use the metric system as its primary system of measurement. What reasons might be given for continuing to use the English system?

Critical Thinking Exercises

Make Sense? In Exercises 92–95, determine whether each statement makes sense or does not make sense, and explain your reasoning.

92. I can run 4000 meters in approximately one hour.
93. I ran 2000 meters and you ran 2000 yards in the same time, so I ran at a faster rate.
94. The most frequent use of dimensional analysis involves changing units within the metric system.
95. When multiplying by a unit fraction, I put the unit of measure that needs to be introduced in the denominator.

In Exercises 96–100, convert to an appropriate metric unit so that the numerical expression in the given measure does not contain any zeros.

96. 6000 cm
97. 900 m
98. 7000 dm
99. 11,000 mm
100. 0.0002 km

SECTION 9.2 Measuring Area and Volume

OBJECTIVES

1. Use square units to measure area.
2. Use dimensional analysis to change units for area.
3. Use cubic units to measure volume.
4. Use English and metric units to measure capacity.

9.2 Measuring Area and Volume

Are you feeling a bit crowded in? Although there are more people on the East Coast of the United States than there are bears, there are places in the Northwest where bears outnumber humans. The most densely populated state is New Jersey, averaging 1171.1 people per square mile. The least densely populated state is Alaska, averaging 1.2 persons per square mile.

A square mile is one way of measuring the area of a state. A state’s area is the region within its boundaries. Its population density is its population divided by its area. In this section, we discuss methods for measuring both area and volume.

Measuring Area

In order to measure a region that is enclosed by boundaries, we begin by selecting a square unit. A square unit is a square, each of whose sides is one unit in length, illustrated in Figure 9.2. The region in Figure 9.2 is said to have an area of one square unit. The side of the square can be 1 inch, 1 centimeter, 1 meter, 1 foot, or one of any linear unit of measure. The corresponding units of area are the square inch (in.²), the square centimeter (cm²), the square meter (m²), the square foot (ft²), and so on. Figure 9.3 illustrates 1 square inch and 1 square centimeter, drawn to actual size.

1 square inch, symbolized 1 in.²
1 cm
1 square centimeter, symbolized 1 cm²