Measurement

SECTION V.1
American Units of Measurement

Two common systems of measurement are the American (or English) system and the metric system. We will discuss American units of measurement in this section and metric units in the next. Some common American units are inches, feet, miles, ounces, pounds, tons, cups, pints, quarts, and gallons. These units are used when measuring length, weight, and capacity.

1 Use a ruler to measure lengths in inches.

A ruler is one of the most common tools used for measuring distances or lengths. The figure below shows part of a ruler. Most rulers are 12 inches (1 foot) long. Since 12 inches = 1 foot, a ruler is divided into 12 equal lengths of 1 inch. Each inch is divided into halves of an inch, quarters of an inch, eighths of an inch, and sixteenths of an inch.

The left end of a ruler can be (but sometimes isn’t) labeled with a 0. Each point on a ruler, like each point on a number line, has a number associated with it. That number is the distance between the point and 0. Several lengths on the ruler are shown below.

**EXAMPLE 1** Find the length of the paper clip shown here.

**Strategy** We will place a ruler below the paper clip, with the left end of the ruler (which could be thought of as 0) directly underneath one end of the paper clip.

**WHY** Then we can find the length of the paper clip by identifying where its other end lines up on the tick marks printed in black on the ruler.
Define American units of length.

The American system of measurement uses the units of inch, foot, yard, and mile to measure length. These units are related in the following ways.

**American Units of Length**

<table>
<thead>
<tr>
<th>Unit</th>
<th>Relationship</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 foot (ft)</td>
<td>= 12 inches (in.)</td>
</tr>
<tr>
<td>1 yard (yd)</td>
<td>= 3 feet</td>
</tr>
<tr>
<td>1 mile (mi)</td>
<td>= 5,280 feet</td>
</tr>
</tbody>
</table>

The abbreviation for each unit is written within parentheses.

The Language of Mathematics  According to some sources, the inch was originally defined as the length from the tip of the thumb to the first knuckle. In some languages the word for *inch* is similar to or the same as *thumb*. For example, in Spanish, *pulgada* is inch and *pulgar* is thumb. In Swedish, *tum* is inch and *tumme* is thumb. In Italian, *pollice* is both inch and thumb.
Convert from one American unit of length to another.

To convert from one unit of length to another, we use unit conversion factors. To find the unit conversion factor between yards and feet, we begin with this fact:

\[ 3 \text{ ft} = 1 \text{ yd} \]

If we divide both sides of this equation by 1 yard, we get

\[ \frac{3 \text{ ft}}{1 \text{ yd}} = 1 \]

Simplify the right side of the equation. A number divided by itself is 1: \( \frac{1 \text{ yd}}{1 \text{ yd}} = 1 \).

The fraction \( \frac{3 \text{ ft}}{1 \text{ yd}} \) is called a unit conversion factor, because its value is 1. It can be read as “3 feet per yard.” Since this fraction is equal to 1, multiplying a length by this fraction does not change its measure; it changes only the units of measure.

To convert units of length in the American system of measurement, we use the following unit conversion factors. Each conversion factor shown below is a form of 1.

<table>
<thead>
<tr>
<th>To convert from</th>
<th>Use the unit conversion factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>feet to inches</td>
<td>( \frac{12 \text{ in.}}{1 \text{ ft}} )</td>
</tr>
<tr>
<td>yards to feet</td>
<td>( \frac{3 \text{ ft}}{1 \text{ yd}} )</td>
</tr>
<tr>
<td>yards to inches</td>
<td>( \frac{36 \text{ in.}}{1 \text{ yd}} )</td>
</tr>
<tr>
<td>miles to feet</td>
<td>( \frac{5,280 \text{ ft}}{1 \text{ mi}} )</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>To convert from</th>
<th>Use the unit conversion factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>inches to feet</td>
<td>( \frac{1 \text{ ft}}{12 \text{ in.}} )</td>
</tr>
<tr>
<td>feet to yards</td>
<td>( \frac{1 \text{ yd}}{3 \text{ ft}} )</td>
</tr>
<tr>
<td>inches to yards</td>
<td>( \frac{1 \text{ yd}}{36 \text{ in.}} )</td>
</tr>
<tr>
<td>feet to miles</td>
<td>( \frac{1 \text{ mi}}{5,280 \text{ ft}} )</td>
</tr>
</tbody>
</table>

**EXAMPLE 3** Convert 8 yards to feet.

**Strategy** We will multiply 8 yards by a carefully chosen unit conversion factor.

**WHY** If we multiply by the proper unit conversion factor, we can eliminate the unwanted units of yards and convert to feet.

**Solution**

To convert from yards to feet, we must use a unit conversion factor that relates feet to yards. Since there are 3 feet per yard, we multiply 8 yards by the unit conversion factor \( \frac{3 \text{ ft}}{1 \text{ yd}} \).

\[
8 \text{ yd} = \frac{8 \text{ yd}}{1 \text{ yd}} \cdot \frac{3 \text{ ft}}{1 \text{ yd}} = 8 \text{ yd} \cdot \frac{3 \text{ ft}}{1 \text{ yd}} = \frac{8 \cdot 3 \text{ ft}}{1} = 24 \text{ ft}
\]

8 yards is equal to 24 feet.

**Success Tip** Notice that in Example 3, we eliminated the units of yards and introduced the units of feet by multiplying by the appropriate unit conversion factor. In general, a unit conversion factor is a fraction with the following form:

\[
\frac{\text{Unit we want to introduce}}{\text{Unit we want to eliminate}}
\]
EXAMPLE 4

Convert $\frac{3}{4}$ feet to inches.

**Strategy** We will multiply $\frac{3}{4}$ feet by a carefully chosen unit conversion factor.

**WHY** If we multiply by the proper unit conversion factor, we can eliminate the unwanted units of feet and convert to inches.

**Solution**

To convert from feet to inches, we must choose a unit conversion factor whose numerator contains the units we want to introduce (inches), and whose denominator contains the units we want to eliminate (feet). Since there are 12 inches per foot, we will use

\[
\frac{12 \text{ in.}}{1 \text{ ft}}
\]

This is the unit we want to introduce.

This is the unit we want to eliminate (the original unit).

To perform the conversion, we multiply.

\[
\frac{\frac{3}{4} \text{ ft}}{1 \text{ ft}} = \frac{7 \text{ ft}}{4} \cdot \frac{12 \text{ in.}}{1 \text{ ft}}
\]

Write $\frac{12}{4}$ as an improper fraction: $\frac{12}{4} = \frac{7}{2}$.

Then multiply by a form of $\frac{1}{1 \text{ ft}}$.

Remove the common units of feet from the numerator and denominator. Notice that the units of inches remain.

\[
= \frac{7 \cdot 12}{4 \cdot 1} \text{ in.}
\]

Multiply the fractions.

\[
= \frac{7 \cdot 3 \cdot 1}{4 \cdot 1} \text{ in.}
\]

To simplify the fraction, factor 12. Then remove the common factor of 4 from the numerator and denominator.

\[
= \frac{7 \cdot 3}{4 \cdot 1} \text{ in.}
\]

Simplify.

\[
= 21 \text{ in.}
\]

$1\frac{3}{4}$ feet is equal to 21 inches.

**Caution!** When converting lengths, if no common units appear in the numerator and denominator to remove, you have chosen the wrong conversion factor.

Sometimes we must use two (or more) unit conversion factors to eliminate the given units while introducing the desired units. The following example illustrates this concept.

EXAMPLE 5

**Football** A football field (including both end zones) is 120 yards long. Convert this length to miles. Give the exact answer and a decimal approximation, rounded to the nearest hundredth of a mile.

Self Check 5

MARATHONS The marathon is a long-distance race with an official distance of 26 miles 385 yards. Convert 385 yards to miles. Give the exact answer and a decimal approximation, rounded to the nearest hundredth of a mile.

Now Try Problem 43
Define American units of weight.

The American system of measurement uses the units of ounce, pound, and ton to measure weight. These units are related in the following ways.

**American Units of Weight**

1 pound (lb) = 16 ounces (oz)  
1 ton (T) = 2,000 pounds

The abbreviation for each unit is written within parentheses.

Convert from one American unit of weight to another.

To convert units of weight in the American system of measurement, we use the following unit conversion factors. Each conversion factor shown below is a form of 1.

<table>
<thead>
<tr>
<th>To convert from</th>
<th>Use the unit conversion factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>pounds to ounces</td>
<td>16 oz</td>
</tr>
<tr>
<td>tons to pounds</td>
<td>1 ton</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>To convert from</th>
<th>Use the unit conversion factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>ounces to pounds</td>
<td>1 lb</td>
</tr>
<tr>
<td>pounds to tons</td>
<td>1 ton</td>
</tr>
</tbody>
</table>

A football field (including the end zones) is exactly \( \frac{3}{11} \) miles long.

We can also present this conversion as a decimal. If we divide 3 by 44 (as shown on the right), and round the result to the nearest hundredth, we see that a football field (including the end zones) is approximately 0.07 mile long.
Self Check 6
Convert 60 ounces to pounds.

Now Try Problem 47

EXAMPLE 6
Convert 40 ounces to pounds.

Strategy
We will multiply 40 ounces by a carefully chosen unit conversion factor.

**WHY** If we multiply by the proper unit conversion factor, we can eliminate the unwanted units of ounces and convert to pounds.

Solution
To convert from ounces to pounds, we must choose a unit conversion factor whose numerator contains the units we want to introduce (pounds), and whose denominator contains the units we want to eliminate (ounces). Since there is 1 pound for every 16 ounces, we will use

\[
\frac{1 \text{ lb}}{16 \text{ oz}} \quad \text{This is the unit we want to introduce.}
\]

\[
\frac{1 \text{ lb}}{16 \text{ oz}} \quad \text{This is the unit we want to eliminate (the original unit).}
\]

To perform the conversion, we multiply.

\[
40 \text{ oz} = \frac{40 \text{ oz}}{1} \times \frac{1 \text{ lb}}{16 \text{ oz}}
\]

\[
= \frac{40 \text{ oz}}{1} \times \frac{1 \text{ lb}}{16 \text{ oz}}
\]

Remove the common units of ounces from the numerator and denominator. Notice that the units of pounds remain.

\[
= \frac{40 \text{ lb}}{16}
\]

Multiply the fractions.

There are two ways to complete the solution. First, we can remove any common factors of the numerator and denominator to simplify the fraction. Then we can write the result as a mixed number.

\[
\frac{40}{16} \text{ lb} = 2 \frac{1}{2} \text{ lb}
\]

A second approach is to divide the numerator by the denominator and express the result as a decimal.

\[
\frac{40 \text{ lb}}{16} = 2.5 \text{ lb}
\]

Perform the division: 40 ÷ 16.

40 ounces is equal to 2 1/2 lb (or 2.5 lb).

Self Check 7
Convert 60 pounds to ounces.

Now Try Problem 51

EXAMPLE 7
Convert 25 pounds to ounces.

Strategy
We will multiply 25 pounds by a carefully chosen unit conversion factor.

**WHY** If we multiply by the proper unit conversion factor, we can eliminate the unwanted units of pounds and convert to ounces.

Solution
To convert from pounds to ounces, we must choose a unit conversion factor whose numerator contains the units we want to introduce (ounces), and whose denominator contains the units we want to eliminate (pounds). Since there are 16 ounces per pound, we will use

\[
\frac{16 \text{ oz}}{1 \text{ lb}} \quad \text{This is the unit we want to introduce.}
\]

\[
\frac{1 \text{ lb}}{} \quad \text{This is the unit we want to eliminate (the original unit).}
\]

To perform the conversion, we multiply.

\[
25 \text{ lb} = \frac{25 \text{ lb}}{1} \cdot \frac{16 \text{ oz}}{1 \text{ lb}} \quad \text{Write 25 lb as a fraction: } 25 \text{ lb} = \frac{25 \text{ lb}}{1}.
\]

\[
= \frac{25}{1} \cdot \frac{16 \text{ oz}}{1} \quad \text{Remove the common units of pounds from the numerator and denominator. Notice that the units of ounces remain.}
\]

\[
= 25 \cdot 16 \text{ oz} \quad \text{Simplify.}
\]

\[
= 400 \text{ oz} \quad \text{Multiply: } 25 \cdot 16 = 400.
\]

25 pounds is equal to 400 ounces.

6 Define American units of capacity.

The American system of measurement uses the units of ounce, cup, pint, quart, and gallon to measure capacity. These units are related as follows.

The Language of Mathematics

The word capacity means the amount that can be contained. For example, a gas tank might have a capacity of 12 gallons.

American Units of Capacity

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1 cup (c)</td>
<td>8 fluid ounces (fl oz)</td>
<td>1 pint (pt) = 2 cups</td>
</tr>
<tr>
<td>1 quart (qt)</td>
<td>2 pints</td>
<td>1 gallon (gal) = 4 quarts</td>
</tr>
</tbody>
</table>

The abbreviation for each unit is written within parentheses.

7 Convert from one American unit of capacity to another.

To convert units of capacity in the American system of measurement, we use the following unit conversion factors. Each conversion factor shown below is a form of 1.

<table>
<thead>
<tr>
<th>To convert from</th>
<th>Use the unit conversion factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>cups to ounces</td>
<td>(\frac{8 \text{ fl oz}}{1 \text{ c}})</td>
</tr>
<tr>
<td>pints to cups</td>
<td>(\frac{2 \text{ c}}{1 \text{ pt}})</td>
</tr>
<tr>
<td>quarts to pints</td>
<td>(\frac{2 \text{ pt}}{1 \text{ qt}})</td>
</tr>
<tr>
<td>gallons to quarts</td>
<td>(\frac{4 \text{ qt}}{1 \text{ gal}})</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>To convert from</th>
<th>Use the unit conversion factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>ounces to cups</td>
<td>(\frac{1 \text{ c}}{8 \text{ fl oz}})</td>
</tr>
<tr>
<td>cups to pints</td>
<td>(\frac{1 \text{ pt}}{2 \text{ c}})</td>
</tr>
<tr>
<td>pints to quarts</td>
<td>(\frac{1 \text{ qt}}{2 \text{ pt}})</td>
</tr>
<tr>
<td>quarts to gallons</td>
<td>(\frac{1 \text{ gal}}{4 \text{ qt}})</td>
</tr>
</tbody>
</table>
Define units of time.

The American system of measurement (and the metric system) uses the units of second, minute, hour, and day to measure time. These units are related as follows.

### Units of Time

- 1 minute (min) = 60 seconds (sec)  
- 1 hour (hr) = 60 minutes  
- 1 day = 24 hours

The abbreviation for each unit is written within parentheses.

To convert units of time, we use the following unit conversion factors. Each conversion factor shown below is a form of 1.

<table>
<thead>
<tr>
<th>To convert from</th>
<th>Use the unit conversion factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>minutes to seconds</td>
<td>$\frac{60 \text{ sec}}{1 \text{ min}}$</td>
</tr>
<tr>
<td>hours to minutes</td>
<td>$\frac{60 \text{ min}}{1 \text{ hr}}$</td>
</tr>
<tr>
<td>days to hours</td>
<td>$\frac{24 \text{ hr}}{1 \text{ day}}$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>To convert from</th>
<th>Use the unit conversion factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>seconds to minutes</td>
<td>$\frac{1 \text{ min}}{60 \text{ sec}}$</td>
</tr>
<tr>
<td>minutes to hours</td>
<td>$\frac{1 \text{ hr}}{60 \text{ min}}$</td>
</tr>
<tr>
<td>hours to days</td>
<td>$\frac{1 \text{ day}}{24 \text{ hr}}$</td>
</tr>
</tbody>
</table>
**EXAMPLE 9 Astronomy** A lunar eclipse occurs when the Earth is between the sun and the moon in such a way that Earth’s shadow darkens the moon. (See the figure below, which is not to scale.) A total lunar eclipse can last as long as 105 minutes. Express this time in hours.

**Strategy** We will multiply 105 minutes by a carefully chosen unit conversion factor.

**WHY** If we multiply by the proper unit conversion factor, we can eliminate the unwanted units of minutes and convert to hours.

**Solution** To convert from minutes to hours, we must choose a unit conversion factor whose numerator contains the units we want to introduce (hours), and whose denominator contains the units we want to eliminate (minutes). Since there is 1 hour for every 60 minutes, we will use

\[
\frac{1 \text{ hr}}{60 \text{ min}}
\]

To perform the conversion, we multiply.

\[
105 \text{ min} = \frac{105 \text{ min}}{1} \cdot \frac{1 \text{ hr}}{60 \text{ min}} = \frac{105}{60} \text{ hr}
\]

\[
= \frac{105}{60} \cdot \frac{1}{1} = \frac{1}{60} \cdot \frac{1}{1} = \frac{7}{4} \text{ hr}
\]

A total lunar eclipse can last as long as 1 hour and 3 minutes.

**Self Check 9**

**THE SUN** A solar eclipse (eclipse of the sun) can last as long as 450 seconds. Express this time in minutes.

**Now Try** Problem 59

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**ANswers to Self Checks**

1. 1\frac{1}{2} in. 2. 1\frac{3}{4} in. 3. 27 ft 4. 18 in. 5. \(\frac{7}{11}\) mi = 0.22 mi 6. 3\frac{1}{4} lb = 3.75 lb 7. 960 oz 8. 40 fl oz 9. 7\frac{1}{4} min
Appendix V Measurement

SECTION V.1 STUDY SET

VOCABULARY

Fill in the blanks.
1. A ruler is used for measuring ________.
2. Inches, feet, and miles are examples of American units of ________.
3. \(\frac{3\text{ ft}}{1\text{ yd}}, \frac{1\text{ ton}}{2,000\text{ lb}},\) and \(\frac{4\text{ qt}}{1\text{ gal}}\) are examples of ________ conversion factors.
4. Ounces, pounds, and tons are examples of American units of ________.
5. Some examples of American units of ________ are cups, pints, quarts, and gallons.
6. Some units of ________ are seconds, minutes, hours, and days.

CONCEPTS

Fill in the blanks.
7. a. 12 inches = ________ foot
    b. ________ feet = 1 yard
    c. 1 yard = ________ inches
    d. 1 mile = ________ feet
8. a. ________ ounces = 1 pound
    b. ________ pounds = 1 ton
9. a. 1 cup = ________ fluid ounces
    b. 1 pint = ________ cups
    c. 2 pints = ________ quart
    d. 4 quarts = ________ gallon
10. a. 1 day = ________ hours
    b. 2 hours = ________ minutes
11. The value of any unit conversion factor is ________.
12. In general, a unit conversion factor is a fraction with the following form:
    
    \[
    \frac{\text{Unit that we want to convert}}{\text{Unit that we want to remove}}
    \]

13. Consider the work shown below.
    \[
    \frac{48\text{ oz}}{1\text{ lb}} \cdot \frac{1\text{ lb}}{16\text{ oz}}
    \]
    a. What units can be removed?
    b. What units remain?
14. Consider the work shown below.
    \[
    \frac{600\text{ yd}}{1\text{ mi}} \cdot \frac{3\text{ ft}}{1\text{ yd}} \cdot \frac{1\text{ mi}}{5,280\text{ ft}}
    \]
    a. What units can be removed?
    b. What units remain?

15. Write a unit conversion factor to convert
    a. pounds to tons
    b. quarts to pints
16. Write the two unit conversion factors used to convert
    a. inches to yards
    b. days to minutes
17. Match each item with its proper measurement.
    a. Length of the U.S. coastline
    b. Height of a Barbie doll
    c. Span of the Golden Gate Bridge
    d. Width of a football field

18. Match each item with its proper measurement.
    a. Weight of the men's shot put used in track and field
    b. Weight of an African elephant
    c. Amount of gold that is worth $500
19. Match each item with its proper measurement.
    a. Amount of blood in an adult
    b. Size of the Exxon Valdez oil spill in 1989
    c. Amount of nail polish in a bottle
    d. Amount of flour to make 3 dozen cookies
20. Match each item with its proper measurement.
    a. Length of first U.S. manned space flight
    b. A leap year
    c. Time difference between New York and Fairbanks, Alaska
    d. Length of Wright Brothers' first flight
21. What unit does each abbreviation represent?
   a. lb
   b. oz
   c. fl oz

22. What unit does each abbreviation represent?
   a. qt
   b. c
   c. pt

Complete each solution.

23. Convert 2 yards to inches.
   \[ 2 \text{ yd} = \frac{2 \text{ yd}}{1 \text{ yd}} \cdot \frac{36 \text{ in.}}{1 \text{ yd}} = 2 \times 36 \text{ in.} = 72 \text{ in.} \]

24. Convert 24 pints to quarts.
   \[ 24 \text{ pt} = \frac{24 \text{ pt}}{1 \text{ pt}} \cdot \frac{1 \text{ qt}}{1 \text{ pt}} = 24 \times \frac{1}{1} \text{ qt} = 24 \text{ qt} \]

25. Convert 1 ton to ounces.
   \[ 1 \text{ ton} = \frac{1 \text{ ton}}{1 \text{ ton}} \cdot \frac{2,000 \text{ lb}}{1 \text{ lb}} \cdot \frac{16 \text{ oz}}{1 \text{ lb}} = 1 \times 2,000 \times 16 \text{ oz} = 32,000 \text{ oz} \]

26. Convert 37,440 minutes to days.
   \[ 37,440 \text{ min} = \frac{37,440 \text{ min}}{1 \text{ min}} \cdot \frac{1 \text{ hr}}{60 \text{ min}} \cdot \frac{1 \text{ day}}{24 \text{ hr}} = \frac{37,440}{60 \times 24} \text{ days} \]

Refer to the given ruler to answer each question. See Example 2.

29. a. Each inch is divided into how many equal parts?
   b. Determine which measurements the arrows point to on the ruler.

30. Find the length of the bolt.

Use a ruler scaled in sixteenths of an inch to measure each object. See Example 2.

31. The width of a dollar bill
32. The length of a dollar bill
33. The length (top to bottom) of this page
34. The length of the word as printed here: supercalifragilisticexpialidocious

Perform each conversion. See Example 3.

35. 4 yards to feet
36. 6 yards to feet
37. 35 yards to feet
38. 33 yards to feet

Perform each conversion. See Example 4.

39. \(3\frac{1}{2}\) feet to inches
40. \(2\frac{2}{3}\) feet to inches
41. \(5\frac{1}{4}\) feet to inches
42. \(6\frac{1}{2}\) feet to inches
Use two unit conversion factors to perform each conversion. Give the exact answer and a decimal approximation, rounded to the nearest hundredth, when necessary. See Example 5.

43.  105 yards to miles
44.  198 yards to miles
45.  1,540 yards to miles
46.  1,512 yards to miles

Perform each conversion. See Example 6.
47.  Convert 44 ounces to pounds.
48.  Convert 24 ounces to pounds.
49.  Convert 72 ounces to pounds.
50.  Convert 76 ounces to pounds.

Perform each conversion. See Example 7.
51.  50 pounds to ounces
52.  30 pounds to ounces
53.  87 pounds to ounces
54.  79 pounds to ounces

Perform each conversion. See Example 8.
55.  8 pints to fluid ounces
56.  5 pints to fluid ounces
57.  21 pints to fluid ounces
58.  30 pints to fluid ounces

Perform each conversion. See Example 9.
59.  165 minutes to hours
60.  195 minutes to hours
61.  330 minutes to hours
62.  80 minutes to hours

Try It Yourself
63.  3 quarts to pints
64.  20 quarts to gallons
65.  7,200 minutes to days
66.  691,200 seconds to days
67.  56 inches to feet
68.  44 inches to feet
69.  4 feet to inches
70.  7 feet to inches
71.  16 pints to gallons
72.  3 gallons to fluid ounces
73.  80 ounces to pounds
74.  8 pounds to ounces
75.  240 minutes to hours
76.  2,400 seconds to hours
77.  8 yards to inches
78.  324 inches to yards
79.  90 inches to yards
80.  12 yards to inches
81.  5 yards to feet
82.  21 feet to yards
83.  12.4 tons to pounds
84.  48,000 ounces to tons
85.  7 feet to yards
86.  $\frac{3}{2}$ yards to feet
87.  15,840 feet to miles
88.  2 miles to feet
89.  $\frac{1}{2}$ mile to feet
90.  1,320 feet to miles
91.  7,000 pounds to tons
92.  2.5 tons to ounces
93.  32 fluid ounces to pints
94.  2 quarts to fluid ounces

Applications
95.  THE GREAT PYRAMID The Great Pyramid in Egypt is about 450 feet high. Express this distance in yards.
96.  THE WRIGHT BROTHERS In 1903, Orville Wright made the world's first sustained flight. It lasted 12 seconds, and the plane traveled 120 feet. Express the length of the flight in yards.
97. THE GREAT SPHINX  The Great Sphinx of Egypt is 240 feet long. Express this in inches.

98. HOOVER DAM  The Hoover Dam in Nevada is 726 feet high. Express this distance in inches.

99. THE SEARS TOWER  The Sears Tower in Chicago has 110 stories and is 1,454 feet tall. To the nearest hundredth, express this height in miles.

100. NFL RECORDS  Emmitt Smith, the former Dallas Cowboys and Arizona Cardinals running back, holds the National Football League record for yards rushing in a career: 18,355. How many miles is this? Round to the nearest tenth of a mile.

101. NFL RECORDS  When Dan Marino of the Miami Dolphins retired, it was noted that Marino’s career passing total was nearly 35 miles! How many yards is this?

102. LEWIS AND CLARK  The trail traveled by the Lewis and Clark expedition is shown below. When the expedition reached the Pacific Ocean, Clark estimated that they had traveled 4,162 miles. (It was later determined that his guess was within 40 miles of the actual distance.) Express Clark’s estimate of the distance in feet.

103. WEIGHT OF WATER  One gallon of water weighs about 8 pounds. Express this weight in ounces.

104. WEIGHT OF A BABY  A newborn baby boy weighed 136 ounces. Express this weight in pounds.

105. HIPPOS  An adult hippopotamus can weigh as much as 9,900 pounds. Express this weight in tons.

106. ELEPHANTS  An adult elephant can consume as much as 495 pounds of grass and leaves in one day. How many ounces is this?

107. BUYING PAINT  A painter estimates that he will need 17 gallons of paint for a job. To take advantage of a closeout sale on quart cans, he decides to buy the paint in quarts. How many cans will he need to buy?

108. CATERING  How many cups of apple cider are there in a 10-gallon container of cider?

109. SCHOOL LUNCHES  Each student attending Eagle River Elementary School receives 1 pint of milk for lunch each day. If 575 students attend the school, how many gallons of milk are used each day?

110. RADIATORS  The radiator capacity of a piece of earth-moving equipment is 39 quarts. If the radiator is drained and new coolant put in, how many gallons of new coolant will be used?

111. CAMPING  How many ounces of camping stove fuel will fit in the container shown?

112. HIKING  A college student walks 11 miles in 155 minutes. To the nearest tenth, how many hours does he walk?

113. SPACE TRAVEL  The astronauts of the Apollo 8 mission, which was launched on December 21, 1968, were in space for 147 hours. How many days did the mission take?

114. AMELIA EARHART  In 1935, Amelia Earhart became the first woman to fly across the Atlantic Ocean alone, establishing a new record for the crossing: 13 hours and 30 minutes. How many minutes is this?

115. a. Explain how to find the unit conversion factor that will convert feet to inches.
   b. Explain how to find the unit conversion factor that will convert pints to gallons.

116. Explain why the unit conversion factor \( \frac{1 \text{ lb}}{16 \text{ oz}} \) is a form of 1.

117. Round 3,673.263 to the
   a. nearest hundred
   b. nearest ten
   c. nearest hundredth
   d. nearest tenth

118. Round 0.100602 to the
   a. nearest thousandth
   b. nearest hundredth
   c. nearest tenth
   d. nearest one
## SECTION V.2

### Metric Units of Measurement

The metric system is the system of measurement used by most countries in the world. All countries, including the United States, use it for scientific purposes. The metric system, like our decimal numeration system, is based on the number 10. For this reason, converting from one metric unit to another is easier than with the American system.

**1 Define metric units of length.**

The basic metric unit of length is the **meter** (m). One meter is approximately 39 inches, which is slightly more than 1 yard. The figure below compares the length of a yardstick to a meterstick.

- **1 yard:** 36 inches
- **1 meter:** about 39 inches

Longer and shorter metric units of length are created by adding **prefixes** to the front of the basic unit, **meter**.

- **kilo** means thousands
- **hecto** means hundreds
- **deka** means tens
- **deci** means tenths
- **centi** means hundredths
- **milli** means thousandths

### Metric Units of Length

<table>
<thead>
<tr>
<th>Prefix</th>
<th>kilometer</th>
<th>hectometer</th>
<th>dekameter</th>
<th>meter</th>
<th>decimeter</th>
<th>centimeter</th>
<th>millimeter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meaning</td>
<td>1,000 meters</td>
<td>100 meters</td>
<td>10 meters</td>
<td>1 meter</td>
<td>1 m or 0.1 m</td>
<td>1 mm or 0.01 m</td>
<td>1 mm or 0.001 m</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>km</td>
<td>hm</td>
<td>dam</td>
<td>m</td>
<td>dm</td>
<td>cm</td>
<td>mm</td>
</tr>
</tbody>
</table>

**The Language of Mathematics** It is helpful to memorize the prefixes listed above because they are also used with metric units of weight and capacity.

The most often used metric units of length are kilometers, meters, centimeters, and millimeters. It is important that you gain a practical understanding of metric lengths just as you have for the length of an inch, a foot, and a mile. Some examples of metric lengths are shown below.

- **1 kilometer** is about the length of 60 train cars.
- **1 meter** is about the distance from a doorknob to the floor.
- **1 centimeter** is about as wide as the nail on your little finger.
- **1 millimeter** is about the thickness of a dime.
2 Use a metric ruler to measure lengths.
Parts of a metric ruler, scaled in centimeters, and a ruler scaled in inches are shown below. Several lengths on the metric ruler are highlighted.

![Metric Ruler Diagram]

**EXAMPLE 1** Find the length of the nail shown below.

**Strategy** We will place a metric ruler below the nail, with the left end of the ruler (which could be thought of as 0) directly underneath the head of the nail.

**WHY** Then we can find the length of the nail by identifying where its pointed end lines up on the tick marks printed in black on the ruler.

**Solution** The longest tick marks on the ruler (those labeled with numbers) mark lengths in centimeters. Since the pointed end of the nail lines up on 6, the nail is 6 centimeters long.

**Self Check 1**
To the nearest centimeter, find the width of the circle.

**Now Try** Problem 23

**EXAMPLE 2** Find the length of the paper clip shown below.

**Strategy** We will place a metric ruler below the paper clip, with the left end of the ruler (which could be thought of as 0) directly underneath one end of the paper clip.

**WHY** Then we can find the length of the paper clip by identifying where its other end lines up on the tick marks printed in black on the ruler.

**Self Check 2**
Find the length of the jumbo paper clip.

**Now Try** Problem 25
Use unit conversion factors to convert metric units of length.

Metric units of length are related as shown in the following table.

### Metric Units of Length

<table>
<thead>
<tr>
<th>Metric Unit</th>
<th>Relationship</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 kilometer (km)</td>
<td>1,000 meters</td>
</tr>
<tr>
<td>1 hectometer (hm)</td>
<td>100 meters</td>
</tr>
<tr>
<td>1 dekameter (dam)</td>
<td>10 meters</td>
</tr>
<tr>
<td>1 meter</td>
<td>10 decimeters (dm)</td>
</tr>
<tr>
<td></td>
<td>100 centimeters (cm)</td>
</tr>
<tr>
<td></td>
<td>1,000 millimeters (mm)</td>
</tr>
</tbody>
</table>

The abbreviation for each unit is written within parentheses.

We can use the information in the table to write unit conversion factors that can be used to convert metric units of length. For example, in the table we see that

\[
\frac{1 \text{ m}}{100 \text{ cm}} = 1 \quad \text{and} \quad \frac{100 \text{ cm}}{1 \text{ m}} = 1
\]

One advantage of the metric system is that multiplying or dividing by a unit conversion factor involves multiplying or dividing by a power of 10.

**Self Check 3**

Convert 860 centimeters to meters.

**Now Try** Problem 31

**EXAMPLE 3**

Convert 350 centimeters to meters.

**Strategy** We will multiply 350 centimeters by a carefully chosen unit conversion factor.

**WHY** If we multiply by the proper unit conversion factor, we can eliminate the unwanted units of centimeters and convert to meters.

**Solution**

To convert from centimeters to meters, we must choose a unit conversion factor whose numerator contains the units we want to introduce (meters), and whose denominator contains the units we want to eliminate (centimeters). Since there is 1 meter for every 100 centimeters, we will use

\[
\frac{1 \text{ m}}{100 \text{ cm}}
\]

This is the unit we want to introduce.

\[
\frac{100 \text{ cm}}{1 \text{ m}}
\]

This is the unit we want to eliminate (the original unit).
To perform the conversion, we multiply 350 centimeters by the unit conversion factor \( \frac{1 \text{ m}}{100 \text{ cm}} \).

\[
350 \text{ cm} = \frac{350 \text{ cm}}{1} \times \frac{1 \text{ m}}{100 \text{ cm}}
\]

Write 350 cm as a fraction: \( 350 \text{ cm} = \frac{350 \text{ cm}}{1} \).

Multiply by a form of 1: \( \frac{1 \text{ m}}{100 \text{ cm}} \).

Remove the common units of centimeters from the numerator and denominator. Notice that the units of meter remain.

\[
= \frac{350 \text{ cm}}{1} \times \frac{1 \text{ m}}{100 \text{ cm}}
\]

Multiply the fractions.

\[
= \frac{350 \text{ cm}}{100 \text{ m}}
\]

Write the whole number 350 as a decimal by placing a decimal point immediately to its right and entering a zero: 350 = 350.0

\[
= \frac{350.0}{100 \text{ m}}
\]

Divide 350.0 by 100 by moving the decimal point 2 places to the left: 3.500.

Thus, 350 centimeters = 3.5 meters.

4 Use a conversion chart to convert metric units of length.

In Example 3, we converted 350 centimeters to meters using a unit conversion factor. We can also make this conversion by recognizing that all units of length in the metric system are powers of 10 of a meter.

To see this, review the table of metric units of length on page A-78. Note that each unit has a value that is \( \frac{1}{10} \) of the value of the unit immediately to its left and 10 times the value of the unit immediately to its right. Converting from one unit to another is as easy as multiplying (or dividing) by the correct power of 10 or, simply moving a decimal point the correct number of places to the right (or left). For example, in the conversion chart below, we see that to convert from centimeters to meters, we move 2 places to the left.

<table>
<thead>
<tr>
<th>largest unit</th>
<th>km</th>
<th>hm</th>
<th>dm</th>
<th>m</th>
<th>dm</th>
<th>cm</th>
<th>mm</th>
<th>smallest unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>To go from centimeters to meters, we must move 2 places to the left.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

If we write 350 centimeters as 350.0 centimeters, we can convert to meters by moving the decimal point 2 places to the left.

350.0 centimeters = 3,500 meters = 3.5 meters

Move 2 places to the left.

With the unit conversion factor method or the conversion chart method, we get 350 cm = 3.5 m.

Caution! When using a chart to help make a metric conversion, be sure to list the units from largest to smallest when reading from left to right.

EXAMPLE 4 Convert 2.4 meters to millimeters.

Strategy On a conversion chart, we will count the places and note the direction as we move from the original units of meters to the conversion units of millimeters.

WHY The decimal point in 2.4 must be moved the same number of places and in that same direction to find the conversion to millimeters.

Self Check 4 Convert 5.3 meters to millimeters.

Now Try Problem 35
Appendix V Measurement

Self Check 5
Convert 5.15 centimeters to kilometers.

Now Try Problem 39

Solution
To construct a conversion chart, we list the metric units of length from largest (kilometers) to smallest (millimeters), working from left to right. Then we locate the original units of meters and move to the conversion units of millimeters, as shown below.

<table>
<thead>
<tr>
<th>km</th>
<th>hm</th>
<th>dam</th>
<th>m</th>
<th>dm</th>
<th>cm</th>
<th>mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3 places to the right

We see that the decimal point in 2.4 should be moved 3 places to the right to convert from meters to millimeters.

2.4 meters = 2 400 millimeters = 2,400 millimeters

Move 3 places to the right.

We can use the unit conversion factor method to confirm this result. Since there are 1,000 millimeters per meter, we multiply 2.4 meters by the unit conversion factor $\frac{1,000 \text{ mm}}{1 \text{ m}}$.

$$2.4 \text{ m} = \frac{2.4 \text{ m}}{1} \times \frac{1,000 \text{ mm}}{1 \text{ m}}$$

Write 2.4 m as a fraction: $2.4 \text{ m} = \frac{2.4 \text{ m}}{1}$.

Multiply by a form $\frac{1,000 \text{ mm}}{1 \text{ m}}$.

Remove the common units of meters from the numerator and denominator. Notice that the units of millimeters remain.

$= \frac{2.4 \text{ m}}{1} \times \frac{1,000 \text{ mm}}{1 \text{ m}}$

$= 2.4 \times 1,000 \text{ mm}$

$= 2,400 \text{ mm}$

Move 3 places to the right: $2.4 \text{ m} = \frac{2.4 \text{ m}}{1} \times \frac{1,000 \text{ mm}}{1 \text{ m}}$

EXAMPLE 5
Convert 3.2 centimeters to kilometers.

Strategy On a conversion chart, we will count the places and note the direction as we move from the original units of centimeters to the conversion units of kilometers.

WHY The decimal point in 3.2 must be moved the same number of places and in that same direction to find the conversion to kilometers.

Solution
We locate the original units of centimeters on a conversion chart, and then move to the conversion units of kilometers, as shown below.

<table>
<thead>
<tr>
<th>km</th>
<th>hm</th>
<th>dam</th>
<th>m</th>
<th>dm</th>
<th>cm</th>
<th>mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5 places to the left

We see that the decimal point in 3.2 should be moved 5 places to the left to convert centimeters to kilometers.

3.2 centimeters = 0.000032 kilometers = 0.000032 kilometers

Move 5 places to the left.

We can use the unit conversion factor method to confirm this result. To convert to kilometers, we must use two unit conversion factors so that the units of centimeters drop out and the units of kilometers remain. Since there is 1 meter for
Define metric units of mass.

The mass of an object is a measure of the amount of material in the object. When an object is moved about in space, its mass does not change. One basic unit of mass in the metric system is the gram (g). A gram is defined to be the mass of water contained in a cube having sides 1 centimeter long. (See the figure below.)

Other units of mass are created by adding prefixes to the front of the basic unit, gram.

**Metric Units of Mass**

<table>
<thead>
<tr>
<th>Prefix</th>
<th>kilogram</th>
<th>hectogram</th>
<th>dekagram</th>
<th>gram</th>
<th>decigram</th>
<th>centigram</th>
<th>milligram</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meaning</td>
<td>1,000 grams</td>
<td>100 grams</td>
<td>10 grams</td>
<td>1 gram</td>
<td>1/10 of a gram</td>
<td>1/100 of a gram</td>
<td>1/1,000 of a gram</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>kg</td>
<td>hg</td>
<td>dag</td>
<td>g</td>
<td>dg</td>
<td>cg</td>
<td>mg</td>
</tr>
</tbody>
</table>

The most often used metric units of mass are kilograms, grams, and milligrams. Some examples are shown below.

- An average bowling ball weighs about 6 kilograms.
- A raisin weighs about 1 gram.
- A certain vitamin tablet contains 450 milligrams of calcium.
The weight of an object is determined by the Earth’s gravitational pull on the object. Since gravitational pull on an object decreases as the object gets farther from Earth, the object weighs less as it gets farther from Earth’s surface. This is why astronauts experience weightlessness in space. However, since most of us remain near Earth’s surface, we will use the words mass and weight interchangeably. Thus, a mass of 30 grams is said to weigh 30 grams.

Metric units of mass are related as shown in the following table.

<table>
<thead>
<tr>
<th>Metric Units of Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 kilogram (kg) = 1,000 grams</td>
</tr>
<tr>
<td>1 hectogram (hg) = 100 grams</td>
</tr>
<tr>
<td>1 dekagram (dag) = 10 grams</td>
</tr>
<tr>
<td>1 gram = 10 decigrams (dg)</td>
</tr>
<tr>
<td>1 gram = 100 centigrams (cg)</td>
</tr>
<tr>
<td>1 gram = 1,000 milligrams (mg)</td>
</tr>
<tr>
<td>The abbreviation for each unit is written within parentheses.</td>
</tr>
</tbody>
</table>

We can use the information in the table to write unit conversion factors that can be used to convert metric units of mass. For example, in the table we see that

\[
1 \text{ kilogram} = 1,000 \text{ grams}
\]

From this fact, we can write two unit conversion factors.

\[
\frac{1 \text{ kg}}{1,000 \text{ g}} = 1 \quad \text{and} \quad \frac{1,000 \text{ g}}{1 \text{ kg}} = 1
\]

To obtain the first unit conversion factor, divide both sides of the equation 1 kg = 1,000 g by 1,000 g. To obtain the second unit conversion factor, divide both sides by 1 kg.

6 Convert from one metric unit of mass to another.

**EXAMPLE 6** Convert 7.86 kilograms to grams.

**Strategy** On a conversion chart, we will count the places and note the direction as we move from the original units of kilograms to the conversion units of grams.

**WHY** The decimal point in 7.86 must be moved the same number of places and in that same direction to find the conversion to grams.

**Solution**

To construct a conversion chart, we list the metric units of mass from largest (kilograms) to smallest (milligrams), working from left to right. Then we locate the original units of kilograms and move to the conversion units of grams, as shown below.

\[
\begin{array}{ccccccc}
\text{largest unit} & \text{kg} & \text{hg} & \text{dag} & \text{g} & \text{dg} & \text{cg} & \text{mg} \\
\text{smallest unit} & & & & & & & \\
\end{array}
\]

We see that the decimal point in 7.86 should be moved 3 places to the right to change kilograms to grams.

\[
7.86 \text{ kilograms} = 7,860,000 \text{ grams} = 7,860 \text{ grams}
\]

Move 3 places to the right.
We can use the unit conversion factor method to confirm this result. To convert to grams, we must choose a unit conversion factor such that the units of kilograms drop out and the units of grams remain. Since there are 1,000 grams per 1 kilogram, we multiply 7.86 kilograms by $\frac{1,000\text{ g}}{1\text{ kg}}$.

$$7.86\text{ kg} = \frac{7.86\text{ kg}}{1} \cdot \frac{1,000\text{ g}}{1\text{ kg}}$$

Remove the common units of kilograms in the numerator and denominator. The units of g remain.

$$= 7.86 \cdot 1,000\text{ g}$$

Simplify.

$$= 7,860\text{ g}$$

Multiply 7.86 by 1,000 by moving the decimal point 3 places to the right.

Example 7  Medications  A bottle of Verapamil, a drug taken for high blood pressure, contains 30 tablets. If each tablet has 180 mg of active ingredient, how many grams of active ingredient are in the bottle?

Strategy  We will multiply the number of tablets in one bottle by the number of milligrams of active ingredient in each tablet.

WHY  We need to know the total number of milligrams of active ingredient in one bottle before we can convert that number to grams.

Solution  Since there are 30 tablets, and each one contains 180 mg of active ingredient, there are

$$30 \cdot 180\text{ mg} = 5,400\text{ mg} = 5,400.0\text{ mg}$$

of active ingredient in the bottle. To use a conversion chart to solve this problem, we locate the original units of milligrams and then move to the conversion units of grams, as shown below.

<table>
<thead>
<tr>
<th>kg</th>
<th>hg</th>
<th>dag</th>
<th>g</th>
<th>dg</th>
<th>cg</th>
<th>mg</th>
</tr>
</thead>
</table>

We see that the decimal point in 5,400.0 should be moved 3 places to the left to convert from milligrams to grams.

$$5,400\text{ milligrams} = 5,400\text{ grams}$$

Multiply the fractions.

There are 5.4 grams of active ingredient in the bottle.

We can use the unit conversion factor method to confirm this result. To convert milligrams to grams, we multiply 5,400 milligrams by $\frac{1\text{ g}}{1,000\text{ mg}}$.

$$5,400\text{ mg} = \frac{5,400\text{ mg}}{1} \cdot \frac{1\text{ g}}{1,000\text{ mg}}$$

Remove the common units of milligrams from the numerator and denominator. The units of g remain.

$$= \frac{5,400}{1,000}\text{ g}$$

Multiply the fractions.

$$= 5.4\text{ g}$$

Divide 5,400 by 1,000 by moving the understood decimal point in 5,400 three places to the left.

Self Check 7  Medications  A bottle of Isoptin (a drug taken for high blood pressure) contains 90 tablets, and each has 200 mg of active ingredient, how many grams of active ingredient are in the bottle?

Now Try  Problems 47 and 95
Define metric units of capacity.

In the metric system, one basic unit of capacity is the liter (L), which is defined to be the capacity of a cube with sides 10 centimeters long. Other units of capacity are created by adding prefixes to the front of the basic unit, liter.

<table>
<thead>
<tr>
<th>Prefix</th>
<th>kilo-litre</th>
<th>hecto-litre</th>
<th>deka-litre</th>
<th>liter</th>
<th>deci-litre</th>
<th>centi-litre</th>
<th>milli-litre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meaning</td>
<td>1,000 liters</td>
<td>100 liters</td>
<td>10 liters</td>
<td>1 liter</td>
<td>$\frac{1}{10}$ or 0.1 of a liter</td>
<td>$\frac{1}{100}$ or 0.01 of a liter</td>
<td>$\frac{1}{1,000}$ or 0.001 of a liter</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>kL</td>
<td>hL</td>
<td>daL</td>
<td>L</td>
<td>dL</td>
<td>cL</td>
<td>mL</td>
</tr>
</tbody>
</table>

The most often used metric units of capacity are liters and milliliters. Here are some examples.

Soft drinks are sold in 2-liter plastic bottles.

The fuel tank of a minivan can hold about 75 liters of gasoline.

A teaspoon holds about 5 milliliters.

Metric units of capacity are related as shown in the following table.

<table>
<thead>
<tr>
<th>Metric Units of Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 kilolitre (kL) = 1,000 liters</td>
</tr>
<tr>
<td>1 hectolitre (hL) = 100 liters</td>
</tr>
<tr>
<td>1 dekalitre (daL) = 10 liters</td>
</tr>
<tr>
<td>1 liter = 10 deciliters (dL)</td>
</tr>
<tr>
<td>1 liter = 100 centiliters (cL)</td>
</tr>
<tr>
<td>1 liter = 1,000 milliliters (mL)</td>
</tr>
</tbody>
</table>

The abbreviation for each unit is written within parentheses.

We can use the information in the table to write unit conversion factors that can be used to convert metric units of capacity. For example, in the table we see that

\[
1 \text{ liter} = 1,000 \text{ milliliters}
\]

From this fact, we can write two unit conversion factors.

\[
\frac{1 \text{ L}}{1,000 \text{ mL}} = 1 \quad \text{and} \quad \frac{1,000 \text{ mL}}{1 \text{ L}} = 1
\]
8 Convert from one metric unit of capacity to another.

**EXAMPLE 8 Soft Drinks** How many milliliters are in three 2-liter bottles of cola?

**Strategy** We will multiply the number of bottles of cola by the number of liters of cola in each bottle.

**WHY** We need to know the total number of liters of cola before we can convert that number to milliliters.

**Solution**

Since there are three bottles, and each contains 2 liters of cola, there are

\[3 \times 2 \text{ L} = 6 \text{ L} = 6.0 \text{ L}\]

of cola in the bottles. To construct a conversion chart, we list the metric units of capacity from largest (kiloliters) to smallest (milliliters), working from left to right. Then we locate the original units of liters and move to the conversion units of milliliters, as shown below.

\[
\begin{array}{cccccccc}
\text{largest unit} & \text{kL} & \text{hL} & \text{daL} & \text{L} & \text{dL} & \text{cL} & \text{mL} & \text{smallest unit} \\
\end{array}
\]

We see that the decimal point in 6.0 should be moved 3 places to the right to convert from liters to milliliters.

\[6 \text{ liters} = 6,000 \text{ milliliters} = 6,000 \text{ milliliters}\]

Move 3 places to the right.

Thus, there are 6,000 milliliters in three 2-liter bottles of cola.

We can use the unit conversion factor method to confirm this result. To convert to milliliters, we must chose a unit conversion factor such that liters drop out and the units of milliliters remain. Since there are 1,000 milliliters per 1 liter, we multiply 6 liters by the unit conversion factor \(\frac{1,000 \text{ mL}}{1 \text{ L}}\).

\[
6 \text{ L} = \frac{6 \text{ L}}{1} \times \frac{1,000 \text{ mL}}{1 \text{ L}}
\]

Remove the common units of liters in the numerator and denominator. The units of mL remain.

\[= 6 \times 1,000 \text{ mL}
\]

Simplify.

\[= 6,000 \text{ mL}\]

Multiply 6 by 1,000 by moving the understood decimal point in 6 three places to the right.

9 Define a cubic centimeter.

Another metric unit of capacity is the **cubic centimeter**, which is represented by the notation cm³ or, more simply, cc. One milliliter and one cubic centimeter represent the same capacity.

\[1 \text{ mL} = 1 \text{ cm}^3 = 1 \text{ cc}\]

The units of cubic centimeters are used frequently in medicine. For example, when a nurse administers an injection containing 5 cc of medication, the dosage can also be expressed using milliliters.

\[5 \text{ cc} = 5 \text{ mL}\]
When a doctor orders that a patient be put on 1,000 cc of dextrose solution, the request can be expressed in different ways.

1,000 cc = 1,000 mL = 1 liter

**SECTION V.2  STUDY SET**

**VOCABULARY**

*Fill in the blanks.*

1. The meter, the gram, and the liter are basic units of measurement in the _______ system.

2. a. The basic unit of length in the metric system is the _______.
   b. The basic unit of mass in the metric system is the _______.
   c. The basic unit of capacity in the metric system is the _______.

3. a. *Deka* means _____.
   b. *Hecto* means _______.
   c. *Kilo* means _______.

4. a. *Deci* means _______.
   b. *Centi* means _______.
   c. *Milli* means _______.

5. We can convert from one unit to another in the metric system using _______ conversion factors or a conversion _______ like that shown below.

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

6. The _______ of an object is a measure of the amount of material in the object.

7. The _______ of an object is determined by the Earth’s gravitational pull on the object.

8. Another metric unit of capacity is the cubic _______, which is represented by the notation cm\(^3\), or, more simply, cc.

**CONCEPTS**

*Fill in the blanks.*

9. a. 1 kilometer = _______ meters
   b. _______ centimeters = 1 meter
   c. _______ millimeters = 1 meter

10. a. 1 gram = _______ milligrams
    b. 1 kilogram = _______ grams

11. a. _______ milliliters = 1 liter
    b. 1 dekaliter = _______ liters

12. a. 1 milliliter = _______ cubic centimeter
    b. 1 liter = _______ cubic centimeters

13. Write a unit conversion factor to convert
   a. meters to kilometers
   b. grams to centigrams
   c. liters to milliliters

14. Use the chart to determine how many decimal places and in which direction to move the decimal point when converting the following.
   a. Kilometers to centimeters
   b. Milligrams to grams
   c. Hectoliters to centiliters

15. Match each item with its proper measurement.
   a. Thickness of a phone book
   b. Length of the Amazon River
   c. Height of a soccer goal

16. Match each item with its proper measurement.
   a. Weight of a giraffe
   b. Weight of a paper clip
   c. Active ingredient in an aspirin tablet
17. Match each item with its proper measurement.
   a. Amount of blood in an adult
      i. 290,000 kL
      ii. 6 L
   b. Cola in an aluminum can
      iii. 355 mL
   c. Kuwait’s daily production of crude oil

18. Of the objects shown below, which can be used to measure the following?
   a. Millimeters
   b. Milligrams
   c. Milliliters

19. Convert 20 centimeters to meters.

\[
20 \text{ cm} = \frac{20 \text{ cm}}{1} \cdot \frac{1 \text{ m}}{100 \text{ cm}} = \frac{20}{100} \text{ m} = \frac{1}{5} \text{ m}
\]

20. Convert 3,000 milligrams to grams.

\[
3,000 \text{ mg} = \frac{3,000 \text{ mg}}{1} \cdot \frac{1 \text{ g}}{1,000 \text{ mg}} = \frac{3,000}{1,000} \text{ g} = \frac{3}{1} \text{ g}
\]

21. Convert 0.2 kilograms to milligrams.

\[
0.2 \text{ kg} = \frac{0.2 \text{ kg}}{1} \cdot \frac{1 \text{ g}}{1 \text{ kg}} \cdot \frac{1,000 \text{ mg}}{1 \text{ g}} = 0.2 \cdot 1,000 \cdot 1,000 \text{ mg} = \frac{200,000}{1} \text{ mg}
\]

22. Convert 400 milliliters to kiloliters.

\[
400 \text{ mL} = \frac{400 \text{ mL}}{1} \cdot \frac{1 \text{ L}}{1,000 \text{ mL}} \cdot \frac{1 \text{ kL}}{1,000 \text{ L}} = \frac{400}{1,000 \cdot 1,000} \text{ kL} = 0.0004 \text{ kL}
\]

**GUIDED PRACTICE**

Refer to the given ruler to answer each question. See Example 1.

23. Determine which measurements the arrows point to on the metric ruler.

24. Find the length of the birthday candle (including the wick).

Refer to the given ruler to answer each question. See Example 2.

25. a. Refer to the metric ruler below. Each centimeter is divided into how many equal parts? What is the length of one of those parts?
   b. Determine which measurements the arrows point to on the ruler.

26. Find the length of the stick of gum.
Use a metric ruler scaled in millimeters to measure each object. See Example 2.

27. The length of a dollar bill
28. The width of a dollar bill
29. The length (top to bottom) of this page
30. The length of the word antidisestablishmentarianism as printed here.

Perform each conversion. See Example 3.

31. 380 centimeters to meters
32. 590 centimeters to meters
33. 120 centimeters to meters
34. 640 centimeters to meters

Perform each conversion. See Example 4.

35. 8.7 meters to millimeters
36. 1.3 meters to millimeters
37. 2.89 meters to millimeters
38. 4.06 meters to millimeters

Perform each conversion. See Example 5.

39. 4.5 centimeters to kilometers
40. 6.2 centimeters to kilometers
41. 0.3 centimeters to kilometers
42. 0.4 centimeters to kilometers

Perform each conversion. See Example 6.

43. 1.93 kilograms to grams
44. 8.99 kilograms to grams
45. 4.531 kilograms to grams
46. 6.077 kilograms to grams

Perform each conversion. See Example 7.

47. 6,000 milligrams to grams
48. 9,000 milligrams to grams
49. 3,500 milligrams to grams
50. 7,500 milligrams to grams

Perform each conversion. See Example 8.

51. 3 liters to milliliters
52. 4 liters to milliliters
53. 26.3 liters to milliliters
54. 35.2 liters to milliliters

TRY IT YOURSELF

Perform each conversion.

55. 0.31 decimeters to centimeters
56. 73.2 meters to decimeters
57. 500 milliliters to liters
58. 500 centiliters to milliliters
59. 2 kilograms to grams
60. 4,000 grams to kilograms
61. 0.074 centimeters to millimeters
62. 0.125 meters to millimeters
63. 1,000 kilograms to grams
64. 2 kilograms to centigrams
65. 658.23 liters to kiloliters
66. 0.0068 hectoliters to kiloliters
67. 4.72 cm to dm
68. 0.593 cm to dam
69. 10 mL = ___ cc
70. 2,000 cc = ___ L
71. 500 mg to g
72. 500 mg to cg
73. 5.689 g to kg
74. 0.0579 km to mm
75. 453.2 cm to m
76. 675.3 cm to m
77. 0.325 dL to L
78. 0.0034 mL to L
79. 675 dam = ____ cm
80. 76.8 hm = ____ mm
81. 0.00777 cm = ____ dam
82. 400 liters to hL
83. 134 m to hm
84. 6.77 mm to cm
85. 65.78 km to dam
86. 5 g to cg

APPLICATIONS

87. SPEED SKATING American Eric Heiden won an unprecedented five gold medals by capturing the men’s 500-m, 1,000-m, 1,500-m, 5,000-m, and 10,000-m races at the 1980 Winter Olympic Games in Lake Placid, New York. Convert each race length to kilometers.
88. **THE SUEZ CANAL** The 163-km-long Suez Canal connects the Mediterranean Sea with the Red Sea. It provides a shortcut for ships operating between European and American ports. Convert the length of the Suez Canal to meters.

89. **SKYSCRAPERS** The John Hancock Center in Chicago has 100 stories and is 343 meters high. Give this height in hectometers.

90. **WEIGHT OF A BABY** A baby weighs 4 kilograms. Give this weight in centigrams.

91. **HEALTH CARE** Blood pressure is measured by a sphygmomanometer (see at right). The measurement is read at two points and is expressed, for example, as 120/80. This indicates a systolic pressure of 120 millimeters of mercury and a diastolic pressure of 80 millimeters of mercury. Convert each measurement to centimeters of mercury.

92. **JEWELRY** A gold chain weighs 1,500 milligrams. Give this weight in grams.

93. **EYE DROPPERS** One drop from an eye dropper is 0.05 mL. Convert the capacity of one drop to liters.

94. **BOTTLING** How many liters of wine are in a 750-mL bottle?

95. **MEDICINE** A bottle of hydrochlorothiazine contains 60 tablets. If each tablet contains 50 milligrams of active ingredient, how many grams of active ingredient are in the bottle?

96. **IBUPROFEN** What is the total weight, in grams, of all the tablets in the box shown at right?

97. **SIX PACKS** Some stores sell Fanta orange soda in 0.5 liter bottles. How many milliliters are there in a six pack of this size bottle?

98. **CONTAINERS** How many deciliters of root beer are in two 2-liter bottles?

99. **OLIVES** The net weight of a bottle of olives is 284 grams. Find the smallest number of bottles that must be purchased to have at least 1 kilogram of olives.

100. **COFFEE** A can of Cafe Vienna has a net weight of 133 grams. Find the smallest number of cans that must be packaged to have at least 1 metric ton of coffee. (Hint: 1 metric ton = 1,000 kg.)

101. **INJECTIONS** The illustration below shows a 3cc syringe. Express its capacity using units of milliliters.

102. **MEDICAL SUPPLIES** A doctor ordered 2,000 cc of a saline (salt) solution from a pharmacy. How many liters of saline solution is this?

103. **To change 3.452 kilometers to meters, we can move the decimal point in 3.452 three places to the right to get 3,452 meters. Explain why.**

104. **To change 7,532 grams to kilograms, we can move the decimal point in 7,532 three places to the left to get 7.532 kilograms. Explain why.**

105. **A centimeter** is one hundredth of a meter. Make a list of five other words that begin with the prefix centi or cent and write a definition for each.

106. **List the advantages of the metric system of measurement as compared to the American system. There have been several attempts to bring the metric system into general use in the United States. Why do you think these efforts have been unsuccessful?**

**Writing**

107. **Write each fraction as a decimal. Use an overbar in your answer.**

108. \( \frac{11}{12} \)

109. \( \frac{7}{90} \)

110. \( \frac{1}{66} \)
SECTION V.3 Converting between American and Metric Units

It is often necessary to convert between American units and metric units. For example, we must convert units to answer the following questions.

- Which is higher: Pikes Peak (elevation 14,110 feet) or the Matterhorn (elevation 4,478 meters)?
- Does a 2-pound tub of butter weigh more than a 1-kilogram tub?
- Is a quart of soda pop more or less than a liter of soda pop?

In this section, we discuss how to answer such questions.

1 Use unit conversion factors to convert between American and metric units.

The following table shows some conversions between American and metric units of length. In all but one case, the conversions are rounded approximations. An \( \approx \) symbol is used to show this. The one exact conversion in the table is 1 inch = 2.54 centimeters.

<table>
<thead>
<tr>
<th>Equivalent Lengths</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>American to metric</strong></td>
</tr>
<tr>
<td>1 in. ( \approx 2.54 ) cm</td>
</tr>
<tr>
<td>1 ft ( \approx 0.30 ) m</td>
</tr>
<tr>
<td>1 yd ( \approx 0.91 ) m</td>
</tr>
<tr>
<td>1 mi ( \approx 1.61 ) km</td>
</tr>
<tr>
<td><strong>Metric to American</strong></td>
</tr>
<tr>
<td>1 cm ( \approx 0.39 ) in.</td>
</tr>
<tr>
<td>1 m ( \approx 3.28 ) ft</td>
</tr>
<tr>
<td>1 m ( \approx 1.09 ) yd</td>
</tr>
<tr>
<td>1 km ( \approx 0.62 ) mi</td>
</tr>
</tbody>
</table>

Unit conversion factors can be formed from the facts in the table to make specific conversions between American and metric units of length.

EXAMPLE 1 Clothing Labels The figure shows a label sewn into some pants made in Mexico that are for sale in the United States. Express the waist size to the nearest inch.

Strategy We will multiply 82 centimeters by a carefully chosen unit conversion factor.

WHY If we multiply by the proper unit conversion factor, we can eliminate the unwanted units of centimeters and convert to inches.

Solution To convert from centimeters to inches, we must choose a unit conversion factor whose numerator contains the units we want to introduce (inches), and whose denominator contains the units we want to eliminate (centimeters). From the first row of the **Metric to American** column of the table, we see that there is approximately 0.39 inch per centimeter. Thus, we will use the unit conversion factor:

\[
\frac{0.39 \text{ in.}}{1 \text{ cm}}
\]

This is the unit we want to introduce.

This is the unit we want to eliminate (the original unit).
To perform the conversion, we multiply.

\[
82 \text{ cm} = \frac{82 \text{ cm}}{1} \cdot \frac{0.39 \text{ in.}}{1 \text{ cm}}
\]

Write 82 cm as a fraction: \(82 \text{ cm} = \frac{82 \text{ cm}}{1}\).

Multiply by a form of \(1\):

\[
\frac{82 \text{ cm}}{1} \cdot \frac{0.39 \text{ in.}}{1 \text{ cm}}
\]

Remove the common units of centimeters from the numerator and denominator. The units of inches remain.

To the nearest inch, the waist size is 32 inches.

EXAMPLE 2   Mountain Elevations   Pikes Peak, one of the most famous peaks in the Rocky Mountains, has an elevation of 14,110 feet. The Matterhorn, in the Swiss Alps, rises to an elevation of 4,478 meters. Which mountain is higher?

Strategy   We will convert the elevation of Pikes Peak, which given in feet, to meters.

WHY   Then we can compare the mountain’s elevations in the same units, meters.

Solution   To convert Pikes Peak elevation from feet to meters we must choose a unit conversion factor whose numerator contains the units we want to introduce (meters) and whose denominator contains the units we want to eliminate (feet). From the second row of the American to metric column of the table, we see that there is approximately 0.30 meter per foot. Thus, we will use the unit conversion factor:

\[
0.30 \text{ m} \quad \text{This is the unit we want to introduce.}
\]

\[
1 \text{ ft} \quad \text{This is the unit we want to eliminate (the original unit).}
\]

To perform the conversion, we multiply.

\[
14,110 \text{ ft} = \frac{14,110 \text{ ft}}{1} \cdot \frac{0.30 \text{ m}}{1 \text{ ft}}
\]

Write 14,110 ft as a fraction: \(14,110 \text{ ft} = \frac{14,110 \text{ ft}}{1}\).

Multiply by a form of \(1\):

\[
\frac{14,110 \text{ ft}}{1} \cdot \frac{0.30 \text{ m}}{1 \text{ ft}}
\]

Remove the common units of feet from the numerator and denominator. The units of meters remain.

Do the multiplication.

Since the elevation of Pikes Peak is about 4,233 meters, we can conclude that the Matterhorn, with an elevation of 4,478 meters, is higher.

Self Check 2

TRACK AND FIELD   Which is longer: a 500-meter race or a 550-yard race?

Now Try Problem 17

We can convert between American units of weight and metric units of mass using the rounded approximations in the following table.

<table>
<thead>
<tr>
<th>Equivalent Weights and Masses</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>American to metric</strong></td>
</tr>
<tr>
<td>1 oz = 28.35 g</td>
</tr>
<tr>
<td>1 lb = 0.45 kg</td>
</tr>
</tbody>
</table>
Self Check 3

Convert 68 pounds to grams. Round to the nearest gram.

Now Try Problem 21

Example 3

Convert 50 pounds to grams.

Strategy
We will use a two-part multiplication process that converts 50 pounds to ounces, and then converts that result to grams.

Why
We must use a two-part process because the conversion table on page A-91 does not contain a single unit conversion factor that converts from pounds to grams.

Solution

Since there are 16 ounces per pound, we can convert 50 pounds to ounces by multiplying by the unit conversion factor \( \frac{16 \text{ oz}}{1 \text{ lb}} \). Since there are approximately 28.35 g per ounce, we can convert that result to grams by multiplying by the unit conversion factor \( \frac{28.35 \text{ g}}{1 \text{ oz}} \).

\[
50 \text{ lb} = \frac{50 \text{ lb}}{1} \cdot \frac{16 \text{ oz}}{1 \text{ lb}} \cdot \frac{28.35 \text{ g}}{1 \text{ oz}}
\]

Write 50 lb as a fraction: \( \frac{50 \text{ lb}}{1} \). Multiply by two forms of 1: \( \frac{16 \text{ oz}}{1 \text{ lb}} \) and \( \frac{28.35 \text{ g}}{1 \text{ oz}} \).

Remove the common units of pounds and ounces from the numerator and denominator. The units of grams remain.

\[
= \frac{50 \cdot 16 \cdot 28.35 \text{ g}}{1 \cdot 1 \cdot 1}
\]

Simplify.

\[
= 800 \cdot 28.35 \text{ g}
\]

Do the multiplication.

Thus, 50 pounds = 22,680 grams.

Self Check 4

Body Weight
Who weighs more, a person who weighs 165 pounds or one who weighs 76 kilograms?

Now Try Problem 25

Example 4

Packaging
Does a 2.5 pound tub of butter weigh more than a 1.5-kilogram tub?

Strategy
We will convert the weight of the 1.5-kilogram tub of butter to pounds.

Why
Then we can compare the weights of the tubs of butter in the same units, pounds.

Solution

To convert 1.5 kilograms to pounds we must choose a unit conversion factor whose numerator contains the units we want to introduce (pounds), and whose denominator contains the units we want to eliminate (kilograms). From the second row of the Metric to American column of the table, we see that there are approximately 2.20 pounds per kilogram. Thus, we will use the unit conversion factor:

\[
\frac{2.20 \text{ lb}}{1 \text{ kg}}
\]

This is the unit we want to introduce.

\[
\frac{1 \text{ kg}}{1}
\]

This is the unit we want to eliminate (the original unit).

To perform the conversion, we multiply.

\[
1.5 \text{ kg} = \frac{1.5 \text{ kg}}{1} \cdot \frac{2.20 \text{ lb}}{1 \text{ kg}}
\]

Write 1.5 kg as a fraction: \( \frac{1.5 \text{ kg}}{1} \). Multiply by a form of 1: \( \frac{2.20 \text{ lb}}{1 \text{ kg}} \).

Remove the common units of kilograms from the numerator and denominator. The units of pounds remain.

\[
= \frac{1.5 \cdot 2.20 \text{ lb}}{1 \cdot 1}
\]

Simplify.

\[
= 3.3 \text{ lb}
\]

Do the multiplication.

Since a 1.5-kilogram tub of butter weighs about 3.3 pounds, the 1.5-kilogram tub weighs more.
We can convert between American and metric units of capacity using the rounded approximations in the following table.

<table>
<thead>
<tr>
<th>Equivalent Capacities</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>American to metric</strong></td>
<td><strong>Metric to American</strong></td>
</tr>
<tr>
<td>1 fl oz = 29.57 mL</td>
<td>1 L = 33.81 fl oz</td>
</tr>
<tr>
<td>1 pt = 0.47 L</td>
<td>1 L = 2.11 pt</td>
</tr>
<tr>
<td>1 qt = 0.95 L</td>
<td>1 L = 1.06 qt</td>
</tr>
<tr>
<td>1 gal = 3.79 L</td>
<td>1 L = 0.264 gal</td>
</tr>
</tbody>
</table>

**THINK IT THROUGH**

**Studying in Other Countries**

"Over the past decade, the number of U.S. students studying abroad has more than doubled."

*From The Open Doors 2008 Report*

In 2006/2007, a record number of 241,791 college students received credit for study abroad. Since students traveling to other countries are almost certain to come into contact with the metric system of measurement, they need to have a basic understanding of metric units.

Suppose a student studying overseas needs to purchase the following school supplies. For each item in red, choose the appropriate metric units.

1. **8 1/2 in. × 11 in. notebook paper:**
   - 216 meters × 279 meters
   - 216 centimeters × 279 centimeters
   - 216 millimeters × 279 millimeters

2. **A backpack that can hold 20 pounds of books:**
   - 9 kilograms
   - 9 grams
   - 9 milligrams

3. **3/4 fluid ounce bottle of Liquid Paper correction fluid:**
   - 22.5 hectoliters
   - 2.5 liters
   - 22.2 milliliters

**EXAMPLE 5**

**Cleaning Supplies**

A bottle of window cleaner contains 750 milliliters of solution. Convert this measure to quarts. Round to the nearest tenth.

**Strategy**

We will use a two-part multiplication process that converts 750 milliliters to liters, and then converts that result to quarts.

**WHY**

We must use a two-part process because the conversion table at the top of this page does not contain a single unit conversion factor that converts from milliliters to quarts.

**Solution**

Since there is 1 liter for every 1,000 mL, we can convert 750 milliliters to liters by multiplying by the unit conversion factor \( \frac{1 \text{ L}}{1,000 \text{ mL}} \). Since there are approximately
2 Convert between Fahrenheit and Celsius temperatures.

In the American system, we measure temperature using degrees Fahrenheit (°F). In the metric system, we measure temperature using degrees Celsius (°C). These two scales are shown on the thermometers on the right. From the figures, we can see that

- 212°F = 100°C Water boils
- 32°F = 0°C Water freezes
- 5°F = -15°C A cold winter day
- 95°F = 35°C A hot summer day

There are formulas that enable us to convert from degrees Fahrenheit to degrees Celsius and from degrees Celsius to degrees Fahrenheit.

### Conversion Formulas for Temperature

If $F$ is the temperature in degrees Fahrenheit and $C$ is the corresponding temperature in degrees Celsius, then

$$C = \frac{5}{9}(F - 32) \quad \text{and} \quad F = \frac{9}{5}C + 32$$

1.06 qt per liter, we can convert that result to quarts by multiplying by the unit conversion factor $\frac{1.06\text{ qt}}{1\text{ L}}$.

$$750\text{ mL} = \frac{750\text{ mL}}{1} \cdot \frac{1\text{ L}}{1000\text{ mL}} \cdot \frac{1.06\text{ qt}}{1\text{ L}}$$

$$= \frac{750\text{ mL}}{1} \cdot \frac{1\text{ L}}{1000\text{ mL}} \cdot \frac{1.06\text{ qt}}{1\text{ L}}$$

$$= \frac{750 \cdot 1.06}{1000}\text{ qt}$$

$$= 0.795\text{ qt}$$

$$= 0.8\text{ qt}$$

The bottle contains approximately 0.8 qt of cleaning solution.
**EXAMPLE 6  Bathing**  Warm bath water is 90°F. Express this temperature in degrees Celsius. Round to the nearest tenth of a degree.

**Strategy**  We will substitute 90 for \( F \) in the formula \( C = \frac{5}{9}(F - 32) \).

**WHY**  Then we can use the rule for the order of operations to evaluate the right side of the equation and find the value of \( C \), the temperature in degrees Celsius of the bath water.

**Solution**

\[
C = \frac{5}{9}(F - 32) \quad \text{This is the formula to find degrees Celsius.} \\
= \frac{5}{9}(90 - 32) \quad \text{Substitute 90 for } F. \\
= \frac{5}{9}(58) \quad \text{Do the subtraction within the parentheses first: } 90 - 32 = 58. \\
= \frac{5}{9} \left( \frac{58}{1} \right) \quad \text{Write } 58 \text{ as a fraction: } \frac{58}{1}. \\
= \frac{290}{9} \quad \text{Multiply the numerators.} \\
= \frac{32.222\ldots}{9} \quad \text{Multiply the denominators.} \\
\approx 32.2 \quad \text{Do the division.} \\
\approx 32.2 \quad \text{Round to the nearest tenth.} 
\]

To the nearest tenth of a degree, the temperature of the bath water is 32.2°C.

**EXAMPLE 7  Dishwashers**  A dishwasher manufacturer recommends that dishes be rinsed in hot water with a temperature of 60°C. Express this temperature in degrees Fahrenheit.

**Strategy**  We will substitute 60 for \( C \) in the formula \( F = \frac{9}{5}C + 32 \).

**WHY**  Then we can use the rule for the order of operations to evaluate the right side of the equation and find the value of \( F \), the temperature in degrees Fahrenheit of the water.

**Solution**

\[
F = \frac{9}{5}C + 32 \quad \text{This is the formula to find degrees Fahrenheit.} \\
= \frac{9}{5}(60) + 32 \quad \text{Substitute 60 for } C. \\
= \frac{540}{5} + 32 \quad \text{Multiply: } \frac{9}{5}(60) = \frac{9(60)}{5} = \frac{540}{5}. \\
= 108 + 32 \quad \text{Do the division.} \\
= 140 \quad \text{Do the addition.} 
\]

The manufacturer recommends that dishes be rinsed in 140°F water.

**ANSWERS TO SELF CHECKS**

1. 30 in.  
2. the 550-yard race  
3. 30, 845 g  
4. the person who weighs 76 kg  
5. 0.4 qt  
6. 43.3°C  
7. yes
**SECTION V.3 STUDY SET**

**VOCABULARY**

*Fill in the blanks.*

1. In the American system, temperatures are measured in degrees _________. In the metric system, temperatures are measured in degrees _________.

2. a. Inches and centimeters are units used to measure _________.
   b. Pounds and grams are used to measure _________. (weight).
   c. Gallons and liters are units used to measure _________.

**CONCEPTS**

3. Which is longer:
   a. A yard or a meter?
   b. A foot or a meter?
   c. An inch or a centimeter?
   d. A mile or a kilometer?

4. Which is heavier:
   a. An ounce or a gram?
   b. A pound or a kilogram?

5. Which is the greater unit of capacity:
   a. A pint or a liter?
   b. A quart or a liter?
   c. A gallon or a liter?

6. a. What formula is used for changing degrees Celsius to degrees Fahrenheit?
   b. What formula is used for changing degrees Fahrenheit to degrees Celsius?

7. Write a unit conversion factor to convert
   a. feet to meters
   b. pounds to kilograms
   c. gallons to liters

8. Write a unit conversion factor to convert
   a. centimeters to inches
   b. grams to ounces
   c. liters to fluid ounces

**NOTATION**

*Complete each solution.*

9. Convert 4,500 feet to meters.
   \[ 4,500 \text{ ft} = \frac{4,500 \text{ ft}}{1} \cdot \frac{1}{1 \text{ ft}} \approx 1,350 \]

10. Convert 8 liters to gallons.
    \[ 8 \text{ L} = \frac{8 \text{ L}}{1 \text{ L}} \approx 2.112 \]

11. Convert 3 kilograms to ounces.
    \[ 3 \text{ kg} = \frac{3 \text{ kg}}{1 \text{ kg}} \cdot \frac{1,000 \text{ g}}{1 \text{ g}} \cdot \frac{0.035 \text{ oz}}{1 \text{ g}} \approx 105 \]

12. Convert 70°C to degrees Fahrenheit.
    \[ F = \frac{9}{5} C + 32 \]
    \[ = \frac{9}{5}(70) + 32 \]
    \[ = 158 \]
    Thus, 70°C = 158

**GUIDED PRACTICE**

*Perform each conversion. Round to the nearest inch.*

9. 25 centimeters to inches
   See Example 1.
   10. 35 centimeters to inches
    11. 88 centimeters to inches
    12. 91 centimeters to inches
    13. 20 pounds to grams
    14. 30 pounds to grams
    15. 75 pounds to grams
    16. 95 pounds to grams

*Perform each conversion. See Example 2.*

17. 8,400 feet to meters
18. 7,300 feet to meters
19. 25,115 feet to meters
20. 36,242 feet to meters

*Perform each conversion. See Example 3.*

21. 20 pounds to grams
22. 30 pounds to grams
23. 75 pounds to grams
24. 95 pounds to grams

*Perform each conversion. See Example 4.*

25. 6.5 kilograms to pounds
26. 7.5 kilograms to pounds
27. 300 kilograms to pounds
28. 800 kilograms to pounds
Perform each conversion. Round to the nearest tenth. See Example 5.

29. 650 milliliters to quarts
30. 450 milliliters to quarts
31. 1,200 milliliters to quarts
32. 1,500 milliliters to quarts

Express each temperature in degrees Celsius. Round to the nearest tenth of a degree. See Example 6.

33. 120°F
34. 110°F
35. 35°F
36. 45°F

Express each temperature in degrees Fahrenheit. See Example 7.

37. 75°C
38. 85°C
39. 10°C
40. 20°C

TRY IT YOURSELF

Perform each conversion. If necessary, round answers to the nearest tenth. Since most conversions are approximate, answers will vary slightly depending on the method used.

41. 25 pounds to grams
42. 7.5 ounces to grams
43. 50°C to degrees Fahrenheit
44. 36.2°C to degrees Fahrenheit
45. 0.75 quarts to milliliters
46. 3 pints to milliliters
47. 0.5 kilograms to ounces
48. 35 grams to pounds
49. 3.75 meters to inches
50. 2.4 kilometers to miles
51. 3 fluid ounces to liters
52. 2.5 pints to liters
53. 12 kilometers to feet
54. 3.212 centimeters to feet
55. 37 ounces to kilograms
56. 10 pounds to kilograms
57. −10°C to degrees Fahrenheit
58. −22.5°C to degrees Fahrenheit
59. 17 grams to ounces
60. 100 kilograms to pounds
61. 7.2 liters to fluid ounces
62. 5 liters to quarts
63. 3 feet to centimeters
64. 7.5 yards to meters
65. 500 milliliters to quarts
66. 2,000 milliliters to gallons
67. 50°F to degrees Celsius
68. 67.7°F to degrees Celsius

APPLICATIONS

Since most conversions are approximate, answers will vary slightly depending on the method used.

73. THE MIDDLE EAST The distance between Jerusalem and Bethlehem is 8 kilometers. To the nearest mile, give this distance in miles.
74. THE DEAD SEA The Dead Sea is 80 kilometers long. To the nearest mile, give this distance in miles.
75. CHEETAHS A cheetah can run 112 kilometers per hour. Express this speed in mph. Round to the nearest mile.
76. LIONS A lion can run 50 mph. Express this speed in kilometers per hour.
77. MOUNT WASHINGTON The highest peak of the White Mountains of New Hampshire is Mount Washington, at 6,288 feet. Give this height in kilometers. Round to the nearest tenth.
78. TRACK AND FIELD Track meets are held on an oval track. One lap around the track is usually 400 meters. However, some older tracks in the United States are 440-yard ovals. Are these two types of tracks the same length? If not, which is longer?

79. HAIR GROWTH When hair is short, its rate of growth averages about ⅛ inch per month. How many centimeters is this a month? Round to the nearest tenth of a centimeter.
80. WHALES An adult male killer whale can weigh as much as 12,000 pounds and be as long as 25 feet. Change these measurements to kilograms and meters.
81. WEIGHTLIFTING The table lists the personal best bench press records for two of the world’s best powerlifters. Change each metric weight to pounds. Round to the nearest pound.

<table>
<thead>
<tr>
<th>Name</th>
<th>Hometown</th>
<th>Bench press</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liz Willet</td>
<td>Ferndale, Washington</td>
<td>187 kg</td>
</tr>
<tr>
<td>Brian Siders</td>
<td>Charleston, W. Virginia</td>
<td>350 kg</td>
</tr>
</tbody>
</table>
82. WORDS OF WISDOM Refer to the wall hanging. Convert the first metric weight to ounces and the second to pounds. What famous saying results?

28.35 grams of prevention is worth 0.45 Kilogram of cure

83. OUNCES AND FLUID OUNCES
   a. There are 310 calories in 8 ounces of broiled chicken. Convert 8 ounces to grams.
   b. There are 112 calories in a glass of fresh Valencia orange juice that holds 8 fluid ounces. Convert 8 fluid ounces to liters. Round to the nearest hundredth.

84. TRACK AND FIELD A shot-put weighs 7.264 kilograms. Convert this weight to pounds. Round to the nearest pound.

85. POSTAL REGULATIONS You can mail a package weighing up to 70 pounds via priority mail. Can you mail a package that weighs 32 kilograms by priority mail?

86. NUTRITION Refer to the nutrition label shown below for a packet of oatmeal. Change each circled weight to ounces.

87. HOT SPRINGS The thermal springs in Hot Springs National Park in central Arkansas emit water as warm as 143°F. Change this temperature to degrees Celsius.

88. COOKING MEAT Meats must be cooked at temperatures high enough to kill harmful bacteria. According to the USDA and the FDA, the internal temperature for cooked roasts and steaks should be at least 145°F, and whole poultry should be 180°F. Convert these temperatures to degrees Celsius. Round up to the next degree.

89. TAKING A SHOWER When you take a shower, which water temperature would you choose: 15°C, 28°C, or 50°C?

90. DRINKING WATER To get a cold drink of water, which temperature would you choose: −2°C, 10°C, or 25°C?

91. SNOWY WEATHER At which temperatures might it snow: −5°C, 0°C, or 10°C?

92. AIR CONDITIONING At which outside temperature would you be likely to run the air conditioner: 15°C, 20°C, or 30°C?

93. COMPARISON SHOPPING Which is the better buy: 3 quarts of root beer for $4.50 or 2 liters of root beer for $3.60?

94. COMPARISON SHOPPING Which is the better buy: 3 gallons of antifreeze for $10.35 or 12 liters of antifreeze for $10.50?

**Writing**

95. Explain how to change kilometers to miles.

96. Explain how to change 50°C to degrees Fahrenheit.

97. The United States is the only industrialized country in the world that does not officially use the metric system. Some people claim this is costing American businesses money. Do you think so? Why?

98. What is meant by the phrase *a table of equivalent measures*?

**Review**

Perform each operation.

99. \[\frac{3}{5} + \frac{4}{3}\]
100. \[\frac{3}{5} - \frac{4}{3}\]
101. \[\frac{3}{5} \div \frac{3}{5}\]
102. \[\frac{3}{5} \cdot \frac{4}{3}\]
103. \[3.25 + 4.8\]
104. \[3.25 - 4.8\]
105. \[3.25 \cdot 4.8\]
106. \[4.8 \sqrt{15.6}\]