CHAPTER 8

The 2000–2004 Chevrolet Corvettes have a standard 5.7-liter engine.

THE METRIC SYSTEM

On a trip to Italy or Spain, you might have a difficult time asking for and understanding directions if you do not speak the language of that country. Purchasing clothing or gasoline may also be difficult in those countries because the measurement system is different than ours. Our neighbors in Mexico and Canada, like almost all countries around the world, also use a different measurement system than we use in the United States. Most countries of the world use the *Système international d'unités*, or abbreviated, the *SI system*. In the United States, the SI system is most commonly referred to as the metric system.

The system of measurement most commonly used in the United States is called the U.S. customary system, but metric units are used in many ways in the United States. You can purchase metric tools at your local hardware store. Some clothing is measured in metric units, as are car tires. Drinks are sold in liter bottles, and vitamins and medicines are labeled in milligrams.

As you study this chapter, you will see the many advantages of the metric system. You eventually may even support the movement to change from the U.S. customary system to the metric system.

8.1 BASIC TERMS AND CONVERSIONS WITHIN THE METRIC SYSTEM

Most countries of the world use the ***Système international d'unités*** or ***SI system***. The SI system is generally referred to as the ***metric system*** in the United States. The metric system was named for the Greek word *metron,* meaning "measure." The standard units in the metric system have gone through many changes since the system was first developed in France during the French Revolution. For example, one unit of measure, the meter, was first defined as one ten-millionth of the distance between the North Pole and the equator. Later, the meter was defined as 1,650,763.73 wavelengths of the orange–red line of krypton 86. Since 1893, the meter has been defined as the distance traveled by light in a vacuum in $\frac{1}{299,792,458}$ of a second.

Two systems of weights and measures exist side by side in the United States today, the ***U.S. customary system*** and the metric system. The metric system is used predominantly in the automotive, construction, farm equipment, computer, and bottling industries and in health-related professions. Furthermore, almost every industry that ships internationally uses at least some metric measures.

In this chapter, we will discuss metric measurements of length, area, volume, mass, and temperature. Using the metric system has many advantages. Some of them are summarized here.

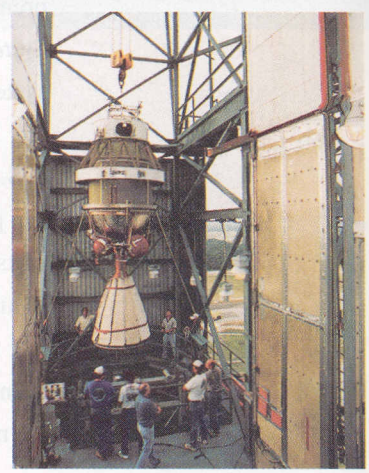
1. The metric system is the worldwide accepted standard measurement system. All industrial nations that trade internationally, except the United States, use the metric system as the official system of measurement.
2. There is only one basic unit of measurement for each physical quantity. In the U.S. customary system, many units are often used to represent the same physical quantity. For example, when discussing length, we use inches, feet, yards, miles, and so on. Converting from one of these units to the other is often a tedious task (consider changing 12 miles to inches). In the metric system, we can make many conversions by simply moving the decimal point.
3. The SI system is based on the number 10, and there is less need for fractions, because most quantities can be expressed as decimals.

DID YOU KNOW

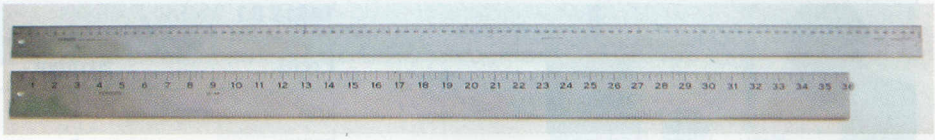
Lost in Space

In September 1999, the United States lost the *Mars Climate Orbiter* as it approached Mars. The loss of the $125 million spacecraft was due to scientists confusing U.S. customary units and metric units. Two spacecraft teams, one at NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California, and the other at a Lockheed Martin facility in Colorado, where the spacecraft was built, were unknowingly exchanging some vital information in different measurement units.

The spacecraft team in Colorado used U.S. customary units of *pounds* of force to describe small forces needed to adjust the spacecraft's orbit. The data were shipped via computer, without units, to the JPL, where the navigation team was expecting to receive the information in newtons, a metric measure of force. The mix-up in units led to the JPL scientists giving the spacecraft's computer wrong information, which threw the spacecraft off course. That, in turn, led to the spacecraft entering the Martian atmosphere, where it burned up. NASA has taken steps to prevent this error from ever happening again.



The missing *Mars Climate Orbiter*



A meter is a little longer than a yard.

Basic Terms

One- and two-liter bottles

Because the official definitions of many metric terms are quite technical, we present them informally.

The ***meter*** (m) is commonly used to measure *length* in the metric system. One meter is a little more than a yard (see the photo above). A door is about 2 meters high.

The ***kilogram*** (kg) is commonly used to measure *mass*. (The difference between mass and weight is discussed in Section 8.3.) One kilogram is about 2.2 pounds. A newborn baby may have a mass of about 3 kilograms. The gram (g), a unit of mass derived from the kilogram, is used to measure small amounts. A nickel has a mass of about 5 grams.

The ***liter*** (ℓ) is commonly used to measure *volume*. One liter is a little more than a quart. The gas tank of a compact car may hold 50 liters of gasoline.

Thus,

$$1 \text{ m} \approx 1 \text{ yd}$$
$$1 \text{ kg} \approx 2.2 \text{ lb}$$
$$1 \ell \approx 1 \text{ qt}$$

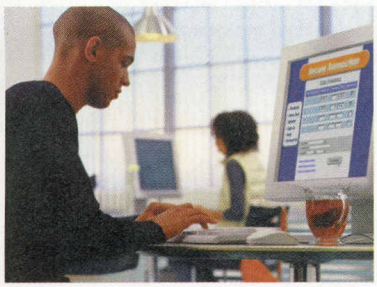
The term ***degree Celsius*** (°C) is used to measure temperature. The freezing point of water is 0°C, and the boiling point of water is 100°C. The temperature on a warm day may be 30°C.

$0°C = 32°F$	Water freezes
$22°C = 71.6°F$	Comfortable room temperature
$37°C = 98.6°F$	Body temperature
$100°C = 212°F$	Water boils

Prefixes

The metric system is based on the number 10 and therefore is a decimal system. Prefixes are used to denote a multiple or part of a base unit. Table 8.1 on page 434 summarizes the more commonly used prefixes and their meanings. In the table, where we mention "base units" we mean metric units without prefixes, such as meter, gram, or liter. From Table 8.1 on page 434, we can determine that a *deka*meter represents 10 meters, and a *centi*meter represents $\frac{1}{100}$ of a meter. Also, 1 kiloliter = 1000 liters, 1 kilogram = 1000 grams, and 1 milliliter = $\frac{1}{1000}$ liter.

In the metric system, as used outside the United States, groups of three digits in large numbers are separated by a space, not a comma. For example, the number for thirty thousand is 30 000, and the number for nine million is 9 000 000. Groups of three digits to the right of the decimal point are also separated by spaces. Commas are not used in the SI system because many countries use the comma as we use the decimal point. For example, 16 millionths is written 0,000 016 in many countries of the world. We will use the decimal point in this book and write 0.000 016. In this section, we will separate groups of three digits using spaces as done outside the United States. Note, however, that the space between groups of three digits is usually omitted if there



The computer's hard drive can store 80 gigabytes (80 GB) of information.

TABLE 8.1 Metric Prefixes

Prefix	Symbol	Meaning
kilo	k	1000 × base unit
hecto	h	100 × base unit
deka	da	10 × base unit
—	—	base unit
deci	d	$\frac{1}{10}$ of base unit
centi	c	$\frac{1}{100}$ of base unit
milli	m	$\frac{1}{1000}$ of base unit

are only four digits to the left or right of the decimal point. Thus, we will write three thousand as 3000 and five ten-thousandths as 0.0005.

For scientific work, which involves very large and very small quantities, the following prefixes are also used: *mega* (M) is one million times the base unit, *giga* (G) is one billion times the base unit, *tera* (T) is one trillion times the base unit, *micro* (μ, the Greek letter mu) is one millionth of the base unit, *nano* (n) is one billionth of the base unit, and *pico* (p) is one trillionth of the base unit.

In this book, the abbreviations or symbols for units of measure are not pluralized, but full names are. For example, 5 milliliters is symbolized as 5 mℓ, not 5 mℓs. Some countries that use the metric system do not use an "s" in their abbreviations, whereas others do.

Conversions within the Metric System

We will use Table 8.2 to help demonstrate how to change from one metric unit to another metric unit (meters to kilometers and so on).

The meters in Table 8.2 can be replaced by grams, liters, or any other base unit of the metric system. Regardless of which unit we choose, the procedure is the same. For purposes of explanation, we have used the meter.

TABLE 8.2 Changing Metric Units

Measure of length	kilometer	hectometer	dekameter	meter	decimeter	centimeter	millimeter
Symbol	km	hm	dam	m	dm	cm	mm
Number of meters	1000 m	100 m	10 m	1 m	0.1 m	0.01 m	0.001 m

Table 8.2 shows that 1 hectometer equals 100 meters and 1 millimeter is 0.001 (or $\frac{1}{1000}$) meter. The millimeter is the smallest unit in the table. A centimeter is 10 times as large as a millimeter, a decimeter is 10 times as large as a centimeter, a meter is 10 times as large as a decimeter, and so on. Because each unit is 10 times as large as the unit on its right, converting from one unit to another is simply a matter of multiplying or dividing by powers of 10.

Our neighbors in Canada (and also Mexico) use the metric system. As you will learn shortly, the distance to the Botanical Gardens is about 0.6 mile and the distance to Niagara-on-the-Lake is about 9 miles from the sign.

Changing Units within the Metric System

1. To change from a smaller unit to a larger unit (for example, from meters to kilometers), move the decimal point in the original quantity one place to the left for each larger unit of measurement until you obtain the desired unit of measurement.
2. To change from a larger unit to a smaller unit (for example from kilometers to meters), move the decimal point in the original quantity one place to the right for each smaller unit of measurement until you obtain the desired unit of measurement.

DID YOU KNOW

Additional Metric Prefaces

There are many publications about the metric system available free from the U.S. government. You may contact the National Institute of Standards and Technology (under the U.S. Department of Customs), through their Web site at www.nist.gov/, or you may write to their office (Gaithersburg, MD 20899). Two worthwhile publications are *Metric Style Guide for the News Media* and *A Brief History of Measurement Systems*. The following interesting chart was selected and modified from the latter.

*Some countries use D for deka.

METRIC PREFIXES

Multiples and Submultiples	Prefixes	Symbols
$1\,000\,000\,000\,000\,000\,000\,000\,000 = 10^{24}$	yotta	Y
$1\,000\,000\,000\,000\,000\,000\,000 = 10^{21}$	zetta	Z
$1\,000\,000\,000\,000\,000\,000 = 10^{18}$	exa	E
$1\,000\,000\,000\,000\,000 = 10^{15}$	peta	P
$1\,000\,000\,000\,000 = 10^{12}$	tera	T
$1\,000\,000\,000 = 10^{9}$	giga	G
$1\,000\,000 = 10^{6}$	mega	M
$1000 = 10^{3}$	kilo	k
$100 = 10^{2}$	hecto	h
$10 = 10^{1}$	deka	da*
$1 = 10^{0}$		
$0.1 = 10^{-1}$	deci	d
$0.01 = 10^{-2}$	centi	c
$0.001 = 10^{-3}$	milli	m
$0.000\,001 = 10^{-6}$	micro	μ
$0.000\,000\,001 = 10^{-9}$	nano	n
$0.000\,000\,000\,001 = 10^{-12}$	pico	p
$0.000\,000\,000\,000\,001 = 10^{-15}$	femto	f
$0.000\,000\,000\,000\,000\,001 = 10^{-18}$	atto	a
$0.000\,000\,000\,000\,000\,000\,001 = 10^{-21}$	zepto	z
$0.000\,000\,000\,000\,000\,000\,000\,001 = 10^{-24}$	yocto	y

EXAMPLE 1 *Changing Units*

a) Convert 462.3 m to km.

b) Convert 14 g to cg.

c) Convert 0.76 ℓ to mℓ.

d) Convert 240 daℓ to kℓ.

SOLUTION:

a) Table 8.2 shows that dekameters, hectometers, and kilometers are all larger units of measurements than meters. Kilometers appear three places to the left of meters in the table. Therefore, to change a measure from meters to kilometers, we must move the decimal point in the given number three places to the left, or

$$462.3 \text{ m} = 0.4623 \text{ km}$$

Note that since we are changing from a smaller unit of measurement (meter) to a larger unit of measurement (kilometer), the answer will be a smaller number of units.

b) Grams are a larger unit of measurement than centigrams. To convert grams to centigrams, we move the decimal point two places to the right, or

$$14 \text{ g} = 1400 \text{ cg}$$

Note that since we are changing from a larger unit of measurement (gram) to a smaller unit of measurement (centigram), the answer will be a larger number of units.

c) $0.76\ \ell = 760\ \text{m}\ell$

d) $240\ \text{da}\ell = 2.40\ \text{k}\ell$ ▲

EXAMPLE 2 *Two More Conversions*

a) Convert 305 mm to hectometers.

b) Convert 6.34 dam to decimeters.

SOLUTION:

a) Table 8.2 shows that hectometers are five places to the left of millimeters. Therefore, to make the conversion, we must move the decimal point in the given number five places to the left, or

$$305\ \text{mm} = 0.003\ 05\ \text{hm}$$

b) Table 8.2 shows that decimeters are two places to the right of dekameters. Therefore, to make the conversion, we must move the decimal point in the given number two places to the right, or

$$6.34\ \text{dam} = 634\ \text{dm}$$ ▲

EXAMPLE 3 *A Metric Road Sign*

The sign in the photo, from Cancun, Mexico, shows that there is a truck crossing 200 meters ahead. Notice that the sign uses "MTS" for meters.

a) Determine the distance in kilometers.

b) Determine the distance in centimeters.

SOLUTION:

a) We must move the decimal point three places to the left to change from meters to kilometers. Therefore,

$$200\ \text{m} = 0.2\ \text{km}$$

b) We must move the decimal point two places to the right to change from meters to centimeters. Therefore,

$$200\ \text{m} = 20\ 000\ \text{cm}$$ ▲

EXAMPLE 4 *Comparing Lengths*

Arrange in order from the smallest to largest length: 3.4 m, 3421 mm, and 104 cm.

SOLUTION:

To be compared, these lengths should all be in the same units of measure. Let's convert all the measures to millimeters, the smallest units of the lengths being compared.

3.4 m = 3400 mm 3421 mm 104 cm = 1040 mm

Since the lengths, in millimeters, from smallest to largest are 1040, 3400, 3421, the lengths arranged in order from smallest to largest are 104 cm, 3.4 m, and 3421 mm. ▲

SECTION 8.1 EXERCISES

Concept/Writing Exercises

1. What is the name commonly used for the Système international d'unités in the United States?
2. What is the name of the system of measurement primarily used in the United States today?
3. List three advantages of the metric system.
4. What metric unit is commonly used to measure
   a) length?
   b) mass?
   c) volume?
   d) temperature?
5. a) Explain how to convert from one metric unit of length to a different metric unit of length. Then use this procedure in parts (b) and (c).
   b) Convert 714.6 cm to kilometers.
   c) Convert 30.8 hm to decimeters.
6. What is the name of the prefix that is
   a) a million times the basic unit?
   b) one millionth of the base unit?
7. Without referring to any table, name as many of the metric system prefixes as you can and give their meanings. If you don't already know all the prefixes in Table 8.1, memorize them now.
8. a) How many times greater is 1 hectometer than 1 centimeter?
   b) Convert 1 hm to centimeters.
   c) Convert 1 cm to hectometers.
9. a) How many times greater is 1 dam than 1 dm?
   b) Convert 1 dam to decimeters.
   c) Convert 1 dm to dekameters.
10. a) What is the freezing temperature of water in the metric system?
    b) What is the boiling point of water in the metric system?
    c) What is normal human body temperature in the metric system?

Practice the Skills

In Exercises 11–16, fill in the blank.

11. One kilogram is a little more than _____ pounds.
12. One meter is a little longer than a _____.
13. One nickel has a mass of about _____ grams.
14. The temperature on a warm day may be _____ °C.
15. A comfortable room temperature may be _____ °C.
16. A door may be _____ meters high.

In Exercises 17–22, match the prefix with the one letter, a–f, that gives the meaning of the prefix.

17. Kilo
18. Milli
19. Hecto
20. Deka
21. Deci
22. Centi

a) $\frac{1}{100}$ of base unit
b) $\frac{1}{1000}$ of base unit
c) 100 times base unit
d) 1000 times base unit
e) 10 times base unit
f) $\frac{1}{10}$ of base unit

23. Complete the following.
    a) 1 dekaliter = 10 liters
    b) 1 centiliter = 1/100 liter
    c) 1 milliliter = 1/1000 liter
    d) 1 deciliter = 1/10 liter
    e) 1 kiloliter = 1000 liters
    f) 1 hectoliter = 100 liters
24. Complete the following.
    a) 1 hectogram = ____ grams
    b) 1 milligram = ____ gram
    c) 1 kilogram = ____ grams
    d) 1 centigram = ____ gram
    e) 1 dekagram = ____ grams
    f) 1 decigram = ____ gram

In Exercises 25–30, without referring to any of the tables or your notes, give the symbol and the equivalent in grams for the unit.

25. Milligram **26.** Centigram **27.** Decigram
28. Dekagram **29.** Hectogram **30.** Kilogram

Aerial Tram Load *In Exercises 31 and 32, use the photo, which shows the maximum load for an aerial tram in Switzerland. (Notice that in some countries, an "s" is used on the metric abbreviations.)*

31. What is the maximum load in grams?
32. What is the maximum load in milligrams?

In Exercises 33–42, fill in the missing values.

33. 2 m = ____ cm
34. 35.7 hg = ____ g
35. 0.095 hℓ = ____ ℓ
36. 7 dam = ____ m
37. 242.6 cm = ____ hm
38. 1.34 mℓ = ____ ℓ
39. 4036 mg = ____ hg
40. 14.27 kℓ = ____ ℓ
41. 1.34 hm = ____ cm
42. 0.000 062 kg = ____ mg

In Exercises 43–50, convert the given unit to the unit indicated.

43. 92.5 kg to grams
44. 7.3 m to millimeters
45. 895 ℓ to milliliters
46. 24 dm to kilometers
47. 240 cg to hectograms
48. 6049 mm to meters
49. 40 302 mℓ to dekaliters
50. 0.034 mℓ to liters

In Exercises 51–56, arrange the quantities in order from smallest to largest.

51. 5.1 dam, 0.47 km, 590 cm
52. 514 hm, 62 km, 680 m
53. 2.2 kg, 2400 g, 24 300 dg
54. 4.3 ℓ, 420 cℓ, 0.045 kℓ
55. 2.6 km, 203 000 mm, 52.6 hm
56. 0.032 kℓ, 460 dℓ, 48 000 cℓ

Problem Solving

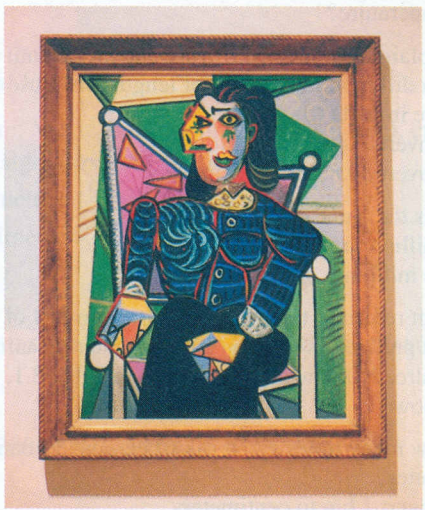
57. ***Who Ran Faster*** Jim ran 100 m, and Bob ran 100 yd in the same length of time. Who ran faster? Explain.

58. ***Walking*** Would you be walking faster if you walked 1 dam in 10 min or 1 hm in 10 min? Explain.

59. ***Water Removal*** One pump removes 1 daℓ of water in 1 min, and another pump removes 1 dℓ of water in 1 min. Which pump removes water faster? Explain.

60. ***Balance*** If 5 kg are placed on one side of a balance and a 15 lb weight is placed on the other side, which way would the balance tip? Explain.

61. ***Framing a Masterpiece*** The painting by Picasso, including the frame, measures 74 cm by 99 cm.



a) How many centimeters of framing were needed to frame the painting?
b) How many millimeters of framing were needed to frame the painting?

62. ***Calcium Tablets*** Dr. Driscoll recommends that Sean take two 250 mg chewable calcium tablets each day.
a) How many milligrams of calcium will Sean take in a week?
b) How many grams of calcium will Sean take in a week?

63. ***A Home Run*** A baseball diamond is a square whose sides are about 27 m in length.
- **a)** How many meters does a batter run if he hits a home run?
- **b)** How many kilometers?
- **c)** How many millimeters?

64. ***Gas Consumption*** Dale Ewen drove 1200 km and used 187 ℓ of gasoline. What was his average rate of gas use for the trip
- **a)** in kilometers per liter?
- **b)** in meters per liter?

65. ***Track and Field*** The high school has a 400 m oval track. If Patty Burgess runs around the track eight times, how many kilometers has she traveled?

66. ***Aerating an Aquarium*** The filter pump on an aquarium circulates 360 mℓ of water every minute. If the aquarium holds 30 ℓ of water, how long will it take to circulate all the water?

67. ***Liters of Soda*** A bottle of soda contains 360 mℓ.
- **a)** How many milliliters are contained in a six-bottle carton?
- **b)** How many liters does the amount in part (a) equal?
- **c)** At \$2.45 for the carton of soda, what is its cost per liter?

68. ***Fill 'er Up*** In Europe, gas may cost the equivalent of about \$1.03 (American) per liter. What will be the cost of filling the gas tank of a car that has a capacity of 37.7 ℓ?

69. ***Turkey Dinner*** After a turkey is cooked it weighs 6.9 kg.
- **a)** What is its weight in grams?
- **b)** If Marie Sinclair cuts off one-third of the turkey and places it in the freezer, how many decigrams of turkey has she placed in the freezer?

70. ***Road Signs*** A road sign indicated that you are 750 km from the city of Kingston, Canada. A while later, while riding on the same road, a different road sign indicated that you are 325 hm from Kingston. How many kilometers have you traveled?

Challenge Exercises/Group Activities

In Exercises 71–74, fill in the blank to make a true statement.

71. 1 gigameter = ____ megameters

72. 1 nanogram = ____ micrograms

73. 1 teraliter = ____ picoliters

74. 1 megagram = ____ nanograms

Calcium *The recommended daily amount of calcium for an American adult is 0.8 g. In Exercises 75–78, how much of the food indicated must an adult eat to satisfy the entire daily allowance using only that food?*

75. Eggs: 1 egg contains 27 mg calcium.

76. Milk: 1 cup contains 288 mg calcium.

77. Broccoli: 1 cup (cooked) contains 195 mg calcium.

78. Raisin bran: 49 g contains 1.6 mg calcium.

Large and Small Numbers *One advantage of the metric system is that by using the proper prefix, you can write large and small numbers without large groups of zeroes. In Exercises 79–84, write an equivalent measurement with an amount greater than one that does not contain any zeroes. For example, you can write 3000 m without zeroes as 3 km and 0.0003 hm as 3 cm.*

79. 5000 cm **80.** 2000 mm **81.** 0.000 06 hg

82. 3000 dm **83.** 0.02 kℓ **84.** 500 cm

Recreational Mathematics

In Exercises 85–94, unscramble the word to make a metric unit of measurement.

85. magr **86.** migradec **87.** rteli

88. raktileed **89.** terem **90.** leritililm

91. reketolim **92.** timenceret **93.** greseed sulesic

94. togmeharc

Internet/Research Activities

95. Write a report on the development of the metric system in Europe. Indicate which individual people had the most influence in its development.

96. Write a report on why you believe many Americans oppose switching to the metric system. Give your opinion about whether the United States will eventually switch to the metric system and, if so, when it might do so.

8.2 LENGTH, AREA, AND VOLUME

This section and the next section are designed to help you *think metric*, that is, to become acquainted with day-to-day usage of metric units. In this section, we consider length, area, and volume.

Length

The basic unit of length is the meter. In all English-speaking countries except the United States, *meter* is spelled "metre." Until 1960, the meter was officially defined by the length of a platinum bar kept in a vault in France. The modern definition of the meter is based on the speed of light, a constant that has been defined with great precision. Other commonly used units of length are the kilometer, centimeter, and millimeter. The meter, which is a little longer than 1 yard, is used to measure things that we normally measure in yards and feet. A man whose height is about 2 meters is a tall man. A tractor trailer unit (an 18-wheeler) is about 18 meters long.

The kilometer is used to measure what we normally measure in miles. For example, the distance from New York to Seattle is about 5120 kilometers. One kilometer is about 0.6 mile, and 1 mile is about 1.6 kilometers.

Centimeters and millimeters are used to measure what we normally measure in inches. The centimeter is a little less than $\frac{1}{2}$ inch (see Fig. 8.1), and the millimeter is a little less than $\frac{1}{20}$ inch. A millimeter is about the thickness of a dime. A book may measure 20 cm by 25 cm with a thickness of about 3 cm. Millimeters are often used in scientific work and other areas in which small quantities must be measured. The length of a small insect may be measured in millimeters.

DID YOU KNOW

1 Yard = 3 Feet = 36 Inches = . . .

In the U.S. Customary system, 27 different units of length are used. How many of them can you name? Don't forget rod, mil, paris line, toise, cubit, and light-year. The different units can be found in the *CRC Handbook of Chemistry and Physics* or at the website www.hbcpnetbase.com.

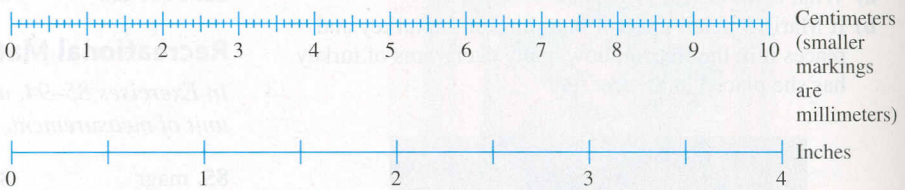


Figure 8.1

EXAMPLE 1 *Choosing an Appropriate Unit of Length*

Determine which metric unit of length you would use to express the following.

a) The length of a guitar
b) The length of your shoe
c) The height of the Sears Tower in Chicago
d) The length of an ant
e) The diameter of a half-dollar
f) The distance between Lexington, Kentucky, and Houston, Texas.
g) The diameter of a round wastepaper basket.
h) The diameter of a pencil
i) Your waist size
j) Your height

SOLUTION:

a) Meters or centimeters
b) Centimeters
c) Meters
d) Millimeters
e) Centimeters or millimeters
f) Kilometers
g) Centimeters
h) Millimeters
i) Centimeters
j) Meters or centimeters

In some parts of this solution, more than one possible answer is listed. Measurements can often be made by using more than one unit. For example, if someone asks your height, you might answer $5\frac{1}{2}$ feet or 66 inches. Both answers are correct. ▲

Area

The area enclosed in a square with 1-centimeter sides (Fig. 8.2) is 1 cm × 1 cm = 1 cm^2. A square whose sides are 2 cm (Fig. 8.3) has an area of 2 cm × 2 cm = 2^2 cm^2 = 4 cm^2.

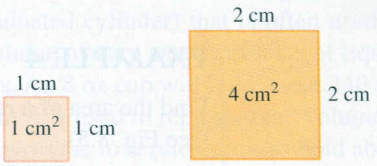


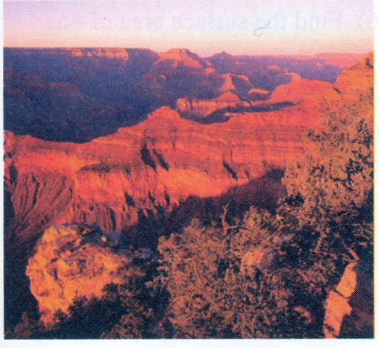
Figure 8.2

Figure 8.3

Areas are always expressed in square units, such as square centimeters, square kilometers, or square meters. When finding areas, be careful that all the numbers being multiplied are expressed in the same units.

In the metric system, the square centimeter replaces the square inch. The square meter replaces the square foot and square yard. In the future, you might purchase carpet or other floor covering by the square meter instead of by the square foot.

For measuring large land areas, the metric system uses a square unit 100 meters on each side (a square hectometer). This unit is called a ***hectare*** (pronounced "hectair" and symbolized ha). A hectare is about 2.5 acres. One square mile of land contains about 260 hectares. Very large units of area are measured in square kilometers. One square kilometer is about $\frac{4}{10}$ square mile.



The Grand Canyon National Park, Arizona, see Example 2a)

EXAMPLE 2 *Choosing an Appropriate Unit of Area*

Determine which metric unit of area you would use to measure the area of the following.

a) The Grand Canyon National Park
b) The top of a kitchen table
c) The floor of the classroom
d) A person's property with an average-sized lot
e) The cover of this book
f) A football field
g) An ice-skating rink
h) A dime
i) A lens in eyeglasses
j) A dollar bill

SOLUTION:

a) Square kilometers or hectares
b) Square meters
c) Square meters
d) Square meters or hectares
e) Square centimeters
f) Hectares or square meters
g) Square meters
h) Square millimeters or square centimeters
i) Square centimeters
j) Square centimeters

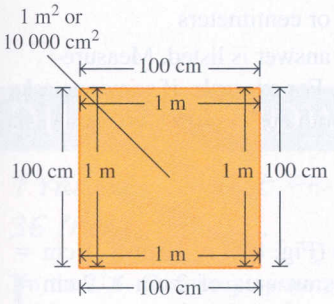


Figure 8.4

EXAMPLE 3 *Same Area, Different Units*

A square meter is how many times as large as a square centimeter?

SOLUTION: Since 1 m equals 100 cm, we can replace 1 m with 100 cm (see Fig. 8.4). The area of $1\ m^2 = 1\ m \times 1\ m = 100\ cm \times 100\ cm = 10\,000\ cm^2$. Thus, the area of one square meter is 10 000 times the area of one square centimeter. This technique can be used to convert from any square unit to a different square unit.

EXAMPLE 4 *Table Top*

Find the area of a rectangular table top if its length is 1.5 m and its width is 1.1 m (see Fig. 8.5).

SOLUTION: To find the area, we use the formula

$$\text{Area} = \text{length} \times \text{width}$$

or

$$A = l \times w$$

Substituting values for l and w, we have

$$A = 1.5\ m \times 1.1\ m$$
$$= 1.65\ m^2$$

Notice that the area is measured in square meters.

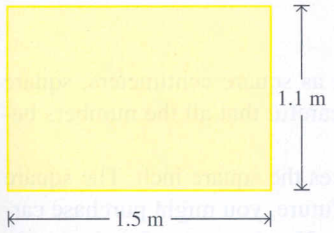


Figure 8.5

EXAMPLE 5 *A Quarter*

A quarter has a diameter of about 2.4 cm (Fig. 8.6). Find the surface area of one side of a quarter.

SOLUTION: The formula for the area of a circle is $A = \pi r^2$, where π is *approximately* 3.14. The radius, r, is one-half the diameter. Since the diameter is about 2.4 cm, the radius is about 1.2 cm. Substituting values for π and r, we get the following.

$$A = \pi r^2$$
$$\approx 3.14(1.2\ cm)^2$$
$$\approx 4.52\ cm^2$$

Thus, the area is approximately 4.52 square centimeters. Recall from earlier chapters that the symbol $\approx$ means "is approximately equal to."

Figure 8.6

TIMELY TIP Many calculators contain a $\boxed{\pi}$ key. If your calculator contains a $\boxed{\pi}$ key, you should use that key to input the value of π. If you do so, you will get a more accurate answer than if you used 3.14 for pi.

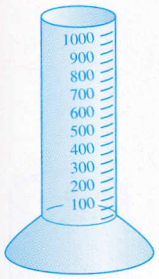


Figure 8.7

Volume

When a figure has only two dimensions—length and width—we can find its area. When a figure has three dimensions—length, width, and height—we can find its volume. The volume of an item can be considered the space occupied by the item.

In the metric system, volume may be expressed in terms of liters or cubic meters, depending on what is being measured. In all English-speaking countries except the United States, *liter* is spelled "litre."

The volume of liquids is expressed in liters. A liter is a little larger than a quart. Liters are used in place of pints, quarts, and gallons. A liter can be divided into 1000 equal parts, each of which is called a milliliter. Figure 8.7 illustrates a type of liter container (a 1000 mℓ graduated cylinder) that is often used in chemistry. Milliliters are used to express the volume of very small amounts of liquid. Drug dosages are often expressed in milliliters. An 8 oz cup will hold about 240 mℓ of liquid.

The kiloliter, 1000 liters, is used to represent the volume of large amounts of liquid. Tank trucks carrying gasoline to service stations hold about 10.5 kℓ of gasoline.

Cubic meters are used to express the volume of large amounts of solid material. The volume of a dump truck's load of topsoil is measured in cubic meters. The volume of natural gas used to heat a house may soon be measured in cubic meters instead of cubic feet.

The liquid in a liter container will fit exactly in a cubic decimeter (Fig. 8.8). Note that 1 ℓ = 1000 mℓ and that 1 dm^3 = 1000 cm^3. Because 1 ℓ = 1 dm^3, *1 mℓ must equal 1 cm^3*. Other useful facts are illustrated in Table 8.3. Thus, within the metric system, conversions are much simpler than in the U.S. customary system. For example, how would you change cubic feet of water into gallons of water?

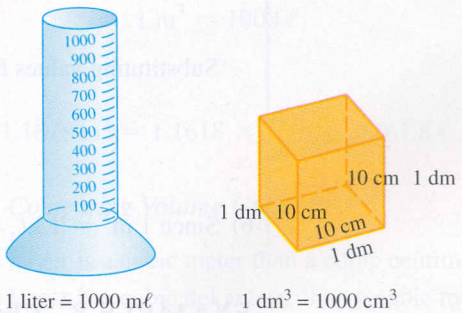


Figure 8.8

TABLE 8.3

Volume in Cubic Units		Volume in Liters
1 cm^3	=	1 mℓ
1 dm^3	=	1 ℓ
1 m^3	=	1 kℓ

The Alaskan pipeline

EXAMPLE 6 *Choosing an Appropriate Unit of Volume*

Determine which metric unit of volume you would use to measure the volume of the following.

a) The oil that flows through the Alaskan pipeline in a day
b) A carton of milk
c) A truckload of topsoil
d) A drug dosage
e) Sand in a paper cup
f) A dime
g) Water in a drinking glass
h) Water in a water bed
i) Space available in a refrigerator
j) Concrete used to lay the foundation for a basement

SOLUTION:

a) Kiloliters
b) Liters
c) Cubic meters
d) Milliliters
e) Cubic centimeters
f) Cubic milliliters
g) Milliliters
h) Liters or kiloliters
i) Cubic meters
j) Cubic meters

EXAMPLE 7 *Swimming Pool Volume*

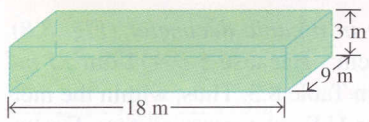


Figure 8.9

A swimming pool is 18 m long and 9 m wide, and it has a uniform depth of 3 m (Fig. 8.9). Find (a) the volume of the pool in cubic meters and (b) the volume of water in the pool in kiloliters.

SOLUTION:

a) To find the volume in cubic meters, we use the formula

$$V = l \times w \times h$$

Substituting values for l, w, and h we have

$$V = 18\text{ m} \times 9\text{ m} \times 3\text{ m}$$
$$= 486\text{ m}^3$$

b) Since $1\text{ m}^3 = 1\text{ k}\ell$, the pool will hold 486 kℓ of water.

EXAMPLE 8 *Choose an Appropriate Unit*

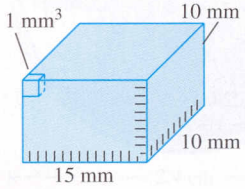


Figure 8.10

Select the most appropriate answer. The volume of a shoe box is approximately

a) 1500 mm^3. b) 6500 ℓ. c) 6500 cm^3.

SOLUTION: A shoe box is not a liquid, so its volume is not expressed in liters. Thus, (b) is not the answer. The volume of the rectangular solid in Fig. 8.10 is approximately 1500 mm^3, so (a) is not an appropriate answer. A shoe box may measure about 33 cm $\times$ 18 cm $\times$ 11 cm, or 6534 cm^3. Therefore, 6500 cm^3 or (c) is the most appropriate answer.

When the volume of a liquid is measured, the abbreviation cc is often used instead of cm^3 to represent cubic centimeters. For example, a nurse may give a patient an injection of 3 cc or 3 mℓ of the drug ampicillin.

EXAMPLE 9 *Measuring Medicine*

A nurse must give a patient 3 cc of the drug gentamicin mixed in 100 cc of a normal saline solution.

a) How many milliliters of the drug will the nurse administer?

b) What is the total volume of the drug and saline solution in milliliters?

SOLUTION:

a) Because 1 cc is equal in volume to 1 mℓ, the nurse will administer 3 mℓ of the drug.

b) The total volume is 3 + 100 or 103 cc, which is equal to 103 mℓ. ▲

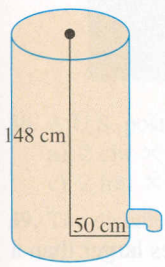


Figure 8.11

EXAMPLE 10 *A Hot-Water Heater*

A hot-water heater, in the shape of a right circular cylinder, has a radius of 50 cm and a height of 148 cm. What is the capacity, in liters, of the hot-water heater?

SOLUTION: The hot-water heater is illustrated in Fig. 8.11. The formula for the volume of a right circular cylinder is $V = \pi r^2 h$, where π is approximately 3.14. If we express all the measurements in meters, the volume will be given in cubic meters. Thus, 50 cm = 0.5 m, and 148 cm = 1.48 m.

$$\begin{aligned} V &= \pi r^2 h \\ &\approx 3.14(0.5)^2(1.48) \\ &\approx 3.14(0.25)(1.48) \approx 1.1618 \text{ m}^3 \end{aligned}$$

We want the volume in liters, so we must change the answer from cubic meters to liters.

$$1 \text{ m}^3 = 1000 \ell$$

So,

$$1.1618 \text{ m}^3 = 1.1618 \times 1000 = 1161.8 \ell$$ ▲

EXAMPLE 11 *Comparing Volume Units*

a) How many times larger is a cubic meter than a cubic centimeter?

b) How many times larger is a cubic dekameter than a cubic meter?

SOLUTION:

a) The procedure used to determine the answer is similar to that used in Example 3 in this section. First we draw a cubic meter, which is a cube 1 m long by 1 m wide by 1 m high. In Fig. 8.12 on page 446, we represent each meter as 100 centimeters. The volume of the cube is its length times its width times its height, or

$$\begin{aligned} V &= l \times w \times h \\ &= 100 \text{ cm} \times 100 \text{ cm} \times 100 \text{ cm} = 1\,000\,000 \text{ cm}^3 \end{aligned}$$

DID YOU KNOW

Metrics and Medicine

Both milliliters and cubic centimeters are commonly used in medicine. In the United States, cubic centimeters are commonly denoted cc rather than the cm^3 used in the metric system. A patient's intake and output of fluids and intravenous injections are commonly measured in cubic centimeters. Drug dosage is measured in milliliters.

The following question is from a nursing exam. Can you determine the correct answer?

In caring for a patient after delivery, you are to give 12 units of Pitocin (in 1000 cc of intravenous fluid). The ampule is labeled 10 units per 0.5 mℓ. How much of the solution would you draw and give?

a) 0.6 cc
b) 1.2 cc
c) 6.0 cc
d) 9.6 cc

Answer: (a)

Since $1\ m^3 = 1\ 000\ 000\ cm^3$, a cubic meter is one million times larger than a cubic centimeter.

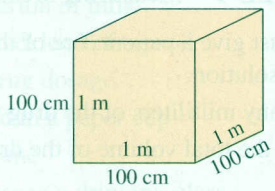


Figure 8.12

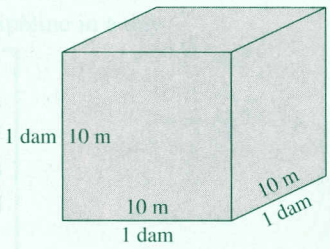


Figure 8.13

b) Work part (b) in a similar manner (Fig. 8.13).

$$V = l \times w \times h$$
$$= 10\ m \times 10\ m \times 10\ m = 1000\ m^3$$

Since $1\ dam^3 = 1000\ m^3$, a cubic dekameter is one thousand times larger than a cubic meter. ▲

SECTION 8.2 EXERCISES

Concept/Writing Exercises

In Exercises 1–12, an object has been measured and the measurement has been written with the unit indicated. Indicate what was measured: length, area, or volume.

1. m^3	**2.** mm	**3.** ha	**4.** m
5. cc	**6.** ℓ	**7.** cm^3	**8.** $k\ell$
9. m^2	**10.** $d\ell$	**11.** cm	**12.** cm^2

13. Estimate your height in (a) centimeters and (b) meters.

14. Estimate, in centimeters, the length of this book.

15. Estimate, in square centimeters, the surface area of this book.

16. Estimate, in meters, the length of the classroom in which your mathematics course is held.

17. Estimate, in centimeters, the length of your arm.

18. Estimate, in square centimeters, the surface area of a dollar bill.

19. One liter of liquid has the equivalent volume of which of the following: a cubic centimeter, a cubic decimeter, or a cubic meter?

20. One cubic meter has the equivalent volume of which of the following liquid measures: a liter, a milliliter, or a kiloliter?

21. One milliliter of liquid has the equivalent volume of which of the following: a cubic centimeter, a cubic decimeter, or a cubic meter?

22. Which metric measurement is used to measure very large areas of land?

23. Is the hectare a measure of length, area, or volume?

24. A hectare has an area of about how many acres: 2.5, 25, or 250?

Practice the Skills

In Exercises 25–36, indicate the metric unit of measurement that you would use to express the following.

25. The length of a calculator

26. The distance between cities

27. The length of a paper clip

28. The width of a Frisbee

29. The length of a newborn infant

30. The diameter of a pencil

31. The diameter of a jump rope

32. The width of an Olympic-size swimming pool

33. The length of a photograph

34. The length of a butterfly

35. The distance to the moon

36. The height of an adult male

In Exercises 37–44, choose the best answer.

37. The distance between home plate and first base is about how long?
a) 27 km **b)** 27 cm **c)** 27 m

38. A U.S. postage stamp is about how wide and how long?
a) 2 cm × 3 cm **b)** 2 mm × 3 mm
c) 2 hm × 3 hm

39. The distance between freeway exits could be how long?
a) 5 mm **b)** 5 m **c)** 5 km

40. A grown woman is about how tall?
a) 160 cm **b)** 160 mm **c)** 160 dm

41. The width of a piece of adhesive tape is about how wide?
a) 2 cm **b)** 2 mm **c)** 2 dm

42. The diameter of a coffee cup is about which of the following?
a) 8 mm **b)** 8 cm **c)** 8 dm

43. The length of the New River Gorge Bridge near Fayetteville, West Virginia is about how long?
a) 1000 dam **b)** 1000 m **c)** 1000 cm

44. The Sears Tower in Chicago is about how tall?
a) 375 cm **b)** 375 km **c)** 375 m

In Exercises 45–50, (a) estimate the item in metric units and (b) measure it with a metric ruler. Record your result.

45. The width of a card from a deck of cards

46. The width of a classroom door

47. The length of a car

48. The diameter of a can of soda

49. The height of a milk carton

50. The thickness of 10 sheets of paper.

In Exercises 51–56, replace the customary measure (shown in parentheses) with the appropriate metric measure.

51. Give him a _____ (inch), and he will take a _____ (mile).

52. There was a crooked man and he walked a crooked _____ (mile).

53. One hundred _____ (yard) dash.

54. I wouldn't touch a skunk with a 10-_____ (foot) pole.

55. I found a _____ (inch) worm.

56. This is a _____ (mile)stone in my life.

In Exercises 57–66, indicate the metric unit of measurement you would use to express the area of the following.

57. A computer monitor screen

58. The city of San Francisco

59. The floor of your classroom

60. The face of a dime

61. A building lot for a house

62. A baseball field

63. A postage stamp

64. A ceiling tile

65. Death Valley National Park

66. A professional basketball court

In Exercises 67–74, choose the best answer.

67. The area of a U.S. flag is about
a) 2.2 cm^2. **b)** 2.2 m^2. **c)** 2.2 km^2.

68. A U.S. postage stamp has an area of about
a) 5 cm^2. **b)** 5 mm^2. **c)** 5 dm^2.

69. The area of a city lot is about
a) 800 m^2. **b)** 800 hm^2. **c)** 800 cm^2.

70. The area of a city lot is about
a) $\frac{1}{8}$ m^2. **b)** $\frac{1}{8}$ ha. **c)** $\frac{1}{8}$ km^2.

71. The area of a ceiling tile is about
a) 360 m^2. **b)** 360 km^2. **c)** 360 cm^2.

72. The area of the face of a dime is about
a) 2.5 cm^2. **b)** 2.5 m^2. **c)** 2.5 mm^2.

73. The area of the screen of a table top TV is about
a) 1200 dm^2. **b)** 1200 mm^2. **c)** 1200 cm^2.

74. The area of the Grand Canyon National Park is about
a) 4900 m^2 **b)** 4900 cm^2 **c)** 4900 km^2

In Exercises 75–80, (a) estimate the area of the item in metric units and (b) measure it in metric units and compute its area.

75. A typical photograph

76. The cover of this book

77. A $5 bill

78. The top of your teacher's desk

79. The bottom of a 12 oz soda can

80. The face of a penny

In Exercises 81–90, determine the metric unit that would best be used to measure the volume of the following.

81. Water flowing over Niagara Falls per minute

Niagara Falls

82. Water in a hot-water heater

83. Liquid in an eye dropper

84. Air in a basketball

85. Oil needed to change the oil in your car

86. A bag of topsoil

87. A truckload of ready-mix concrete

88. Asphalt needed to pave a driveway

89. Soda in a bottle of soda

90. Air in a hot air balloon

In Exercises 91–98, choose the best answer to indicate the volume of the following.

91. A shoe box
a) 7780 mm^3 **b)** 7780 dm^3 **c)** 7780 cm^3

92. A quarter
a) 0.5 cm^3 **b)** 0.5 mm^3 **c)** 0.5 dm^3

93. Water in a 24-ft-diameter above-ground circular swimming pool
a) 55 ℓ **b)** 55 $m\ell$ **c)** 55 $k\ell$

94. Soda in a can of soda
a) 355 ℓ **b)** 355 $m\ell$ **c)** 355 m^3

95. A can of vegetables
a) 550 cm^3 **b)** 550 mm^3 **c)** 550 dm^3

96. Juice that can be squeezed out of an orange
a) 120 $k\ell$ **b)** 120 $m\ell$ **c)** 120 ℓ

97. Air in a balloon with a diameter of 4 meters
a) 30 m^3 **b)** 30 cm^3 **c)** 30 km^3

98. Air in a basketball
a) 14 000 m^3 **b)** 14 000 cm^3 **c)** 14 000 mm^3

In Exercises 99–102, (a) estimate the volume in metric units and (b) compute the actual volume of the item.

99. Air in a cardboard box that is 61 cm long, 61 cm wide, and 41 cm tall (Use $V = lwh$.)

100. Water in a water bed that is 2 m long, 1.5 m wide, and 25 cm deep

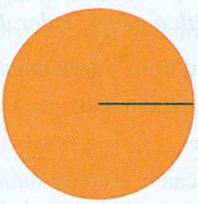
101. Oil in a barrel that has a height of 1 m and a diameter of 0.5 m (Use $V = \pi r^2 h$.)

102. Water in a cylindrical tank that is 40 cm in diameter and 2 m high

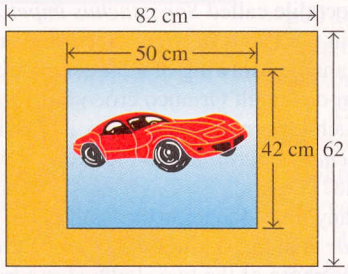
Problem Solving

103. ***Area*** Use a metric ruler to measure the length and width of the sides of the rectangle. Then compute the area of the rectangle. Give your answers in metric units.

104. ***Area*** Use a metric ruler to find the radius of the circle. Then compute the area of the circle. Give your answers in metric units.



105. ***A Mat for a Picture*** A framed picture is shown. Find the matted area.

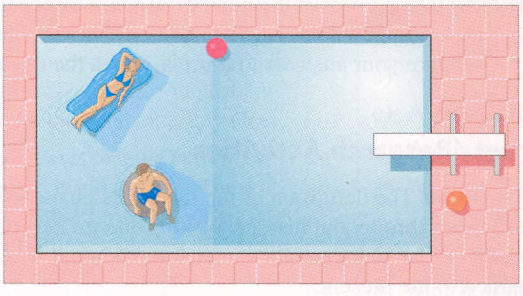


106. ***A Walkway*** A rectangular building 50 m by 70 m is surrounded by a walk 1.5 m wide.
a) Find the area of the region covered by the building and the walk.
b) Find the area of the walk.

107. ***Farmland*** Mrs. Manecki has purchased a farm that is in the shape of a rectangle. The dimensions of the piece of land are 1.4 km by 3.75 km.
a) How many square kilometers of land did she purchase?
b) If 1 km^2 equals 100 ha, determine the amount of land she purchased in hectares.

108. ***Area of a Garden*** Mr. Baumgarten's garden is 22.5 m by 18.3 m.
a) How large is his garden in square meters?
b) If 1 m^2 equals 0.0001 ha, determine the area of his garden in hectares.

109. ***Volume of Water*** **a)** What is the volume of water in a swimming pool that is 18 m long and 10 m wide and has an average depth of 2.5 m? Give your answer in cubic meters.
b) How many kiloliters of water will the pool hold?



110. ***Cost of Paint*** The first coat of paint for the outside of a building requires 1 ℓ of paint for each 10 m^2. The second coat requires 1 ℓ for every 15 m^2. If the paint costs \$4.75 per liter, what will be the cost of two coats of paint for the four outside walls of a building 20 m long, 12 m wide, and 6 m high?

111. ***Fish Tank Volume*** A rectangular fish tank is 70 cm long, 40 cm wide, and 20 cm high.
a) How many cubic centimeters of water will the tank hold?
b) How many milliliters of water will the tank hold?
c) How many liters of water will the tank hold?

112. ***How Much Soup?*** A can of Campbell's Home Cookin' chicken vegetable soup has a diameter of 8.0 cm and a height of 12.5 cm. Determine the volume of soup in the can (assume that the can is filled with soup).

113. How many times larger is a square dekameter than a square meter?

114. How many times larger is a square kilometer than a square dekameter?

115. How many times larger is a cubic meter than a cubic decimeter?

116. How many times larger is a cubic centimeter than a cubic millimeter?

In Exercises 117–124, replace the question mark with the appropriate value.

117. 1 m^2 = ? mm^2
118. 1 hm^2 = ? cm^2
119. 1 km^2 = ? hm^2
120. 1 cm^2 = ? m^2
121. 1 mm^3 = ? cm^3
122. 1 dm^3 = ? mm^3
123. 1 m^3 = ? cm^3
124. 1 hm^3 = ? km^3

In Exercises 125–128, fill in the blank.

125. 435 cm^3 = ____ $m\ell$
126. 435 cm^3 = ____ ℓ
127. 76 $k\ell$ = ____ m^3
128. 4.2 ℓ = ____ cm^3

Glacier *In Exercises 129 and 130, assume that a part of a glacier that contains 60 cubic meters of ice calves (or breaks) off and falls into the ocean.*

A Glacier in Alaska

129. When the ice that has fallen into the ocean melts, determine the approximate amount of water, in deciliters, obtained from the ice.

130. When the ice melts, determine the approximate amount of water, in cubic centimeters, obtained from the ice.

Challenge Problems/Group Activities

131. Starting with a straight piece of wood of sufficient size, construct a meter stick. Indicate decimeters, centimeters, and millimeters on the meter stick. Use the centimeter measure in Fig. 8.1 as a guide.

132. Construct a metric tape measure from a piece of tape or rope and then determine your waist measurement.

In Exercises 133 and 134, fill in the blank to make a true statement.

133. 6.7 kℓ = ____ dm^3 **134.** 1.4 ha = ____ cm^2

135. ***Conversions*** In Example 3, we illustrated how to change an area in a metric unit to an area measured with a different metric unit.
- **a)** Using Example 3 as a guide, change 1 square mile to square inches.
- **b)** Is converting from one unit of area to a different unit of area generally easier in the metric system or the U.S. customary system? Explain.

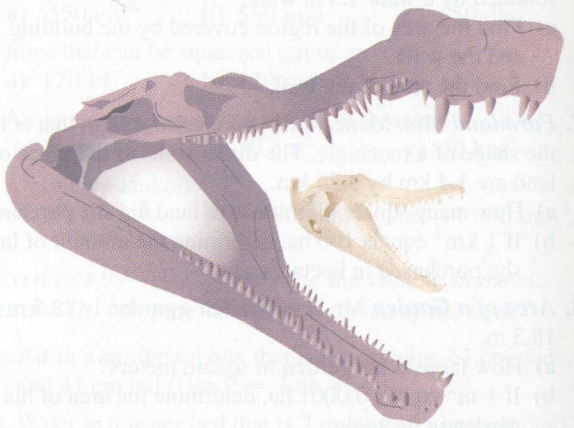
136. ***Conversions*** In Example 11, we illustrated how to change a volume in one metric unit to a volume measured with a different metric unit.
- **a)** Using Example 11 as a guide, change 6 yd^3 (a volume 1 yard by 2 yards by 3 yards) into cubic inches.
- **b)** Is converting from one unit of volume to a different unit of volume generally easier in the metric system or the U.S. customary system? Explain.

Recreational Mathematics

137. ***Find the Words*** In the box below, the following words are spelled out: METER, MILLIMETER, CENTIMETER, LITER, HECTARE, SQUARE METER, MILLILITER. You can find these words by moving from square to square, vertically, horizontally, or diagonally (either up and down or forward or backward). You may leave a square and then return to that square to use that letter again. You can use the same squares to make the different words. There is no space left in the box between the words square meter. How many of the words can you find?

C	E	H	M	I
T	U	Q	S	L
A	R	E	I	L
T	I	M	E	T
N	E	C	E	R

138. ***Crocodiles*** The following drawing shows a complete 1.5-meter-long fossil skull of an estimated 110-million-year-old crocodile called *Sarcosuchus imperator*, which was found in the 1960s in Niger. Superimposed on the drawing is another drawing of a 50-centimeter-long skull of a modern-day adult Orinoco crocodile.
- **a)** How much longer, in centimeters, is the skull of the *Sarcosuchus imperator* than the skull of the Orinoco crocodile?
- **b)** How many times longer is the skull of the *Sarcosuchus imperator* than the skull of the Orinoco crocodile?
- **c)** Does this photo of the two skulls give a true perspective of the relative sizes of the two skulls? Explain.



139. ***Water Usage*** **a)** How much water do we use daily? On the average, people in the United States use more water than people anywhere else in the world. Take a guess at the number of liters of water used per day per person in the United States.
- **b)** Now take a guess at the number of liters used per day per person in the United Kingdom.

Compare your answers to those given in the answer section.

Internet/Research Activities

140. ***The Meter*** The definition of the meter has changed several times throughout history. Write a one- to two-page report on the history of the meter, from when it was first named to the present.

8.3 MASS AND TEMPERATURE

In this section, we discuss the metric measurements of mass and temperature. As with Section 8.2, the focus of this section is on thinking metric.

Mass

Weight and mass are not the same. ***Mass*** is a measure of the amount of matter in an object. It is determined by the molecular structure of the object, and it will not change

DID YOU KNOW

The Kilogram

Since 1889, a single platinum–iridium bar has been sealed in an airtight jar in the International Bureau of Weights and Measures in Sèvres, France.

Nicknamed "Le Grand K," this bar constitutes the one and only true kilogram. Of all the standard international units of measure, the kilogram remains the only one whose definition relies on a physical artifact. All the other units have their definitions rooted in constants of nature, such as the speed of light or atomic vibrations.

As part of an international effort, researchers at the U.S. National Institute of Standards and Technology in Washington, D.C., want to redefine the kilogram in a way that will make the standard absolute, unchanging, and accessible to anyone, anywhere.

One problem is that the current standard tends to drift a bit. The kilogram has varied by as much as 0.05 part per million in the last 100 years. The cause of that variance remains unknown.

Orcas (or killer whales) at Sea World.

from place to place. Weight is a measure of the gravitational pull on an object. For example, the gravitational pull of Earth is about six times as great as the gravitational pull of the moon. Thus, a person on the moon weighs about $\frac{1}{6}$ as much as on Earth, even though the person's mass remains the same. In space, where there is no gravity, a person has no weight.

Even on Earth, the gravitational pull varies from point to point. The closer you are to Earth's center, the greater the gravitational pull. Thus, a person weighs very slightly less on a mountain than in a nearby valley. Because the mass of an object does not vary with location, scientists generally use mass rather than weight.

Although weight and mass are not the same, on Earth they are proportional to each other (the greater the weight, the greater the mass). Therefore, for our purposes, we can treat weight and mass as the same.

The *kilogram* is the basic unit of mass in the metric system. It is a little more than 2 lb. The official kilogram is a cylinder of platinum–iridium alloy kept by the International Bureau of Weights and Measures, located in Sèvres, near Paris. (See the Did You Know in the margin.)

Items that we normally measure in pounds are usually measured in kilograms in other parts of the world. For example, an average-sized man has a mass of about 75 kg.

The *gram* (a unit that is 0.001 kg) is relatively small and is used in place of the ounce. A nickel has a mass of about 5 g, a cube of sugar has a mass of about 2 g, and a large paper clip has a mass of about 1 g.

The *milligram* is used extensively in the medical and scientific fields as well as in the pharmaceutical industry. Nearly all bottles of tablets are now labeled in either milligrams or grams.

The *metric tonne* (t) is used to express the mass of heavy items. One metric tonne equals 1000 kg. It is a little larger than our customary ton of 2000 lb. The mass of a large truck may be expressed in metric tonnes.

EXAMPLE 1 *Choosing the Appropriate Unit*

Determine which metric unit you would use to express the mass of the following.

a) An orca (or killer whale)
b) A newborn child
c) A teaspoon of sugar
d) A box of cereal
e) A quarter
f) A fly
g) A frog
h) A refrigerator

SOLUTION:

a) Metric tonnes
b) Kilograms
c) Grams
d) Grams
e) Grams
f) Milligrams
g) Grams
h) Kilograms

One kilogram of water has a volume of exactly 1 liter. In fact, a liter is defined to be the volume of 1 kilogram of water at a specified temperature and pressure. Thus, mass and volume are easily interchangeable in the metric system. Converting from weight to volume is not nearly as convenient in the U.S. customary system. For example, how would you change pounds of water to cubic feet or gallons of water in our customary system?

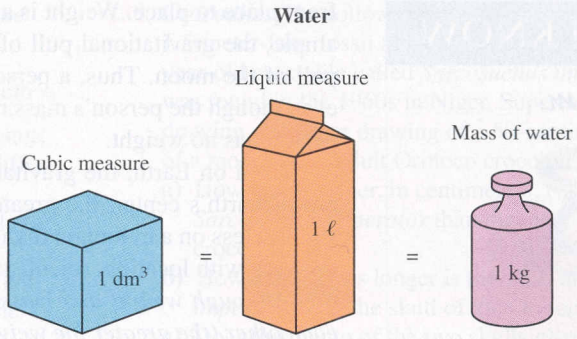


Figure 8.14

Since 1 dm^3 = 1000 cm^3, 1ℓ = 1000 mℓ, and 1kg = 1000g, we have the following relationship.

$$\begin{array}{rrcrcr} & 1000\ cm^3 & = & 1000\ m\ell & = & 1000\ g \\ \text{or,} & 1\ cm^3 & = & 1\ m\ell & = & 1\ g \end{array}$$

Figure 8.14 illustrates the relationship between volume of water in cubic decimeters, in liters, and mass in kilograms. Table 8.4 expands on this relationship between the volume and mass of water.

TABLE 8.4 Volume and Mass of Water

Volume in Cubic Units		Volume in Liters		Mass of Water
1 cm^3	=	1 mℓ	=	1 g
1 dm^3	=	1 ℓ	=	1 kg
1 m^3	=	1 kℓ	=	1 t (1000 kg)

TIMELY TIP In Chapter 9, we provide formulas and discuss procedures for finding the area and volume of many geometric figures. The procedures and formulas for finding area and volume are the same regardless of whether the units are metric units or customary units. When finding areas and volumes, each side of the figure must be given in (or converted to) the same unit.

EXAMPLE 2 *A Fish Tank's Capacity*

A fish tank is 1 m long, 50 cm high, and 250 mm wide (Fig. 8.15).

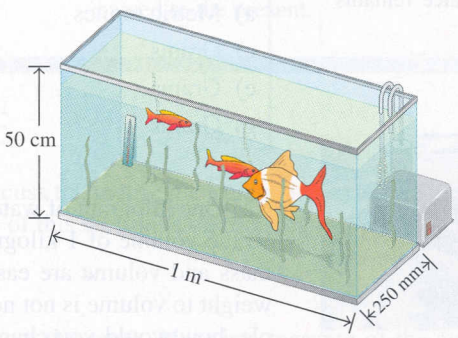


Figure 8.15

DID YOU KNOW

Penny-wise, Kilo-foolish

Steven Thoburn

Steven Thoburn, 36, a British grocer, has been charged in the northern England town of Sunderland with violating British law. His crime: He used a nonmetric scale to sell bananas to undercover officers. This year-old law was instituted to bring Britain in harmony with European Union standards. If convicted, Thoburn could have faced a fine of £7300 (about $11,500) and a six-month jail sentence.

Thoburn pleaded not guilty and did not dispute the facts. His defense argued that the laws that required metrification of scales were invalid. A district judge disagreed and in April 2002 handed Thoburn a six-month conditional discharge (suspended sentence). The trial has already cost Thoburn in excess of £35,000 (about $55,000), but he has indicated that he will appeal the ruling. For further information, see www.metricmartyrs.com.

a) Determine the number of liters of water the tank holds.

b) What is the mass of the water in kilograms?

SOLUTION:

a) We must convert all the measurements to the same units. Let's convert them all to meters: 50 cm is 0.5 m, and 250 mm is 0.25 m.

$$\begin{aligned} V &= l \times w \times h \\ &= 1 \times 0.25 \times 0.5 \\ &= 0.125 \text{ m}^3 \end{aligned}$$

Since 1 m^3 of water = 1 kℓ of water,

$$0.125 \text{ m}^3 = 0.125 \text{ k}\ell, \text{ or } 125 \ \ell \text{ of water}$$

b) Since 1 ℓ = 1 kg, 125 ℓ = 125 kg of water. ▲

To convince yourself of the advantages of the metric system, do a similar problem involving the customary system of measurement, such as Challenge Problems/Group Activities Exercise 73 at the end of this section.

Temperature

The Celsius scale is used to measure temperatures in the metric system. Figure 8.16 on page 454 shows a thermometer with the Fahrenheit scale on the left and the Celsius scale on the right.

The Celsius scale was named for the Swedish astronomer Anders Celsius (1701–1744), who first devised it in 1742. On the Celsius scale, water freezes at 0°C and boils at 100°C. In the past, the Celsius thermometer was called a "centigrade thermometer." Recall that *centi* means $\frac{1}{100}$, and there are 100 degrees between the freezing point of water and the boiling point of water. Thus, 1°C is $\frac{1}{100}$ of this interval. Table 8.5 gives some common temperatures in both degrees Celsius (°C) and degrees Fahrenheit (°F).

TABLE 8.5

Celsius Temperature		Fahrenheit Temperature
−18°C	A very cold day	0°F
0°C	Freezing point of water	32°F
10°C	A warm winter day	50°F
20°C	A mild spring day	68°F
30°C	A warm summer day	86°F
37°C	Body temperature	98.6°F
100°C	Boiling point of water	212°F
177°C	Oven temperature for baking	350°F

At a temperature of −40° the Celsius and Fahrenheit temperatures are the same. That is, −40°C = −40°F. See Exercise 72.

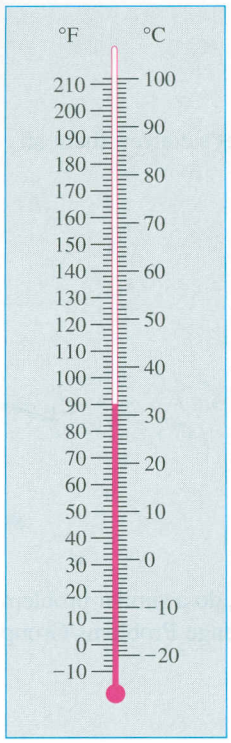


Figure 8.16

EXAMPLE 3 *Think Metric Temperatures*

Choose the best answer. (Refer to the dual-scale thermometer in Fig. 8.16.)

a) Buffalo, New York, on New Year's Day might have a temperature of
   i) −15°C. ii) 15°C. iii) 40°C.

b) Washington, D.C., on July 4 might have a temperature of
   i) 15°C. ii) 30°C. iii) 40°C.

c) The oven temperature for baking a cake might be
   i) 60°C. ii) 100°C. iii) 175°C.

SOLUTION:

a) A temperature of 15°C is possible if it is a very mild winter, but 40°C is much too hot. The best answer for a normal winter is −15°C.

b) The best estimate is 30°C. A temperature of 15°C is too chilly, and 40°C is too hot for July 4.

c) A cake bakes at temperatures well above boiling, so the only reasonable answer is 175°C. ▲

Comparing the temperature in Table 8.5, we see that the Celsius scale has 100° from the boiling point of water to the freezing point of water and the Fahrenheit scale has 180° from the boiling point of water to the freezing point of water. Therefore, one Celsius degree represents a greater change in temperature than one Fahrenheit degree does. In fact, one Celsius degree is the same as $\frac{180}{100}$, or $\frac{9}{5}$ Fahrenheit degrees. When converting from one system to the other system, use the following formulas.

From Celsius to Fahrenheit

$$F = \frac{9}{5}C + 32$$

From Fahrenheit to Celsius

$$C = \frac{5}{9}(F - 32)$$

EXAMPLE 4 *Convert to °C*

A typical setting for home thermostats is 72°F. What is the equivalent temperature on the Celsius thermometer?

SOLUTION: We use the formula $C = \frac{5}{9}(F - 32)$ to convert from °F to °C. Substituting $F = 72$ gives

$$\begin{aligned} C &= \frac{5}{9}(72 - 32) \\ &= \frac{5}{9}(40) \\ &\approx 22.2 \end{aligned}$$

Thus, the equivalent temperature of 72°F is about 22.2°C. ▲

EXAMPLE 5 *Convert to °F*

If the temperature outdoors is 28°C, will you need to wear a sweater if going outdoors?

SOLUTION: We use the formula $F = \frac{9}{5}C + 32$ to convert from °C to °F. Substituting $C = 28$ yields

$$F = \frac{9}{5}(28) + 32$$
$$= 50.4 + 32$$
$$= 82.4$$

Since the temperature is about 82.4°F, you will not need to wear a sweater. ▲

DID YOU KNOW

It's a Metric World

The United States is the only westernized country not currently using the metric system as its primary system of measurement. The only countries in the world besides the United States not using or committed to using the metric system are Yemen, Brunei, and a few small islands; see Fig. 8.17.

The European Union (EU) adopted a directive that requires all exporters to EU nations to indicate the dimensions of their products in metric units. Currently, U.S. manufacturers who export goods are doing so. Little by little, the United States is becoming more metric. For example, soft drinks come in liter bottles and prescription drug dosages are given in metric units. Maybe in the not too distant future gasoline will be measured in liters, not gallons, as it is in Canada and Mexico.

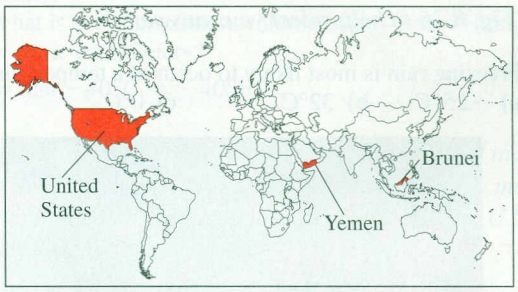


Figure 8.17

SECTION 8.3 EXERCISES

Concept/Writing Exercises

1. What is the basic unit of mass in the metric system?
2. The mass of a nickel is about how many grams?
3. One kilogram is a little more than how many pounds?
4. What unit of mass is used to express the mass of very heavy items?
5. Give an estimate of the temperature, in degrees Celsius, in Florida in August.
6. Give an estimate of the temperature, in degrees Celsius, in North Dakota in February.
7. Give an estimate, in degrees Celsius, of what you would consider an ideal outdoor temperature.
8. **a)** Is a person's mass the same in space as on Earth? Explain.
   b) Is a person's weight the same in space as on Earth? Explain.

Practice the Skills

In Exercises 9–18, indicate the metric unit of measurement that would best express the mass of the following.

9. A quarter
10. A man
11. A pair of eyeglasses
12. A box of cereal
13. A new pencil
14. An SUV
15. A refrigerator
16. A mosquito
17. A roll of paper towels
18. A calculator

In Exercises 19–24, select the best answer.

19. The mass of a 5 lb bag of flour is about how much?
    a) 2.26 g **b)** 2.26 kg **c)** 2.26 dag
20. The mass of a dime is about how much?
    a) 9.1 mg **b)** 9.1 kg **c)** 9.1 g

21. The mass of a child's pail filled with sand is about how much?
a) 1.4 mg **b)** 1.4 kg **c)** 1.4 g

22. The mass of a box of cornflakes is about how much?
a) 0.45 t **b)** 0.45 g **c)** 0.45 kg

23. The mass of a full-grown elephant is about how much?
a) 2800 g **b)** 2800 kg **c)** 2800 dag

24. The mass of a full-size car is about how much?
a) 1 962 000 hg **b)** 380 kg **c)** 1.6 t

In Exercises 25–28, estimate the mass of the item. If a scale with metric measure is available, find the mass.

25. Your body
26. A telephone book
27. A gallon of water
28. A tomato

In Exercises 29–38, choose the best answer. Use Table 8.5 and Fig. 8.16 to help select your answers.

29. Freezing rain is most likely to occur at a temperature of
a) −25°C. **b)** 32°C. **c)** 0°C.

Rochester, New York

30. A cup of coffee might have a temperature of
a) 15°C. **b)** 50°C. **c)** 90°C.

31. The thermostat for an air conditioner was set for 80°F. This setting is closest to
a) 2°C. **b)** 27°C. **c)** 57°C.

32. The temperature of the water in a certain lake is 5°C. You could
a) ice fish.
b) dress warmly and walk along the lake.
c) swim in the lake.

33. What might be the temperature at which a refrigerator is set?
a) 30°C **b)** 5°C **c)** 0°C

34. The weather forecast calls for a high of 32°C. You should plan to wear
a) a down-lined jacket.
b) a sweater.
c) a bathing suit.

35. What might be the temperature of an apple pie baking in the oven?
a) 90°C **b)** 100°C **c)** 177°C

36. The temperature of the water in a car's radiator when the car's engine is operating at its normal temperature might be
a) 70°C. **b)** 300°C. **c)** 110°C.

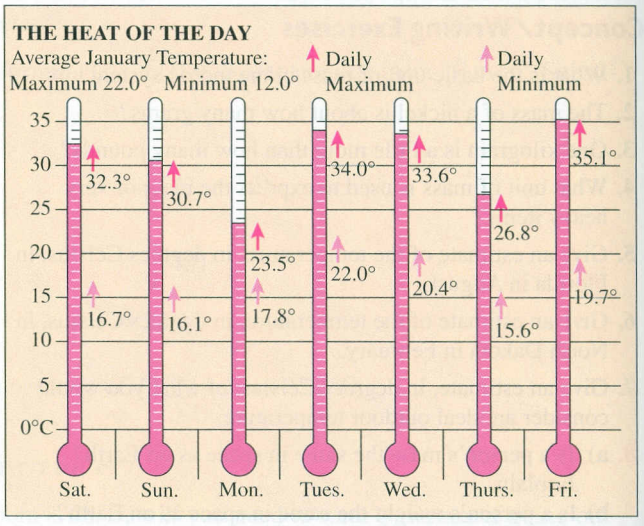
37. What might be the temperature at which a home freezer is set?
a) −20°C **b)** −7°C **c)** 2°C

38. The temperature of water in a hot tub might be
a) 30°C. **b)** 50°C. **c)** 40°C.

In Exercises 39–52, convert each temperature as indicated. Give your answer to the nearest tenth of a degree.

39. 30°C = ____°F
40. −5°C = ____°F
41. 92°F = ____°C
42. −10°F = ____°C
43. 180°F = ____°C
44. 98°F = ____°C
45. 37°C = ____°F
46. −4°C = ____°F
47. 13°F = ____°C
48. 75°F = ____°C
49. 45°C = ____°F
50. 60°C = ____°F
51. −20°F = ____°C
52. 425°F = ____°C

In Exercises 53–58, use the following graph, which shows the daily low and high temperatures, in degrees Celsius, for the week in a country that uses the metric system. The week illustrated was unseasonably warm. Determine the following temperatures in degrees Fahrenheit.



53. The average January maximum temperature

54. The maximum temperature for the week

55. The maximum temperature on Friday

56. The maximum temperature on Saturday

57. The range of temperatures on Monday

58. The range of temperatures on Tuesday

Problem Solving

The photo shows the cost of Crest Grower Crumbles and corn at a farm market in Fiji. Use the information provided in the photo to answer Exercises 59 and 60. In the photo, kilo is an abbreviation for kilogram.

59. ***Crest Grower Crumbles*** Determine the cost, in dollars, of 6.2 kg of Crest Grower Crumbles. (Grower Crumbles is a poultry feed.)

60. ***Corn*** Determine the cost, in dollars, of 1.3 kg of corn.

61. ***Salt and Soda*** A mixture of 45 g of salt and 29 g of baking soda is poured into 370 mℓ of water. What is the total mass of the mixture in grams?

62. ***Jet Fuel*** A jet can travel about 1 km on 17 kg of fuel. How many metric tonnes of fuel will the jet use flying nonstop between Baltimore and Los Angeles, a distance of about 4320 km?

63. ***A Storage Tank*** The dimensions of a storage tank are length 16 m, width 12 m, and height 12 m. If the tank is filled with water, determine

a) the volume of water in the tank in cubic meters.

b) the number of kiloliters of water the tank will hold.

c) the mass of the water in metric tonnes.

64. ***A Water Heater*** A hot-water heater in the shape of a right circular cylinder has a radius of 50 cm and a height of 150 cm. If the tank is filled with water, determine

a) the volume of water in the tank in cubic meters.

b) the number of liters of water the tank will hold.

c) the mass of the water in kilograms.

65. ***What's the Problem?*** A temperature display at a bank flashes the temperature in degrees Fahrenheit and then flashes the temperature in degrees Celsius. If it flashes 78°F, then 20°C, is there a problem? Explain.

66. ***Fever or Chills?*** Maria's body temperature is 38.2°C. Should she take an aspirin or put on a sweater? Explain.

In Exercises 67–70, convert as indicated

67. 4.2 kg = ____ t

68. 9.52 t = ____ kg

69. 17.4 t = ____ g

70. 1 460 000 mg = ____ t

Challenge Problems/Group Activities

71. ***Gatorade*** Gatorade is poured into a plastic bottle that holds 1.2 ℓ of liquid. The bottle is then placed in a freezer. When the bottle is removed from the freezer, the plastic is cut away, leaving just the frozen Gatorade.

a) What is the approximate mass of the frozen Gatorade in grams?

b) What is the approximate volume of the frozen Gatorade in cubic centimeters?

72. Show that $-40°C = -40°F$.

In Example 2, we showed how to find the volume and mass of water in a fish tank. Exercise 73 demonstrates how much more complicated solving a similar problem is in the U.S. customary system.

73. ***Fish Tank*** A fish tank is 1 yd long by 1.5 ft high by 15 in. wide.

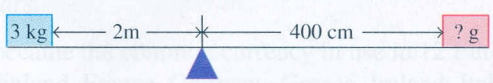
a) Determine the volume of water in the fish tank in cubic feet.

b) Determine the weight of the water in pounds. One cubic foot of water weighs about 62.5 lb.

c) If 1 gal of water weighs about 8.3 lb, how many gallons will the tank hold?

Recreational Mathematics

74. ***Balance the Scale*** Determine the quantity to replace the question mark to make the scale balance. The weight times the distance on both sides of the fulcum (the triangle) must be the same to make the scale balance.



75. ***Interesting Facts*** The 2003 Guinness Book of World Records provides some interesting facts.

a) The lowest temperature ever recorded in the United States was −62.11°C on January 23, 1971, in Prospect Creek, Alaska. What is this temperature in degrees Fahrenheit?

b) International Falls, Minnesota, has the lowest annual mean temperature in the United States (including Alaska). Its mean annual temperature is about 2.5°C. What is this temperature in degrees Fahrenheit?

c) The highest temperature produced in a laboratory was about 918,000,000°F. What is this temperature in degrees Celsius?

Ice Box Day, International Falls, MN

Internet/Research Activity

76. Do industries in your area export goods? If so, are they training employees to use and understand the metric system? Contact local industries that export goods and write a report on your findings.

8.4 DIMENSIONAL ANALYSIS AND CONVERSIONS TO AND FROM THE METRIC SYSTEM

You may sometimes need to change units of measurement in the metric system to equivalent units in the U.S. customary system. To do so, use ***dimensional analysis***, which is a procedure used to convert from one unit of measurement to a different unit of measurement. To perform dimensional analysis, you must first understand what is meant by a unit fraction. A ***unit fraction*** is any fraction in which the numerator and denominator contain different units and the value of the fraction is 1. From Table 8.6, we can obtain many unit fractions involving U.S. customary units.

TABLE 8.6 U.S. Customary Units

1 foot = 12 inches
1 yard = 3 feet
1 mile = 5280 feet
1 pound = 16 ounces
1 ton = 2000 pounds
1 cup (liquid) = 8 fluid ounces
1 pint = 2 cups
1 quart = 2 pints
1 gallon = 4 quarts
1 minute = 60 seconds
1 hour = 60 minutes
1 day = 24 hours
1 year = 365 days

Examples of Unit Fractions

$$\frac{12 \text{ in.}}{1 \text{ ft}} \quad \frac{1 \text{ ft}}{12 \text{ in.}} \quad \frac{16 \text{ oz}}{1 \text{ lb}} \quad \frac{1 \text{ lb}}{16 \text{ oz}} \quad \frac{60 \text{ min}}{1 \text{ hr}} \quad \frac{1 \text{ hr}}{60 \text{ min}}$$

In each of these examples, the numerator equals the denominator, so the value of the fraction is 1.

To convert an expression from one unit of measurement to a different unit, multiply the given expression by the unit fraction (or fractions) that will result in the answer having the units you are seeking. When two fractions are being multiplied and the same unit appears in the numerator of one fraction and the denominator of the other fraction, then that common unit may be divided out. For example, suppose we want to convert 30 inches to feet. We consider the following:

$$30 \text{ in.} = ? \text{ ft}$$

Since inches are given, we will need to eliminate them. Thus, inches will need to appear in the denominator of the unit fraction. We need to convert to feet, so feet will need to appear in the numerator of the unit fraction. If we multiply a quantity in inches by a unit fraction containing feet/inches, the inches will divide out as follows, leaving feet. In the following illustration we have omitted the numbers in the unit fraction so we can concentrate on the units.

$$(\cancel{\text{in.}})\left(\frac{\text{ft}}{\cancel{\text{in.}}}\right) = \text{ft}$$

Thus, to convert 30 inches to feet, we do the following.

$$30 \text{ in.} = (30 \cancel{\text{in.}})\left(\frac{1 \text{ ft}}{12 \cancel{\text{in.}}}\right) = \frac{30}{12}\text{ft} = 2.5 \text{ ft}$$

In Examples 1 through 3, we will give examples that do not involve the metric system. After that, we will use dimensional analysis to make conversions to and from the metric system.

EXAMPLE 1 *Using Dimensional Analysis*

A container contains 26 ounces of salt. Convert 26 ounces to pounds.

SOLUTION: One pound is 16 ounces. Therefore, we write

$$26 \text{ oz} = (26 \cancel{\text{oz}})\left(\frac{1 \text{ lb}}{16 \cancel{\text{oz}}}\right) = \frac{26}{16}\text{lb} = 1.625 \text{ lb}$$

Thus, 26 oz equals 1.625 lb. ▲

EXAMPLE 2 *Euro Dollars*

On January 1, 2002, the euro became the common currency in use in 12 European countries (Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, and Spain). On May 1, 2003, $1 U.S. could be exchanged for about 0.91 euros. What was the amount in U.S. dollars of 1260 euros?

SOLUTION:

$$1260 \text{ euros} = 1260 \cancel{\text{euros}}\left(\frac{\$1.00}{0.91 \cancel{\text{euros}}}\right) = \$\frac{1260}{0.91} \approx \$1384.62$$

Thus, 1260 euros had a value of about $1384.62. ▲

DID YOU KNOW

The Importance of Measurements

John Quincy Adams, 6th president of the United States

We all realize how important the abilities to read and to write are. Yet do we realize how important an understanding of measurements is to our society and our daily lives? As John Quincy Adams wrote in his report to the U.S. Congress in 1821:

"Weights and measures may be ranked among the necessities of life to every individual of human society. They enter into the economical arrangements and daily concerns of every family. They are necessary to every occupation of human industry; to the distribution and security of every species of property; to every transaction of trade and commerce; to the labors of the husbandman; to the ingenuity of the artificer; to the studies of the philosopher; to the researches of the antiquarian; to the navigation of the mariner, and the marches of the soldier; to all the exchanges of peace, and all the operations of war. The knowledge of them, as in established use, is among the first elements of education, and is often learned by those who learn nothing else, not even to read and write. This knowledge is riveted in the memory by the habitual application of it to the employments of men throughout life."

If more than one unit needs to be changed, more than one multiplication may be needed, as illustrated in Example 3.

EXAMPLE 3 *Using Several Unit Fractions*

Convert 60 miles per hour to feet per second.

SOLUTION: Let's consider the units given and where we want to end up. We are given $\frac{\text{mi}}{\text{hr}}$ and wish to end with $\frac{\text{ft}}{\text{sec}}$. Thus, we need to change miles into feet and hours into seconds. Because two units need to be changed, we will need to multiply the given quantity by two unit fractions, one for each conversion. First we show how to convert the units of measurement from miles per hour to feet per second:

$$\left(\frac{\cancel{\text{mi}}}{\cancel{\text{hr}}}\right)\left(\frac{\text{ft}}{\cancel{\text{mi}}}\right)\left(\frac{\cancel{\text{hr}}}{\text{sec}}\right) \quad \text{gives an answer in} \quad \frac{\text{ft}}{\text{sec}}$$

Now we multiply the given quantity by the appropriate unit fractions to obtain the answer:

$$60\frac{\text{mi}}{\text{hr}} = \left(60\frac{\cancel{\text{mi}}}{\cancel{\text{hr}}}\right)\left(\frac{5280\text{ ft}}{1\ \cancel{\text{mi}}}\right)\left(\frac{1\ \cancel{\text{hr}}}{3600\text{ sec}}\right) = \frac{(60)(5280)}{(1)(3600)}\frac{\text{ft}}{\text{sec}}$$

$$= 88\frac{\text{ft}}{\text{sec}}$$

Note that $\left(60\frac{\text{mi}}{\text{hr}}\right)\left(\frac{1\text{ hr}}{3600\text{ sec}}\right)\left(\frac{5280\text{ ft}}{1\text{ mi}}\right)$ will give the same answer. ▲

Conversions to and from the Metric System

Now we will apply dimensional analysis to the metric system.

Table 8.7 on page 461 is used in making conversions to and from the metric system. The values given in Table 8.7 are often approximations. A more exact table of conversion factors may be found in many science books at your college's library or on the Internet. However, we can use this table to obtain many unit fractions.

Table 8.7 shows that 1 in. = 2.54 cm. From this equality, we can write the two unit fractions

$$\frac{1\text{ in.}}{2.54\text{ cm}} \quad \text{or} \quad \frac{2.54\text{ cm}}{1\text{ in.}}$$

Examples of other unit fractions from Table 8.7 are

$$\frac{1\text{ yd}}{0.9\text{ m}}, \quad \frac{0.9\text{ m}}{1\text{ yd}}, \quad \frac{1\text{ gal}}{3.8\ \ell}, \quad \frac{3.8\ \ell}{1\text{ gal}}, \quad \frac{1\text{ lb}}{0.45\text{ kg}}, \quad \text{and} \quad \frac{0.45\text{ kg}}{1\text{ lb}}$$

To change from a metric unit to a customary unit or vice versa, multiply the given quantity by the unit fraction whose product will result in the units you are seeking.

TABLE 8.7 Conversions Table

Length

1 inch (in.)	=	2.54	centimeters (cm)
1 foot (ft)	=	30	centimeters (cm)
1 yard (yd)	=	0.9	meter (m)
1 mile (mi)	=	1.6	kilometers (km)

Area

1 square inch ($in.^2$)	=	6.5	square centimeters (cm^2)
1 square foot (ft^2)	=	0.09	square meter (m^2)
1 square yard (yd^2)	=	0.8	square meter (m^2)
1 square mile (mi^2)	=	2.6	square kilometers (km^2)
1 acre	=	0.4	hectare (ha)

Volume

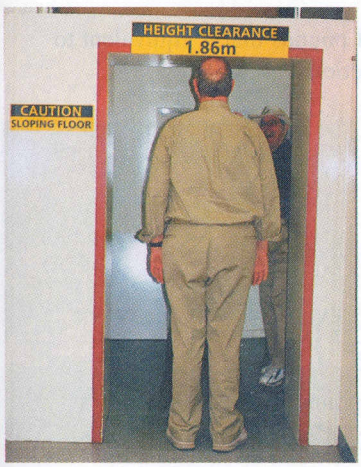
1 teaspoon (tsp)	=	5	milliliters (mℓ)
1 tablespoon (tbsp)	=	15	milliliters (mℓ)
1 fluid ounce (fl oz)	=	30	milliliters (mℓ)
1 cup (c)	=	0.24	liter (ℓ)
1 pint (pt)	=	0.47	liter (ℓ)
1 quart (qt)	=	0.95	liter (ℓ)
1 gallon (gal)	=	3.8	liters (ℓ)
1 cubic foot (ft^3)	=	0.03	cubic meter (m^3)
1 cubic yard (yd^3)	=	0.76	cubic meter (m^3)

Weight (Mass)

1 ounce (oz)	=	28	grams (g)
1 pound (lb)	=	0.45	kilogram (kg)
1 ton (T)	=	0.9	tonne (t)

For example, to convert 5 in. to centimeters, multiply 5 in. by a unit fraction with centimeters in the numerator and inches in the denominator.

$$5 \text{ in.} = (5 \text{ in.})\left(\frac{2.54 \text{ cm}}{1 \text{ in.}}\right)$$
$$= 5(2.54) \text{ cm}$$
$$= 12.7 \text{ cm}$$



EXAMPLE 4 *Volume and Length Conversions*

a) A recipe for chicken soup requires $4\frac{1}{2}$ cups of water. How many liters does this amount equal?

b) A man measures 1.86 m (see photo). What is his height in feet?

SOLUTION:

a) In Table 8.7, under the heading of volume, we see that 1 cup = 0.24 ℓ. Thus, the unit fractions involving cups and liters are

$$\frac{1 \text{ cup}}{0.24 \text{ ℓ}} \quad \text{or} \quad \frac{0.24 \text{ ℓ}}{1 \text{ cup}}$$

We need to convert from cups to liters. Since $4\frac{1}{2}$ is 4.5 in decimal form, we write

$$4.5 \text{ cups} = 4.5 \text{ cups}\left(\frac{0.24\ \ell}{1 \text{ cup}}\right) = (4.5)(0.24)\ \ell = 1.08\ \ell$$

b) In Table 8.7, under the heading of length, we see that there is no conversion given from meters to feet. There are a number of ways this example could be worked. One method is to convert meters to yards and then convert yards to feet. The procedure is shown below.

$$\begin{aligned} 1.86 \text{ m} &= (1.86 \text{ m})\left(\frac{1 \text{ yd}}{0.9 \text{ m}}\right)\left(\frac{3 \text{ ft}}{1 \text{ yd}}\right) \\ &= \frac{(1.86)(3)}{0.9} \text{ ft} \\ &\approx 6.2 \text{ ft} \end{aligned}$$

Thus, the man is about 6.2 ft. ▲

EXAMPLE 5 *Area Conversion*

The photo shows an area of 31.46 hectares for sale. Find the area in acres.

SOLUTION: From Table 8.7, we determine that 1 acre = 0.4 ha. Thus,

$$31.46 \text{ ha} = (31.46 \text{ ha})\left(\frac{1 \text{ acre}}{0.4 \text{ ha}}\right) = \frac{31.46}{0.4} \text{acres} = 78.65 \text{ acres}$$ ▲

Land for sale in Fiji, measured in hectares.

EXAMPLE 6 *Weight (Mass) Conversion*

The photo shows that tangelos cost $2.45 per kilogram. Determine the cost per pound for the tangelos.

SOLUTION: First, we will determine the number of pounds that is equivalent to 1 kilogram. From Table 8.7, we obtain the unit fraction

$$\frac{0.45 \text{ kg}}{1 \text{ lb}}$$

We use this unit fraction to determine the tangelos's cost per pound.

$$\begin{aligned} \frac{\$2.45}{1 \text{ kg}} &= \left(\frac{\$2.45}{1 \text{ kg}}\right)\left(\frac{0.45 \text{ kg}}{1 \text{ lb}}\right) \\ &= \$2.45(0.45) \text{ per pound} \\ &\approx \$1.10 \text{ per pound} \end{aligned}$$

Therefore, the tangelos cost about $1.10 per pound. ▲

EXAMPLE 7 *Administering a Medicine*

A nurse must administer 4 cc of codeine elixir to a patient.

a) How many milliliters of the drug will be administered?

b) How many ounces is this dosage equivalent to?

SOLUTION:

a) Since 1 cc = 1 mℓ, the nurse will administer 4 mℓ of the drug.

b) Since 1 fl oz = 30 mℓ,

$$4 \text{ m}\ell = (4 \text{ m}\cancel{\ell})\left(\frac{1 \text{ fl oz}}{30 \text{ m}\cancel{\ell}}\right) = \frac{4}{30}\text{fl oz} \approx 0.13 \text{ fl oz}$$

Suppose we want to convert 150 millimeters to inches. Table 8.7 does not have a conversion factor from millimeters to inches, but it does have one for inches to centimeters. Because 1 inch = 2.54 centimeters and 1 centimeter = 10 millimeters, we can reason that 1 inch = 25.4 millimeters. Therefore, unit fractions we may use are as follows.

$$\frac{1 \text{ in.}}{25.4 \text{ mm}} \quad \text{or} \quad \frac{25.4 \text{ mm}}{1 \text{ in.}}$$

We can solve the problem as follows.

$$150 \text{ mm} = (150 \text{ m}\cancel{\text{m}})\left(\frac{1 \text{ in.}}{25.4 \text{ m}\cancel{\text{m}}}\right) = \frac{150}{25.4}\text{in.}$$

$$\approx 5.91 \text{ in.}$$

If we wish, we can use dimensional analysis using two unit fractions to make the conversion. The procedure follows:

$$150 \text{ mm} = (150 \text{ m}\cancel{\text{m}})\left(\frac{1 \text{ c}\cancel{\text{m}}}{10 \text{ m}\cancel{\text{m}}}\right)\left(\frac{1 \text{ in.}}{2.54 \text{ c}\cancel{\text{m}}}\right) = \frac{150}{(10)(2.54)}\text{in.}$$

$$\approx 5.91 \text{ in.}$$

EXAMPLE 8 *Converting a Speed*

The photo shows that a road in Cancun, Mexico, has a speed limit of 50 kilometers per hour (kph). Determine the speed limit in miles per hour.

SOLUTION: In kilometers per hour and miles per hour, the time unit, hour, is the same. Therefore, we just need to convert 50 kilometers to miles. From Table 8.7, we find unit fractions

$$\frac{1 \text{ mi}}{1.6 \text{ km}} \quad \text{or} \quad \frac{1.6 \text{ km}}{1 \text{ mi}}$$

$$50 \text{ km} = (50 \text{ k}\cancel{\text{m}})\left(\frac{1 \text{ mi}}{1.6 \text{ k}\cancel{\text{m}}}\right) = \frac{50}{1.6}\text{mi} = 31.25 \text{ mi}$$

Since 50 km equals 31.25 mi, 50 kph is equivalent to 31.25 mph.

EXAMPLE 9 *Understanding the Label*

The label on a bottle of Vicks Formula 44D Cough Syrup indicates that the active ingredient is dextromethorphan hydrobromide and that 5 mℓ (1 teaspoon) contains 10 mg of this ingredient. If the recommended dosage for adults is 3 teaspoons, determine the following.

a) How many milliliters of cough medicine should be taken?

b) How many milligrams of the active ingredient should be taken?

c) If the bottle contains 8 fluid ounces of medicine, how many milligrams of the active ingredient are in the bottle?

SOLUTION:

a) Since each teaspoon contains 5 mℓ and 3 teaspoons should be taken, 15 mℓ of the cough medicine should be taken.

$$3 \text{ tsp} = (3 \cancel{\text{tsp}})\left(\frac{5 \text{ m}\ell}{1 \cancel{\text{tsp}}}\right) = 15 \text{ m}\ell$$

b) Since each teaspoon contains 10 mg of the active ingredient, 30 mg of the active ingredient should be taken.

$$3 \text{ tsp} = (3 \cancel{\text{tsp}})\left(\frac{10 \text{ mg}}{1 \cancel{\text{tsp}}}\right) = 30 \text{ mg}$$

c) Table 8.7 shows that each fluid ounce contains 30 mℓ. Since each 5 mℓ contains 10 mg of the active ingredient, we can work the problem as follows.

$$8 \text{ fl oz} = (8 \cancel{\text{fl oz}})\left(\frac{30 \cancel{\text{m}\ell}}{1 \cancel{\text{fl oz}}}\right)\left(\frac{10 \text{ mg}}{5 \cancel{\text{m}\ell}}\right) = \frac{8(30)(10)}{5} \text{ mg} = 480 \text{ mg}$$

Therefore, there are 480 mg (or 0.48 g) of the active ingredient in the bottle of cough syrup.

EXAMPLE 10 *Determining Dosage by Weight*

Drug dosage is often administered according to a patient's weight. For example, 30 mg of the drug vancomicin is to be given for each kilogram of a person's weight. If Martha Greene, who weighs 136 lb, is to be given the drug, what dosage should she be given?

SOLUTION: First we need to convert Martha's weight into kilograms. From Table 8.7, we see that 1 lb = 0.45 kg. We obtain our unit fraction from this information. Next, we need to determine the number of milligrams of the drug for Martha's weight in kilograms. To do so, write the given ratio of 30 mg of the drug for each kilogram as $\frac{30 \text{ mg}}{1 \text{ kg}}$. Note that this ratio is not a unit fraction since the numerator and denominator are not equivalent. The answer may be found as follows.

$$136 \text{ lb} = (136 \cancel{\text{lb}})\left(\frac{0.45 \cancel{\text{kg}}}{1 \cancel{\text{lb}}}\right)\left(\frac{30 \text{ mg}}{1 \cancel{\text{kg}}}\right) = (136)(0.45)(30) \text{ mg} = 1836 \text{ mg}$$

Thus, 1836 mg, or 1.836 g, of the drug should be given.

MATHEMATICS *Everywhere*

The Seven Base Units

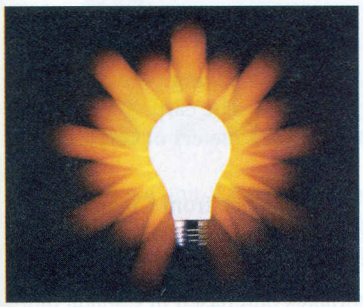
We all realize how important measurements are to daily life. The Système international d'unités (SI), the modern version of the metric system, provides a logical and interconnected framework for all measurements in science, industry, and commerce. The SI is built upon a foundation of seven base units, as explained below. All other SI units are derived from these units. The base units for time, electric current, amount of substance, and luminous intensity are the same in both the metric system and the U.S. customary system.

Length : Meter The meter is the length of the path traveled by light in a vacuum during a time interval of $\frac{1}{299,792,458}$ second. Thus, the speed of light in a vacuum is 299 792 458 meters per second.

Time : Second The second is the duration of 9,192,631,770 cycles of the radiation associated with a specific transition of the cesium 133 atom.

Electric Current : Ampere The ampere is the current that, if maintained in each of two infinitely long parallel wires separated by 1 m in free space, would produce a force between the two wires (due to their magnetic fields) of 2×10^{-7} newton for each meter of length. The electrical terms *volt, watt, and ohm* are derived using amperes.

Luminous Intensity : Candela The candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540×10^{12} hertz (Hz) and that has a radiant intensity in that direction of $\frac{1}{683}$ watt per steradian.



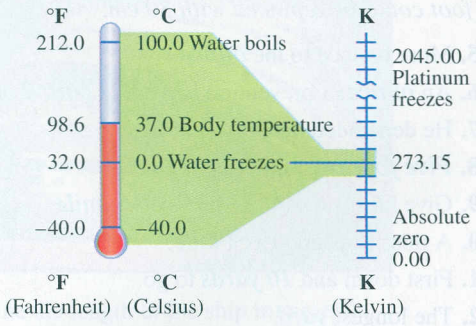
Temperature : Kelvin A kelvin is the fraction $\frac{1}{273.16}$ of the thermodynamic temperature of the triple point of water. The temperature 0 K is commonly referred to as "absolute zero." In the widely used Celsius temperature, 0°C corresponds to 273.15 K. Thus, water freezes at 273.15 K.

Mass : Kilogram The kilogram is a cylinder of platinum–iridium alloy kept by the International Bureau of Weights and Measures in Sèvres, France. A duplicate in the custody of the U.S. National Institute of Standards and Technology serves as the mass standard for the United States. The kilogram is the only base unit still defined by an artifact.

Amount of Substance : Mole The mole is the amount of substance of a system that contains as many elementary entities as there are atoms in 0.012 kilogram of carbon 12. When the mole is used, the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles, or specific groups of such particles. The SI unit of concentration (of amount of substance) is the *mole per cubic meter* (mol/m^3).

Some of these definitions provided here are quite complex, but they form the basis for all measurements in the metric system. For more complete definitions of unknown terms and for additional information, contact the U.S. Department of Commerce, National Institute of Standards and Technology (www.nist.gov).

Temperature Measurement Systems



SECTION 8.4 EXERCISES

Concept/Writing Exercises

1. What is dimensional analysis?
2. What is a unit fraction?
3. Give a unit fraction that relates seconds and minutes. Explain how you determined the unit fraction.
4. Give a unit fraction that relates feet and yards. Explain how you determined the unit fraction.
5. When converting from centimeters to feet, which unit fraction would you use? Explain.

$$\frac{1 \text{ ft}}{30 \text{ cm}} \quad \text{or} \quad \frac{30 \text{ cm}}{1 \text{ ft}}$$

6. When converting from kilograms to pounds, which unit fraction would you use? Explain.

$$\frac{1 \text{ lb}}{0.45 \text{ kg}} \quad \text{or} \quad \frac{0.45 \text{ kg}}{1 \text{ lb}}$$

7. When converting from gallons to liters, which unit fraction would you use? Explain.

$$\frac{1 \text{ gal}}{3.8\ \ell} \quad \text{or} \quad \frac{3.8\ \ell}{1 \text{ gal}}$$

8. When converting from square yards to square meters, which unit fraction would you use? Explain.

$$\frac{1 \text{ yd}^2}{0.8 \text{ m}^2} \quad \text{or} \quad \frac{0.8 \text{ m}^2}{1 \text{ yd}^2}$$

Practice the Skills

In Exercises 9–24, convert the quantity to the indicated units.

9. 52 in. to centimeters
10. 9 lb to kilograms
11. 4.2 ft to meters
12. 427 g to ounces
13. 15 yd^2 to square meters
14. 160 kg to pounds
15. 39 mi to kilometers
16. 765 mm to inches
17. 675 ha to acres
18. 192 oz to grams
19. 15.6 ℓ to pints
20. 4 T to tonnes
21. 45.6 mℓ to fluid ounces
22. 1.6 km^2 to square miles
23. 120 lb to kilograms
24. 6.2 acres to hectares

In Exercises 25–32, replace the measurement(s) indicated in blue with an equivalent metric measure(s). For example, a foot could be replaced with 30 cm.

25. More bounce to the ***ounce***.
26. An ***ounce*** of prevention is worth a ***pound*** of cure.
27. He demanded his ***pound*** of flesh.
28. ***Five foot two*** and eyes of blue.
29. Give him an ***inch*** and he'll take a ***mile***.
30. A miss is as good as a ***mile***.
31. First down and ***10 yards*** to go.
32. The longest ***yard***.

In Exercises 33–36, use the part of the scorecard, which shows the distance in meters for the first four holes of the Millbrook Resort Golf Course in Queenstown, New Zealand. Determine the distances indicated.

HOLE	BLACK Tees	BLUE Tees	HANDICAP	PAR					WHITE Tees	RED Tees
1	505	505	3	5					466	414
2	185	175	15	3					137	91
3	366	357	11	4					344	287
4	396	376	7	4					376	303

33. Hole 1, black tees, in yards
34. Hole 2, blue tees, in yards
35. Hole 3, white tees, in feet
36. Hole 4, red tees, in feet

Problem Solving

37. ***Speed Limit*** The speed limit for the sharp curve shown in the photo is 85 kph. Determine the speed in miles per hour.

38. ***How Far?*** Carol Ann Harle's new car traveled 105 mi on 5 gal of gasoline. How many kilometers can Carol Ann's car travel with the same amount of gasoline?

39. ***Buying Carpet*** Victoria Montoya is buying outdoor carpet for her lanai, which is 6 yd by 9 yd. The carpeting is sold in square meters. How many square meters of carpeting will she need?

40. ***Cincinnati to Columbus*** The distance from Cincinnati, Ohio, to Columbus, Ohio, is about 110 mi. What is the distance in kilometers?

41. ***Cornflakes*** A box of cornflakes purchased in Canada indicates that it contains 400 grams of cornflakes. How many ounces of cornflakes are contained in the box?

42. ***The QEW*** Part of the Queen Elizabeth Way in Canada has a speed limit of 80 kph. What is the speed in miles per hour?

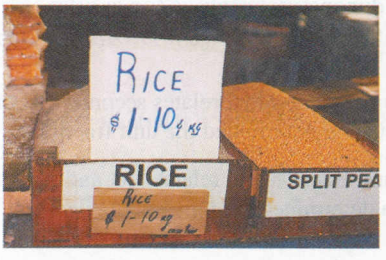
43. ***Milliliters in a Glass*** A glass holds 8 fl oz. How many milliliters will it hold?

44. ***Swimming Pool*** A swimming pool holds 12,500 gal of water. What is this volume in kiloliters?

45. ***Building a Basement*** A basement is to be 50 ft long, 30 ft wide, and 8 ft high. How much dirt will have to be removed when this basement is built? Answer in cubic meters.

46. ***Area of Yosemite National Park*** Yosemite National Park has an area of 1189 mi^2. What is its area in square kilometers?

47. ***Cost of Rice*** If rice costs $1.10 per kilogram, determine the cost of a pound of rice.



48. *Weight of a Car* A German-made car has a weight of 1.3 t.
a) How many tons does this weight equal?
b) How many pounds?

49. *Capacity of a Tank Truck* A tank truck holds 34.5 kℓ of gasoline. How many gallons does it hold?

50. *Cost per Gram* A 0.25 oz bottle of Chanel perfume costs $80. What is the cost per gram?

51. *A Weight in Stones* Some scales in Europe measure a person's weight both in kilograms and in stones. From the photo, we see that a weight of 70 kg is equal to about 11 stones.

a) Using a unit fraction, determine the weight, in kilograms, of a person who weighs 8 stones.
b) Determine the person's weight in pounds.

52. *A Precious Stone* One gram is the same as five carats. David Erich's new ring contains a precious stone that is $\frac{1}{8}$ carat. Find the weight of the stone in grams.

53. *Death Valley Elevation* The lowest elevation in the United States is −282 ft at Badwater in Death Valley, California. Determine this elevation in
a) centimeters.
b) meters.

54. *Car's Engine* A specific car's engine has a capacity of 5.7 ℓ of oil. How many quarts of oil does the engine have?

55. *Square Meters to Square Feet* One meter is about 3.3 ft. Use this information to determine
a) the equivalent of one square meter in square feet.
b) the equivalent of one cubic meter in cubic feet.

56. *Square Feet to Square Centimeters* One foot is about 30 cm. Use this information to determine
a) the equivalent of one square foot in square centimeters.
b) the equivalent of one cubic foot in cubic centimeters.

57. *Dosage for a Child* The recommended dosage of the drug codeine for pediatric patients is 1 mg per kilogram of a child's weight. What dosage of codeine should be given to April Adam, who weighs 56 lb?

58. *Dosage for a Man* For each kilogram of a person's weight, 1.5 mg of the antibiotic drug gentamicin is to be administered. If Ron Gigliotti weighs 170 lb, how much of the drug should he receive?

59. *Ampicillin* The recommended dosage of the drug ampicillin for pediatric patients is 200 mg per kilogram of a patient's weight. If Janine Baker weighs 76 lb, how much ampicillin should she receive?

60. *Medicine for a Dog* For each kilogram of weight of a dog, 5 mg of the drug bretylium is to be given. If Blaster, an Irish setter, weighs 82 lb, how much of the drug should be given?

61. *Active Ingredients* The label on the bottle of Triaminic expectorant indicates that each teaspoon (5 mℓ) contains 12.5 mg of the active ingredient phenylpropanolamine hydrochloride.
a) Determine the amount of the active ingredient in the recommended adult dosage of 2 teaspoons.
b) Determine the quantity of the active ingredient in a 12 oz bottle.

62. *Stomach Ache Remedy* The label on the bottle of Maximum Strength Pepto-Bismol indicates that each tablespoon contains 236 mg of the active ingredient bismuth subsalicyate.
a) Determine the amount of the active ingredient in the recommended dosage of 2 tablespoons.
b) If the bottle contains 8 fl oz, determine the quantity of the active ingredient in the bottle.

63. *Disney Magic* The Disney Magic Cruise Ship is 964 feet long, has a weight of 85,000 tons, and can travel 28 mph.

a) Determine the length of the ship in meters.
b) Determine the weight in tonnes.
c) Determine the speed in kilometers per hour.

64. *Making Cookies* Change all the measurements in the cookie recipe to metric units. Do not forget pan size, temperature, and size of cookies.

Magic Cookie Bar

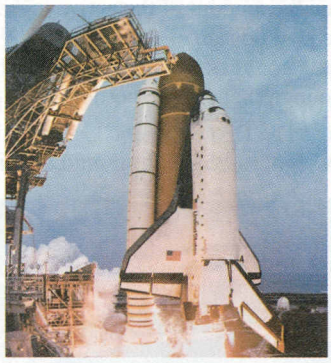
$\frac{1}{2}$ c graham cracker crumbs
12 oz nuts
8 oz chocolate pieces
$1\frac{1}{3}$ c flaked coconut
$1\frac{1}{3}$ c condensed milk

Coat the bottom of a 9 in. × 13 in. pan with melted margarine. Add rest of ingredients one by one: crumbs, nuts, chocolate, and coconut. Pour condensed milk over all. Bake at 350°F for 25 minutes. Allow to cool 15 minutes before cutting. Makes about two dozen $1\frac{1}{2}$ in. by 3 in. bars.

65. ***The Space Shuttle*** Write each of the metric units, labeled (*a*) through (*n*), in U.S. customary units.

The first human flight, December 17, 1903, was (*a*) *37 m*. Just 66 years later, Neil Armstrong stepped on the moon after journeying (*b*) *370 140 km*. On April 12, 1981, a new era in space flight began when the space shuttle embarked on its maiden voyage.

Here are some characteristics of and facts about the space shuttle. The two solid rocket boosters are jettisoned at (*c*) *44 km*. During reentry, portions of the orbiter's exterior reach temperatures up to (*d*) *1260°C*. The orbiter lands at a speed of (*e*) *335 kph*. It can deliver to orbit up to (*f*) *29 484 kg* of payload in its huge (*g*) *4.5 m* × *18 m* cargo bay. Propellants can be supplied to the engines at a rate of about (*h*) *171 396 ℓ*/min of hydrogen and (*i*) *63 588 ℓ*/min of oxygen. The external tank is (*j*) *46.89 m* long and (*k*) *8.4 m* in diameter. When fully loaded, the tank contains (*l*) *632 772 kg* of liquid oxygen and (*m*) *106 142 kg* of cold liquid hydrogen at about (*n*) *−251°C*.



Challenge Problems/Group Activities

66. ***Nursing Question*** The following question was selected from a nursing exam. Can you answer it?

In caring for a patient after delivery, you are to give 0.2 mg Ergotrate Maleate. The ampule is labeled $\frac{1}{300}$ grain/mℓ. How much would you draw and give? (60 mg = 1 grain)
a) 15 cc **b)** 1.0 cc **c)** 0.5 cc **d)** 0.01 cc

67. ***How Much Beef*** Paul Gosse is planning a picnic and plans on purchasing 0.18 kg of ground beef for each 100 lb of weight of guests who will be in attendance. If he expects 15 people whose average weight is 130 lb, how many pounds of beef should he purchase?

68. ***An Auto Engine*** The displacement of automobile engines is measured in liters. A 2003 Ford Explorer has a 4.0 ℓ engine.
a) Determine the displacement of the engine in cubic centimeters.
b) Determine the displacement of the engine in cubic inches.

Recreational Mathematics

In Exercises 69–74, answer the question, What metric unit am I?

69. I am a length greater than a yard, but less than a kitchen tabletop.

70. I am a weight greater than a calculator, but less than a wooden chair.

71. I am an area greater than an acre, but less than a square kilometer.

72. I am a liquid volume greater than a quart, but less than a gallon.

73. I am a weight greater than a ton, but less than a full-grown elephant.

74. I am a length greater than an inch, but less than a yard.

In Exercises 75–84, try to solve the puzzle. What is

75. 2000 pounds of Chinese soup?

76. 1 millionth of a mouthwash?

77. 1000 aches?

78. 448 grahams of cake?

79. 1 million phones?

80. 1 million bicycles?

81. 2000 mockingbirds?

82. 10 cards?

83. 10 rations?

84. 1 millionth of a fish?

CHAPTER 8 SUMMARY

IMPORTANT FACTS

Metric Units

Prefix	Symbol	Meaning
kilo	k	1000 × base unit
hecto	h	100 × base unit
deka	da	10 × base unit
		base unit
deci	d	$\frac{1}{10}$ of base unit
centi	c	$\frac{1}{100}$ of base unit
milli	m	$\frac{1}{1000}$ of base unit

Water

Volume in Cubic Units		Volume in Liters		Mass of Water
1 cm^3	=	1 mℓ	=	1g
1 dm^3	=	1 ℓ	=	1 kg
1 m^3	=	1 kℓ	=	1 t (1000 kg)

Temperature

$$°C = \frac{5}{9}(°F - 32)$$

$$°F = \frac{9}{5}°C + 32$$

CHAPTER 8 REVIEW EXERCISES

8.1

In Exercises 1–6, indicate the meaning of the prefix.

1. Centi **2.** Kilo **3.** Milli
4. Hecto **5.** Deka **6.** Deci

In Exercises 7–12, change the given quantity to that indicated.

7. 20 cg to grams
8. 3.2 ℓ to centiliters
9. 0.0004 cm to millimeters
10. 1 000 000 mg to kilograms
11. 4.62 kℓ to liters
12. 192.6 dag to decigrams

In Exercises 13 and 14, arrange the quantities from smallest to largest.

13. 2.67 kℓ, 3000 mℓ, 14 630 cℓ
14. 0.047 km, 4700 m, 47 000 cm

8.2, 8.3

In Exercises 15–24, indicate the metric unit of measurement that would best express the following.

15. The length of a telephone
16. The mass of a cellular telephone
17. The temperature of the sun's surface
18. The diameter of a quarter
19. The area of a room of a house
20. The volume of a glass of milk
21. The length of an ant
22. The mass of a car
23. The distance from Philadelphia, Pennsylvania, to Irvine, Texas
24. The height a dolphin can jump

In Exercises 25 and 26, (a) first estimate the following in metric units and then (b) measure with a metric ruler. Record your results.

25. Your height
26. The length of a new pencil

In Exercises 27–32, select the best answer.

27. The length of the distance between Los Angeles and San Francisco is about
a) 8000 m. **b)** 2000 km. **c)** 650 km.

28. The mass of a full-grown border collie is about
a) 600 g. **b)** 20 kg. **c)** 100 kg.

29. The volume of a gallon of orange juice is about
a) 0.1 kℓ. **b)** 0.5 ℓ. **c)** 4 ℓ.

30. The area of a large vegetable garden in a person's yard may be
a) 200 m^2. **b)** 0.5 ha. **c)** 0.02 km^2.

31. The temperature on a hot summer day in Georgia may be
a) 34°C. **b)** 55°C. **c)** 25°C.

32. The height of a giant sequoia tree is about
a) 300 m. **b)** 3000 cm. **c)** 0.3 m.

33. Convert 2500 kg to tonnes.

34. Convert 6.3 t to grams.

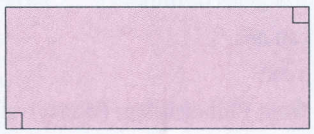
35. If the temperature outside is 18°C, what is the Fahrenheit temperature?

36. If the room temperature is 68°F, what is the Celsius temperature?

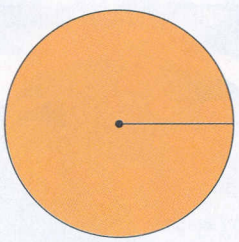
37. If your outdoor thermometer shows a temperature of −6°F, what is the Celsius temperature?

38. If Lynn Colgin's body temperature is 39°C, what is her Fahrenheit temperature?

39. Measure, in centimeters, each of the line segments, then compute the area of the figure.



40. Measure, in centimeters, the radius of the circle, then compute the area of the circle.



41. **a)** ***A Swimming Pool's Volume*** What is the volume of water in a full rectangular swimming pool that is 10 m long and 4 m wide and has an average depth of 2 m? Answer in cubic meters.
b) What is the mass of the water in kilograms?

42. ***Area*** A rectangular lot measures 22 m by 30 m. Determine
a) the area in square meters.
b) the area in square kilometers.

43. ***Volume of a Fish Tank*** A small fish tank measures 80 cm long, 40 cm wide, and 30 cm high.
a) What is its volume in cubic centimeters?
b) What is its volume in cubic meters?
c) How many milliliters of water will the tank hold?
d) How many kiloliters of water will the tank hold?

44. A square kilometer is a square with length and width both 1 km. How many times larger is a square kilometer than a square dekameter?

8.4

In Exercises 45–58, change the given quantity to the indicated quantity. When appropriate, round answers to the nearest hundredth.

45. 20 cm = ____ in.
46. 105 kg = ____ lb
47. 83 yd = ____ m
48. 100 m = ____ yd
49. 45 mph = ____ kph
50. 40 ℓ = ____ qt
51. 15 gal = ____ ℓ
52. 40 m^3 = ____ yd^3
53. 83 cm^2 = ____ $in.^2$
54. 4 qt = ____ ℓ
55. 15 yd^3 = ____ m^3
56. 62 mi = ____ km
57. 27 cm = ____ ft
58. $3\frac{1}{4}$ in. = ____ mm

59. ***Building a Chimney*** Anne Kelly bought 700 bricks to build a chimney. Each brick has a mass of 1.5 kg.
a) What is the total mass of the bricks in kilograms?
b) What is the total weight of the bricks in pounds?

60. ***Carpeting a Room*** Patricia Burgess is buying new carpet for her family room. The room is 15 ft wide and 24 ft long. The carpeting is sold only in square meters. How many square meters of carpeting will she need? Round your answer to the nearest square meter.

61. ***Milk Tank*** A cylindrical milk tank can store 50,000 gal of milk.
a) Determine the volume in kiloliters.
b) Estimate the weight of the milk in kilograms. Assume that milk has the same weight as water.

62. ***The Speed Limit*** The speed limit on a certain road is 35 mph. What is the speed limit in
a) kilometers per hour?
b) meters per hour?

63. ***A Water Tank*** A rectangular tank used to test leaks in tires is 90 cm by 70 cm by 40 cm deep.
a) Determine the number of liters of water the tank holds.
b) What is the mass of the water in kilograms?

64. ***Oranges*** If the cost of oranges is $3.50 per kilogram, determine the cost of 1 lb of oranges.

CHAPTER 8 TEST

1. Change 204 cℓ to daℓ.
2. Change 123 km to mm.
3. How many times greater is a kilometer than a dekameter?
4. ***Jogging*** A high school track is an oval that measures 400 m around. If Dave Camp jogs around the track six times, how many kilometers has he gone?

In Exercises 5–9, choose the best answer.

5. The length of this page is about
   a) 10 cm.
   b) 25 cm.
   c) 60 cm.
6. The surface area of the top of a kitchen table is about
   a) 2 m^2.
   b) 200 cm^2.
   c) 2000 cm^2.
7. The amount of gasoline that an automobile's gas tank can hold is about
   a) 200 ℓ.
   b) 20 ℓ.
   c) 75 ℓ.
8. The mass of a cellular telephone is about
   a) 0.1 t.
   b) 2 kg.
   c) 150 g.
9. The outside temperature on a snowy day is about
   a) 18°C.
   b) −2°C.
   c) −40°C.
10. How many times greater is a square meter than a square centimeter?
11. How many times greater is a cubic meter than a cubic millimeter?
12. Convert 452 in. to centimeters.
13. How far, in yards, is the Marriott from the sign?

Cancun, Mexico

14. Change −10°F to degrees Celsius.
15. Change 20°C to degrees Fahrenheit.
16. ***Giraffe*** A giraffe may be 12 ft tall. How many centimeters is this?
17. ***At the Aquarium*** A fish tank at an aquarium is 20 m long by 20 m wide by 8 m deep.
    a) Determine the volume of the tank in cubic meters.
    b) Determine the number of liters of water the tank holds.
    c) Determine the weight of the water in kilograms.
18. ***Cost of Paint*** The first coat of paint for the outside walls of a building requires 1 ℓ of paint for each 10 m^2 of wall surface. The second coat requires 1 ℓ for every 15 m^2. If the paint costs $3.50 per liter, what will be the cost of two coats of paint for the four outside walls of a building 20 m long, 15 m wide, and 6 m high?

GROUP PROJECTS

Health and Medicine

Throughout this chapter, we have shown the importance of the metric system in the medical professions. The following two questions involve applications of the metric system to medicine.

1. **a)** Twenty milligrams of the drug lincomycin is to be given for each kilogram of a person's weight. The drug is to be mixed with 250 cc of a normal saline solution, and the mixture is to be administered intravenously over a 1 hr period. Clyde Dexter, who weighs 196 lb, is to be given the drug. Determine the dosage of the drug he will be given.
   b) At what rate per minute should the 250 cc solution be administered?
2. **a)** At a pharmacy, a parent asks a pharmacist why her child needs such a small dosage of a certain medicine. The pharmacist explains that a general formula may be used to estimate a child's dosage of certain medicines. The formula is

$$\text{Child's dose} = \frac{\left(\begin{array}{c}\text{child's weight}\\ \text{in kilograms}\end{array}\right)}{67.5 \text{ kg}} \times \text{adult dose}$$

   What is the amount of medicine you would give a 60 lb child if the adult dosage of the medicine is 70 mg?
   b) At what weight, in pounds, would the child receive an adult dose?

Traveling to Other Countries

3. Dale Pollinger is a buyer at General Motors and travels frequently on business to foreign countries. He always plans ahead and does his holiday shopping overseas where he can purchase items not easily found in the United States.
   a) On a trip to Tokyo, he decides to buy a kimono for his sister, Kathy. To determine the length of a kimono, one measures, in centimeters, the distance from the bottom of a person's neck to 5 cm above the floor. If the distance from the bottom of Dale's sister's neck to the floor is 5 ft 2 in., calculate the length of the kimono that Dale should purchase.
   b) If the conversion rate at the time is 1 U.S. dollar = 118.25 yen and the kimono cost 8695.5 yen, determine the cost of the kimono in U.S. dollars.
   c) On a trip to Mexico City, Mexico, Dale finds a small replica of a Mayan castle that he wants to purchase for his wife, Sue. He is going directly from Mexico to Rome, so he wants to mail the castle back to the United States. The mailing rate from Mexico to the United States is 10 pesos per hundred grams. Determine the mailing cost, in U.S. dollars, if the castle weighs 6 lb and the exchange rate is 1 peso = 0.095 U.S. dollar.
   d) This question has three parts. While traveling to New Zealand, Dale finds that unleaded plus gasoline cost \$0.929 per liter in New Zealand dollars.

How much will it cost him, in New Zealand dollars, to fill the 53 ℓ gas tank of his rented car? If the exchange rate is \$1 New Zealand = \$0.584 U.S., what will it cost in U.S. dollars to fill the tank? What is the cost, in U.S. dollars, of a gallon of gasoline at this gas station?