Appendix The Metric System

A.1 Metric Units of Measurement

Inching Toward the Metric System

Quick, name one country that uses the metric system! Almost any country will do, *except* the United States. At the present time, the United States is the only industrialized country in the world that has not officially adopted the metric system. Since the United States exports many industrial products, the manufacturers of these products have been forced to use the metric system for automobiles, machinery, measuring devices, tools, and so on. Complete industries are changing to the metric system because of its convenience and simplicity. Of course, many products sold in the United States are already measured in the metric system (or in both the metric and the U.S. systems). Look at your soda bottles or your cereal boxes! Now suppose you are on a romantic vacation near Paris, France. It is a cool day and you want to take a 30-minute walk to a nearby village and get some cheese and wine. What units would you use to measure the temperature, the distance you walked, the weight of the cheese, and the amount of wine you are about to buy? In this section, you will study the units you need—length, weight, volume, and temperature—in the **metric system.**

The metric system is a **decimal** system using multiples or submultiples of 10, eliminating the difficult calculations encountered in the U.S. customary system. (For example, do you know how many feet there are in 2 miles or how many rods in a furlong?) Moreover, all metric measurements are derived from a single base unit, the meter. Other basic units are then derived from the meter. For example, a **liter** is the volume of a cube 10 centimeters on each edge and the **kilogram** is the mass of 1 liter of water at constant temperature. Clearly, the metric system is much more standardized than the U.S. system. Some of the measures from which the U.S. system is derived are the **cubit,** the length of the forearm from the elbow to the tip of the middle finger (about 18 in.); the **foot,** equivalent to 12 thumb-widths, called "uncias" (the Roman word for $\frac{1}{12}$); and the **mile,** called "milia passuum" by the Romans and equivalent to 1000 paces. All these measurements were dependent on whose **cubit, foot,** or **paces** were used. ▶

In an effort to standardize measurements, the National Assembly of France in 1790 requested the French Academy of Sciences to "deduce an invariable standard for all the measures and all the weights." The result was the metric system.

In 1960, the General Conference on Weights and Measures adopted a revised and simplified version of the metric system, the **International System of Units,** which is now called **SI** (after the French name, *Le Système International d'Unités*). The SI is the system that we study in the following pages.

A. Metric Units

The metric system is a decimal system of weights and measures. The basic units in the metric system are the following:

1. The **meter** (the unit of length, a little longer than a yard)
2. The **liter** (the unit of volume or capacity, a little more than a quart)
3. The **gram** (the unit of weight, about the weight of a regular paper clip)
4. The **second** (the unit of time)

Multiples and subdivisions of the basic units are given in powers of 10. The prefixes shown in Table A.1 in boldface are commonly used in everyday life, and we shall study them in this chapter. Note the abbreviations in parentheses. It is customary to use these prefix abbreviations only with the abbreviations of the units themselves. For example, kg means kilograms, ml means milliliters, and so on.

TABLE A.1

kilo- **(*k*)**	*hecto-* (*h*)	*deka-* (*dk*)	*Standard Unit*	*deci-* (*d*)	***centi-*** **(*c*)**	***milli-*** **(*m*)**
1000 units	100 units	10 units	1 unit	0.1 unit	0.01 unit	0.001 unit

Now, to convert from one unit to another, we can substitute the correct equivalence. This is the same as multiplying or dividing by the appropriate power of 10. For example, to find how many meters there are in 5 km—that is, to find 5 km = _____ m, we write

$$5\ \text{km} = 5 \cdot 1000\ \text{m} = 5000\ \text{m} \qquad (1\ \text{km} = 1000\ \text{m})$$

Similarly,

$$750\ \text{ml} = 750 \cdot 0.001\ \text{liters} = 0.750\ \text{liters} \qquad (1\ \text{ml} = 0.001\ \text{liter})$$

EXAMPLE 1 ► Converting Metric Units

Fill in the following blanks with the appropriate numbers:

(a) 1.2 m = _____ cm (b) 2 liters = _____ ml

(c) 1 g = _____ kg

Solution

(a) Since 1 m = 100 cm, to change from meters to centimeters we multiply by 100—that is, move the decimal *two* places to the right. Thus, $1.2\ \text{m} = 1.2 \times 100\ \text{cm} = \underline{120}\ \text{cm}$.

(b) Since 1 liter is 1000 ml, $2\ \text{liters} = 2 \cdot 1000\ \text{ml} = \underline{2000}\ \text{ml}$.

(c) Since 1 kg = 1000 g, $1\ \text{g} = \frac{1}{1000}\ \text{kg} = \underline{0.001}\ \text{kg}$. ■

B. Which Unit to Use

Let us see how the metric system would relate to you. You are probably accustomed to seeing carpet sold by the square yard. In the metric system, it would be sold by the square *meter.* In stating traveling distances, you now use miles; in the metric system, you would use *kilometers.* Smaller dimensions, such as tool sizes, would be measured in *centimeters* or in *millimeters.* While studying the following examples, remember the following relations:

U.S. and Metric Relations

1 quart (qt)	is about	1 liter (l)
1 inch (in.)	is about	2.5 centimeters (cm)
2.2 pounds (lb)	is about	1 kilogram (kg)
1 ounce (oz)	is about	28 grams (g)

EXAMPLE 2 ► Determining Reasonable Units

What metric unit should be used for the following products?

(a) A glue stick weighing about $\frac{1}{4}$ oz

(b) A small ruler about 6 in. long

(c) A half-gallon of milk

Solution

(a) The ounce is a small unit of weight; so use grams.

(b) About 6 in. is a short length; so use centimeters.

(c) A half-gallon is 2 qt; so use liters. ■

C. Length (Linear Measure)

As we indicated, the standard metric unit of length is the **meter.** The meter (39.37 in.) is a little longer than a yard and was originally defined to be 1 ten-millionth of the distance from the North Pole to the Equator. However, the 1960 conference redefined it in terms of the wavelength of the orange-red line in the spectrum of krypton 86. In 1983, the conference redefined the meter to be $\frac{1}{299{,}792{,}458}$, multiplied by the distance light travels in one second. This definition makes it easy for any scientific laboratory in the world to reproduce the length of the meter.

A yard is divided into 36 equal parts (inches), whereas a meter is divided into 100 equal parts (centimeters). The centimeter is about 0.4 in., and the inch is about 2.5 cm. To give you an idea of the relative lengths of the inch and the centimeter, here are two line segments 1 in. and 1 cm long, respectively.

_____ 1 in.

_____ 1 cm

In the metric system we measure small distances (the length of a pencil, the width of a book, your height) in centimeters. For long distances, we use the kilometer. The kilometer is about 0.6 mi, and the mile is about 1.6 km. If you recall that **kilo-** means **1000,** then you know that a kilometer is 1000 m. Table

A.2 shows the relationships among some metric units of length. Notice that the prefixes (km, hm, etc.) are the familiar ones already mentioned. The abbreviations for the more commonly used units are in boldface type.

TABLE A.2

kilometer (***km***)	*hectometer* (*hm*)	*dekameter* (*dkm*)	*meter* (***m***)	*decimeter* (*dm*)	*centimeter* (***cm***)	*millimeter* (***mm***)
1000 m	100 m	10 m	1 m	0.1 m	0.01 m	0.001 m

To remember the prefixes, remember the phrase "**K**ing **H**enry **D**ied **M**onday **D**rinking **C**hocolate **M**ilk."

As you can see from the table, each metric unit of length is a multiple or a submultiple of the basic unit, the **meter.** Thus, to change from one unit to another, we simply substitute the correct equivalence. This is the same as multiplying or dividing by the correct power of 10. For example, if we wish to know how many centimeters there are in 3 km, we proceed as follows:

$$\begin{aligned} 1 \text{ km} &= 1000 \text{ m} \\ &= 1000 \times (100 \text{ cm}) \\ &= 100{,}000 \text{ cm} \end{aligned}$$

Hence, 3 km is 300,000 cm.

Another way to change from one unit to another is to notice that *a shift of one place to the right in Table A.2 moves the decimal point one place to the right, and a shift of one place to the left moves the decimal point one place to the left.* Thus, to change 3 km to centimeters, a shift of **five** places to the right in Table A.2, we move the decimal point after the 3 **five** places to the right to obtain 300,000 cm. Similarly, to change 256 mm to meters, a shift of **three** places to the left in the table, we move the decimal point after the 256 **three** places to the left to get 256 mm = 0.256 m.

EXAMPLE 3 ► Converting Metric Units to Represent Distance

(a) The height of a basketball player is 205 cm. How many meters is that?

(b) The display screen on a pocket calculator is 65 mm long. How many centimeters is that?

Solution

(a) From Table A.2, we see that

$$1 \text{ cm} = 0.01 \text{ m}$$

Thus,

$$205 \text{ cm} = 205 \times 0.01 \text{ m} = 2.05 \text{ m}$$

Note that to go from centimeters to meters in Table A.2, we move **two** places left. Thus, to change 205 cm to meters, we move the decimal point after the 205 **two** places to the left to obtain 2.05 m as before.

(b) Table A.2 shows that to go from millimeters to centimeters, we move the decimal point one place to the left. Hence,

$$65 \text{ mm} = 6.5 \text{ cm}$$ ■

As Example 3 illustrates, a change from one metric unit of length to another requires us to move the decimal point the correct number of places: to the *right* if converting to a *smaller* unit, or to the *left* if converting to a *larger* unit.

D. Volume (Capacity) Units

The standard metric unit of volume (or capacity) is the liter. Table A.3 shows the relationships among the various units. As before, the abbreviations in boldface are for the most commonly used units.

TABLE A.3

kiloliter (***kl***)	*hectoliter* (*hl*)	*dekaliter* (*dkl*)	*liter* (***l***)	*deciliter* (*dl*)	*centiliter* (***cl***)	*milliliter* (***ml***)
1000 liters	100 liters	10 liters	1 liter	0.1 liter	0.01 liter	0.001 liter

EXAMPLE 4 ► Determining Metric Units That Represent Volume

(a) A soft drink bottle contains 0.946 liters. How many milliliters is that?

(b) To make six 250-ml servings of ice cream, how many liters of ice cream are required?

Solution

(a) Table A.3 shows that there are 1000 ml in 1 liter. Thus,

$$0.946 \text{ liters} = 0.946 \times 1000 \text{ ml} = 946 \text{ ml}$$

Note that to go from liters to milliliters in Table A.3, we must move three places to the right. Thus, 0.946 liters = 946 ml.

(b) The six servings would require

$$6 \times 250 \text{ ml} = 1500 \text{ ml}$$

Since 1 ml = 0.001 liters, we just move the decimal point three places to the left in 1500. Thus, 1.5 liters are required. ■

E. Units of Weight

Many people use the words *mass* and *weight* as though they were synonyms, but the two concepts are entirely different. The **mass** of an object is the *quantity of matter* in the object. The **weight** of the object is the *force* with which the Earth pulls on it. To measure your weight, you can stand on a spring scale; but to measure your mass, you would have to sit on a balance scale and be balanced against some standard masses. Suppose you are on the Moon. The gravitational pull of the Moon is only one-sixth the gravitational pull of Earth. Thus, if your Earth weight were 150 lb, your Moon weight would be only one-sixth of that, or 25 lb. However, your mass on the Moon is exactly the same as it is on Earth.

The basic unit of *mass* is the gram, originally defined to be the mass of one cubic centimeter of water. However, for most everyday affairs, the gram is simply regarded as the basic unit of *weight;* it is the *weight* of one cubic centimeter of water under certain standard conditions on the surface of Earth. (This does not

apply to scientific work, where a separate unit of weight must be defined.) The gram is used to weigh small objects. For example, a candy bar, the contents of a tuna fish can, and your breakfast cereal are suitably weighed in grams. Very small objects, such as pills, are weighed in milligrams. For heavier objects, we use the kilogram. Thus, we would buy meat, vegetables, and coffee in kilograms. A kilogram is about 2.2 lb, and a pound is about 0.45 kg. Table A.4 gives the relationships among the customary metric units of weight. As before, the abbreviations for the most commonly used units are in boldface type.

TABLE A.4

kilogram (***kg***)	*hectogram* (*hg*)	*dekagram* (*dkg*)	*gram* (***g***)	*decigram* (*dg*)	*centigram* (***cg***)	*milligram* (***mg***)
1000 g	100 g	10 g	1 g	0.1 g	0.01 g	0.001 g

EXAMPLE 5 ▶ Determining Metric Units That Represent Weight

(a) A box of Kellogg's Kenmei Rice Bran weighs 629 g. How many kilograms is that?

(b) A certain antacid stomach tablet contains about 250 mg of calcium carbonate. What fraction of a gram is that?

Solution

(a) Table A.4 shows that

$$1 \text{ kg} = 1000 \text{ g}$$

so that

$$1 \text{ g} = 0.001 \text{ kg}$$

Thus,

$$629 \text{ g} = 629 \times 0.001 \text{ kg} = 0.629 \text{ kg}$$

Note that to go from grams to kilograms in Table A.4, we must move three places to the left; thus, 629 grams = 0.629 kg.

(b) From Table A.4 we see that

$$1 \text{ mg} = 0.001 \text{ g}$$

Thus,

$$250 \text{ mg} = 250 \times 0.001 \text{ g} = 0.25 \text{ g} = \tfrac{1}{4} \text{ g}$$ ■

F. Temperature

We have now discussed length, volume, and weight. What about temperature? The temperature scale we normally use was invented by Gabriel Robert Fahrenheit. In the **Fahrenheit** scale, the boiling point of water is 212°F, and the freezing point of water is 32°F. The temperature scale was modified by Anders Celsius, who avoided the awkward numbers 32 and 212. In the **Celsius** scale, the freezing and boiling points of water are 0°C and 100°C, respectively. Because this

scale is based on the number 100, it is sometimes called the **centigrade** scale. Figure A.1 shows the comparison between the two scales.

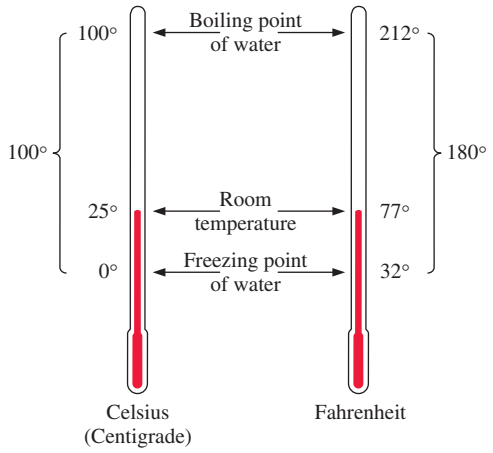

FIGURE A.1

The formulas for converting from one scale to the other are displayed below for easy reference.

Celsius-Fahrenheit Conversion Formulas

To convert a reading from Fahrenheit to Celsius, use the formula

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

To convert a reading from Celsius to Fahrenheit, use the formula

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

Online Study Center

To further explore the topics of this section, access link A.1.1 on this textbook's Online Study Center and click on the topic you want! There is even a temperature converter for you!

Note that there are 100°C and 180°F between the freezing and boiling points of water (Figure A.1). Therefore, any piece of the temperature scale has $\frac{100}{180} = \frac{5}{9}$ as many Celsius as Fahrenheit degrees. If we subtract 32 from the Fahrenheit reading to bring the freezing point back to 0, then the Celsius reading must be given by $C = \frac{5}{9}(F - 32)$. Similar reasoning leads to the formula $F = \frac{9}{5}C + 32$.

EXAMPLE 6 ▶ Converting from Fahrenheit to Celsius

Desi had the flu. Her temperature was 104°F. What is that on the Celsius scale?

Solution

We replace F by 104 in the formula.

$$C = \frac{5(F - 32)}{9} = \frac{5(104 - 32)}{9} = \frac{5(72)}{9} = 40$$

Thus, her temperature was 40°C. ■

EXAMPLE 7 ▶ Converting from Celsius to Fahrenheit

The melting point of gold is 1000°C. What is that on the Fahrenheit scale?

Solution

We substitute 1000 for C in the formula.

$$F = \frac{9C}{5} + 32 = \frac{9(1000)}{5} + 32 = 1800 + 32 = 1832$$

Hence, the melting point of gold is 1832°F. ■

EXERCISES A.1

A Metric Units

1. Fill in each blank with the appropriate number:
- **a.** 1 kiloliter = _____ liters
- **b.** 1 milligram = _____ grams
- **c.** 1 meter = _____ centimeters
- **d.** 1 kilometer = _____ meters

B Which Unit to Use

2. Indicate the appropriate metric units for each of the following items:
- **a.** A quart of vinegar
- **b.** A 100-lb bag of cement
- **c.** $\frac{1}{4}$-in.-wide tape
- **d.** 14-in. shoelaces
- **e.** A 2-oz candy bar

In problems 3–8, select the answers that are most nearly correct.

3. The height of a professional basketball player is
a. 200 mm. **b.** 200 m. **c.** 200 cm.

4. The dimensions of the living room in an ordinary home are
a. 4 by 5 m. **b.** 4 by 5 cm.
c. 4 by 5 mm.

5. The diameter of an aspirin tablet is
a. 1 cm. **b.** 1 mm. **c.** 1 m.

6. The length of the 100-yd dash is about
a. 100 cm. **b.** 100 mm. **c.** 100 m.

7. The weight of an average human male is
a. 70 kg. **b.** 70 g. **c.** 70 mg.

8. The length of an ordinary lead pencil is
a. 19 mm. **b.** 19 cm. **c.** 19 m.

C Length (Linear Measure)

In problems 9 and 10, fill in each blank with the correct number.

9.
- **a.** 8 km = _____ m
- **b.** 4 m = _____ cm
- **c.** 3409 cm = _____ m
- **d.** 49.4 mm = _____ cm

10.
- **a.** 8413 mm = _____ m
- **b.** 7.3 m = _____ mm
- **c.** 319 mm = _____ m
- **d.** 758 m = _____ km

11. A bed is 210 cm long. How many meters is that?

12. The diameter of a vitamin C tablet is 6 mm. How many centimeters is that?

13. The length of a certain race is 1.5 km. How many meters is that?

14. The depth of a swimming pool is 1.6 m. How many centimeters is that?

15. Dr. James Strange of the University of South Florida wishes to explore Mount Ararat in Turkey in search of Noah's ark. According to the book of Genesis, the dimensions of the ark are as given below. If a cubit is 52.5 cm, give each dimension in meters.
- **a.** Length, 300 cubits
- **b.** Breadth, 50 cubits
- **c.** Height, 30 cubits

D Volume (Capacity) Units

16. Fill in each blank with the correct number.
- **a.** 6.3 kl = _____ liters
- **b.** 72.3 ml = _____ liters
- **c.** 1.3 liters = _____ ml
- **d.** 3479 ml = _____ kl

17. Since a liter is the volume of a cube that is 10 cm on each edge, the volume of a cube that is 1 m on each edge is how many liters?

18. A person drank 60 ml of milk. Is that more or less than half a liter of milk?

19. Sea water contains 3.5 g of salt per liter. How many grams of salt are there in 1000 ml of sea water?

20. Hydrogen weighs about 0.0001 g per milliliter. How much would 1 liter of hydrogen weigh?

21. A liter is equivalent to 1000 cm^3. How many liters of liquid will a rectangular container 50 cm long and 20 cm wide hold when filled to a depth of 10 cm?

22. A gallon of gas is about 3.8 liters. A U.S. car takes about 20 gal of gas. How many liters is that?

23. A certain medicine has 20 ml of medication per liter of solution. How many milliliters of solution are needed to obtain 5 ml of medication?

24. A tanker truck delivers 10 kl of gasoline to a service station.
- **a.** How many liters is that?
- **b.** If 100 liters is about 26.4 gal, how many gallons were delivered?

E Units of Weight

In problems 25 and 26, fill in each blank with the correct number.

25. **a.** 14 kg = _____ g **b.** 4.8 kg = _____ g
c. 2.8 g = _____ kg **d.** 3.9 g = _____ mg

26. **a.** 37 mg = _____ g **b.** 49 mg = _____ kg
c. 41 g = _____ kg **d.** 3978 g = _____ kg

27. A gram is the weight of 1 cubic centimeter (cm^3) of water (under certain standard conditions). What is the weight of 1 liter of water? (See problem 17.)

In problems 28–30, select the answers that are most nearly correct.

28. The amount of milk in a quart carton is about
a. 100 ml. **b.** 1 liter. **c.** 1 kl.

29. The water needed to fill a 1-liter bottle weighs
a. 0.5 kg. **b.** 1 kg. **c.** 2 kg.

30. The weight of a newborn baby is about
a. 8 kg. **b.** 0.35 kg. **c.** 3.5 kg.

F Temperature

In problems 31–40, fill in each blank with the correct number.

31. 59°F = _____ °C **32.** 113°F = _____ °C

33. 86°F = _____ °C **34.** −4°F = _____ °C

35. −22°F = _____ °C **36.** 0°F = _____ °C

37. 10°C = _____ °F **38.** 25°C = _____ °F

39. −10°C = _____ °F

40. −15°C = _____ °F

41. In an Air Force experiment, heavily clothed men endured temperatures of 500°F. How many degrees Celsius is that?

42. The temperature in Death Valley has been recorded at 131°F. How many degrees Celsius is that?

43. A temperature of 41°C is a dangerously high body temperature for a human being. How many degrees Fahrenheit is that?

44. For a very short time in September 1933, the temperature in Coimbra, Portugal, rose to 70°C. What is that on the Fahrenheit scale?

45. The average normal human body temperature is 98.6°F. What is that on the Celsius scale?

46. Tungsten, which is used for the filament in electric light bulbs, has a melting point of 3410°C. What is that on the Fahrenheit scale?

47. What Celsius temperatures should we use for the following?
- **a.** Cool to 41°F
- **b.** Boil at 212°F

48. During the second quarter of an NFL playoff game in Cincinnati, the wind-chill factor reached −58°F. (It got worse later.) What is the equivalent Celsius wind-chill factor?

49. Dry ice changes from a solid to a vapor at −78°C. Express this temperature in degrees Fahrenheit.

In Other Words

50. Describe in your own words how the metric units of length (the meter), weight (the gram), and volume (the liter) are defined.

Using Your Knowledge

51. The *humerus* is the bone in a person's upper arm. With this bone as a clue, an anthropologist can tell about how tall a person was. If the bone is that of a female, then the height of the person is about

$$(2.75 \times \text{humerus length}) + 71.48 \text{ cm}$$

Suppose the humerus of a female was found to be 31 cm long. About how tall was the person?

In problems 52 and 53, match each item in the first column with an appropriate measure in the second column.

52.

i.	A letter-sized sheet of paper	**a.**	20×25 mm
ii.	A newspaper	**b.**	54×86 mm
iii.	A credit card	**c.**	70×150 mm
iv.	A regular bank check	**d.**	21.5×28 cm
v.	A postage stamp	**e.**	35×56 cm

53.

i.	A person	**a.**	80 mg
ii.	A book	**b.**	68 g
iii.	A small automobile	**c.**	1 kg
iv.	A common pin	**d.**	72 kg
v.	An orange	**e.**	1000 kg

Discovery

In 1848, Lord Kelvin, a British physicist, proposed using a Celsius scale in which temperatures were moved downward so that 0K (read "0 degrees Kelvin") would be the temperature at which all molecular motion was believed to cease (also called *absolute zero*). This point occurred at -273.15°C. In the Kelvin scale water boils at 373.15K and it freezes at 273.15K.

54. Can you use points of the form (C, K) to discover a relationship between the Celsius and Kelvin scales? [*Hint:* Use the points (373.15, 100) and (273.15, 0).]

A.2 Convert If You Must

Metric Adages

What do you think would happen if the United States adopted the metric system right this minute? Many people believe that they would have to be making conversions from U.S. to metric and from metric to U.S. constantly. This is just not true! For example, you probably buy soda or spring water in 1- and 2-liter bottles, but this does not require that you convert liters to quarts. You may have a foreign car that is totally metric, but you do not need to convert tire or engine sizes to the U.S. system. However, if you insist on converting, here are a few items you may want to convert to the metric system first. Table A.5 will help.

TABLE A.5 Units and Metric Equivalents

1 in. = 2.54 cm*	1 cm ≈ 0.394 in.
1 yd ≈ 0.914 m†	1 m ≈ 1.09 yd
1 mi ≈ 1.61 km	1 km ≈ 0.621 mi
1 lb ≈ 0.454 kg	1 kg ≈ 2.20 lb
1 qt ≈ 0.946 liter	1 liter ≈ 1.06 qt

*The inch is legally defined to be *exactly* 2.54 cm.
†The symbol ≈ means "is approximately equal to."

1. A miss is as good as _____ km.
(a mile)

2. I wouldn't touch it with a _____ -m pole.
(10-ft)

3. He was so stubborn he wouldn't give _____ cm.
(an inch)

4. Walk _____ km in my shoes.
(a mile)

5. _____ grams of prevention [are] worth _____ kilograms of cure.
(An ounce) (a pound) ▶

A. U.S. and Metric Conversions

As you can see from Table A.5, with the exception of the inches to centimeters conversion, the relationships are all approximate. Some of these numbers are stated with two decimal places and some with three. The reason is that these numbers are either the results of certain measurements or else are rounded-off approximations to the true values. For example, when we say that a yard is 0.914 m, we are giving the result to the nearest thousandth of a meter; the actual equivalence is between 0.9135 and 0.9145. Thus, in calculations with the numbers in the table, we must use the round-off rules and the rules for approximate numbers given in Section 5.4 in the text.

Let us look at the conversion from centimeters to inches. We have the exact equivalence 1 in. = 2.54 cm. To express centimeters in terms of inches, we must divide by 2.54 to get

$$\tfrac{1}{2.54}\text{ in.} = \tfrac{2.54}{2.54}\text{ cm}$$

or

$$\text{cm} = \tfrac{1}{2.54}\text{ in.}$$

If we carry out this division, we find

$$\tfrac{1}{2.54} = 0.3937007\cdots$$

which, rounded off to three decimal places, gives the result in Table A.5, 0.394.

PROBLEM SOLVING

U.S. to Metric and Metric to U.S. Conversions

❶ **Read** the problem.

Use Table A.5 to do the following conversions:

(a) 10 in. to centimeters (b) 3 m to yards

(c) 8 mi to kilometers (d) 9 kg to pounds

(e) 2 qt to liters

❷ **Select** the unknown.

You have to convert inches to centimeters, meters to yards, miles to kilometers, kilograms to pounds, and quarts to liters.

(continued)

❸ **Think** of a plan.

❹ **Use** Table A.5 to determine the proper substitution for finding the required equivalent measure.

Use Table A.5 to find the proper conversions.

(a) Since 1 in. = 2.54 cm
10 in. = 10 · 2.54 cm
= 25.4 cm

(b) 1 m ≈ 1.09 yd
Thus, 3 m ≈ 3 · 1.09 yd
≈ 3.27 yd

(c) 1 mi ≈ 1.61 km
Hence, 8 mi ≈ 8 · 1.61 km
≈ 12.9 km (rounded from 12.88 km)

(d) 1 kg ≈ 2.2 lb
So, 9 kg ≈ 9 · 2.2 lb
≈ 19.8 lb

(e) 1 qt ≈ 0.946 liter
Thus, 2 qt ≈ 2 · 0.946 liter
≈ 1.89 liters (rounded from 1.892 liters)

❺ **Verify** your answers. Did you use the correct procedure when rounding off answers?

If you do not remember how to round numbers or how to determine the number of significant digits in a decimal, review Section 5.4 in the text before you go on!

TRY EXAMPLE 1 NOW.

Cover the solution, write your own solution, and then check your work.

EXAMPLE 1 ▶ Yards to Meters

The record distance reached by a boomerang before it started to return to the thrower is about 90 yd (to the nearest yard). How many meters is that?

Solution

From Table A.5, we see that 1 yd ≈ 0.914 m. Thus, we must multiply 90 by 0.914 and get 82.26. Since 90 yd is correct to the nearest yard, 90 has two significant digits and our answer must be rounded to two significant digits. Hence, we see that 90. yd ≈ 82 m. (Note that we have followed the custom of putting a decimal point after an integer with terminal 0s when all the 0s are significant.) ■

EXAMPLE 2 ▶ Grams to Ounces

How many grams are there in an ounce?

Solution

From Table A.5, we see that 1 lb ≈ 0.454 kg. Since there are 16 oz in a pound and 1000 g in a kilogram, we have

16 oz ≈ 454 g
1 oz ≈ $\frac{454}{16}$ g

If we divide 454 by 16, we get 28.375, but this must be rounded to three significant digits because there are only three significant digits in 0.454. Therefore,

$$1 \text{ oz} \approx 28.4 \text{ g}$$ ■

EXAMPLE 3 ► Miles per Hour to Kilometers per Hour

The maximum speed limit on many highways is 55 mph. How many kilometers per hour (km/hr) is this? (Assume the 55 to be exact.)

Solution

From Table A.5, we have 1 mi ≈ 1.61 km. Thus, we multiply 1.61 by 55 and get 88.55. This result must be rounded to agree with the three significant digits in the 1.61. Therefore,

$$55 \text{ mph} \approx 88.6 \text{ km/hr}$$ ■

EXAMPLE 4 ► Kilometers per Hour to Miles per Hour

The top speed of a certain European car is 200 km/hr. How many miles per hour is this? (Assume the 200 to be exact.)

Solution

$$\begin{aligned} 1 \text{ km} &\approx 0.621 \text{ mi} \\ 200 \text{ km} &\approx 200 \times 0.621 \text{ mi} \\ &\approx 124 \text{ mi (rounded from 124.2)} \end{aligned}$$

Thus, 200 km/hr is equivalent to 124 mph. ■

EXAMPLE 5 ► Quarts to Liters

Mary bought 3 qt of milk. How many liters of milk is this?

Solution

$$\begin{aligned} 1 \text{ qt} &\approx 0.946 \text{ liter} \\ 3 \text{ qt} &\approx 3 \times 0.946 \text{ liter} \\ &\approx 2.84 \text{ liters (rounded from 2.838)} \end{aligned}$$ ■

Finally, here is a conversion that you probably see almost every day: gallons to liters, or liters to gallons. As approximations, 1 gal is about 3.7854 liters, and 4 liters is a little more than 1 gal.

Precise Relationships Between Liters and Gallons

$$1 \text{ liter} \approx 0.2642172 \text{ gal}$$
$$1 \text{ gal} \approx 3.785412 \text{ liters}$$

Online Study Center

To further explore the metric system, access link A.2.1 on this textbook's Online Study Center. To further explore calculated conversions, access link A.2.2.

Suppose you fill your tank, and it takes 38 liters of gasoline. To the nearest tenth of a gallon, how many gallons of gas would that be? We write

$$\begin{aligned} 38 \text{ liters} &\approx (38)(0.2642172 \text{ gal}) \\ &\approx 10.040254 \text{ gal} \\ &\approx 10.0 \text{ gal} \end{aligned}$$

EXAMPLE 6 ▶ Gallons to Liters

The gas tank of a car has a capacity of 13.2 gal. To the nearest liter, how many liters is that?

Solution

We write

$$13.2 \text{ gal} \approx (13.2)(3.785412 \text{ liters})$$
$$\approx 49.967438 \text{ liters}$$
$$\approx 50 \text{ liters}$$

■

EXERCISES A.2

A U.S. and Metric Conversions

In problems 1–28, use Table A.5 to fill in each blank with the appropriate number. (Assume the given numbers are all exact and round your answers to the nearest hundredth.)

1. 8 in. = _____ cm

2. 5.2 in. = _____ cm

3. 12 cm = _____ in.

4. 25 cm = _____ in.

5. 51 yd = _____ m

6. 1.2 yd = _____ m

7. 3.7 m = _____ yd

8. 4.5 m = _____ yd

9. 4 mi = _____ km

10. 6.1 mi = _____ km

11. 3.7 km = _____ mi

12. 14 km = _____ mi

13. 6 lb = _____ kg

14. 8 lb = _____ kg

15. 5 kg = _____ lb

16. 1.2 kg = _____ lb

17. 5 qt = _____ liters

18. 6.1 qt = _____ liters

19. 8.1 liters = _____ qt

20. 11 liters = _____ qt

21. 75 cm = _____ ft

22. 800 m = _____ ft

23. 1 in.^3 = _____ cm^3

24. 1 cm^3 = _____ in.^3

25. 2 yd = _____ cm

26. 3 yd = _____ cm

27. 78 cm = _____ yd

28. 100 cm = _____ yd

In the remaining problems, use Table A.5 and assume the given numbers are exact.

29. The speed limit is 40 mph. How many kilometers per hour is that? (Answer to the nearest kilometer per hour.)

30. Find the distance, to the nearest kilometer, from Tampa, Florida to the following:
a. Zephyrhills, Florida, 22 mi
b. Ocala, Florida, 93 mi

31. The longest field goal in National Football League competition was 63 yd. How many meters is that?

32. The U.S.S. *New Jersey* is one of the longest battleships, measuring 296 yd long. How many meters is that?

33. Mount Everest is 8848 m high. How many feet is that? (Answer to the nearest hundred feet.)

34. The screen of a television set measures 24 in. diagonally. How many centimeters is that?

35. The largest omelet ever made weighed 1234 lb. How many kilograms is that? (Answer to the nearest kilogram.)

36. Miss Helge Anderson of Sweden has been drinking 20 qt of water per day since 1922. How many liters per day is that?

37. The longest street in the world is Figueroa Street in Los Angeles. This street is 30 mi long. How many kilometers is that?

38. A car is traveling 125 km/hr. How many miles per hour is that?

39. The maximum allowable weight for a flyweight wrestler is 52 kg. How many pounds is that?

40. The largest car ever built was the Bugatti Royale, type 41, with an eight-cylinder engine of 12.7-liter capacity. What quart capacity is this?

41. Two adjacent sides of a rectangle are measured and found to be 52.3 and 96.84 m long, respectively. How many meters long is the perimeter of the rectangle?

42. A rectangle is measured to be 21.5 by 32.63 ft. How many meters long is the perimeter?

43. A road sign warns of a bridge with a safe load of 14 tons. A metric ton is 1000 kg (very close to 2200 lb). What is the safe load of the bridge in metric tons? (Answer to the nearest tenth.)

44. Another road sign warns of a bridge with a safe load of 15 tons. What is this safe load in metric tons? (See problem 43.)

45. The Pontiac 1000 had a highway mileage estimated to be 40 mi/gal. To the nearest tenth, how many kilometers per liter is that?

In Other Words

46. Discuss three reasons why it is easier to measure distances in the metric system than in the U.S. customary system.

Using Your Knowledge

47. A Boeing 747 requires about 1900 m for a takeoff runway. About how many miles is this?

48. A fully loaded Boeing 747 weighs about 320,000 kg. About how many tons is this? (1 ton = 2000 lb)

49. The longest recorded distance for throwing (and catching) a raw hen's egg without breaking it is 316 ft $5\frac{3}{4}$ in. About how many meters is this?

50. The largest champagne bottle made is called a *Nebuchadnezzar;* it holds 16 liters. How many gallons is this?

51. In 1954, the winner of the Miss World contest had the Junoesque measurements 40-26-38. These measurements are in inches. What would the measurement be in centimeters?

52. An 1878 bottle (1 liter) of Chartreuse (a liqueur) sold for $42. About how much per ounce is this?

53. You have probably heard the expression "Hang in there!" Well, Rudy Kishazy did just that. He hung onto a glider that took off from Mount Blanc and landed 35 min later at Servoz, France, a distance of 15 mi. How many kilometers is that?

54. Romantic young ladies always dream about that knight in shining armor, but do you know what the longest recorded ride in full armor is? It is 146 mi. How many kilometers is that? (By the way, Dick Brown took the ride on June 12–15, 1973.)

55. Do you get thirsty on a hot summer day? Of course, you do! But nothing compares with the unquenchable thirst of Miss Helge Anderson of Sweden. She has been drinking 40 pt of water every day since 1922. About how many liters of water per day is that? (Remember that 2 pt = 1 qt.)

56. Do you know how to knit? If you do, you might try to equal the feat of Mrs. Gwen Mathewman of Yorkshire, England. In 1974, she knitted 836 garments. How much wool do you think she used? An unbelievable 9770 oz! How many grams is that?

57. What did you have for breakfast today? An omelet? We'll bet that you couldn't eat the largest omelet ever made—it weighed 1234 lb. About how many grams is that?