EXAMPLE EXERCISE 2.1 Uncertainty in Measurement

Which measurements are consistent with the metric rulers shown in Figure 2.2?

(a) Ruler A: 2 cm, 2.0 cm, 2.05 cm, 2.5 cm, 2.50 cm

(b) Ruler B: 3.0 cm, 3.3 cm, 3.33 cm, 3.35 cm, 3.50 cm

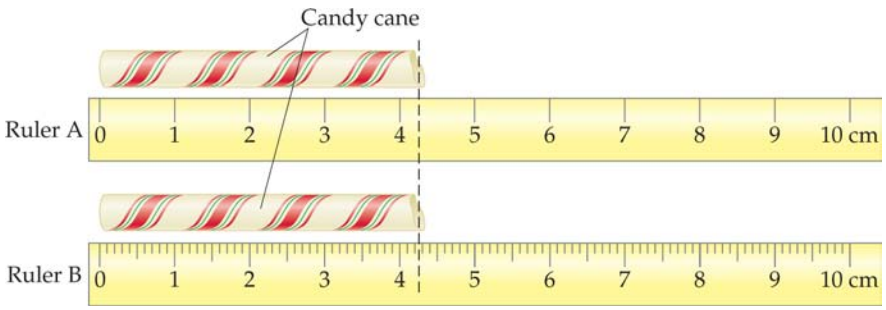


Figure 2.2 Metric Rulers for Measuring Length On Ruler A, each division is 1 cm. On Ruler B, each division is 1 cm and each subdivision is 0.1 cm.

Solution

Ruler A has an uncertainty of ±0.1 cm, and Ruler B has an uncertainty of ±0.05 cm. Thus,

(a) Ruler A can give the measurements 2.0 cm and 2.5 cm.

(b) Ruler B can give the measurements 3.35 cm and 3.50 cm.

Practice Exercise

Which measurements are consistent with the metric rulers shown in Figure 2.2?

(a) Ruler A: 1.5 cm, 1.50 cm, 1.55 cm, 1.6 cm, 2.00 cm

(b) Ruler B: 0.5 cm, 0.50 cm, 0.055 cm, 0.75 cm, 0.100 cm

Answers: (a) 1.5 cm, 1.6 cm; (b) 0.50 cm, 0.75 cm

EXAMPLE EXERCISE 2.1 Uncertainty in Measurement

Continued

Concept Exercise

What high-tech instrument is capable of making an exact measurement?

Answer: See Appendix G.

EXAMPLE EXERCISE 2.2 Significant Digits

State the number of significant digits in the following measurements:

(a)	12,345 cm	(b)	0.123 g
(c)	0.5 mL	(d)	102.0 s

Solution

In each example, we simply count the number of digits. Thus,

(a)	5	(b)	3
(c)	1	(d)	4

Notice that the leading zero in (b) and (c) is not part of the measurement but is inserted to call attention to the decimal point that follows.

Practice Exercise

State the number of significant digits in the following measurements:

(a)	2005 cm	(b)	25.000 g
(c)	25.0 mL	(d)	0.25 s

Answers: (a) 4; (b) 5; (c) 3; (d) 2

Concept Exercise

What type of measurement is exact?

Answer: See Appendix G.

EXAMPLE EXERCISE 2.3 Significant Digits

State the number of significant digits in the following measurements:

(a)	0.025 cm	(b)	0.2050 g
(c)	25.0 mL	(d)	2500 s

Solution

In each example, we count the number of significant digits and disregard placeholder zeros. Thus,

(a)	2	(b)	4
(c)	3	(d)	2

Practice Exercise

State the number of significant digits in the following measurements:

(a)	0.050 cm	(b)	0.0250 g
(c)	50.00 mL	(d)	1000 s

Answers: (a) 2; (b) 3; (c) 4; (d) 1

Concept Exercise

What type of measurement has infinite significant digits?

Answer: See Appendix G.

EXAMPLE EXERCISE 2.4 Rounding Off

Round off the following numbers to three significant digits:

(a) 22.250 (b) 0.34548

(c) 0.072038 (d) 12,267

Solution

To locate the first nonsignificant digit, count three digits from left to right. If the first nonsignificant digit is less than 5, drop all nonsignificant digits. If the first nonsignificant digit is 5 or greater, add 1 to the last significant digit.

(a) 22.3 (Rule 2) (b) 0.345 (Rule 1)

(c) 0.0720 (Rule 1) (d) 12,300 (Rule 2)

In (d), notice that two placeholder zeros must be added to 123 to obtain the correct decimal place.

Practice Exercise

Round off the following numbers to three significant digits:

(a) 12.514748 (b) 0.6015261

(c) 192.49032 (d) 14652.832

Answers: (a) 12.5 (Rule 1); (b) 0.602 (Rule 2); (c) 192 (Rule 1); (d) 14,700 (Rule 2)

Concept Exercise

How many significant digits are in the exact number 155?

Answer: See Appendix G.

EXAMPLE EXERCISE 2.5 Addition/Subtraction and Rounding Off

Add or subtract the following measurements and round off your answer:

(a) 106.7 g + 0.25 g + 0.195 g (b) 35.45 mL – 30.5 mL

Solution

In addition or subtraction operations, the answer is limited by the measurement with the most uncertainty.

(a) Let's align the decimal places and perform the addition.

$$\begin{array}{rl} 106.7 & \text{g} \\ 0.25 & \text{g} \\ +\quad 0.195 & \text{g} \\ \hline 107.145 & \text{g} \end{array}$$

Since 106.7 g has the most uncertainty (±0.1 g), the answer rounds off to one decimal place. The correct answer is **107.1 g** and is read "**one hundred and seven point one grams.**"

(b) Let's align the decimal places and perform the subtraction.

$$\begin{array}{rl} 35.45 & \text{mL} \\ -\ 30.5 & \text{mL} \\ \hline 4.95 & \text{mL} \end{array}$$

Since 30.5 mL has the most uncertainty (±0.1 mL), we round off to one decimal place. The answer is **5.0 mL** and is read "**five point zero milliliters**."

EXAMPLE EXERCISE 2.5 Addition/Subtraction and Rounding Off

Continued

Practice Exercise

Add or subtract the following measurements and round off your answer:

(a) 8.6 cm + 50.05 cm (b) 34.1 s – 0.55 s

Answers: (a) 58.7 cm; (b) 33.6 s

Concept Exercise

When adding or subtracting measurements, which measurement in a set of data limits the answer?

Answer: See Appendix G.

EXAMPLE EXERCISE 2.6 Multiplication/Division and Rounding Off

Multiply or divide the following measurements and round off your answer:
(a) 50.5 cm × 12 cm (b) 103.37 g/20.5 mL

Solution

In multiplication and division operations, the answer is limited by the measurement with the least number of significant digits.

(a) In this example, 50.5 cm has three significant digits and 12 cm has two.

$$(50.5 \text{ cm})\ (12 \text{ cm}) = 606 \text{ cm}^2$$

The answer is limited to two significant digits and rounds off to **610 cm^2** after inserting a placeholder zero. The answer is read "**six hundred and ten square centimeters.**"

(b) In this example, 103.37 g has five significant digits and 20.5 mL has three.

$$\frac{103.37 \text{ g}}{20.5 \text{ mL}} = 5.0424 \text{ g/mL}$$

The answer is limited to three significant digits and rounds off to **5.04 g/mL**. Notice that the unit is a ratio; the answer is read as "**five point zero four grams per milliliter.**"

EXAMPLE EXERCISE 2.6 Multiplication/Division and Rounding Off

Continued

Practice Exercise

Multiply or divide the following measurements and round off your answer.

(a) (359 cm) (0.20 cm) (b) 73.950 g/25.5 mL

Answers: (a) 72 cm^2; (b) 2.90 g/mL

Concept Exercise

When multiplying or dividing measurements, which measurement in a set of data limits the answer?

Answer: See Appendix G.

EXAMPLE EXERCISE 2.7 Converting to Powers of 10

Express each of the following ordinary numbers as a power of 10:

(a) 100,000 (b) 0.000 000 01

Solution

The power of 10 indicates the number of places the decimal point has been moved.

(a) We must move the decimal five places to the left; thus, 1×10^{5}.

(b) We must move the decimal eight places to the right; thus, 1×10^{-8}.

Practice Exercise

Express each of the following ordinary numbers as a power of 10:

(a) 10,000,000 (b) 0.000 000 000 001

Answers: (a) 1×10^{7}; (b) 1×10^{-12}

Concept Exercise

Which of the following lengths is less: 1×10^{3} cm or 1×10^{-3} cm?

Answer: See Appendix G.

EXAMPLE EXERCISE 2.8 Converting to Ordinary Numbers

Express each of the following powers of 10 as an ordinary number:

(a) 1×10^{4} (b) 1×10^{-9}s

Solution

The power of 10 indicates the number of places the decimal point has been moved.

(a) The exponent in 1×10^{4} is positive 4, and so we must move the decimal point four places to the right of 1, thus, 10,000.

(b) The exponent in 1×10^{-9} is negative 9, and so we must move the decimal point nine places to the left of 1, thus, 0.000 000 001.

Practice Exercise

Express each of the following powers of 10 as an ordinary number:

(a) 1×10^{10} (b) 1×10^{-5}

Answers: (a) 10,000,000,000; (b) 0.000 01

Concept Exercise

Which of the following masses is less: 0.000 001 g or 0.000 01 g?

Answer: See Appendix G.

EXAMPLE EXERCISE 2.9 Scientific Notation

Express each of the following values in scientific notation:

(a) There are 26,800,000,000,000,000,000,000 helium atoms in a one liter balloon filled with helium gas.

(b) The mass of one helium atom is 0.000 000 000 000 000 000 000 006 65 g.

Solution

We can write each value in scientific notation as follows:

(a) Place the decimal after the 2, followed by the other significant digits (2.68). Next, count the number of places the decimal has moved. The decimal is moved to the left 22 places, so the exponent is +22. Finally, we have the number of helium atoms in 1.00 L of gas: 2.68×10^{22} atoms.

(b) Place the decimal after the 6, followed by the other significant digits (6.65). Next, count the number of places the decimal has shifted. The decimal has shifted 24 places to the right, so the exponent is –24. Finally, we have the mass of a helium atom: 6.65×10^{-24} g.

Practice Exercise

Express each of the following values as ordinary numbers:

(a) The mass of one mercury atom is 3.33×10^{-22} g.

(b) The number of atoms in 1 mL of liquid mercury is 4.08×10^{22}.

Answers: (a) 0.000 000 000 000 000 000 000 333 g; (b) 40,800,000,000,000,000,000,000 atoms

Concept Exercise

Which of the following masses is greater: 1×10^{-6} g or 0.000 01 g?

Answer: See Appendix G.

EXAMPLE EXERCISE 2.10 Unit Conversion Factors

Write the unit equation and the two corresponding unit factors for each of the following:

(a) pounds and ounces (b) quarts and gallons

Solution

We first write the unit equation and then the corresponding unit factors.

(a) There are 16 ounces in a pound, and so the unit equation is 1 pound = 16 ounces. The two associated unit factors are

$$\frac{1\ \text{pound}}{16\ \text{ounces}} \quad \text{and} \quad \frac{16\ \text{ounces}}{1\ \text{pound}}$$

(b) There are 4 quarts in a gallon, and so the unit equation is 1 gallon = 4 quarts. The two unit factors are

$$\frac{1\ \text{gallon}}{4\ \text{quarts}} \quad \text{and} \quad \frac{4\ \text{quarts}}{1\ \text{gallon}}$$

Practice Exercise

Write the unit equation and the two corresponding unit factors for each of the following:

(a) hours and days (b) hours and minutes

Answers: (a) 1 day = 24 hours; 1 day/24 hours and 24 hours/1 day; (b) 1 hour = 60 minutes; 1 hour/60 minutes and 60 minutes/1 hour

EXAMPLE EXERCISE 2.10 Unit Conversion Factors

Continued

Concept Exercise

How many significant digits are in the following unit equation?

1 hour = 3600 seconds

Answer: See Appendix G.

EXAMPLE EXERCISE 2.11 Unit Analysis Problem Solving

A can of soda contains 12 fluid ounces (fl oz). What is the volume in quarts (given that 1 qt = 32 fl oz)?

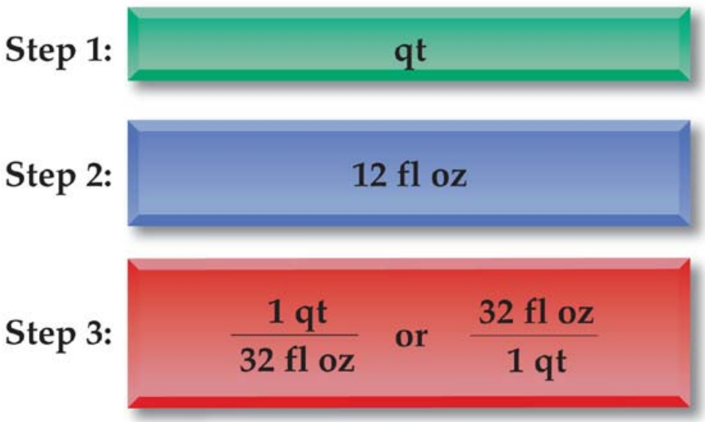
Dr. Pepper A 12 fl oz can of soda contains 355 mL

EXAMPLE EXERCISE 2.11 Unit Analysis Problem Solving

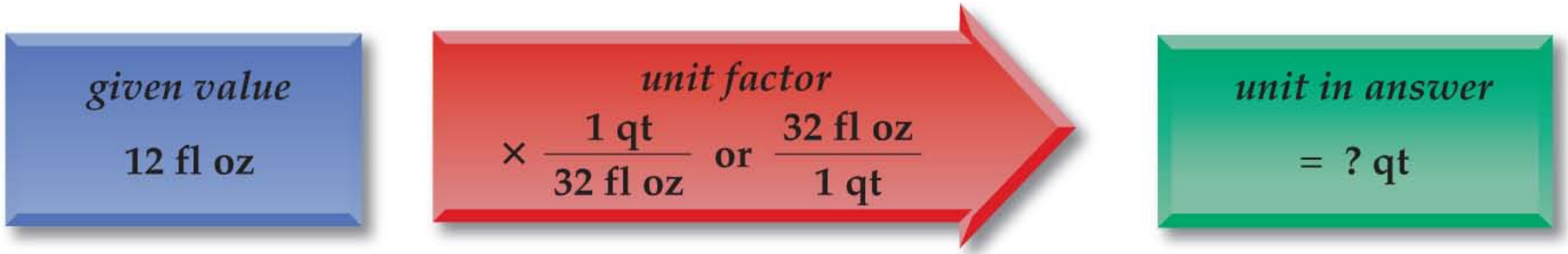
Continued

Strategy Plan

Step 1: What unit is asked for in the answer?
Step 2: What given value is related to the answer?
Step 3: What unit factor should we apply? Since the unit equation is 1 qt = 32 fl oz, the two unit factors are 1 qt/32 fl oz, and its reciprocal 32 fl oz/1 qt.



Unit Analysis Map



EXAMPLE EXERCISE 2.11 Unit Analysis Problem Solving

Continued

Solution

We should apply the unit factor 1 qt/32 fl oz to cancel fluid ounces (~~fl oz~~), which appears in the denominator.

$$12\ \cancel{\text{fl oz}} \times \frac{1\ \text{qt}}{32\ \cancel{\text{fl oz}}} = 0.38\ \text{qt}$$

The given value, 12 fl oz, limits the answer to two significant digits. Since the unit factor 1 qt/32 fl oz is derived from an exact equivalent, 1 qt = 32 fl oz, it does not affect the significant digits in the answer.

Practice Exercise

A can of soda contains 355 mL. What is the volume in liters (given that 1 L = 1000 mL)?

Answer: 0.355 L

Concept Exercise

How many significant digits are in the following unit equation?

$$1\ \text{L} = 1000\ \text{mL}$$

Answer: See Appendix G.

EXAMPLE EXERCISE 2.12 Uncertainty in Measurement

A marathon covers a distance of 26.2 miles (mi). If 1 mile is exactly equal to 1760 yards, what is the distance of the race in yards?

Strategy Plan

Step 1: What unit is asked for in the answer?
Step 2: What given value is related to the answer?
Step 3: What unit factor should we apply? Since the unit equation is 1 mi = 1760 yd, the two unit factors are 1 mi/1760 yd, and its reciprocal 1760 yd/1 mi.

Step 1: yd

Step 2: 26.2 mi

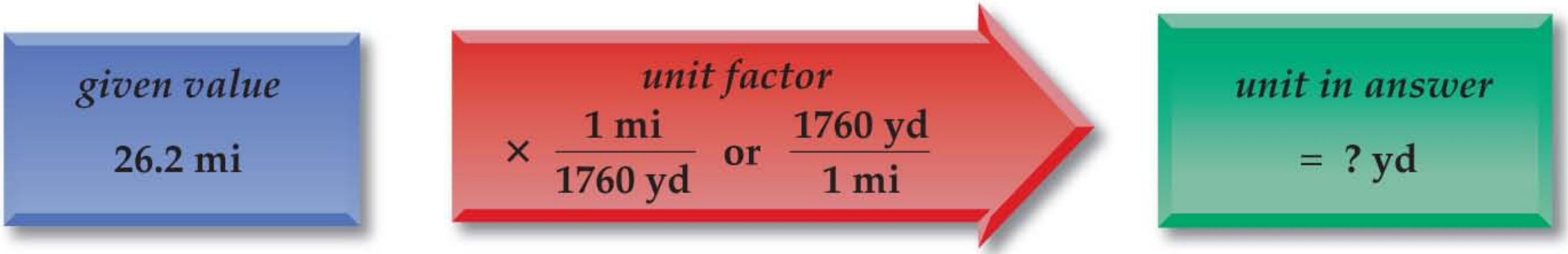
Step 3: $\frac{1\ \text{mi}}{1760\ \text{yd}}$ or $\frac{1760\ \text{yd}}{1\ \text{mi}}$

Boston Marathon Marathon athletes run a distance of 26.2 miles.

EXAMPLE EXERCISE 2.12 Uncertainty in Measurement

Continued

Unit Analysis Map



Solution

We should apply the unit factor 1760 yd/1 mi to cancel miles (mi), which appears in the denominator.

$$26.2\ \cancel{\text{mi}} \times \frac{1760\ \text{yd}}{1\ \cancel{\text{mi}}} = 46{,}100\ \text{yd}$$

The given value, 26.2 mi, limits the answer to three significant digits. Since the unit factor 1760 yd/1 mi is derived from an exact equivalent, 1 mi = 1760 yd, it does not affect the significant digits in the answer.

EXAMPLE EXERCISE 2.12 Uncertainty in Measurement

Continued

Practice Exercise

Given that a marathon is 26.2 miles, what is the distance in kilometers (given that 1 km = 0.62 mi)?

Answer: 42 km

Concept Exercise

How many significant digits are in the following unit equation?

$$1 \text{ km} = 0.62 \text{ mi}$$

Answer: See Appendix G.

EXAMPLE EXERCISE 2.13 The Percent Concept

Sterling silver contains silver and copper metals. If a sterling silver chain contains 18.5 g of silver and 1.5 g of copper, what is the percent of silver?

Sterling Silver Sterling silver has a high luster and is found in fine utensils and jewelry.

EXAMPLE EXERCISE 2.13 The Percent Concept

Continued

Strategy Plan

Step 1: What is asked for in the answer?
Step 2: What given value is related to the answer?
Step 3: What unit factor should we apply?
No unit factor is required.

Step 1: %

Step 2: 18.5 g and 1.5 g

Step 3: none

Solution

To find percent, we compare the mass of silver metal to the total mass of the silver and copper in the chain, and multiply by 100%.

$$\frac{18.5\ \cancel{g}}{(18.5 + 1.5)\ \cancel{g}} \times 100\% = 92.5\%$$

Genuine sterling silver is cast from 92.5% silver and 7.5% copper. If you carefully examine a piece of sterling silver, you may see the jeweler's notation .925, which indicates the item is genuine sterling silver.

EXAMPLE EXERCISE 2.13 The Percent Concept

Continued

Practice Exercise

A 14-karat gold ring contains 7.45 g of gold, 2.66 g of silver, and 2.66 g of copper. Calculate the percent of gold in the 14-karat ring.

Answer: 58.3%

Concept Exercise

If a gold alloy contains 20% silver and 5% copper, what is the percent of gold in the alloy?

Answer: See Appendix G.

EXAMPLE EXERCISE 2.14 Percent as a Unit Factor

The Moon and Earth have a similar composition and each contains 4.70% iron, which supports the theory that the Moon and Earth were originally a single planet. What is the mass of iron in a lunar sample that weighs 235 g?

Strategy Plan

Step 1: What unit is asked for in the answer?
Step 2: What given value is related to the answer?
Step 3: What unit factor should we apply?
From the definition of percent, 4.70 g iron = 100 g sample; the two unit factors are 4.70 g iron/100 g sample, and its reciprocal 100 g sample/4.70 g iron.

Step 1: g iron

Step 2: 235 g sample

Step 3: $\frac{4.70 \text{ g iron}}{100 \text{ g sample}}$ or $\frac{100 \text{ g sample}}{4.70 \text{ g iron}}$

Unit Analysis Map

given value
235 g sample

unit factor
$\times \frac{4.70 \text{ g iron}}{100 \text{ g sample}}$ or $\frac{100 \text{ g sample}}{4.70 \text{ g iron}}$

unit in answer
= g iron

EXAMPLE EXERCISE 2.14 Percent as a Unit Factor

Continued

Solution

We should apply the unit factor 4.70 g iron/100 g sample to cancel grams sample (~~g sample~~), which appears in the denominator.

$$235\ \cancel{\text{g sample}} \times \frac{4.70\ \text{g iron}}{100\ \cancel{\text{g sample}}} = 11.0\ \text{g iron}$$

The given value and unit factor each limits the answer to three significant digits.

Practice Exercise

A Moon sample is found to contain 7.50% aluminum. What is the mass of the lunar sample if the amount of aluminum is 5.25 g?

Answer: 70.0 g sample

Concept Exercise

Water is 11.2% hydrogen by mass. What two unit factors express the percent hydrogen in water?

Answer: See Appendix G.