Chapter 2 Measurements

2.1 Units of Measurement
Measurement

You make a measurement every time you
• measure your height
• read your watch
• take your temperature
• weigh a cantaloupe
Measurement in Chemistry

In chemistry we

- measure quantities
- do experiments
- calculate results
- use numbers to report measurements
- compare results to standards
Measurement

- A measuring tool is used to compare some dimension of an object to a standard.
- An electronic balance is the measuring tool used to determine the mass of a nickel.
Stating a Measurement

In every measurement, a number is followed by a unit.

Observe the following examples of measurements:

<table>
<thead>
<tr>
<th>Number</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>35</td>
<td>m</td>
</tr>
<tr>
<td>0.25</td>
<td>L</td>
</tr>
<tr>
<td>225</td>
<td>lb</td>
</tr>
<tr>
<td>3.4</td>
<td>h</td>
</tr>
</tbody>
</table>
The metric system and SI (international system) are

- decimal systems based on 10
- used in most of the world
- used everywhere by scientists
## Units in the Metric System

In the metric and SI systems, one unit is used for each type of measurement:

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Metric</th>
<th>SI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>meter (m)</td>
<td>meter (m)</td>
</tr>
<tr>
<td>Volume</td>
<td>liter (L)</td>
<td>cubic meter (m³)</td>
</tr>
<tr>
<td>Mass</td>
<td>gram (g)</td>
<td>kilogram (kg)</td>
</tr>
<tr>
<td>Time</td>
<td>second (s)</td>
<td>second (s)</td>
</tr>
<tr>
<td>Temperature</td>
<td>degree Celsius (°C)</td>
<td>Kelvin (K)</td>
</tr>
</tbody>
</table>
Length Measurement

Length

- is measured using a meterstick
- has the unit **meter (m)** in both the metric and SI systems
Inches and Centimeters

The unit of an inch (in.)
• is equal to exactly 2.54 cm in the metric and SI systems.

1 in. = 2.54 cm
Volume Measurement

Volume

- is the space occupied by a substance
- has the unit **liter (L)** in the metric system
  
  \[ 1 \text{ L} = 1.057 \text{ qt} \]

- has the unit **m}^3 (cubic meter)** in the SI system
- is measured using a graduated cylinder
Mass Measurement

The mass of an object

- is the quantity of material it contains
- is measured on a balance
- has the unit **gram** (*g*) in the metric system
- has the unit **kilogram** (*kg*) in the SI system
Temperature Measurement

The temperature

- indicates how hot or cold it is
- is measured on the Celsius (°C) scale in the metric system
- is measured on the Kelvin (K) scale in the SI system
- on this thermometer is 18 °C or 64 °F
Time Measurement

**Time** measurement

- uses the unit **second(s)** in both the metric and SI systems
- is based on an atomic clock that uses a frequency emitted by cesium atoms
For each of the following, indicate whether the unit describes 1) length 2) mass or 3) volume.

_____ A. A bag of onions has a mass of 2.6 kg.
 _____ B. A person is 2.0 m tall.
 _____ C. A medication contains 0.50 g of aspirin.
 _____ D. A bottle contains 1.5 L of water.
Solution

For each of the following, indicate whether the unit describes 1) length 2) mass or 3) volume.

2. A bag of onions has a mass of 2.6 kg.
1. B. A person is 2.0 m tall.
2. C. A medication contains 0.50 g of aspirin.
3. D. A bottle contains 1.5 L of water.
Learning Check

Identify the measurement that has an SI unit.

A. John’s height is _____.
   1) 1.5 yd         2) 6 ft         3) 2.1 m

B. The race was won in _____.
   1) 19.6 s         2) 14.2 min     3) 3.5 h

C. The mass of a lemon is _____.
   1) 12 oz         2) 0.145 kg     3) 0.6 lb

D. The temperature is _____.
   1) 85 °C         2) 255 K        3) 45 °F
Solution

A. John’s height is _____.
   3) 2.1 m

B. The race was won in _____.
   1) 19.6 s

C. The mass of a lemon is _____.
   2) 0.145 kg

D. The temperature is _____.
   2) 255 K
2.2 Scientific Notation

\[ 8 \times 10^{-6} \, \text{m} \]
Scientific Notation

Scientific notation

- is used to write very large or very small numbers
- for the width of a human hair (0.000 008 m) is written as
  \[ 8 \times 10^{-6} \text{ m} \]
- for a large number such as 4 500 000 s is written as
  \[ 4.5 \times 10^6 \text{ s} \]
Scientific Notation

- A number written in scientific notation contains a coefficient and a power of 10.
  
  \[
  \text{coefficient} \quad \text{power of ten} \\
  1.5 \times 10^2 \\
  7.35 \times 10^{-4}
  \]

- To write a number in scientific notation, the decimal point is moved after the first digit.
- The spaces moved are shown as a power of ten.
  
  \[
  52000. = 5.2 \times 10^4 \\
  0.00378 = 3.78 \times 10^{-3}
  \]

  4 spaces left \quad 3 spaces right
### Some Powers of Ten

<table>
<thead>
<tr>
<th>Number</th>
<th>Multiples of 10</th>
<th>Scientific Notation</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 000</td>
<td>$10 \times 10 \times 10 \times 10$</td>
<td>$1 \times 10^4$</td>
</tr>
<tr>
<td>1000</td>
<td>$10 \times 10 \times 10$</td>
<td>$1 \times 10^3$</td>
</tr>
<tr>
<td>100</td>
<td>$10 \times 10$</td>
<td>$1 \times 10^2$</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>$1 \times 10^1$</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>$1 \times 10^0$</td>
</tr>
<tr>
<td>0.1</td>
<td>$\frac{1}{10}$</td>
<td>$1 \times 10^{-1}$</td>
</tr>
<tr>
<td>0.01</td>
<td>$\frac{1}{10} \times \frac{1}{10}$</td>
<td>$1 \times 10^{-2}$</td>
</tr>
<tr>
<td>0.001</td>
<td>$\frac{1}{10} \times \frac{1}{10} \times \frac{1}{10}$</td>
<td>$1 \times 10^{-3}$</td>
</tr>
<tr>
<td>0.0001</td>
<td>$\frac{1}{10} \times \frac{1}{10} \times \frac{1}{10} \times \frac{1}{10}$</td>
<td>$1 \times 10^{-4}$</td>
</tr>
</tbody>
</table>

Some positive powers of 10

Some negative powers of 10
# Comparing Numbers in Standard and Scientific Notation

Here are some numbers written in standard format and in scientific notation.

<table>
<thead>
<tr>
<th>Number in</th>
<th>Standard Format</th>
<th>Scientific Notation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter of the Earth</td>
<td>12 800 000 m</td>
<td>$1.28 \times 10^7$ m</td>
</tr>
<tr>
<td>Mass of a human</td>
<td>68 kg</td>
<td>$6.8 \times 10^1$ kg</td>
</tr>
<tr>
<td>Length of a virus</td>
<td>0.000 03 cm</td>
<td>$3 \times 10^{-5}$ cm</td>
</tr>
</tbody>
</table>
Learning Check

Select the correct scientific notation for each.

A. 0.000 008
   1) $8 \times 10^6$  2) $8 \times 10^{-6}$  3) $0.8 \times 10^{-5}$

B. 72 000
   1) $7.2 \times 10^4$  2) $72 \times 10^3$  3) $7.2 \times 10^{-4}$
Solution

Select the correct scientific notation for each.

A. 0.000 008
   2) $8 \times 10^{-6}$

B. 72 000
   1) $7.2 \times 10^{4}$
Learning Check

Write each as a standard number.

A. $2.0 \times 10^{-2}$
   1) 200  
   2) 0.0020  
   3) 0.020

B. $1.8 \times 10^5$
   1) 180 000  
   2) 0.000 018  
   3) 18 000
Solution

Write each as a standard number.

A. $2.0 \times 10^{-2}$
   3) 0.020

B. $1.8 \times 10^5$
   1) 180 000
2.3
Measured Numbers and Significant Figures
Measured Numbers

A measuring tool
• is used to determine a quantity such as the length or the mass of an object
• provides numbers for a measurement called measured numbers
The markings on the meterstick at the end of the orange line are read as
The first digit 2
plus the second digit 2.7
The last digit is obtained by estimating.
The end of the line might be estimated between 2.7–2.8 as half-way (0.05) or a little more (0.06), which gives a reported length of 2.75 cm or 2.76 cm.
Known + Estimated Digits

In the length reported as 2.76 cm,

- the digits 2 and 7 are **certain** (*known*)
- the final digit 6 was **estimated** (*uncertain*)
- all three digits (2.76) are **significant** including the **estimated digit**
Learning Check

What is the length of the red line?
1) 9.0 cm
2) 9.03 cm
3) 9.04 cm
The length of the red line could be reported as

2) 9.03 cm

or 3) 9.04 cm

The estimated digit may be slightly different. Both readings are acceptable.
For this measurement, the first and second known digits are 4.5.

Because the line ends on a mark, the *estimated digit* in the hundredths place is 0.

This measurement is reported as **4.50 cm**.
Significant Figures in Measured Numbers

- Significant figures obtained from a measurement include all of the known digits plus the estimated digit.
- The number of significant figures reported in a measurement depends on the measuring tool.
# Significant Figures

## TABLE 2.4 Significant Figures in Measured Numbers

<table>
<thead>
<tr>
<th>Rule</th>
<th>Measured Number</th>
<th>Number of Significant Figures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.</strong> A number is a <em>significant figure</em> if it is</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. not a zero</td>
<td>4.5 g</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>122.35 m</td>
<td>5</td>
</tr>
<tr>
<td>b. a zero between nonzero digits</td>
<td>205 m</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>5.082 kg</td>
<td>4</td>
</tr>
<tr>
<td>c. a zero at the end of a decimal number</td>
<td>50. L</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>25.0 °C</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>16.00 g</td>
<td>4</td>
</tr>
<tr>
<td>d. in the coefficient of a</td>
<td>5.5 ( \times ) 10(^{-9}) kg</td>
<td>2</td>
</tr>
<tr>
<td>number written in scientific notation</td>
<td>3.00 ( \times ) 10(^{2}) m(^3)</td>
<td>3</td>
</tr>
<tr>
<td><strong>2.</strong> A zero is <em>not a significant figure</em> if it is</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. at the beginning of a decimal number</td>
<td>0.0004 s</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>0.075 cm</td>
<td>2</td>
</tr>
<tr>
<td>b. used as a placeholder in a large</td>
<td>850 000 m</td>
<td>2</td>
</tr>
<tr>
<td>number without a decimal point</td>
<td>1 250 000 g</td>
<td>3</td>
</tr>
</tbody>
</table>
Counting Significant Figures

All nonzero numbers in a measured number are significant.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Number of Significant Figures</th>
</tr>
</thead>
<tbody>
<tr>
<td>38.15 cm</td>
<td>4</td>
</tr>
<tr>
<td>5.6 ft</td>
<td>2</td>
</tr>
<tr>
<td>65.6 lb</td>
<td>3</td>
</tr>
<tr>
<td>122.55 m</td>
<td>5</td>
</tr>
</tbody>
</table>
Sandwiched Zeros

Sandwiched zeros
• occur between nonzero numbers
• are significant

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Number of Significant Figures</th>
</tr>
</thead>
<tbody>
<tr>
<td>50.8 mm</td>
<td>3</td>
</tr>
<tr>
<td>2001 min</td>
<td>4</td>
</tr>
<tr>
<td>0.0702 lb</td>
<td>3</td>
</tr>
<tr>
<td>0.40505 m</td>
<td>5</td>
</tr>
</tbody>
</table>
Trailing Zeros

Trailing zeros

- follow nonzero numbers in numbers *without* decimal points
- are placeholders
- are not significant

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Number of Significant Figures</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 000 cm</td>
<td>2</td>
</tr>
<tr>
<td>200 kg</td>
<td>1</td>
</tr>
<tr>
<td>48 600 mL</td>
<td>3</td>
</tr>
<tr>
<td>25 005 000 g</td>
<td>5</td>
</tr>
</tbody>
</table>
Leading Zeros

Leading zeros

• precede nonzero digits in a decimal number
• are placeholders
• are not significant

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Number of Significant Figures</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.008 mm</td>
<td>1</td>
</tr>
<tr>
<td>0.0156 oz</td>
<td>3</td>
</tr>
<tr>
<td>0.0042 lb</td>
<td>2</td>
</tr>
<tr>
<td>0.000262 mL</td>
<td>3</td>
</tr>
</tbody>
</table>
**Significant Figures in Scientific Notation**

In scientific notation:
- all digits including zeros in the coefficient are significant

<table>
<thead>
<tr>
<th>Scientific Notation</th>
<th>Number of Significant Figures</th>
</tr>
</thead>
<tbody>
<tr>
<td>$8 \times 10^4 \text{ m}$</td>
<td>1</td>
</tr>
<tr>
<td>$8.0 \times 10^4 \text{ m}$</td>
<td>2</td>
</tr>
<tr>
<td>$8.00 \times 10^4 \text{ m}$</td>
<td>3</td>
</tr>
</tbody>
</table>
Learning Check

State the number of significant figures in each of the following measurements:
A. 0.030 m
B. 4.050 L
C. 0.0008 g
D. 2.80 m
Solution

State the number of significant figures in each of the following measurements:

A. 0.030 m 2
B. 4.050 L 4
C. 0.0008 g 1
D. 2.80 m 3
Learning Check

A. Which answer(s) contain three significant figures?
   1) 0.4760   2) 0.00476   3) 4.76 x 10^3

B. All the zeros are significant in
   1) 0.00307   2) 25.300   3) 2.050 x 10^3

C. The number of significant figures in 5.80 x 10^2 is
   1) one   2) three
Solution

A. Which answer(s) contain three significant figures?
   2) 0.00476
   3) $4.76 \times 10^3$

B. All the zeros are significant in
   2) 25.300
   3) $2.050 \times 10^3$

C. The number of significant figures in $5.80 \times 10^2$
   is
   3) three
In which set(s) do both numbers contain the *same* number of significant figures?

1) 22.0 and 22.00
2) 400.0 and 4.00 \( \times 10^2 \)
3) 0.000015 and 150 000
Solution

In which set(s) do both numbers contain the same number of significant figures?

3) 0.000015 and 150 000

Both numbers contain two (2) significant figures.
Exact Numbers

An **exact number** is obtained

- when objects are counted
  
  **Example**: counting objects
  
  2 baseballs
  4 pizzas

- from numbers in a defined relationship
  
  **Example**: defined relationships
  
  1 foot = 12 inches
  1 meter = 100 cm
### Examples of Some Exact Numbers

<table>
<thead>
<tr>
<th>Counted Numbers</th>
<th>Defined Equalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 doughnuts</td>
<td>1 ft = 12 in.</td>
</tr>
<tr>
<td>2 baseballs</td>
<td>1 qt = 4 cups</td>
</tr>
<tr>
<td>5 caps</td>
<td>1 lb = 16 ounces (oz)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>U.S. System</th>
<th>Metric System</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 L = 1000 mL</td>
<td>1 kg = 1000 g</td>
</tr>
</tbody>
</table>

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Learning Check

A. Exact numbers are obtained by
   1. using a measuring tool
   2. counting
   3. definition

B. Measured numbers are obtained by
   1. using a measuring tool
   2. counting
   3. definition
Solution

A. Exact numbers are obtained by
   2. counting
   3. definition

B. Measured numbers are obtained by
   1. using a measuring tool
Learning Check

Classify each of the following as exact (E) or measured numbers (M). Explain your answer.

A. ___Gold melts at 1064 °C.
B. ___1 yd = 3 ft
C. ___The diameter of a red blood cell is $6 \times 10^{-4}$ cm.
D. ___There are 6 hats on the shelf.
E. ___A can of soda contains 355 mL of soda.
Solution

Classify each of the following as exact (E) or measured numbers (M).

A. M A measuring tool is required.
B. E This is a defined relationship.
C. M A measuring tool is used to determine length.
D. E The number of hats is obtained by counting.
E. M The volume of soda is measured.
Chapter 2 Measurements

2.4 Significant Figures in Calculations
Rounding Off Answers

In calculations

- answers must have the same number of significant figures as the measured numbers
- calculated answers are usually rounded off
- rounding rules are used to obtain the correct number of significant figures
Rounding Off Calculated Answers

- When the first digit dropped is **4 or less**, the retained numbers remain the same.
  
  to round off 45.832 to 3 significant figures
  
  drop the digits 32 = 45.8

- When the first digit dropped is **5 or greater**, the last retained digit is increased by 1.
  
  to round off 2.4884 to 2 significant figures
  
  drop the digits 884 = 2.5 (increase by 0.1)
Adding Significant Zeros

- Sometimes a calculated answer requires more significant digits. Then one or more zeros are added.

<table>
<thead>
<tr>
<th>Calculated Answer</th>
<th>Zeros Added to Give 3 Significant Figures</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>4.00</td>
</tr>
<tr>
<td>1.5</td>
<td>1.50</td>
</tr>
<tr>
<td>0.2</td>
<td>0.200</td>
</tr>
<tr>
<td>12</td>
<td>12.0</td>
</tr>
</tbody>
</table>
Learning Check

Adjust the following calculated answers to give answers with three significant figures:

A. 824.75 cm

B. 0.112486 g

C. 8.2 L
Solution

Adjust the following calculated answers to give answers with three significant figures:

A. 825 cm  first digit dropped is greater than 5

B. 0.112 g  first digit dropped is 4

C. 8.20 L  significant zero added
Calculations with Measured Numbers

In calculations with measured numbers, significant figures or decimal places are used to determine the correct number of figures in the final answer.
When multiplying or dividing, use

- the same number of significant figures (SFs) as in the measurement with the fewest significant figures
- rounding rules to obtain the correct number of significant figures

**Example**

\[ 110.5 \times 0.048 = 5.304 = 5.3 \text{ (rounded)} \]

\[ 4 \text{ SFs} \quad 2 \text{ SFs} \quad \text{calculator} \quad 2 \text{ SFs} \]
Learning Check

Give an answer for each with the correct number of significant figures.

A. \(2.19 \times 4.2 = \)
   1) 9        2) 9.2        3) 9.198

B. \(4.311 \div 0.07 = \)
   1) 61.59     2) 62        3) 60

C. \(2.54 \times 0.0028 = \)
   \(0.0105 \times 0.060 \)
   1) 11.3     2) 11        3) 0.041
Solution

A. $2.19 \times 4.2 = 2) \ 9.2$

B. $4.311 \div 0.07 = 3) \ 60$

C. \[
\frac{2.54 \times 0.0028}{0.0105 \times 0.060} = 2) \ 11
\]

On a calculator, enter each number followed by the operation key.

\[
2.54 \times 0.0028 \div 0.0105 \div 0.060 = 11.28888889 = 11 \ (rounded \ off)
\]
Addition and Subtraction

When adding or subtracting, use

- the same number of decimal places as the measurement with the fewest decimal places
- rounding rules to adjust the number of digits in the answer

\[
\begin{align*}
25.2 & \quad \text{one decimal place} \\
+ 1.34 & \quad \text{two decimal places} \\
26.54 & \quad \text{calculated answer} \\
26.5 & \quad \text{final answer (one decimal place)}
\end{align*}
\]
Learning Check

For each calculation, round the answer to give the correct number of digits.

A. $235.05 + 19.6 + 2 =$
   1) 257  2) 256.7  3) 256.65

B. $58.925 - 18.2 =$
   1) 40.725  2) 40.73  3) 40.7
Solution

A. 235.05 hundredths place (2 decimal places)
    +19.6 tenths place (1 decimal place)
    + 2 ones place

    256.65 rounds to 257 answer (1)

B. 58.925 thousandths place (3 decimal places)
    -18.2 tenths place (1 decimal place)

    40.725 round to 40.7 answer (3)
Chapter 2  Measurements

2.5
Prefixes and Equalities
Prefixes

A prefix

• in front of a unit increases or decreases the size of that unit
• makes units larger or smaller that the initial unit by one or more factors of 10
• indicates a numerical value

\[
\text{prefix} = \text{value} \\
1 \text{ kilometer} = 1000 \text{ meters} \\
1 \text{ kilogram} = 1000 \text{ grams}
\]
# Metric and SI Prefixes

## TABLE 2.6 Metric and SI Prefixes

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Symbol</th>
<th>Numerical Value</th>
<th>Scientific Notation</th>
<th>Equality</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Prefixes That Increase the Size of the Unit</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>peta</td>
<td>P</td>
<td>1 000 000 000 000 000</td>
<td>$10^{15}$</td>
<td>$1 \text{ Pg} = 1 \times 10^{15} \text{ g}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$1 \text{ g} = 1 \times 10^{-15} \text{ Pg}$</td>
</tr>
<tr>
<td>tera</td>
<td>T</td>
<td>1 000 000 000 000</td>
<td>$10^{12}$</td>
<td>$1 \text{ Ts} = 1 \times 10^{12} \text{ s}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$1 \text{ s} = 1 \times 10^{-12} \text{ Ts}$</td>
</tr>
<tr>
<td>giga</td>
<td>G</td>
<td>1 000 000 000</td>
<td>$10^9$</td>
<td>$1 \text{ Gm} = 1 \times 10^9 \text{ m}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$1 \text{ m} = 1 \times 10^{-9} \text{ Gm}$</td>
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<td>$1 \text{ s} = 1 \times 10^{15} \text{ fs}$</td>
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</table>
Select the unit you would use to measure

A. Your height in ______
   1) millimeters    2) meters    3) kilometers

B. Your mass in ______
   1) milligrams    2) grams    3) kilograms

C. The distance between two cities in ______
   1) millimeters    2) meters    3) kilometers

D. The width of an artery in ______
   1) millimeters    2) meters    3) kilometers
Solution

A. Your height in ______
   2) meters

B. Your mass in ______
   3) kilograms

C. The distance between two cities in ______
   3) kilometers

D. The width of an artery in ______
   1) millimeters
Indicate the unit that matches the description.

1. A mass that is 1000 times greater than 1 gram.
   1) kilogram  2) milligram  3) megagram

2. A length that is 1/100 of 1 meter.
   1) decimeter  2) centimeter  3) millimeter

3. A unit of time that is 1/1000 of a second.
   1) nanosecond  2) microsecond  3) millisecond
Solution

Indicate the unit that matches the description.

1. A mass that is 1000 times greater than 1 gram.
   1) kilogram

2. A length that is 1/100 of 1 meter.
   2) centimeter

3. A unit of time that is 1/1000 of a second.
   3) millisecond
An equality

- states the same measurement in two different units
- can be written using the relationships between two metric units

Example:

1 meter is the same length as 100 cm and 1000 mm.

\[
\begin{align*}
1 \text{ m} &= 100 \text{ cm} \\
1 \text{ m} &= 1000 \text{ mm} \\
100 \text{ cm} &= 1000 \text{ mm}
\end{align*}
\]
Metric Equalities for Length

1 cm = 10 mm

1 dm = 10 cm

1 meter = 10 dm = 100 cm = 1000 mm
Metric Equalities for Volume

Volume = 10 cm × 10 cm × 10 cm
      = 1000 cm³
      = 1000 mL
      = 1 L
Metric Equalities for Mass

Several equalities can be written for mass in the metric (SI) system.

Example:
1 gram is the same mass as 1000 mg and 0.001 kg.

\[
egin{align*}
1 \text{ kg} & = 1000 \text{ g} \\
1 \text{ g} & = 1000 \text{ mg} \\
1 \text{ mg} & = 0.001 \text{ g} \\
1 \text{ mg} & = 1000 \mu\text{g}
\end{align*}
\]
Indicate the unit that completes each of the following equalities:

A. 1000 m = ______
   1) 1 mm  2) 1 km  3) 1 dm

B. 0.001 g = ______
   1) 1 mg  2) 1 kg  3) 1 dg

C. 0.01 m = ______
   1) 1 mm  2) 1 cm  3) 1 dm
Solution

Indicate the unit that completes each of the following equalities:

A. 2) \[1000 \text{ m} = 1 \text{ km}\]
B. 1) \[0.001 \text{ g} = 1 \text{ mg}\]
C. 2) \[0.01 \text{ m} = 1 \text{ cm}\]
Learning Check

Complete each of the following equalities:

A. 1 kg = ______
   1) 10 g  2) 100 g  3) 1000 g

B. 1 mm = ______
   1) 0.001 m  2) 0.01 m  3) 0.1 m
Solution

Complete each of the following equalities:

A. \(1 \text{ kg} = 1000 \text{ g}\) (3)

B. \(1 \text{ mm} = 0.001 \text{ m}\) (1)
Chapter 2  Measurements

2.5  Prefixes and Equalities
Prefixes

A prefix

- in front of a unit increases or decreases the size of that unit
- makes units larger or smaller that the initial unit by one or more factors of 10
- indicates a numerical value

\[
\text{prefix} = \text{value}
\]

1 kilometer = 1000 meters
1 kilogram = 1000 grams
# Metric and SI Prefixes

## TABLE 2.6 Metric and SI Prefixes

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Symbol</th>
<th>Numerical Value</th>
<th>Scientific Notation</th>
<th>Equality</th>
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<td>(10^{15})</td>
<td>(1 \text{ Pg} = 1 \times 10^{15} \text{ g}) (1 \text{ g} = 1 \times 10^{-15} \text{ Pg})</td>
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Learning Check

Select the unit you would use to measure

A. Your height in _____
   1) millimeters   2) meters   3) kilometers

B. Your mass in _____
   1) milligrams   2) grams   3) kilograms

C. The distance between two cities in _____
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Solution

A. Your height in ______
   2) meters
B. Your mass in ______
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C. The distance between two cities in ______
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Indicate the unit that matches the description.

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An equality

- states the same measurement in two different units
- can be written using the relationships between two metric units

**Example:**

1 meter is the same length as 100 cm and 1000 mm.

\[
\begin{align*}
1 \text{ m} & = 100 \text{ cm} \\
1 \text{ m} & = 1000 \text{ mm}
\end{align*}
\]

\[
100 \text{ cm} = 1000 \text{ mm}
\]
Metric Equalities for Length

1 mm
1 cm = 10 mm

1 dm

1 meter
10 dm
100 cm
1000 mm
Metric Equalities for Volume

Volume = 10 cm × 10 cm × 10 cm
= 1000 cm³
= 1000 mL
= 1 L

10 cm = 1 dm

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Metric Equalities for Mass

- Several equalities can be written for mass in the metric (SI) system.

**Example:**

1 gram is the same mass as 1000 mg and 0.001 kg.

\[
\begin{align*}
1 \text{ kg} &= 1000 \text{ g} \\
1 \text{ g} &= 1000 \text{ mg} \\
1 \text{ mg} &= 0.001 \text{ g} \\
1 \text{ mg} &= 1000 \mu\text{g} \\
\end{align*}
\]
Indicate the unit that completes each of the following equalities:

A. 1000 m = _____
   1) 1 mm  2) 1 km  3) 1 dm

B. 0.001 g = _____
   1) 1 mg  2) 1 kg  3) 1 dg

C. 0.01 m = _____
   1) 1 mm  2) 1 cm  3) 1 dm
Indicate the unit that completes each of the following equalities:

A. 2) \( 1000 \text{ m} = 1 \text{ km} \)
B. 1) \( 0.001 \text{ g} = 1 \text{ mg} \)
C. 2) \( 0.01 \text{ m} = 1 \text{ cm} \)
Learning Check

Complete each of the following equalities:

A. $1 \text{ kg} = \underline{\text{______}}$
   1) $10 \text{ g}$  2) $100 \text{ g}$  3) $1000 \text{ g}$

B. $1 \text{ mm} = \underline{\text{______}}$
   1) $0.001 \text{ m}$  2) $0.01 \text{ m}$  3) $0.1 \text{ m}$
Complete each of the following equalities:

A. \( 1 \text{ kg} = 1000 \text{ g} \) \hspace{1em} (3)

B. \( 1 \text{ mm} = 0.001 \text{ m} \) \hspace{1em} (1)
A health professional obtains a measured volume from a vial for an injection.
Given and Needed Units

To solve a problem
- identify the **given** unit
- identify the **needed** unit

**Problem:**
A person has a height of 2.0 m. What is that height in inches?

The *given unit* is the initial unit of height.

given unit = meters (m)

The *needed unit* is the unit for the answer.

needed unit = inches (in.)
Learning Check

An injured person loses 0.30 pints of blood. How many milliliters of blood would that be?

Identify the given and needed units in this problem.

\[
\begin{align*}
\text{Given unit} & \quad = \quad \underline{\phantom{00000}} \\
\text{Needed unit} & \quad = \quad \underline{\phantom{00000}} 
\end{align*}
\]
Solution

An injured person loses 0.30 pints of blood. How many milliliters of blood would that be?

Identify the given and needed units in this problem

Given unit = pints
Needed unit = milliliters
Guide to Problem Solving Using Conversion Factors

**STEP 1** State the given and needed quantities.

**STEP 2** Write a plan to convert the given unit to the needed unit.

**STEP 3** State the equalities and conversion factors needed to cancel units.

**STEP 4** Set up problem to cancel units and calculate answer.

\[
\frac{\text{Unit 1}}{} \times \frac{\text{Unit 2}}{\text{Unit 1}} = \text{Unit 2}
\]

<table>
<thead>
<tr>
<th>Given unit</th>
<th>Conversion factor</th>
<th>Needed unit</th>
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</table>
The steps in the Guides to Problem Solving Using Conversion Factors are useful in setting up a problem with conversion factors.
Setting up a Problem

How many minutes are 2.5 hours?

**STEP 1**  
**Given**  2.5 h  
**Need**  min

**STEP 2**  
**Plan**  hours $\longrightarrow$ minutes

**STEP 3**  
**Equalities**  $1 \text{ h} = 60 \text{ min}$

**STEP 4**  
**Set up problem**

$$
\frac{2.5 \text{ h}}{1 \text{ h}} \times \frac{60 \text{ min}}{1 \text{ h}} = 150 \text{ min}
$$

(given conversion needed unit) (2 SFs)

*Given unit*  *conversion factor*  *needed unit*
Learning Check

A rattlesnake is 2.44 m long. How long is the snake in centimeters?
1) 2440 cm
2) 244 cm
3) 24.4 cm
A rattlesnake is 2.44 m long. How long is the snake in centimeters?

**STEP 1**
Given: 2.44 m  
Need: centimeters

**STEP 2**
Plan: meters $\rightarrow$ centimeters

**STEP 3**
Equality: $1 \text{ m} = 100 \text{ cm}$
Factors: $\frac{1 \text{ m}}{100 \text{ cm}}$ and $\frac{100 \text{ cm}}{1 \text{ m}}$

**STEP 4**
Set up problem:
\[ 2.44 \text{ m} \times \frac{100 \text{ cm}}{1 \text{ m}} = 244 \text{ cm} \text{ (answer 2)} \]
Using Two or More Factors

- Often, two or more conversion factors are required to obtain the unit needed for the answer.

  Unit 1 $\rightarrow$ Unit 2 $\rightarrow$ Unit 3

- Additional conversion factors are placed in the setup to cancel each preceding unit.

  Given unit $\times$ factor 1 $\times$ factor 2 = needed unit

  Unit 1 $\times$ Unit 2 $\times$ Unit 3 = Unit 3
Example: Problem Solving

How many minutes are in 1.4 days?

**STEP 1** Given 1.4 days Need minutes

**STEP 2** Plan days → hours → minutes

**STEP 3** Equalties: 1 day = 24 h
1 h = 60 min

**STEP 4** Set up problem:

\[
1.4 \text{ days} \times \frac{24 \text{ h}}{1 \text{ day}} \times \frac{60 \text{ min}}{1 \text{ h}} = 2.0 \times 10^3 \text{ min}
\]

2 SFs Exact Exact = 2 SFs
Check the Unit Cancellation

- Be sure to check your unit cancellation in the setup.
- The units in the conversion factors must cancel to give the correct unit for the answer.

**Example:**

What is wrong with the following setup?

\[
1.4 \text{ day} \times \frac{1 \text{ day}}{24 \text{ hr}} \times \frac{1 \text{ hr}}{60 \text{ min}}
\]

Units = \( \text{day}^2/\text{min} \), which is *not the unit needed.*

Units do not cancel properly; the setup is wrong.
Using the GPS

What is 165 lb in kilograms?

STEP 1  Given 165 lb  Need  kg

STEP 2  Plan lb  →  kg

STEP 3  Equalities/conversion factors

\[ 1 \text{ kg} = 2.20 \text{ lb} \quad \frac{2.20 \text{ lb}}{1 \text{ kg}} \quad \text{and} \quad \frac{1 \text{ kg}}{2.20 \text{ lb}} \]

STEP 4  Set up problem

\[ 165 \text{ lb} \times \frac{1 \text{ kg}}{2.20 \text{ lb}} = 74.8 \text{ kg} \quad (3 \text{ SFs}) \]
Learning Check

A bucket contains 4.65 L water. How many gallons of water is that?
Solution

STEP 1  Given  4.65 L  Need  gallons

STEP 2  Plan  liters  quarts  gallons

STEP 3  Equalities

1 L = 1.057 qt  1 gal = 4 qt

STEP 4  Set Up Problem

\[
\frac{4.65 \text{ L}}{1} \times \frac{1.057 \text{ qt}}{1} \times \frac{1 \text{ gal}}{4 \text{ qt}} = 1.23 \text{ gal}
\]

3 SFs      4 SFs      Exact      3 SFs
Learning Check

If a ski pole is 3.0 feet in length, how long is the ski pole in mm?
Solution

STEP 1  Given  3.0 ft    Need mm

STEP 2  Plan  ft  → in.  → cm  → mm

STEP 3  Equalities  1 ft = 12 in., 2.54 cm = 1 in.,
           1 cm = 10 mm

STEP 4  Set up problem

\[
3.0 \text{ ft} \times \frac{12 \text{ in.}}{1 \text{ ft}} \times \frac{2.54 \text{ cm}}{1 \text{ in.}} \times \frac{10 \text{ mm}}{1 \text{ cm}} = 910 \text{ mm (2 SFs)}
\]

Check initial unit:   ft
Check factor setup:    units cancel properly
Check needed unit:   mm
Learning Check

If your pace on a treadmill is 65 meters per minute, how many minutes will it take for you to walk a distance of 7500 feet?
Solution

STEP 1 Given 7500 ft; 65 m/min   Need min

STEP 2 Plan ft → in. → cm → m → min

STEP 3 Equalities 1 ft = 12 in. 1 in. = 2.54 cm

1 m = 100 cm

1 min = 65 m (walking pace)

STEP 4 Set Up Problem

\[
\begin{align*}
7500 \text{ ft} &\times \frac{12 \text{ in.}}{1 \text{ ft}} \times \frac{2.54 \text{ cm}}{1 \text{ in.}} \times \frac{1 \text{ m}}{100 \text{ cm}} \times \frac{1 \text{ min}}{65 \text{ m}} \\
&= 35 \text{ min} \\
\text{Answer rounded off (2 SFs)}
\end{align*}
\]
Percent Factor in a Problem

If the thickness of the skin fold at the waist indicates 11% of body fat, how much fat, in kg, does a person have with a body mass of 86 kg?

**STEP 1**  **Given**  86 kg; 11% fat  **Need**  kg fat

**STEP 2**  **Plan**  kg body mass $\rightarrow$ kg fat

**STEP 3**  **Equalities/Conversion factors**

$100 \text{ kg of body mass} = 11 \text{ kg of fat}$

$100 \text{ kg body mass and } 11 \text{ kg fat}$

$11 \text{ kg fat} \quad \quad \quad 100 \text{ kg body mass}$

**STEP 4**  **Set Up Problem**

$86 \text{ kg mass} \times \frac{11 \text{ kg fat}}{100 \text{ kg mass}} = 9.5 \text{ kg of fat}$
How many lb of sugar are in 120 g of candy if the candy is 25% (by mass) sugar?
Solution

STEP 1 Given 120 g of candy
Need lb of sugar

STEP 2 Plan g → lb of candy → lb of sugar

STEP 3 Equalities 1 lb = 453.6 g
100 g of candy = 25 g of sugar

STEP 4 Set Up Problem % factor

\[
\frac{120 \text{ g candy}}{453.6 \text{ g candy}} \times \frac{1 \text{ lb candy}}{} \times \frac{25 \text{ lb sugar}}{100 \text{ lb candy}} = 0.066 \text{ lb of sugar}
\]