1.7 The statement "that is just a theory" is generally taken to mean that there is no scientific proof behind the statement. This statement is the opposite of the meaning in the context of the scientific theory, where theories are tested again and again.

1.8 Matter can be classified according to its state—solid, liquid, or gas—and according to its composition.

1.9 In solid matter, atoms or molecules pack close to each other in fixed locations. Although the atoms and molecules in a solid vibrate, they do not move around or past each other. Consequently, a solid has a fixed volume and rigid shape.

In liquid matter, atoms or molecules pack about as closely as they do in solid matter, but they are free to move relative to each other, giving liquids a fixed volume but not a fixed shape. Liquids assume the shape of their container.

In gaseous matter, atoms or molecules have a lot of space between them and are free to move relative to one another, making gases compressible. Gases always assume the shape and volume of their container.

1.10 Solid matter may be crystalline, in which case its atoms or molecules are arranged in patterns with long-range, repeating order, or it may be amorphous, in which case its atoms or molecules do not have any long-range order.

1.11 A pure substance is composed of only one type of atom or molecule. In contrast, a mixture is a substance composed of two or more different types of atoms or molecules that can be combined in variable proportions.

1.12 An element is a pure substance which cannot be decomposed into simpler substances. A compound is composed of two or more elements in fixed proportions.

1.13 A homogeneous mixture has the same composition throughout, while a heterogeneous mixture has different compositions in different regions.

1.14 If a mixture is composed of an insoluble solid and a liquid, the two can be separated by filtration, in which the mixture is poured through filter paper (usually held in a funnel).

1.15 Mixtures of miscible liquids (substances that easily mix) can usually be separated by distillation, a process in which the mixture is heated to boil off the more volatile (easily vaporizable) liquid. The volatile liquid is then recondensed in a condenser and collected in a separate flask.

1.16 A physical property is one that a substance displays without changing its composition, whereas a chemical property is one that a substance displays only by changing its composition via a chemical change.

1.17 Changes that alter only state or appearance, but not composition, are called physical changes. The atoms or molecules that compose a substance do not change their identity during a physical change. For example, when water boils, it changes its state from a liquid to a gas, but the gas remains composed of water molecules, so this a physical change. When sugar dissolves in water, the sugar molecules are separated from each other, but the molecules of sugar and water remain intact.

In contrast, changes that alter the composition of matter are called chemical changes. During a chemical change, atoms rearrange, transforming the original substances into different substances. For example, the rusting of iron, the combustion of natural gas to form carbon dioxide and water, and the denaturing of proteins when an egg is cooked are examples of chemical changes.

1.18 In chemical and physical changes, matter often exchanges energy with its surroundings. In these exchanges, the total energy is always conserved; energy is neither created nor destroyed. Systems with high potential energy tend to change in the direction of lower potential energy, releasing energy into the surroundings.

1.19 Chemical energy is potential energy. It is the energy that is contained in the bonds that hold the molecules together. This energy arises primarily from electrostatic forces between the electrically charged particles (protons and electrons) that compose atoms and molecules. Some of these arrangements—such as the one within the molecules that compose gasoline—have a much higher potential energy than others.
undergoes combustion the arrangement of these particles changes, creating molecules with much lower potential energy and transferring a great deal of energy (mostly in the form of heat) to the surroundings. A raised weight has a certain amount of potential energy (dependent on the height the weight is raised) that can be converted to kinetic energy when the weight is released.

1.20 The SI base units include the meter (m) for length, the kilogram (kg) for mass, the second (s) for time, and the Kelvin (K) for temperature.

1.21 The three different temperature scales are Kelvin (K), Celsius (°C), and Fahrenheit (°F). The size of the degree is the same in the Kelvin and the Celsius scales, and they are 1.8 times larger than the degree size for the Fahrenheit scale.

1.22 Prefix multipliers are used with the standard units of measurement to change the value of the unit by powers of 10.

For example, the kilometer has the prefix “kilo,” meaning 1000 or $10^3$. Therefore:

1 kilometer = 1000 meters = $10^3$ meter

Similarly, the millimeter has the prefix “milli,” meaning 0.001 or $10^{-3}$.

1 millimeter = 0.001 meters = $10^{-3}$ meters

1.23 A derived unit is a combination of other units. Examples of derived units include: speed in meters per second (m/s), volume in meters cubed ($m^3$), and density in grams per cubic centimeter (g/cm$^3$).

1.24 The density ($d$) of a substance is the ratio of its mass ($m$) to its volume ($V$):

$$\text{Density} = \frac{\text{mass}}{\text{Volume}} \quad \text{or} \quad d = \frac{m}{V}$$

The density of a substance is an example of an intensive property, one that is independent of the amount of the substance. Mass is one of the properties used to calculate the density of a substance. Mass, in contrast, is an extensive property, one that depends on the amount of the substance.

1.25 An intensive property is a property that is independent of the amount of the substance. An extensive property is a property that depends on the amount of the substance.

1.26 Measured quantities are reported so that the number of digits reflects the uncertainty in the measurement. The non-place-holding digits in a reported number are called significant figures.

In multiplication or division, the result carries the same number of significant figures as the factor with the fewest significant figures.

In addition or subtraction, the result carries the same number of decimal places as the quantity with the fewest decimal places.

When rounding to the correct number of significant figures, round down if the last (or left-most) digit dropped is four or less; and round up if the last (or left-most) digit dropped is five or more.

1.30 Accuracy refers to how close the measured value is to the actual value. Precision refers to how close a series of measurements are to one another or how reproducible they are. A series of measurements can be precise (close to one another in value and reproducible) but not accurate (not close to the true value).

1.31 Random error is error that has equal probability of being too high or too low. Almost all measurements have some degree of random error. Random error can, with enough trials, average itself out. Systematic error is error that tends towards being either too high or too low. Systematic error does not average out with repeated trials.

1.32 Using units as a guide to solving problems is often called dimensional analysis. Units should always be included in calculations; they are multiplied, divided, and canceled like any other algebraic quantity.
Chapter 1 Matter, Measurement, and Problem Solving

The Scientific Approach to Knowledge

1.33  
(a) This statement is a theory because it attempts to explain why. It is not possible to observe individual atoms.
(b) This statement is an observation.
(c) This statement is a law because it summarizes many observations and can explain future behavior.
(d) This statement is an observation.

1.34  
(a) This statement is a law because it summarizes many observations and can explain future behavior.
(b) This statement is a law because it summarizes many observations and can explain future behavior.
(c) This statement is a law because it summarizes many observations and can explain future behavior.
(d) This statement is a theory because it attempts to explain why.

1.35  
(a) If we divide the mass of the oxygen by the mass of the carbon the result is always 4/3.
(b) If we divide the mass of the oxygen by the mass of the hydrogen the result is always 16.
(c) These observations suggest that the masses of elements in molecules are ratios of whole numbers (4 and 3; and 16 and 1, respectively).
(d) Atoms combine in small whole number ratios and not as random weight ratios.

1.36  
There are many hypotheses that may be developed. One hypothesis is that a large explosion generated galaxies with fragments that are still moving away from each other.

The Classification and Properties of Matter

1.37  
(a) Sweat is a homogeneous mixture of water, sodium chloride, and other components.
(b) Carbon dioxide is a pure substance that is a compound (two or more elements bonded together).
(c) Aluminum is a pure substance that is an element (element 13 in the periodic table).
(d) Vegetable soup is a heterogeneous mixture of broth, chunks of vegetables, and extracts from the vegetables.

1.38  
(a) Wine is a generally homogeneous mixture of water, ethyl alcohol, and other components from the grapes. In some cases, there may be sediment present and so it would be a heterogeneous mixture.
(b) Beef stew is a heterogeneous mixture of thick broth and chunks of vegetables.
(c) Iron is a pure substance that is an element (element 26 in the periodic table).
(d) Carbon monoxide is a pure substance that is a compound (two or more elements bonded together).

1.39

<table>
<thead>
<tr>
<th>Substance</th>
<th>Type (element or compound)</th>
</tr>
</thead>
<tbody>
<tr>
<td>aluminum</td>
<td>element</td>
</tr>
<tr>
<td>apple juice</td>
<td>mixture</td>
</tr>
<tr>
<td>hydrogen peroxide</td>
<td>pure</td>
</tr>
<tr>
<td>chicken soup</td>
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1.40

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<th>Substance</th>
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<th>Type (Element or Compound)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>Pure</td>
<td>Compound</td>
</tr>
<tr>
<td>Coffee</td>
<td>Mixture</td>
<td>Neither – mixture</td>
</tr>
<tr>
<td>Ice</td>
<td>Pure</td>
<td>Compound</td>
</tr>
<tr>
<td>Carbon</td>
<td>Pure</td>
<td>Element</td>
</tr>
</tbody>
</table>

1.41 (a) Pure substance that is a compound (one type of molecule that contains two different elements)
(b) Heterogeneous mixture (two different molecules that are segregated into regions)
(c) Homogeneous mixture (two different molecules that are randomly mixed)
(d) Pure substance that is an element (individual atoms of one type)

1.42 (a) Pure substance that is an element (individual atoms of one type)
(b) Homogeneous mixture (two different molecules that are randomly mixed)
(c) Pure substance that is a compound (one type of molecule that contains two different elements)
(d) Pure substance that is a compound (one type of molecule that contains two different elements)

1.43 (a) Physical property (color can be observed without making or breaking chemical bonds)
(b) Chemical property (must observe by making or breaking chemical bonds)
(c) Physical property (the phase can be observed without making or breaking chemical bonds)
(d) Physical property (density can be observed without making or breaking chemical bonds)
(e) Physical property (mixing does not involve making or breaking chemical bonds, so this can be observed without making or breaking chemical bonds)

1.44 (a) Physical property (color can be observed without making or breaking chemical bonds)
(b) Physical property (odor can be observed without making or breaking chemical bonds)
(c) Chemical property (must observe by making or breaking chemical bonds)
(d) Chemical property (decomposition involves breaking bonds, so bonds must be broken to observe this property)
(e) Physical property (the phase of a substance can be observed without making or breaking chemical bonds)

1.45 (a) Chemical property (burning involves breaking and making bonds, so bonds must be broken and made to observe this property)
(b) Physical property (shininess is a physical property and so can be observed without making or breaking chemical bonds)
(c) Physical property (odor can be observed without making or breaking chemical bonds)
(d) Chemical property (burning involves breaking and making bonds, so bonds must be broken and made to observe this property)

1.46 (a) Physical property (vaporization is a phase change and so can be observed without making or breaking chemical bonds)
(b) Physical property (sublimation is a phase change and so can be observed without making or breaking chemical bonds)
(c) chemical property (rusting involves the reaction of iron with oxygen to form iron oxide; observing this process involves making and breaking chemical bonds)

(d) physical property (color can be observed without making or breaking chemical bonds)

(a) chemical change (new compounds are formed as methane and oxygen react to form carbon dioxide and water)

(b) physical change (vaporization is a phase change and does not involve the making or breaking of chemical bonds)

(c) chemical change (new compounds are formed as propane and oxygen react to form carbon dioxide and water)

(d) chemical change (new compounds are formed as the metal in the frame is converted to oxides)

Units in Measurement

(a) To convert from °F to °C, first find the equation that relates these two quantities. °C = \(\frac{\text{°F} - 32}{1.8}\). Now substitute °F into the equation and compute the answer. Note: The number of digits reported in this answer follow significant figure conventions, covered in Section 1.6. °C = \(\frac{\text{°F} - 32}{1.8}\) = 0. °C

(b) To convert from K to °F, first find the equations that relate these two quantities.

K = °C + 273.15 and °C = \(\frac{\text{°F} - 32}{1.8}\)

Since these equations do not directly express K in terms of °F, you must combine the equations and then solve the equation for °F. Substituting for °C:

K = \(\frac{\text{°F} - 32}{1.8} + 273.15\) rearrange K = 273.15 = \(\frac{\text{°F} - 32}{1.8}\)

rearrange 1.8 (K - 273.15) = (°F - 32) finally °F = 1.8 (K - 273.15) + 32 Now substitute K into the equation and compute the answer.

°F = 1.8 (77 - 273.15) + 32 = 1.8 (-196) + 32 = -353 + 32 = -321 °F
(c) To convert from °F to °C, first find the equation that relates these two quantities. °C = \( \frac{9}{5}F - \frac{32}{1.8} \)
Now substitute °F into the equation and compute the answer.
\[ °C = \frac{-109°F - 32°F}{1.8} = \frac{-141}{1.8} = -78.3°C \]

(d) To convert from °F to K, first find the equations that relate these two quantities.
\[ K = °C + 273.15 \text{ and } °C = \frac{-F - 32}{1.8} \]
Since these equations do not directly express K in terms of °F, you must combine the equations and then solve the equation for K. Substituting for °C: \( K = \frac{-F - 32}{1.8} + 273.15 \)
Now substitute °F into the equation and compute the answer.
\[ K = \frac{(98.6 - 32)}{1.8} + 273.15 = \frac{66.6}{1.8} + 273.15 = 37.0 + 273.15 = 310.2 K \]

(a) To convert from °F to °C, first find the equation that relates these two quantities. °C = \( \frac{9}{5}F - \frac{32}{1.8} \)
Now substitute °F into the equation and compute the answer. Note: The number of digits reported in this answer follow significant figure conventions, covered in Section 1.6.
\[ °C = \frac{212°F - 32°F}{1.8} = \frac{180}{1.8} = 100°C \]

(b) Begin by finding the equation that relates the quantity that is given (°C) and the quantity you are trying to find (K). \( K = °C + 273.15 \)
Since this equation gives the temperature in K directly, simply substitute in the correct value for the temperature in °C and compute the answer.
\[ K = 22°C + 273.15 = 295 K \]

(c) To convert from K to °F, first find the equations that relate these two quantities: \( K = °C + 273.15 \) and \( °C = \frac{9}{5}F - \frac{32}{1.8} \)
Since these equations do not directly express K in terms of °F, you must combine the equations and then solve the equation for °F. Substituting for °C: \( K = \frac{-F - 32}{1.8} + 273.15 \), rearrange \( K - 273.15 = \frac{-F - 32}{1.8} \) or rearrange \( 1.8(K - 273.15) = (-F - 32) \), rearrange \( °F = 1.8(K - 273.15) + 32 \).
Now substitute K into the equation and compute the answer.
\[ °F = 1.8(0.00K - 273.15) + 32 = 1.8(-273.15K) + 32 = -491.67 + 32 = -459.67°F \]

(d) Begin by finding the equation that relates the quantity that is given (°C) and the quantity you are trying to find (K). \( K = °C + 273.15 \)
Since this equation does not directly express °C in terms of K, you must solve the equation for °C. \( °C = K - 273.15 \).
Now substitute K into the equation and compute the answer. \( °C = 2.735 - 273.15 = -270.42°C \)

To convert from °F to °C, first find the equation that relates these two quantities. °C = \( \frac{9}{5}F - \frac{32}{1.8} \)
Now substitute °F into the equation and compute the answer. Note: The number of digits reported in this answer follow significant figure conventions, covered in Section 1.6.
\[ °C = \frac{-80.6°F - 32°F}{1.8} = \frac{-112}{1.8} = -62.2°C \]

Begin by finding the equation that relates the quantity that is given (°C) and the quantity you are trying to find (K). \( K = °C + 273.15 \).
Since this equation gives the temperature in K directly, simply substitute in the correct value for the temperature in °C and compute the answer. \( K = -62.2°C + 273.15 = 210.9 K \)

To convert from °F to °C, first find the equation that relates these two quantities. °C = \( \frac{9}{5}F - \frac{32}{1.8} \)
Now substitute °F into the equation and compute the answer. Note: The number of digits reported in this answer follow significant figure conventions, covered in Section 1.6.
\[ °C = \frac{-134°F - 32°F}{1.8} = \frac{-102}{1.8} = 56.6667°C = 56.7°C \]

Begin by finding the equation that relates the quantity that is given (°C) and the quantity you are trying to find (K). \( K = °C + 273.15 \).
Since this equation gives the temperature in K directly, simply substitute in the correct value for the temperature in °C and compute the answer. \( K = 56.6667°C + 273.15 = 329.8 K \)
The Reliability of a Measurement and Significant Figures

1.73 In order to obtain the readings, look to see where the bottom of the meniscus lies. Estimate the distance between two markings on the device.
   (a) 73.0 mL – the meniscus appears to be sitting on the 73 mL mark.
   (b) 88.2 °C – the mercury is between the 84 °C mark and the 85 °C mark, but it is closer to the lower number.
   (c) 645 mL – the meniscus appears to be just above the 640 mL mark.

1.74 In order to obtain the readings, look to see where the bottom of the meniscus lies. Estimate the distance between two markings on the device. Use all digits on a digital device.
   (a) 4.50 mL – the meniscus appears to be on the 4.5 mL mark.
   (b) 27.43 °C – the mercury is just above the 27.4 °C mark. Note that the 10s digit is only labeled every 10 °C.
   (c) 0.873 g – read all the places on the digital display.

1.75 Remember that
1. interior zeroes (zeroes between two numbers) are significant.
2. leading zeroes (zeroes to the left of the first non-zero number) are not significant. They only serve to locate the decimal point.
3. trailing zeroes (zeroes at the end of a number) are categorized as follows:
   • Trailing zeroes after a decimal point are always significant.
   • Trailing zeroes before an implied decimal point are ambiguous and should be avoided by using scientific notation or by inserting a decimal point at the end of the number.

   (a) 1,050,501 km
   (b) 0.00020 m
   (c) 8.881040 cm
   (d) 90,201 m
1.77 Remember all of the rules from Section 1.7.

(a) Three significant figures. The 3, 1, and the 2 are significant (rule 1). The leading zeroes only mark the decimal place and are therefore not significant (rule 3).

(b) Ambiguous. The 3, 1, and the 2 are significant (rule 1). The trailing zeroes occur before an implied decimal point and are therefore ambiguous (rule 4). Without more information, we would assume 3 significant figures. It is better to write this as $3.12 \times 10^5$ to indicate three significant figures or as $3.12000 \times 10^5$ to indicate six (rule 4).

(c) Three significant figures. The 3, 1, and the 2 are significant (rule 1).

(d) Five significant figures. The 1s, 3, 2, and 7 are significant (rule 1).

(e) Ambiguous. The 2 is significant (rule 1). The trailing zeroes occur before an implied decimal point and are therefore ambiguous (rule 4). Without more information, we would assume one significant figure. It is better to write this as $2 \times 10^3$ to indicate one significant figure or as $2.000 \times 10^3$ to indicate four (rule 4).

1.78 Remember all of the rules from Section 1.7.

(a) Four significant figures. The 1s are significant (rule 1). The leading zeroes only mark the decimal place and are therefore not significant (rule 3).

(b) One significant figure. The 7 is significant (rule 1). The leading zeroes only mark the decimal place and are therefore not significant (rule 3).

(c) Ambiguous. The 1, 8, and the 7 are significant (rule 1). The first 0 is significant, since it is an interior 0 (rule 2). The trailing zeroes occur before an implied decimal point and are therefore ambiguous (rule 4). Without more information, we would assume 4 significant figures. It is better to write this as $1.087 \times 10^5$ to indicate 4 significant figures or as $1.08700 \times 10^5$ to indicate six (rule 4).

(d) Seven significant figures. The 1, 5, 6, and 3s are significant (rule 1). The trailing zeroes are significant because they are to the right of the decimal point and non-zero numbers (rule 4).

(e) Ambiguous. The 3 and 8 are significant (rule 1). The first 0 is significant because the first one is an interior zero. The trailing zeroes occur before an implied decimal point and are therefore ambiguous (rule 4). Without more information, we would assume three significant figures. It is better to write this as $3.08 \times 10^4$ to indicate three significant figures or as $3.0800 \times 10^4$ to indicate five (rule 4).

1.79 (a) This is not exact because $\pi$ is an irrational number. The number 3.14 only shows three of the infinite number of significant figures that $\pi$ has.

(b) This is an exact conversion because it comes from a definition of the units, and so has an unlimited number of significant figures.

(c) This is a measured number and so it is not an exact number. There are two significant figures.

(d) This is an exact conversion because it comes from a definition of the units, and so has an unlimited number of significant figures.

1.80 (a) This is a measured number and so it is not an exact number. There are nine significant figures.

(b) This is an exact conversion, so it has an unlimited number of significant figures.

(c) This is a measured number and so it is not an exact number. There are three significant figures.

(d) This is an exact conversion because it comes from a definition of the units and so has an unlimited number of significant figures.
1.81  (a) 156.9 – The 8 is rounded up since the next digit is a 5.
(b) 156.8 – The last two digits are dropped since 4 is less than 5.
(c) 156.8 – The last two digits are dropped since 4 is less than 5.
(d) 156.9 – The 8 is rounded up since the next digit is a 9, which is greater than 5.

1.82  (a) \(7.98 \times 10^4\) – The last digits are dropped since 4 is less than 5.
(b) \(1.55 \times 10^7\) – The 8 is rounded up since the next digit is a 9, which is greater than 5.
(c) \(2.35\) – The 4 is rounded up since the next digit is a 9, which is greater than 5.
(d) \(4.54 \times 10^{-5}\) – The 3 is rounded up since the next digit is an 8, which is greater than 5.

**Significant Figures in Calculations**

1.83  (a) \(9.15 + 4.970 = 1.84\) – Three significant figures are allowed to reflect the three significant figures in the least precisely known quantity (9.15).
(b) \(1.54 \times 0.03060 \times 0.69 = 0.033\) – Two significant figures are allowed to reflect the two significant figures in the least precisely known quantity (0.69). The intermediate answer (0.03251556) is rounded up since the first non-significant digit is a 5.
(c) \(27.5 \times 1.82 \div 100.94 = 0.500\) – Three significant figures are allowed to reflect the three significant figures in the least precisely known quantity (27.5 and 1.82). The intermediate answer (0.50029988) is truncated since the first non-significant digit is a 2, which is less than 5.
(d) \((2.990 \times 10^6) + (6.7 \times 10^4) = 34\) – Two significant figures are allowed to reflect the two significant figures in the least precisely known quantity (6.7 \times 10^4). The intermediate answer (34.17910448) is truncated since the first non-significant digit is a 3, which is less than 5.

1.84  (a) \(89.3 \times 77.0 \times 0.08 = 6 \times 10^2\) – One significant figure is allowed to reflect the one significant figure in the least precisely known quantity (0.08). The intermediate answer (5.50088 \times 10^2) is rounded up since the first non-significant digit is a 5.
(b) \((5.01 \times 10^5) \div (7.8 \times 10^2) = 6.4 \times 10^2\) – Two significant figures are allowed to reflect the two significant figures in the least precisely known quantity (7.8 \times 10^2). The intermediate answer (6.423076923 \times 10^2) is truncated since the first non-significant digit is a 2, which is less than 5.
(c) \(4.005 \times 74 \times 0.007 = 2\) – One significant figure is allowed to reflect the one significant figure in the least precisely known quantity (0.007). The intermediate answer (2.07459) is truncated since the first non-significant digit is a 0, which is less than 5.
(d) \(453 \div 2.031 = 223\) – Three significant figures are allowed to reflect the three significant figures in the least precisely known quantity (453). The intermediate answer (223.042836) is truncated since the first non-significant digit is a 0, which is less than 5.

1.85  (a) \(43.7 - 2.341\)
\[41.359 = 41.4\]

Round the intermediate answer to one decimal place to reflect the quantity with the fewest decimal places (43.7). Round the last digit up since the first non-significant digit is 5.

(b) 17.6 + 2.838 + 2.3 + 110.77
\[133.508 = 133.5\]
Round the intermediate answer to one decimal place to reflect the quantity with the fewest decimal places (2.3). Truncate non-significant digits since the first non-significant digit is 0.

(c) 

\[
\begin{align*}
19.6 &+ 58.33 \\
- 4.974 &
\end{align*}
\]

\[72.956 = 73.0\]

Round the intermediate answer to one decimal place to reflect the quantity with the fewest decimal places (19.6). Round the last digit up since the first non-significant digit is 5.

(d) 

\[
\begin{align*}
5.99 &- 5.572 \\
0.418 &
\end{align*}
\]

Round the intermediate answer to two decimal places to reflect the quantity with the fewest decimal places (5.99). Round the last digit up since the first non-significant digit is 8.

(a) 

\[
\begin{align*}
0.004 &+ 0.09879 \\
0.10279 &
\end{align*}
\]

Round the intermediate answer to three decimal places to reflect the quantity with the fewest decimal places (0.004). Round the last digit up since the first non-significant digit is 9.

(b) 

\[
\begin{align*}
1239.3 &+ 9.73 + 3.42 \\
1252.45 &
\end{align*}
\]

Round the intermediate answer to one decimal place to reflect the quantity with the fewest decimal places (1239.3). Round the last digit up since the first non-significant digit is 5.

(c) 

\[
\begin{align*}
2.4 &- 1.777 \\
0.623 &
\end{align*}
\]

Round the intermediate answer to one decimal place to reflect the quantity with the fewest decimal places (2.4). Truncate non-significant digits since the first non-significant digit is 2.

(d) 

\[
\begin{align*}
532 &+ 7.3 \\
490.777 &
\end{align*}
\]

Round the intermediate answer to zero decimal places to reflect the quantity with the fewest decimal places (532). Round the last digit up since the first non-significant digit is 7.

Perform operations in parentheses first. Keep track of significant figures in each step, by noting which is the last significant digit in an intermediate result.

(a) 

\[
\begin{align*}
(24.6681 \times 2.38) + 332.58 &= 58.710078 \\
332.58 &
\end{align*}
\]

\[391.290078 = 391.3\]

The first intermediate answer has one significant digit to the right of the decimal, because it is allowed three significant figures (reflecting the quantity with the fewest significant figures (2.38)). Underline the most significant digit in this answer. Round the next intermediate answer to one decimal place to reflect the quantity with the fewest decimal places (58.7). Round the last digit up since the first non-significant digit is 9.
Chapter 1 Matter, Measurement, and Problem Solving

(b) \[
\frac{85.3 - 21.489}{0.0059} = \frac{63.811}{0.0059} = 1.081542 \times 10^4 = 1.1 \times 10^4
\]
The first intermediate answer has one significant digit to the right of the decimal, to reflect the quantity with the fewest decimal places (85.3). Underline the most significant digit in this answer. Round the next intermediate answer to two significant figures to reflect the quantity with the fewest significant figures (0.0059). Round the last digit up since the first non-significant digit is 8.

(c) \[
512 \div 986.7 + 5.44 = 0.5189014 + 5.44
\]
\[
5.9589014 = 5.96
\]
The first intermediate answer has three significant figures and three significant digits to the right of the decimal, reflecting the quantity with the fewest significant figures (512). Underline the most significant digit in this answer. Round the next intermediate answer to two decimal places to reflect the quantity with the fewest decimal places (5.44). Round the last digit up since the first non-significant digit is 8.

(d) \[
\left(28.7 \times 10^5\right) \times 48.533 + 144.99 = 59135.01 + 144.99
\]
\[
59280.01 = 59300 = 5.93 \times 10^4
\]
The first intermediate answer has three significant figures, reflecting the quantity with the fewest significant figures (28.7 x 10^5). Underline the most significant digit in this answer. Since the number is so large this means that when the addition is performed, the most significant digit is the 100's place. Round the next intermediate answer to the 100's places and put in scientific notation to remove any ambiguity. Note that the last digit is rounded up since the first non-significant digit is 8.

Perform operations in parentheses first. Keep track of significant figures in each step, by noting which is the last significant digit in an intermediate result.

(a) \[
\left(1.7 \times 10^6\right) - \left(2.63 \times 10^5\right) + 7.33 = 6.463878 + 7.33
\]
\[
13.793878 = 13.8
\]
The first intermediate answer has one significant digit to the right of the decimal, because it is allowed two significant figures (reflecting the quantity with the fewest significant figures (1.7 x 10^6)). Underline the most significant digit in this answer. Round the next intermediate answer to one decimal place to reflect the quantity with the fewest decimal places (6.5). Round the last digit up since the first non-significant digit is 9.

(b) \[
\left(568.99 - 232.1\right) \div 5.3 = 336.89 + 5.3 = 63.564151 = 64
\]
The first intermediate answer has one significant digit to the right of the decimal, to reflect the quantity with the fewest decimal places (232.1). Underline the most significant digit in this answer. Round the next intermediate answer to two significant figures to reflect the quantity with the fewest significant figures (5.3). Round the last digit up since the first non-significant digit is 5.

(c) \[
\left(9443 + 45 - 9.9\right) \times 8.1 \times 10^6 = 9478.1 \times 8.1 \times 10^6 = 7.677 \times 10^8 = 7.7 \times 10^10
\]
The first intermediate answer only has significant digits to the left of the decimal, reflecting the quantity with the fewest significant figures (9443 and 45). Underline the most significant digit in this answer. Round the next intermediate answer to two significant figures to reflect the quantity with the fewest significant figures (8.1 x 10^6). Round the last digit up since the first non-significant digit is 7.

(d) \[
\left(3.14 \times 2.4367 - 2.34\right) \div 7.6 = 2.34
\]
\[
5.311238 = 5.31
\]
The first intermediate answer has three significant figures, reflecting the quantity with the fewest significant figures (3.14). Underline the most significant digit in this answer. This number has two significant digits to the right of the decimal point. Round the next intermediate answer to two significant
digits to the right of the decimal point, since both numbers have two significant digits to the right of the decimal point. Note that the last digit is truncated since the first non-significant digit is 1.

### Unit Conversions

#### 1.89

(a) **Given:** 154 cm  
**Find:** in  
**Conceptual Plan:** cm $\rightarrow$ in  
\[
\text{Solution: } 154 \text{ cm} \times \frac{1 \text{ in}}{2.54 \text{ cm}} = 60.62992 \text{ in} = 60.6 \text{ in}
\]
**Check:** The units (in) are correct. The magnitude of the answer (60.6) makes physical sense because an inch is a larger unit than a cm. Three significant figures are allowed because 154 cm has three significant figures.

(b) **Given:** 3.14 kg  
**Find:** g  
**Conceptual Plan:** kg $\rightarrow$ g  
\[
\text{Solution: } 3.14 \text{ kg} \times \frac{1000 \text{ g}}{1 \text{ kg}} = 3.14 \times 10^3 \text{ g}
\]
**Check:** The units (g) are correct. The magnitude of the answer ($10^3$) makes physical sense because a kg is a much larger unit than a gram. Three significant figures are allowed because 3.14 kg has three significant figures.

(c) **Given:** 3.5 L  
**Find:** qt  
**Conceptual Plan:** L $\rightarrow$ qt  
\[
\text{Solution: } 3.5 \text{ L} \times \frac{1.057 \text{ qt}}{1 \text{ L}} = 3.6995 \text{ qt} = 3.7 \text{ qt}
\]
**Check:** The units (qt) are correct. The magnitude of the answer (3.7) makes physical sense because a L is a smaller unit than a qt. Two significant figures are allowed because 3.5 L has two significant figures. Round the last digit up because the first non-significant digit is a 9.

(d) **Given:** 109 mm  
**Find:** in  
**Conceptual Plan:** mm $\rightarrow$ m $\rightarrow$ in  
\[
\text{Solution: } 109 \text{ mm} \times \frac{1 \text{ m}}{1000 \text{ mm}} \times \frac{39.37 \text{ in}}{1 \text{ m}} = 4.29133 \text{ in} = 4.29 \text{ in}
\]
**Check:** The units (in) are correct. The magnitude of the answer (4) makes physical sense because a mm is a much smaller unit than an inch. Three significant figures are allowed because 109 mm has three significant figures.

#### 1.90

(a) **Given:** 1.4 in  
**Find:** mm  
**Conceptual Plan:** in $\rightarrow$ cm $\rightarrow$ m $\rightarrow$ mm  
\[
\text{Solution: } 1.4 \text{ in} \times \frac{2.54 \text{ cm}}{1 \text{ in}} \times \frac{1 \text{ m}}{100 \text{ cm}} = 35.56 \text{ mm} = 36 \text{ mm}
\]
**Check:** The units (mm) are correct. The magnitude of the answer (36) makes physical sense because a mm is smaller than an inch. Two significant figures are allowed because 1.4 in has two significant figures. Round the last digit up because the first non-significant digit is a 5.

(b) **Given:** 116 ft  
**Find:** cm  
**Conceptual Plan:** ft $\rightarrow$ in $\rightarrow$ cm  
\[
\text{Solution: } 116 \text{ ft} \times \frac{12 \text{ in}}{1 \text{ ft}} \times \frac{2.54 \text{ cm}}{1 \text{ in}} = 3.5357 \times 10^3 \text{ cm} = 3.54 \times 10^3 \text{ cm}
\]