## Ch. 2: Measurement and Problem Solving

Learning Outcomes: By the end of this chapter you should be able to:
(1) Convert numbers in and out of scientific notation (2.2).
(2) Count significant figures in a number and use them appropriately in calculations (2.3-4).
(3) Convert from metric prefixes to base units and vice versa (2.5).
(4) Use dimensional analysis to solve word problems and convert units, including units raised to a power (2.6-9).
(5) Calculate the density of an object. Or, using the density, find the mass or volume. Use density in dimensional analysis word problems as a conversion factor (2.10).

## Equations and Constants

The Metric Prefixes
$1 \mathrm{~mL}=1 \mathrm{~cm}^{3}=1 \mathrm{cc}$
density $=\frac{\text { mass }}{\text { volume }}$

## (1) Math Review and Scientific Notation

The Order of Operations gives a standard way to compute problems with multiple mathematic operations. An acronym to remember it is "Please Excuse My Dear Aunt Sally".

- $P$ :
- E:
- M:
- D:
- A:
- S:

Ex. 1) Perform the following calculations.
(1) $(8+11) * 4=$
(2) $\frac{4 * 6}{2}=$
(3) $7-5 * 4=$
(4) $\frac{(18-12)}{3}=$

Operations that are commutative can be done in any order.

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- Which operations are commutative?
- Which operations are NOT commutative?

Ex. 2) Perform the following calculations.
(1) $62+39+54=$
(2) $6 * 18 * 2=$
(3) $56-32-5=$
(4) $54 \div 3 \div 2=$

Exponents take a number and "raise it to" a certain power.

- Squared means:
- Cubed means:
- Write the symbol for the exponent button on YOUR calculator:

Ex. 3) Perform the following calculations.
(1) $4+3^{2} \times 5=$
(2) $(1+12) * 4^{2}=$
(3) $5^{2}+\frac{3 \times 6}{3}=$
(4) $(3 * 6+4)^{3} \times 2^{-1}=$

Scientific Notation is a way to abbreviate very large or very small numbers and eliminate placeholder zeroes.

Ex. 4) speed of light $=299800000$

- Step 1:
- Step 2:
- Step 3:

Ex. 5) Convert the following to scientific notation:
(1) 0.000063
(2) 92100000
(3) 0.0020902

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(4) 999020
(5) $3.81 \times 10^{-7}$
(6) $8.5 \times 10^{6}$
(7) $7.01 \times 10^{-4}$
(8) $1.131 \times 10^{2}$

- Write the symbol for the scientific notation button on YOUR calculator:
- How would you enter $2.998 \times 10^{8}$ in your calculator?

Ex. 6) Perform the following calculations.
(1) $\left(1.63 \times 10^{-4}+9.4 \times 10^{-5}\right) \div 6.731 \times 10^{-3}=$
(2) $\left(4.2 \times 10^{-2}\right)^{3}+6.24 \times 10^{-4}=$
(3) $\left(5.31 \times 10^{-6}+8.476 \times 10^{-5}\right) \div 3.2=$
(4) $4.27 \times 10^{-3} \times 6.54 \times 10^{4}+8.931 \times 10^{2}=$
(5) $3.32 \times 10^{6}-2.4 \times 10^{5} \cdot 3.8 \times 10^{5}=$
(6) $5.432 \times 10^{-4} \div 6.25 \times 10^{-3}+2.478 \times 10^{1}-3.62 \times 10^{-4}=$
(7) $\left(6.854 \times 10^{2}+8.73 \times 10^{4}\right)^{2} \div 5.43 \times 10^{3}+6.42 \times 10^{5}=$
(8) $\left(1.87 \times 10^{4}\right)^{1 / 2}+6.23=$
(9) $(7.54+8.32) 6 \div 6.197+7.3147-3.6^{2}=$

## (2) Significant Figures

Significant Figures provide a way to express uncertainty when measuring data in the laboratory as well as a universal system of rounding to ensure all answers are reported to the same digits.

Measured data in the laboratory should always be read to $\qquad$ position past the markings. (For example, if the glassware is marked to two decimal places, then $\qquad$ should be recorded)

- Certain digits in a measurement are always:
- Estimated digits in a measurement are always:

To IDENTIFY significant figures:

- All NONZERO integers are (always/sometimes/never) significant.


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- ZEROES are (always/sometimes/never) significant.
- Leading (to the left) zeroes are (always/sometimes/never) significant.
- Interior (middle, neighbored) zeroes are (always/sometimes/never) significant.
- Trailing (to the right) zeroes are (always/sometimes/never) significant.
- If a decimal place IS written $\rightarrow$ (significant/not significant)
- If a decimal place is NOT written $\rightarrow$ (significant/not significant)

Ex. 7) Count how many significant figures are in the following numbers.
(1) 864.012
(2) 760.1
(3) 09760410
(4) 5300000
(5) 8200.
(6) 00.2090

When rounding, look at the next number to the right of where you want to end.

- If the number is $\geq 5$, then round (up/down) by (increasing/leaving alone) the digit.
- If the number is $\leq 4$, then round (up/down) by (increasing/leaving alone) the digit.

Ex. 8) Round the following numbers to three significant figures.
(1) 4062198
(2) 0.009325
(3) 320109

Always maintain the same number of significant figures when converting in and out of scientific notation.

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Certain quantities have infinite significant figures (no uncertainty).

- Exact Numbers:
- Defined Quantities:
- Integral Numbers:

Any answer reported in this class must always be to correct significant figures.
Rounding rules for significant figures depends on the mathematical operation being done.

- Multiplication/Division:

Ex. 9) Perform the following calculations to correct significant figures.
(1) $89.10 \times 92.457=$
(2) $9200 \div 8.13=$
(3) $(9184 \times 32.1) \div 820$. $=$
(4) $73.0 \times 2.6=$
(5) $8.654 \div 6.9135=$
(6) $921 \times 6.0=$

- Addition/Division:

Ex. 10) Perform the following calculations to correct significant figures.
(1) 8.42
$\underline{-6.935}$
(2) 798.25
6.3
92.16

528

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(5) $89.3+64-98.25=$

Ex. 11) Perform the following calculations to correct significant figures.
(1) $104.31-62.18 \times 5.60=$
(2) $(92.1+8.03) \div 30=$
(3) $8.12 \times 10^{-2}+6.45 \times 10^{-3}+9.21 \times 10^{-1}=$
(4) $86.1 \times 9^{2} \div 2.1=$
(5) $3.20 \times 10^{2} \times 6.1 \times 10^{-1} \div 8.001 \times 10^{1}=$
(6) $86.24 \times 9.31-6.054=$
(7) $(18.6 \div 2.540)^{2}+8.0189=$
(8) $6.03 \times 10^{3} \div 9.2160 \times 10^{1}+6.50 \times 10^{2}=$
(9) $8.5432 \times 10^{3}-\left(6.21 \times 10^{1} \times 7.854 \times 10^{-1}\right)^{2}=$

## (3) The Metric System

The Metric System (International System of Units or Systeme International, SI) are the units used scientifically.

Base units can be directly measured and include:

| UNIT | SYMBOL | MEASUREMENT |
| :--- | :--- | :--- |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |

Metric prefixes multiply the base unit by factors of 10 .
All metric conversions are defined quantities.

- To convert FROM prefix TO base unit:

Ex. 12) Convert the following.
(1) $2 \mathrm{~km}=$ ? m
(2) $3.6 \mathrm{Mg}=? \mathrm{~g}$

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(3) $6.321 \mu \mathrm{~g}=$ ? g
(4) $4.28 \times 10^{2} \mathrm{~ms}=$ ? s
(5) $7.1 \times 10^{6} \mathrm{~nm}=? \mathrm{~m}$

- To convert TO prefix FROM base unit:

Ex. 13) Convert the following.
(1) $3.2 \mathrm{~s}=$ ? ms
(2) $9.61 \times 10^{5} \mathrm{~L}=$ ? GL
(3) $2.8 \times 10^{-10} \mathrm{~g}=? \mathrm{pg}$
(4) $3.45 \times 10^{-3} \mathrm{~K}=\mathrm{mK}$

- To convert BETWEEN prefixes:

Ex. 14) Convert the following.
(1) $2 \mathrm{~km}=$ ? cm
(2) $6.21 \times 10^{10} \mathrm{~mm}=? \mathrm{Mm}$
(3) $7.56 \times 10^{6} \mathrm{~ns}=$ ? ks

## (4) Dimensional Analysis

Dimensional Analysis is a method to solving word problems by using conversion factors to change from one unit to another.

- How many eggs are in 3 dozen?
- If beef costs $\$ 8$ per pound and you have $\$ 40$, how many pounds of beef can you buy?


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Identifying the pieces of information in the word problem can help you isolate what you need (and what you don't).

- Given Information:
- Conversion Factor:
- Desired Unit:

Always cancel your units in each step (top $\rightarrow$ bottom).
Ex. 15) Your car gest 16 miles to the gallon. How many miles can you travel on 13 gallons of gas?

Ex. 16) If gas costs $\$ 3.50$ per gallon, how much does 13 gallons of gas cost?

Ex. 17) How many miles can your car travel on $\$ 25.50$ ?

Ex. 18) Convert 76 kg to lbs.

Ex. 19) Light travels at $2.998 \times 10^{8} \mathrm{~m} / \mathrm{s}$ in a vacuum. A beam of light takes 1.2822 seconds to travel from the earth to the moon. How many miles apart are the moon and earth? $(1.61 \mathrm{~km}=1 \mathrm{mi})$

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Ex. 20) The world record for the 100.0 m dash is 9.58 seconds. How many hours would it take to run $2.39 \times 10^{5} \mathrm{mi}$ (the distance between the earth and the moon) at this speed?

Ex. 21) An electron weighs $9.109 \times 10^{-28} \mathrm{~g}$. How many electrons would equal a 5.0 lb weight? ( $1 \mathrm{~kg}=2.205 \mathrm{lbs}$ )

Ex. 22) The average person needs 3.0 L of water per day. If a cup of coffee contributes 8.12 fl . oz. of water, how many cups of coffee should someone drink per day? ( $1 \mathrm{gal} .=$ $3.7854 \mathrm{~L}, 128 \mathrm{fl} . \mathrm{oz} .=1 \mathrm{gal} ., 1.0567 \mathrm{qt} .=1 \mathrm{~L}, 4 \mathrm{qt} .=1 \mathrm{gal}$.

Ex. 23) Assuming you work 40 hours per week for 48 weeks per year, how many seconds do you work in a year? $(60 \mathrm{~min} .=1$ hour, $1 \mathrm{~min} .=60 \mathrm{sec})$

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Ex. 24) The diameter of the earth is 12756.2 km . A penny has an edge height of 0.0629 in. How many pennies would need to be stacked to stretch across the diameter of the earth? ( $1 \mathrm{in} .=2.54 \mathrm{~cm}$ )

Derived Units are calculated from base units.

- Area (unit of length ${ }^{2}$ ) $=$
- Volume (unit of length ${ }^{3}$ ) $=$

Ex. 25) A wall measures 3.2 m by $4.8 \times 10^{2} \mathrm{~cm}$.
(1) Calculate the area of the wall, in $\mathrm{m}^{2}$.
(2) Convert the area in (1) to square inches ( $1 \mathrm{in} .=2.54 \mathrm{~cm}$ ).
(3) Convert the area in (2) to square feet (1 ft. = 12 in.$)$.

Ex. 26) A shape measures 6.3 cm by 8.41 cm by 10.3 cm .
(1) Calculate the volume of the shape, in $\mathrm{cm}^{3}$.

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(2) Convert the volume in (1) to L.

Ex. 27) What is the volume, in L , of a shape that is 2.61 in . by 0.95 in . by 3.82 cm ?

Ex. 28) A wall measures 16 m by 4.51 m . If one gallon of paint covers $5500 \mathrm{~cm}^{2}$, how many gallons of paint are needed?

## (5) Density

Density is a measure of how closely packed a substance is.

- Density =

| Substance | $\mathrm{H}_{2} \mathrm{O}(\mathrm{I})$ | $\mathrm{Au}(\mathrm{s})$ | Hexane (I) | Cork | $\mathrm{H}_{2} \mathrm{O}(\mathrm{s})$ |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Density $(\mathrm{g} / \mathrm{mL})$ | 1.00 | 19.3 | 0.66 | 0.24 | 0.92 |

The (more/less) dense the substance, the (higher/lower) it will be found in a mixture.

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Ex. 29) Calculate the density of an object that weighs 42.1 g and has a volume of 21.5 mL .

Displacement is an indirect way to measure the volume of an object by using a known amount of liquid.

Ex. 30) Find the density of an object that weighs 16.921 g and changes the volume of 200.0 mL of water to 236.5 mL .

Ex. 31) Calculate the density of a solution made from 4 tbsp. of sugar ( $1 \mathrm{tbsp} .=12.6 \mathrm{~g}$ ) in enough water to make 29.58 mL of solution.

Ex. 32) A liquid has a density of $0.896 \mathrm{~g} / \mathrm{cm}^{3}$.
(1) How much does 12.0 mL of the liquid weigh?
(2) What is the volume of 9.0 g of the liquid?

Ex. 33) A yellow metal ring weighs 0.5632 kg and is 0.063 L . Is it gold?

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Ex. 34) How much would a 0.063 L gold ring weigh?

Ex. 35) Osmium (the densest known element) has a density of $2.2610 \times 10^{4} \mathrm{~kg} / \mathrm{m}^{3}$. How many kg would 8.58 L (NBA regulation basketball) of osmium weigh?

