Lab 1: Calculations

Rules for Addition: An answer obtained by adding or subtracting has the same number of decimal places as the measurement with the **fewest decimal places** (look to the right of the decimal).

\[
\begin{align*}
25.2 & \quad \text{one decimal place} \\
+ 1.34 & \quad \text{two decimal places} \\
\hline
26.54 & \quad \text{calculated answer}
\end{align*}
\]

Final Answer 26.5 answer with one decimal place

Another problem:
\[
\begin{align*}
235.05 & \quad \text{Your final answer goes to the farthest right a} \\
+ 19.6 & \quad \text{as your least significant number} \\
\hline
86000000 & \quad \text{Ans} = 86000000
\end{align*}
\]

256.65 rounds to 257

Rules for Multiplication: An answer obtained by multiplying or dividing has the same number of significant figures as the measurement with the **fewest significant figures** (look for the fewest significant figures).

Use rounding to limit the number of digits in the answer.

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

4 SF 2 SF

The final answer is rounded off to give

2 significant figures = 5.3 (2 SF).

Another problem:

\[
40.311 \div 0.007 = 60
\]

Mixed Multiplication and Addition: Do each operation separately.
**Dimensional analysis**

This is a very important lab. You will use what you learn in this lab EVERYDAY during lecture and lab. Dimensional analysis is a problem-solving technique.

What will you learn: A Mathematical Technique, to solve EVERY problem we encounter.

Every Problem You Solve Will Look Like: 

\[
\frac{\text{numerator}}{\text{denominator}} \times \frac{\text{numerator}}{\text{denominator}} \times \ldots =
\]

The Math Principle is a Beginning Algebra concept of cross cancellation:

\[
\frac{A}{B} \times \frac{B}{C} \times \frac{C}{1} = A
\]

You are expected to solve ALL of your problems using this method, hence the reason for spending 2 days on this lab.

**What Problems Can You Solve Using This Method?**

You'll learn to solve many types of problems. For example how many mL’s are in 2.83qts, or how many inches are in 259 cm? You'll learn to use the steps of DIMENSIONAL ANALYSIS as a model to solve these types of problems.

To solve a dimensional analysis problem we must learn what a conversion factor is first.

Here are 2 examples of conversion factors.

\[
1 \text{ ft} = 12 \text{ in} \Rightarrow \frac{1 \text{ ft}}{12 \text{ in}} \quad \text{or} \quad \frac{12 \text{ in}}{1 \text{ ft}} \quad \boxed{\text{There are millions of conversion factors!}}
\]

\[
2.54 \text{ cm} = 1 \text{ in} \Rightarrow \frac{2.54 \text{ cm}}{1 \text{ in}} \quad \text{or} \quad \frac{1 \text{ in}}{2.54 \text{ cm}}
\]

Note: these are exact relationships between two totally different units i.e. ft \(\Rightarrow\) in or cm \(\Rightarrow\) in
A conversion factor is important in math because they are equal to 1 and are therefore useful in chemistry to help us do calculations.

For example, we know that 1 ft = 12 in, how is this equal to 1.

We know 1 ft = 12 in

To obtain the conversion factors \( \frac{1 \text{ ft}}{12 \text{ in}} \) or \( \frac{12 \text{ in}}{1 \text{ ft}} \) we had to divide by 12 in. and 1 ft respectively.

\[
\begin{align*}
1 \text{ ft} &= 12 \text{ in}, \text{ now divide both sides by 12 in or} \\
\frac{1 \text{ ft}}{12 \text{ in}} &= \frac{12 \text{ in}}{1 \text{ ft}} = 1
\end{align*}
\]

\[
\begin{align*}
1 \text{ ft} &= 12 \text{ in}, \text{ now divide both sides by 1 ft or} \\
\frac{12 \text{ in}}{1 \text{ ft}} &= \frac{1 \text{ ft}}{1 \text{ ft}} = 1
\end{align*}
\]

We use these conversion factors when solving Dimensional Analysis Problems.

**Dimensional Analysis**

Let’s examine the problem already asked: How many inches are in 259 cm?

Use the conversion factor found on the first page that shows the relationship between inches and centimeters. The answer would look like the following:

\[
\begin{align*}
? \text{ inches} &= \frac{259 \text{ cm}}{1} \times \frac{1 \text{ inch}}{2.54 \text{ cm}} = 102 \text{ inches}
\end{align*}
\]

**Use unit analysis to solve the following problems.**

1. 4 dollars = _______ dimes

   Hint: there are 10 dimes = 1 dollar

   \[
   \begin{align*}
   \text{Solution:} \quad \frac{4 \text{ dollars}}{1} \times \frac{10 \text{ dimes}}{1 \text{ dollar}} &= 40 \text{ dimes}
   \end{align*}
   \]
What is Dimensional Analysis? This is what it looks like.

\[
\frac{\text{old unit}}{\text{old unit}} \times \frac{\text{new unit}}{\text{old unit}} = \text{answer in new units}
\]

Notice how the “old unit” cancels in the numerator and denominator. This is why Dimensional Analysis is so easy, you do NOT have to think in advance of all the steps. Dimensional Analysis is a VISUAL MATHEMATICAL METHOD; you have a visual way of looking at your solution by looking at what units cancel.

If you are still trying to solve these problems in your head I hope the next problem convinces you to give up your old ways and try Dimensional Analysis!

In the fictitious country of Nolenville, 1.00 nolenzels equals 0.50 US dollars. How many nolenzels are equal to 700 US dollars?

Solution using Dimensional Analysis:

\[
?\text{nolenzels} = \frac{700}{0.50} \times \frac{1.00 \text{ nolenzels}}{1.00 \text{ nolenzels}} = 1400 \text{nolenzels}
\]

Notice that the “$” cancel. Only “nolenzels” remains in the numerator and since it does not cancel so that, is your final unit.

Students often purchase calculators that cost upwards of $200.00 and yet they do not know how to use them. In this section, you should learn to MASTER your scientific calculator.

All Calculators have different key setups …so you will have to figure out where you SCIENTIFIC NOTATION button is on your calculator. Locate ONE of the following scientific notation buttons on your calculator (it may not even be listed here):

1. EE (Some Sharp)
2. EXP (Casio, TI, Shape, HP)
3. 2nd Function EE (many TI’s)

At this point you will want to practice with your calculator.

First, enter the following

\[
1 \times 10^2 \times 5 \times 10^3 = \]

You should get either 500,000 or \(5 \times 10^5\) and either is correct. IF YOU DID NOT GET THAT ANSWER THEN……..read on………

DO NOT’s of Scientific calculators.
1. DO NOT USE the $10^x$ key. DO NOT enter the above numbers as $1 \times 10^2$ times $5 \times 10^3$ even though you get the same answer....IT IS A WASTE OF KEY STROKES...you do not have time to waste typing extra keystrokes. USE THE EE OR EXP BUTTON---THAT’S WHAT YOUR VERY EXPENSIVE CALCULATOR IS MADE FOR.

2. DO NOT use the $X^2$ or $X^3$ buttons, again a waste of time.

Try this one

$1 \times 10^{-12}$

Times

$5 \times 10^{-5}$

= 

You can only get ONE ANSWER $5 \times 10^{-17}$...... IF YOU DID NOT GET THAT ANSWER THEN.......read on.........

You MUST ALSO learn to switch your calculator into SCIENTIFIC MODE.

**Standard Deviation**

$$S = \left( \frac{\sum (x_i - \bar{x})^2}{n - 1} \right)^{\frac{1}{2}}$$

Calculate the **standard deviation** for the following set of coins, and express to the appropriate number of significant figures:

7.691 g, 7.753 g, 7.658 g, 7.664 g, 7.553 g, 7.672 g, 7.561 g

Solution: First we must find the mean or average.

$$\bar{x} = \frac{\sum x_i}{n}$$

$\Sigma$ = is a math symbol for adding. The $x_i$ is a set of numbers, in this case the set of number in our problem.
Σ: Note when adding line numbers over the decimal

\[ \overline{x} = \sum_{i} \frac{x_i}{n} \]

7.961
7.753
7.658
7.664
7.553
7.672
7.561
53.822

Above, when adding we look for the least number of accurate places to the right. So above, all of the numbers are 3 places to the right, so our answer, 53.822, must have 3 places to the right; which makes it a 5 sig fig number.

\[
mean = \overline{x} = \frac{53.822}{7} = 7.689 g
\]

Our final answer, 7.689 has 5 sig figs, the same number of sig figs as 53.822 because division looks for the number with the fewest sig figs (not like addition) so 53.822 has 5 sig figs and “7” is just a counting number (it is not a 1 sig fig number, but an infinite number of sig figs).

Next we work on the following function.

\[
s = \left( \frac{\left( \sum_{i} (x_i - \overline{x})^2 \right)}{n - 1} \right)^{\frac{1}{2}}
\]
It is best to set up a table. Work in the inner most bracket first, always pay attention to powers.

Remember, when we do subtraction, look to the right, so the first column only has 3 places to the right, so our final answer can only have 3 places to the right.

<table>
<thead>
<tr>
<th></th>
<th>(x_i - \bar{x}) (sig figs)</th>
<th>((x_i - \bar{x})^2) (sig figs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7.961 - 7.6889 = .272 (3)</td>
<td>.0740 (3)</td>
</tr>
<tr>
<td>2</td>
<td>7.753 - 7.6889 = .064 (2)</td>
<td>.0041 (2)</td>
</tr>
<tr>
<td>3</td>
<td>7.658 - 7.6889 = -.031 (2)</td>
<td>.00096 (2)</td>
</tr>
<tr>
<td>4</td>
<td>7.664 - 7.6889 = -.025 (2)</td>
<td>.00063 (2)</td>
</tr>
<tr>
<td>5</td>
<td>7.553 - 7.6889 = -.136 (3)</td>
<td>.0185 (3)</td>
</tr>
<tr>
<td>6</td>
<td>7.672 - 7.6889 = -.017 (2)</td>
<td>.00029 (2)</td>
</tr>
<tr>
<td>7</td>
<td>7.561 - 7.6889 = -.128 (3)</td>
<td>.0164 (3)</td>
</tr>
<tr>
<td>Σ</td>
<td>53.822</td>
<td>.1149</td>
</tr>
</tbody>
</table>

\[
s = \left( \frac{\sum (x_i - \bar{x})^2}{n-1} \right)^{\frac{1}{2}} \]

\[
0.0409 = 0.0826
\]

Taking the square of a number is multiplying 2 numbers together, so, the number of sig figs in our final answer can only have as many sig figs as our worst measurement.

When adding numbers align the numbers over the decimal, and look for the number with the least amount of accuracy to the right. In this example 2\(^{nd}\), 5\(^{th}\), and 7\(^{th}\) numbers only have accuracy 4 places to the right, so the final number can only have 4 places past the decimal of accuracy.

.0409 is a 3 sig fig so in the final multiplication sequence, our answer can only have 3 sig figs.
P&P Lab 1: Calculations

MATH CONCEPTS IN CHEMISTRY

State the basic symbol for the following quantizes.

a. length = \( m \)
b. volume = \( L \) or \( mL \)
c. mass = \( g \)
d. temperature = \( K \) or \( ^\circ C \)
e. time = \( s \) or \( sec \)
f. density = \( g/mL \) or \( g/cm^3 \)

SIGNIFICANT DIGITS

State the number of significant digits in the following measurements.

a. 0.707 g = 3
b. 0.10000 cm = 5
c. 2500 mL = 3
d. 0.0000110 g = 3
e. 100,000. cm = 6
f. 100,000 mL = 1
g. 0.0002
h. 36000
i. 36000.
j. 36000.00

Name ________________________________
Date _________________________________
ROUNDING OFF NONSIGNIFICANT DIGITS

Round off the following measurements to three significant digits:

a. $12.59 \text{ mL} = 12.6 \text{ mL}$  
b. $0.03662 \text{ g} = 0.037 \text{ g}$

c. $31559745 \text{ cm} = 3160000 \text{ cm}$  
d. $202577.94 \text{ mL} = 203000 \text{ mL}$

e. $0.0002 \text{ cm} = 0.0002 \text{ cm}$  
f. $3 \text{ cm} = 3 \text{ cm}$

ADDITION AND SUBTRACTION

Perform the indicated mathematical operation. Express the answer with the proper units and significant digits.

\[
\begin{align*}
5000. \text{ cm} & + 0.0256 \text{ cm} & + 0.00050 \text{ cm} \\
172.0 \text{ mL} & + 15.99 \text{ mL} & + 9.100 \text{ km}
\end{align*}
\]

MULTIPLICATION & DIVISION OF SIGNIFICANT DIGITS

Perform the indicated mathematical operation. Express the answer with the proper units and significant digits.

a. $21.1 \text{ cm} \times 20 \text{ cm} = 400 \text{ cm}^2$  
b. $5.150 \text{ cm} \times 12.55 \text{ cm} \times 1.90 \text{ cm} = 123 \text{ cm}^3$

c. $\frac{131.78 \text{ cm}^3}{19.26 \text{ cm}} = 6.942 \text{ cm}^2$
Calculate the standard deviation for the following numbers:


\[ \bar{x} = \frac{\sum x_i}{n} \]

\[ \bar{x} = \frac{39.051}{4} = 9.7628 \]

\[ \sum (x_i - \bar{x})^2 = 0.0067 + 0.0121 + 0.0506 + 0.0352 = 0.1086 \]

\[ s = \sqrt{\frac{0.1086}{3}} = 0.1903 \]
CALCULATORS AND SIGNIFICANT Digits, write in ordinary notation, do the entire calculation without doing 2 separate calculations for the numerator and separate denominator.

\[(4.65 \times 10^5)(9.5 \times 10^2) \div 440,000,000,000\]

b. \[\frac{(3.22 \times 10^6)(4.10 \times 10^{-19})}{(5.56 \times 10^{-15})}\] \[= 23,7\]

c. \[\frac{(2.6 \times 10^{-5})(7.606 \times 10^{-3})(5.22 \times 10^{-4})}{(7.747 \times 10^{-5})(6.65 \times 10^{-9})}\] \[= 2.0 \times 10^2\] (this is the only way to write \[200\) as a 2 significant figures.)

TEMPERATURE

Learn the following 3 formulas for temperature formulas for your next exam

\[\text{oF} = \frac{9}{5} \text{oC} + 32\]
\[\text{oC} = \frac{5}{9} (\text{oF} - 32)\]
\[K = \text{oC} + 273\]

Express the following temperatures in degrees Celsius.

-40.0 °F:
\[\frac{5}{9} (-40 - 32) = \frac{5}{9} (-72) = -40.0 \circ C\]

Convert the following temperatures in degrees Fahrenheit.

420.0 °C:
\[\frac{9}{5} (420 + 32) = 756.0 + 32 = 788.0 \circ F\]

Express the following in Kelvin units.

983 °F:
\[\frac{5}{9} (983 - 32) = \frac{5}{9} (951) = 528 \circ C\]
\[K = 528 + 273 = 801 K\]
METRIC - METRIC CONVERSIONS

Convert the following metric system measurements using two conversion factors.

a. 120 mm to Mm

\[
\frac{Mm}{10^6 \text{ m}} \times \frac{10^{-3} \text{ m}}{\text{mm}} \times 120 \text{ mm} = 1.2 \times 10^{-2} \text{ Mm}
\]

b. 1.55 cm to km

\[
\frac{\text{km}}{1000 \text{ m}} \times \frac{\text{m}}{100 \text{ cm}} \times 1.55 \text{ cm} = 1.55 \times 10^{-5} \text{ km}
\]

METRIC - ENGLISH CONVERSIONS

Convert the given measurements into the units indicated. Note: 454 g = 1 lb, 2.54 cm = 1 in

a. 15.51 lb to kg

\[
\frac{\text{kg}}{1000 \text{ g}} \times \frac{454 \text{ g}}{1 \text{ lb}} \times 15.51 \text{ lb} = 7.042 \text{ kg}
\]

b. 3660 cm to ft

\[
\frac{\text{ft}}{12 \text{ in}} \times \frac{1 \text{ in}}{2.54 \text{ cm}} \times 3660 \text{ cm} = 120. \text{ ft}
\]

GENERAL EXERCISES

Solve the following: SHOW ALL OF YOUR WORK FOR FULL CREDIT!

1. How many feet in 365.0 yards? Use: 1 m = 1.0936 yards, 100 cm = 1 m, 1 foot = 30.48 cm

\[
\frac{\text{ft}}{30.48 \text{ cm}} \times \frac{100 \text{ cm}}{1 \text{ m}} \times \frac{1 \text{ m}}{1.0936 \text{ yd}} \times 365.0 \text{ yd} = 1095. \text{ ft}
\]
2. Light travels at a constant $3.0 \times 10^{10}$ cm/sec. If the distance from the earth to the sun is 93,000,000 miles how long does it take for light to travel from the sun to earth? (use the following: 5280 ft = 1 mile and 2.54 cm = 1 inch)

$$\frac{\text{sec}}{3.0 \times 10^{16} \text{ cm}} \times \frac{2.54 \text{ cm}}{1 \text{ in}} \times \frac{12 \text{ in}}{1 \text{ ft}} \times \frac{5280 \text{ ft}}{1 \text{ mile}} \times \frac{93,000,000 \text{ miles}}{1} = 5.10 \times 10^2 \text{ sec}$$

3. What is the cost of 1.5 pound of sugar if sugar costs $1.37 per 5.0 pounds?

$$\frac{\$1.37}{5.0 \text{ lbs}} \times \frac{1.5 \text{ lbs}}{1} = \$4.1$$

4. The following relationships describe an antiquated set of British liquid units.

- 1 hogshead = 7 firkin
- 18 pottle = 1 firkin
- 140 pottle = 1 puncheon
- 504 pottle = 1 tun

Use dimensional analysis to determine the number of tuns in 144 hogshead. NOTE: Write it out in ONE continuous formula.

$$\frac{1 \text{ tun}}{504 \text{ pottle}} \times \frac{18 \text{ pottle}}{1 \text{ firkin}} \times \frac{7 \text{ firkin}}{1 \text{ hogshead}} \times \frac{144 \text{ hogshead}}{1} = 36.0 \text{ tuns}$$
5. How many aspirin tablets can be made from 100. g of aspirin if each tablet contains 5.00 grains of aspirin? (7.00 × 10^3 grains is equal to one pound) (454 g = 1 lb)

\[
\text{tablet} \times \frac{7,000 \times 10^3 \text{ grain}}{5,000 \text{ grain}} \times \frac{1 \text{ lb}}{115 \text{ grain}} \times \frac{100 \text{ grain}}{454 \text{ grain}} = 308 \text{ tablets}
\]

6. What is the cost of 300.0 grams of aspirin if each tablet contains 5.00 grains of aspirin and 100 tablets cost $2.35? (7.00 × 10^3 grains is equal to one pound, 454 g is equal one pound.)

\[
\frac{2.35}{100 \text{ tablets}} \times \frac{\text{tablet}}{7,000 \text{ grains}} \times \frac{1 \text{ lb}}{115 \text{ grain}} \times \frac{100 \text{ grain}}{454 \text{ grain}} = \$21.74
\]

7. Find the number of cm^3 in 2.60 cubic foot.

\[
\left(\frac{2.54 \text{ cm}}{1 \text{ in}}\right)^3 \times \left(\frac{12 \text{ in}}{1 \text{ ft}}\right)^3 \times 2.60 \text{ ft}^3 = 73,600 \text{ cm}^3
\]
8. Determine the number of liters of gas required to fill an automobile’s 15 gallon tank? (1.000 L = 1.057 quarts, 4 quarts = 1 gallon)

\[
\frac{1.000 \text{ L}}{1.057 \text{ qt}} \times \frac{4 \text{ qt}}{15 \text{ gal}} = 5.97 \text{ L}
\]

9. If one atom has a diameter of 0.372 nm and you have \(2.62 \times 10^{22}\) atoms (typical number of atoms in a backpack), and you alien those atoms into a single chain, one atom after another, how many miles would this atomic string be? The distance to the sun is 93,000,000 miles, how many times can you go to the sun and back (round trips). (use the following: 5280 ft = 1 mile and 2.54 cm = 1 inch)

\[
\text{Sun} \quad \overrightarrow{\text{Earth}} \quad \overrightarrow{\text{Sun}}
\]

73,000,000 miles so 1 Round Trip = 186,000,000 miles

\[
\frac{\text{1 Round Trip}}{186,000,000 \text{ miles}} = \frac{1 \text{ mile}}{5280 \text{ ft}} \times \frac{1 \text{ ft}}{12 \text{ in}} \times \frac{1 \text{ in}}{2.54 \text{ cm}} \times \frac{100 \text{ cm}}{1 \text{ m}} \times \frac{1.2 \times 10^{-9} \text{ nm}}{1 \text{ ft} \times \frac{1 \text{ m}}{1.97 \times 10^{10} \text{ cm}}}
\]

10. How much does 1.00 ft\(^3\) of gold weigh in pounds; the density of gold is 19.3 g/cm\(^3\)?

\[
\frac{15}{36} \times \frac{19.3}{1000} \times \left(\frac{2.54 \text{ cm}}{1 \text{ in}}\right)^3 \times \left(\frac{12 \text{ in}}{1 \text{ ft}}\right)^3 \times 1 \text{.00 ft}^3
\]

\[
= 1.20 \times 10^3 \text{ lbs}
\]

\[
\approx 1200 \text{ lbs}
\]