Introduction

Experimental observations can be expressed either qualitatively or quantitatively. Qualitative observations describe the characteristics of the system in non-numerical terms. “The apple is red” is an example. Qualitative observations are sometimes sufficient in describing a phenomenon or system and when comparing two things. Quantitative observations involve a measurement or a count. “The apple weighs 525 grams” is a quantitative observation. Quantitative observations are more objective, since they do not depend on the observer’s methods of measurement or cultural history, and are equally understood anywhere in the world.

To understand the difference, try to buy two cans of red paint at two different stores. Matching your concept of red to that of the salesman can be extremely difficult. Now add to the equation trying to buy the paint in a store where the salesman doesn’t speak English. However, both of you probably know precisely what is meant by “2” fingers held up, regardless of language or culture.

Ideally the system of measure that we use should also be objective. The French tried to achieve this objectivity and did away with their old system of units of measure and established one based on physical parameters that would have the same values no matter when or where they were measured. We refer to this as the metric system of measurement (also the Systeme International or SI).

Conversion between metric and American system is fairly easy. The creation of a conversion factor allows for the switch between the two systems. A conversion factor is a ratio that consists of a numerator and a denominator. The numerator is what you are converting TO and the denominator is what you are converting FROM. If the appropriate conversion factor isn’t available, you can ‘string together’ several conversion factors to get the value that you are looking for.

Let us try an example: How many inches are there in 3 meters?

1) We are ultimately converting TO inches FROM meters using multiple conversion factors (CF). Using Table 1 at the end of this ‘lab manual’ we know that 1 m is 3.28 ft. We also should know that 1 ft is 12 inches. We can now create our various CF.

2) CF1 is converting FROM meters (denominator) TO feet (numerator) and would be:

\[
\frac{3.28 \text{ feet}}{1 \text{ m}}
\]

3) CF2 is converting FROM feet (denominator) TO inches (numerator) and would be:

\[
\frac{12 \text{ inches}}{1 \text{ foot}}
\]

4) ? in = 3 m x CF1 x CF2 or

\[
3 \text{ m} \times \frac{3.28 \text{ ft}}{1 \text{ m}} \times \frac{12 \text{ in}}{1 \text{ ft}}
\]

5) The meter in the numerator and denominator can be canceled; the same is true of feet. This leaves you with:

\[
3 \times 3.28 \times 12 \text{ inches} = 118.08 \text{ inches}
\]

The goal is to be able to cancel out all of the units with the exception of what we are looking for, i.e. inches.

Another advantage of the metric system is that the units are based on multiple of tens. There is an established set of prefixes that represent the powers of ten. These can be used to create conversion factors as above. Table 2 at the end of this ‘lab manual’ lists some commonly used prefixes. The prefixes may be applied to meters, liters or grams.

Let us try an example. How many liters is 3325 milliliters?

1) Determine the powers of the measure you are converting between from their prefixes. In our examples, the power of milliliters is –3. Since liter has no prefix, its power is 0.

2) Subtract the power of the measure you are converting TO (liters) from the power of the measure you are converting FROM (milliliters). In our example: The equation is (-3) – 0 = -3

3) The difference is the power of ten of the converted measure. So in our example, 3325 ml = 3325 x 10^-3 L or 3.325 L
Since the power of ten is negative, we can simplify the answer by moving the decimal that many spaces to the left. If there had not been enough spaces to the left, we could fill in with zeros. Had the power been positive, we would move the decimal point to the right and add zeros as needed.

You will be able to practice some of these conversions factors in your homework assignment that is due at the start of the next lab period. Use whichever method to perform conversions that is easiest for you and show your work. Be very familiar with these methods as they will show up on your exams.

Laboratory Procedure

To give you experience in working with the metric units of measures in the laboratory setting, you will perform exercises in which you will determine the density of water, the density of vegetable oil or a sucrose solution as well as some other objects. The density of a substance is its mass per unit volume. Density is determined by recording the masses of increasingly larger volumes of the substance. Once the data is collected, a graph of MASS vs VOLUME is plotted and the slope of the straight line that passes closest to the most points is calculated. This slope is the density of the substance.

Exercise 1 – Determination of the density of water

1) Find on your bench the following items: a pipette bulb, a 5 mL pipette, a 10 mL pipette and a weighing boat.

2) Turn on the automatic balance at your site, and if it reads other than 0, press the tare button so that the scale will read 0.

3) Place the weighing boat on the pan of the automatic balance and determine the mass. Record this value on your worksheet.

4) Now press the tare button and note that the balance again reads 0. The balance automatically “subtracts” the mass of the weighing boat from future readings in a process of taring.

5) Place the pipette bulb on the end of the 5 mL pipette and measure 1 ml of distilled water into the weighing boat. NOTE: The 5 ml pipette is capable of holding 5 ml of liquid; the pipette is divided into 1/10 th increments. Therefore 1 ml would consist of 10 small lines. Record the mass of the water on your worksheet.

6) Leaving the weigh boat with the 1 ml of water on the scale, use the same pipette to place an additional 2 mL of water into the boat (total 3 mL). Record the mass of the water on your worksheet.

7) Repeat Step 6 with an additional 2 mL of water (total 5 mL). Record the mass of the water on your worksheet.

8) Repeat step 6 with an additional 5 ml of water (total 10 mL). Record the mass of the water on your worksheet.

9) Repeat step 6 using the 10 mL pipette to add 10 mL of water (total 20 ml). Record the mass of the water on your worksheet.

10) Empty the water from the weigh boat, dry and repeat Steps 3 through 9 an additional 2 times (a total of 3 measurements per volume). Each run through of the experiment is called a trial or replicate. As you increase the number of trials you can decrease the level of error.

11) Using the data from your worksheet, draw a graph from your data using the volumes as your independent variable (the variable you measured with the least error) plotted along the horizontal axis and the masses as your dependent variable (the variable you determined as an unknown with error) along the vertical axis. You will have 3 points for each volume.

12) Draw a straight line so that it passes through or near most of the points on your graph. This line is known as the best-fit line. DO NOT connect
13) Calculate the slope of this line – the slope of this line is equal to the density of water. Remember, a volume of 0 has no mass, so you know that the line must pass through the origin as one of the points on your graph. The slope can be calculated by choosing 2 points on the line that are easy to determine the coordinates. Label them as point 1 and point 2. Record the location of the points as \((x_1,y_1)\) for point 1 and \((x_2,y_2)\) for point 2. The slope is then rise over run or:

\[
\frac{y_2 - y_1}{x_2 - x_1}
\]

**Exercise 2** - Determination of the density of an unknown liquid.

Repeat the steps from Exercise 1 to determine the density of either vegetable oil or a sucrose solution obtained from the instructor. Record the sample name on your worksheet. Only complete one trial for this exercise. You will graph the data on the graph for water density. This way you will be able to compare the density of this substance compared to the density of water.

**Exercise 3** – Determination of the density of a solid.

The density of a solid can be determined if both the volume and the mass is known. For solids with regular shapes (spheres, cylinders, cubes etc) the volume can be calculated directly using measurements obtained from the object and the known geometric formulae. For irregularly shaped solid objects, the volume can be determined by displacement of a liquid. The volume of water displaced will indicate the volume of the irregular shaped object. You are responsible for determining the density of an irregular shaped object that you get from the instructor.

1) Obtain a 25 or 100 mL graduated cylinder and the solid object for which you are to determine the density from the instructor.

2) Fill the graduated cylinder part way with water and record the volume. Remember to read the volume at the bottom of the meniscus at the surface of the water.

3) Determine the mass of the object on the scale. DO this first so as not to have to worry about a wet object.

4) Drop the solid into the graduated cylinder. Read the new volume of the water. The volume of the solid is the difference between this volume and the previous one.

**Thought Problem:**

Measure the thickness of a solid.

As an extension to this lab, you will be given a sheet of some material: aluminum, copper, etc. and your group is to determine its thickness. Decide what you know about the object that you are given and decide what you need to measure to answer the question. You may find that there are things you do not know that you will need to look up. The teacher will have the necessary source available to you.
# Metric Units Encountered in Biology and Their American Equivalents

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Unit</th>
<th>Symbol</th>
<th>American Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>Meter</td>
<td>m</td>
<td>1m = 3.28 feet</td>
</tr>
<tr>
<td>Mass</td>
<td>Kilogram</td>
<td>kg</td>
<td>1 kg = 2.2 pound</td>
</tr>
<tr>
<td>Temperature</td>
<td>Kelvin (Centigrade)</td>
<td>K (C)</td>
<td>$T_c , ^\circ C = (T_f , ^\circ F - 32)/1.8 \quad T_k , K = T_c , ^\circ C + 273.15$</td>
</tr>
<tr>
<td>Time</td>
<td>Second</td>
<td>s</td>
<td>Same</td>
</tr>
<tr>
<td>Volume</td>
<td>Cubic meter (Liter)</td>
<td>Dm$^3$</td>
<td>1L = 1.06 quart; 1cc = 1 cm$^3$ = 1 mL</td>
</tr>
</tbody>
</table>

## Prefixes for Metric Units of Measure

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Symbol</th>
<th>Power</th>
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</thead>
<tbody>
<tr>
<td>Giga-</td>
<td>G</td>
<td>$10^9$</td>
</tr>
<tr>
<td>Mega-</td>
<td>M</td>
<td>$10^6$</td>
</tr>
<tr>
<td>Kilo-</td>
<td>k</td>
<td>$10^3$</td>
</tr>
<tr>
<td>Centi-</td>
<td>c</td>
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<tr>
<td>Milli-</td>
<td>m</td>
<td>$10^{-3}$</td>
</tr>
<tr>
<td>Micro-</td>
<td>µ</td>
<td>$10^{-6}$</td>
</tr>
<tr>
<td>Nano-</td>
<td>n</td>
<td>$10^{-9}$</td>
</tr>
<tr>
<td>Pico-</td>
<td>p</td>
<td>$10^{-12}$</td>
</tr>
</tbody>
</table>
Complete the following conversions using the above charts. SHOW ALL YOUR WORK!

1. How many liters in one gallon?

2. One inch equals how many centimeters?

Hint: 3 teaspoons equal 1 tablespoon and 4 tablespoons equal ¼ of a cup.

3. How many milliliters in a teaspoon?

4. How many milliliters in a tablespoon?

5. A 10 gigabyte hard drive will hold how many 200 megabyte files?

6. How many microns (another term for micrometers) in a centimeter?

7. How many grams in an ounce? (Hint: 16 ounces in a pound)

8. How many cubic centimeters in 4.67 liters?

9. Convert your weight to kilograms.

10. Convert your height to centimeters.

Additional work to turn in:

1. Completed table of data for all exercises.
2. Completed graph with lines for Exercises 1 and 2.
3. The slope of each line in the above graph.
4. Description of the solid in Exercise 3 and its density.
5. Calculations for Thought Problem.
Biology of the Cell (Biol 1021)  Lab 1  
Conversions and Introduction to Lab Equipment

Exercise 1 – Density of water:

Trial 1
1) Weight of the weighing boat before taring: _______________________
2) Weight of 1 mL of water: ______________________________
3) Weight after 2nd addition of water: _______________________
4) Weight after 3rd addition of water: _______________________
5) Weight after 4th addition of water: _______________________
6) Weight after final addition of water: _______________________

Trial 2
1) Weight of the weighing boat before taring: _______________________
2) Weight of 1 mL of water: ______________________________
3) Weight after 2nd addition of water: _______________________
4) Weight after 3rd addition of water: _______________________
5) Weight after 4th addition of water: _______________________
6) Weight after final addition of water: _______________________

Trial 3
1) Weight of the weighing boat before taring: _______________________
2) Weight of 1 mL of water: ______________________________
3) Weight after 2nd addition of water: _______________________
4) Weight after 3rd addition of water: _______________________
5) Weight after 4th addition of water: _______________________
6) Weight after final addition of water: _______________________

Exercise 2 – Density of second liquid

Liquid _______________________
1) Weight of the weighing boat before taring: _______________________
2) Weight of 1 mL of unknown: ______________________________
3) Weight after 2nd addition of unknown: _______________________ 
4) Weight after 3rd addition of unknown: _______________________
5) Weight after 4th addition of unknown: _______________________
6) Weight after final addition of unknown: _______________________

Exercise 3 – Density of a Solid:

Description of solid: ___________________________________________
1) Volume of water before adding the object: _______________________
2) Mass of the object: _________________________________________
3) Volume of water after adding the object: _______________________

Thought Problem: