LAB 1 – The Scientific Method and Metric System

Overview

In this laboratory you will first watch a brief video on the importance of laboratory safety, organization and cleanliness. You will then focus on principles relating to the scientific method and the presentation of experimental data after which you will perform an experiment applying these principles. In the second part of this laboratory you will make a variety of measurements in metric units, and practice converting units within the metric system.

Part 1: The Scientific Method

The field of science is based on observation and measurement. If a scientist cannot observe and measure something that can be described and repeated by others, then it is not considered to be objective and scientific.

In general, the scientific method is a process composed of several steps:

1. **observation** – a certain pattern or phenomenon of interest is observed which leads to a question such as “What could explain this observation?”
2. **hypothesis** – an educated guess is formulated to explain what might be happening
3. **experiment** – an experiment or study is carefully designed to test the hypothesis, and the resulting data are presented in an appropriate form
4. **conclusion** – the data is concluded to “support” or “not support” the hypothesis

To illustrate the scientific method, let’s consider the following observation:

*A scientist observes that Compound X appears to increase plant growth, which leads to the question: “Does Compound X really increase plant growth?”*

Hypotheses

The next step in applying the scientific method to a question such as this would be to formulate a hypothesis. For a hypothesis to be good or useful it should be a statement that:

a) uses objective and clearly defined terms
b) can be tested experimentally (i.e., is “testable”)
A reasonable hypothesis regarding the observation on the previous page would be:

*Increasing amounts of compound X correlate with increased plant height.*

In this case there is nothing vague or subjective in the terminology of the hypothesis. It can easily be tested experimentally and thus is a good hypothesis. Keep in mind that a good hypothesis is not necessarily correct. If a hypothesis is clear and testable and experimentation does *not* support it, valuable information has been gained nonetheless. For example, if one were to test the hypothesis “compound Y is an effective sunscreen”, it would be very valuable to know if experimental data does *not* support this hypothesis (i.e., that compound Y is *not* an effective sunscreen).

**Exercise 1A – Assessing hypotheses**

Indicate if you think each hypothesis listed on your worksheet is good, and if not, suggest changes that would make it a good hypothesis.

**Experimentation**

**Experiments** are designed to test hypotheses. A simple test of the hypothesis on the previous page would be to plant the seeds of identical pea plants in pots. Each pot must have the same type of soil, be exposed to the same temperature, pH, amount of sunlight, water, etc. The height of each plant is then measured after a 5 week period. The only difference between these plants will be amounts of Compound X given each day, which are as follows:

<table>
<thead>
<tr>
<th>Pea Plant</th>
<th>Compound X per Day (grams)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>6</td>
<td>9</td>
</tr>
</tbody>
</table>

In testing the effects of Compound X on pea plant growth, it is common sense that you should devise an experiment in which multiple pea plants are grown under identical conditions except for 1 difference or **variable**, the amount of Compound X given to each plant. In this way any differences in plant height should be due to the only condition that varies among the plants, the amount of Compound X.

When you design an experiment or a study such as this, it is important to consider all of its components. Even though we design the experiment to contain only 1 variable component, we need to consider all other components including the outcome of the experiment and any
control experiments that are done. Thus, when designing an experiment you need to account for the following:

**independent variable**
the treatment or condition you choose to VARY among the groups

**dependent variable**
the MEASUREMENTS or outcomes recorded at the end of the experiment (e.g., height of pea plants)

**standardized variables**
al l *other* factors or conditions in the experiment that must be kept the same (e.g., type of soil, amount of water, amount of sunlight) so their influence on the dependent variable remains constant (i.e., we want to measure the effect of the independent variable *only*)

**experimental groups/treatments**
the subjects (e.g., plants) that receive the different treatments

**control group/treatment**
the subjects that receive NO treatment, i.e., the independent variable is eliminated (set to “zero”) or set to a background or default level

(NOTE: control treatments for independent variables such as temperature and pH that cannot be eliminated are generally at a “background” level such as room temperature or pH = 7)

**Repetition** is also important for an experimental result to be convincing. There needs to be a sufficient number of subjects and repetitions of the experiment. For example, to make this experiment more convincing multiple plants would be tested at each level of the independent variable and it would be repeated multiple times.

**Data Collection & Presentation**

Upon completion of an experiment, the results need to be collected or measured, and presented in an appropriate format. For our sample experiment, after 5 weeks the height of the pea plants is measured and the following data are collected:

<table>
<thead>
<tr>
<th>Pea Plant</th>
<th>Compound X per Day (grams)</th>
<th>Height of Plant (centimeters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>4.0</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>9.9</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>13.2</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>15.1</td>
</tr>
<tr>
<td>5</td>
<td>7</td>
<td>16.8</td>
</tr>
<tr>
<td>6</td>
<td>9</td>
<td>17.0</td>
</tr>
</tbody>
</table>
Now that you have the raw data for the experiment, it is important to present it in a form that is easy to interpret. Frequently this will be in the form of a table, chart or graph. The data above are presented in a table, however the overall results will be easier to interpret if presented in a graph.

There are many ways to present data graphically, but the two most common types of graphs are **line graphs** and **bar graphs**. When graphing data in this way, it is customary to place the *independent* variable on the **X-axis** (horizontal) and the *dependent* variable on the **Y-axis** (vertical). The independent variable in this experiment is the “amount of Compound X added” and the dependent variable is the height of pea plants after 5 weeks. Below are the Compound X data presented in a line graph on the left and a bar graph on the right:

![Line Graph](image1)

![Bar Graph](image2)

Which type of graph is best for this data? It depends on the nature of the independent variable on the X-axis. If the independent variable is **continuous** (i.e., there is essentially an infinite number of values for the independent variable including values that fall between those actually tested), then a line graph would be appropriate. This would be the case if the independent variable covered a range of values for time, temperature, distance, weight, or volume for example. In our example, the “grams of Compound X” is clearly a continuous variable for which there are values in between those tested, therefore a line graph is appropriate. By drawing a line or curve through the points, you can clearly estimate what the “in between” values are likely to be, something you cannot do as easily with a bar graph.

If the independent variable is discontinuous or **discrete** (i.e., there are very limited or finite values for the independent variable), then a bar graph would be appropriate. For example, if you wanted to graph the average GPA of students at each of the nine LACCD community colleges, the independent variable would be the specific school (the dependent variable would be the average GPA). There are only nine possible “values” for the independent variable, so in this case a bar graph would be most appropriate.
When you’re ready to create a graph, you need to determine the range of values for each axis and to scale and label each axis properly. Notice that the range of values on the axes of these graphs are just a little bit larger than the range of values for each variable. As a result there is little wasted space and the graph is well spread out and easy to interpret. It is also essential that the units (e.g., grams or centimeters) for each axis be clearly indicated, and that each interval on the scale represents the same quantity. By scaling each axis regularly and evenly, each value plotted on the graph will be accurately represented in relation to the other values.

**Conclusions**

Once the data from an experiment are collected and presented, a conclusion is made with regard to the original hypothesis. Based on the graph on the previous page it is clear that all of the plants that received Compound X grew taller than the control plant which received no Compound X. In fact, there is a general trend that increasing amounts of Compound X cause the pea plant to grow taller (except for plants 5 and 6 which are very close).

These data clearly support the hypothesis, but they by no means prove it. In reality, you can never prove a hypothesis with absolute certainty, you can only accumulate experimental data that support it. However if you consistently produce experimental data that do not support a hypothesis, you should discard it and come up with a new hypothesis to test.

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**Exercise 1B – Effect of distance on making baskets**

In this exercise, you will design an experiment to determine the effect of distance on the accuracy of shooting paper balls into a beaker (and also determine which person in your group is the best shot!). Each student will attempt to throw small paper balls into a large beaker at 3 different distances in addition to the control (which should be 0 cm, i.e., a slam dunk!). You will measure each distance using the metric system and determine how many attempts are made out of 10 total attempts at each distance.

1. State your hypothesis and identify your independent and dependent variables.

2. Place the large beaker on your lab table at each test distance and record how many attempts out of 10 you make.

3. Graph the data for each member of your group on a single graph (use different curves for each person) and answer the corresponding questions on your worksheet.

4. Conclude whether or not the data support your hypothesis and answer any other associated questions on your worksheet.
Applying the Scientific Method to the Game “Purble Shop”  
(optional)

“Purble Shop” is a game found on PCs that run the Windows 7 operating system. In the game you try to guess the colors of various parts of a “Purble” (a funny looking animated creature) in as few guesses as possible. So what does this have to do with scientific inquiry? Like science, the game is about finding out something which is unknown. The approach to discovering “the unknown” in this game has much in common with the scientific method: asking questions, formulating hypotheses, testing hypotheses, and reaching conclusions based on test results. Let’s review the game to see just how scientific this game really is…

Each Purble has 5 features or parts (hat, eyes, nose, mouth, clothes), each of which can be one of 5 colors (red, purple, yellow, blue or green). The computer will generate a hidden Purble with unknown colors for all 5 features. Your job is to make a series of guesses as to the color of each Purble feature until you arrive at the correct color combination. After each guess you will be informed how many of your color choices are “right color, right feature” or “right color, wrong feature”. There are a limited number of guesses, so just guessing randomly will get you nowhere. However if you take a logical and scientific approach you can guess the color scheme of the mystery Purble in 8 attempts or less.

The key to success is to make guesses (hypotheses and experiments) that when tested will yield information (results and conclusions) that is useful in formulating your next guess, which you test and so on... Science generally works this way. The answer to a scientific question usually requires multiple experiments, with the conclusions of one experiment providing information used to formulate the next hypothesis and experiment. In this way, just as in Purble Shop, the ultimate answer being sought is arrived at step by step.
Your instructor will go through a sample game for the class to give you an idea how to approach the process, after which you can practice with your group for a bit. There are many different ways to approach this game, several of which your instructor will show you. Ideally you will devise your own approach with the help of your lab mates. Whatever approach you take, it should be logical and it should minimize the number of guesses required to identify the Purble.

When your group is ready, you will play an “official” game while recording each step and the corresponding thought process on your worksheet. As you play, keep in mind the following suggestions:

1) Limit your first few guesses to one or two colors each. This will give you reliable information you can use for subsequent guesses. If you use all 5 colors for your first guess it will be difficult to come to any conclusions you can rely on for the next guess.

2) Each guess should be consistent with the results of all previous guesses. Take your time to carefully examine each guess (hypothesis) you are considering and make sure it meets the criteria you have already deduced from previous guesses. If it doesn’t, discard that hypothesis, it is not worth testing, and come up with another that is consistent with the criteria you have deduced.

Keep in mind that this doesn’t have to be perfect, you will likely find mistakes in your logic and conclusions along the way. The important thing is to learn the process and to realize how similar this is to the scientific method. But don’t forget that identifying the Purble in as few guesses as possible is the goal. In the real world, science costs money, and scientists who answer important questions with the least amount of experimentation (i.e., time and money) have the most success.

**Exercise 1C (optional) – A game of “Purble Shop”**

Once you and members of your group are familiar with the game of “Purble Shop”, play a single game as a group, recording each guess (hypothesis and experiment), result and conclusion on your worksheet as the game progresses until you identify the Purble.
Part 2: The Metric System of Measurement

How many teaspoons are in a cup? How many inches are in a mile? How many ounces are in a pound? If you know the answers to all of these questions, you are one of the few people in the world who can completely understand the English System of Measurement. The United States is one of the few countries of the 186 members of the United Nations that still uses the English System of Measurement (not even England uses it!).

The English System was developed over many centuries by the kings and noblemen of the Roman and British empires. In fact, the foot was literally the length of the actual foot of an English king, which happens to be 12 inches (each inch being the length of three seeds of barley).

The following are units used in the English System today:

LENGTH

1 mile = 8 furlongs = 1,760 yards = 5,280 feet = 63,360 inches

VOLUME

1 gallon = 4 quarts = 8 pints = 16 cups = 128 ounces = 256 tablespoons

MASS

1 ton = 2,000 pounds = 32,000 ounces = 2.24 x 10^8 grains

TEMPERATURE

Fahrenheit - Water freezes at 32 ºF and boils at 212 ºF

How do you convert from one unit to the next using this system? Watch:

A person has 5 gallons of water. How many ounces of water does this equal?

5 gallons x 128 ounces = 640 ounces
gallon

Did you know how to do this already? Probably not. Very few scientists, much less everyday citizens, can remember how to convert units within this system, even though they’ve used it their entire lives. Basically, the English system is so difficult to work with that most countries in the world, and all scientists, have adopted a much easier system called the Metric System of Measurement.

The metric system of measurement has been adopted by 99% of the countries in the world and all scientists for two primary reasons: 1) there is a single, basic unit for each type of measurement (meter, liter, gram, ºC) and 2) each basic unit can have prefixes that are based on powers of 10 making conversions much easier. Once you learn the basic units and the multiples of 10 associated with each prefix, you will have the entire system mastered.
Basic Units of the Metric System

LENGTH - The basic unit of length in the metric system is the **meter**, abbreviated by the single letter **m**. A meter was originally calculated to be one ten-millionth of the distance from the north pole to the equator, and is ~3 inches longer than a yard.

VOLUME – The basic unit of volume in the metric system is the **liter**, abbreviated by the single letter **l** or **L**. A liter is defined as the volume of a box that is 1/10 of a meter on each side. A liter is just a little bit larger than a quart (1 liter = 1.057 quarts)

MASS – The basic unit of mass in the metric system is the **gram**, abbreviated by the single letter **g**. A gram is defined as the mass of a volume of water that is 1/1000 of a liter. [Note: 1/1000 of a liter = 1 milliliter = 1 cubic centimeter = 1 cm$^3$ = 1 cc).

TEMPERATURE – The basic unit of temperature in the metric system is a degree Celsius (°C). Water freezes at 0 ºC and boils at 100 ºC.

Prefixes used in the Metric System

Unlike the English System, the metric system is based on the meter (**m**), liter (**L** or **l**) and gram (**g**), and several prefixes that denote various multiples of these units. Specifically, each basic unit can be modified with a prefix indicating a particular “multiple of 10” of that unit. Here are the more commonly used prefixes and what they mean:

<table>
<thead>
<tr>
<th>mega (M)</th>
<th>kilo (k)</th>
<th>BASIC UNIT</th>
<th>deci (d)</th>
<th>centi (c)</th>
<th>milli (m)</th>
<th>micro (µ)</th>
<th>nano (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10$^6$</td>
<td>10$^5$</td>
<td>10$^4$</td>
<td>10$^3$</td>
<td>10$^2$</td>
<td>10$^1$</td>
<td>10$^{-1}$</td>
<td>10$^{-2}$</td>
</tr>
</tbody>
</table>

Mega (M)  = 10$^6$ = 1,000,000  
kilo (k)  = 10$^3$ = 1,000  
no prefix  = 10$^0$ = 1  
deci (d)  = 10$^{-1}$ = 1/10 (or 0.1)  
centi (c) = 10$^{-2}$ = 1/100 (or 0.01)  
milli (m) = 10$^{-3}$ = 1/1,000 (or 0.001)  
micro (µ) = 10$^{-6}$ = 1/1,000,000 (or 0.000001)  
nano (n)  = 10$^{-9}$ = 1/1,000,000,000 (or 0.000000001)

Here is how simple the metric system is using the basic units and the prefixes:

What is one thousandth of a meter? **a millimeter (mm)**  
What is one one-millionth of a liter? **a microliter (µl)**  
What is 1,000 grams? **a kilogram (kg)**
Let us now examine these units more closely by using them to make actual measurements and converting from one metric unit to another.

**Exercise 2A – Measuring distance**

1. Obtain a wooden meter stick. If you look on the back of the meter stick, one meter is approximately 39 inches or about 3 inches longer than one yard (36 inches). Using the meter stick, estimate the size of the laboratory by measuring its width and length to the nearest meter.

2. Observe that the meter is divided into 100 equal units called centimeters. A centimeter is about the width of a small finger. Using the meter stick, estimate the dimensions of a regular piece of notebook paper to the nearest centimeter.

3. How tall are you? Go over to the medical weight and height scale to measure how tall you are to the nearest centimeter.

4. Next, obtain a small plastic metric ruler. Observe that each centimeter is divided into 10 small units called millimeters. A millimeter is about the thickness of a fingernail. Using the small plastic ruler, estimate the diameter of a hole on a regular piece of notebook paper to the nearest millimeter.

In the United States, when we travel by car, distances are measured in miles. For example, from the Mission College to downtown Los Angeles is about 20 miles. In almost every other country, such distances are measured in kilometers. One kilometer is exactly 1,000 meters and approximately 0.6 miles. Thus, 1 km = 0.6 miles.

How does one convert miles to kilometers? How many kilometers are in 20 miles?

\[
20 \text{ miles} \times \frac{1 \text{ km}}{0.6 \text{ miles}} \approx 33 \text{ km}
\]

Do the following distance conversions for practice:

Distance from Los Angeles to San Diego: 145 miles \( \times \) \( \approx \) _______ km
Distance from Los Angeles to New York: 2,500 miles \( \times \) \( \approx \) _______ km

What are some real-world examples of other metric units of length?

One micrometer (\( \mu \text{m} \)) is \(1/1,000^{\text{th}}\) the size of a millimeter or \(1/1,000,000^{\text{th}}\) of a meter. When you observe a cheek cell under the microscope in a future lab, it is about 40 \( \mu \text{m} \) in diameter. Typical bacteria are about 5-10 \( \mu \text{m} \) in diameter.

One nanometer (\( \text{nm} \)) is \(1/1,000^{\text{th}}\) the size of a micrometer or \(1/1,000,000,000^{\text{th}}\) of a meter. Objects this small are far too tiny to observe even in a light microscope. If you line up five water molecules side-by-side, the length would be about 1 nanometer.
Exercise 2B – Measuring volume

1. Obtain a one liter (L or l) beaker. One liter is equal to 1,000 cubic centimeters (cc = cm$^3$ = milliliter = ml). Fill the beaker with one liter of water. To do this, add water until the meniscus (top level of the water) reaches the 1 liter marker on the beaker. Pour the water into a 2 liter soda bottle.

   Once again, fill the beaker with one liter of water by adding water until the meniscus reaches the 1 liter mark. Pour the water into the 2 liter soda bottle.

   Once again, fill the beaker with one liter of water by adding water until the meniscus reaches the 1 liter mark. Over the sink, add the 1 liter of water to the 1 quart container provided. Notice that 1 liter is just a little bit more than 1 quart. In fact, 1 liter = 1.057 quarts.

2. One way to measure the volume of a fluid in a laboratory is to use a graduated cylinder. Whereas beakers are generally used to hold fluids, graduated cylinders are used to accurately measure volumes.

   Obtain a 50 milliliter (ml) graduated cylinder. Fill the graduated cylinder with water until the meniscus reaches the 50 ml mark. Add the water to a 1 liter (1,000 ml) beaker. Notice that 50 ml is equal to 1/20th of a liter. Next, measure the fluid in the flask labeled “A” to the nearest 0.1 ml.

3. Pipettes are used to measure smaller liquid volumes whereas graduated cylinders are used to measure larger volumes. Obtain a 10 ml glass pipette and attach it snugly to a pipette pump.

   Notice whether or not the pipette is a delivery or blowout pipette. Blowout pipettes are designed for measuring fluids all the way to the end of the pipette so that the liquid measured can be completely “blown out” of the pipette. Delivery pipettes have a gap at the end of the pipette and are designed to “deliver” the liquid down to the desired marking only. The remainder is discarded or returned to the original container. (NOTE: blowing out a delivery pipette will give a wrong volume)

   Using the roller on the pipette pump, gradually suck up some water until the meniscus reaches the 0 ml mark. Measure 10 ml of the water into the sink by rolling the roller in the opposite direction. Next, measure the amount of fluid in the test tube labeled B to the nearest 0.1 ml using the 10 ml pipette.
**Exercise 2C – Measuring mass**

A balance scale is used to measure the mass of a sample in grams (g).

1. Place an empty 50 ml graduated cylinder on the balance and determine its mass in grams.

2. Next, fill the graduated cylinder with 50 ml of water and measure the mass of both the cylinder and the water. From this value subtract the mass of the cylinder to get the mass of the water.

*By definition, one gram is the mass of exactly 1.0 ml of water, thus 50 ml of water has a mass of 50.0 grams. How far off was your measured mass from the true mass of 50 ml of water?*

3. Next, take a large paper clip and place it on the balance and determine its mass in grams.

**Exercise 2D – Measuring temperature**

The metric unit for temperature is °Celsius (°C). Water freezes at 0 °C and boils at 100 °C. Note that this is much easier to remember than the corresponding values of 32 °F and 212 °F.

1. Use a thermometer to measure the following in degrees Celsius:
   - A) the ambient temperature of the lab
   - B) a bucket of ice water
   - C) a beaker of boiling water

2. Convert the temperatures on your worksheet from °C to °F or °F to °C with the following formulas:

   °C = \( \frac{5}{9} \times (°F - 32) \)

   °F = \( \frac{9}{5} \times °C + 32 \)
Converting Units in the Metric System

In science, numerical values are commonly represented using scientific notation. Scientific notation is a standardized form of exponential notation in which all values are represented by a number between 1 and 10 times 10 to some power. For example, 3500 in scientific notation would be $3.5 \times 10^3$, and 0.0035 would be $3.5 \times 10^{-3}$.

Scientific notation is much more practical when dealing with extremely large or small values. For example, consider the masses of the earth and a hydrogen atom:

- Earth: $5.97 \times 10^{27}$ grams = $5,970,000,000,000,000,000,000,000,000,000,000$ grams
- Hydrogen atom: $1.66 \times 10^{-24}$ grams = $0.00000000000000000000000166$ grams

In these examples scientific notation is clearly much more practical. Since numerical values for any metric unit can be represented in decimal or scientific notation, it is important that you be able to convert between the two as outlined below:

**Converting from decimal notation to scientific notation**

**STEP 1** – Convert the number to a value *between 1 and 10* by moving the decimal point to the right of the 1st non-zero digit:

- e.g. $0.00105$ OR $1,050$
- $1.05$
- $1.05$

**STEP 2** – Multiply by a power of 10 (i.e., $10^n$) to compensate for moving the decimal:

- the power will equal the number of places you moved the decimal
- the sign of the exponent negative (-) if the original number is less than 1, and positive (+) if the original number is greater than 1

- e.g. $0.00105 = 1.05 \times 10^{-3}$
- $1,050 = 1.05 \times 10^{3}$

**Some things to remember about the conventions of writing numbers in decimal notation:**

- if there is no decimal in the number, it is after the last digit ($1,050 = 1050.0$)
- zeroes after the last non-zero digit to the right of the decimal can be dropped (e.g., $1.050 = 1.05$)
- all simple numbers less than 1 are written with a zero to the left of the decimal ($0.105 = 0.105$)

**Exercise 2E (optional) – Converting decimal notation to exponential notation**

Complete the conversions of simple numbers to exponential numbers on your worksheet.
Converting from exponential notation to decimal notation

You simply move the decimal a number of places equal to the exponent. If the exponent is negative, the number is less than one and the decimal should be moved to the left:

\[ 1.05 \times 10^{-3} = 0.00105 \]

If the exponent is positive, the number is greater than one and the decimal should be moved to the right:

\[ 1.05 \times 10^{3} = 1,050 \]

Exercise 2F (optional) – Converting exponential notation to decimal notation

Complete the conversions of exponential numbers to simple numbers on your worksheet.

Converting Units within the Metric System

Once you are familiar with the units and prefixes in the metric system, converting from one unit to another requires two simple steps:

1) divide the original metric prefix by the metric prefix you are converting to
   - e.g., converting mg to µg: milli/micro = \(10^{-3}/10^{-6}\) or \(0.001/0.000001 = 10^3\) or 1000

2) multiply this value by the number in front of the original unit
   - e.g., \(28 \text{ mg} = 28 \times 1000 \text{ µg} = 28,000 \text{ µg}\)

To illustrate this let’s look at an example:

\[ 2.4 \text{ kg} = \_\_\_\_ \text{ mg} \]

In this case you’re converting from kilo-grams to milli-grams. Since the prefix kilo- refers to 1000 and the prefix milli- refers to 1/1000 or 0.001 (see page 7), divide 1000 by 0.001. This gives a value of 1,000,000 which is multiplied by 2.4 to get the mass in milligrams:

\[ 2.4 \text{ kg} = 2.4 \times 1,000,000 \text{ mg} = 2,400,000 \text{ mg} \]

You may find it simpler to associate each metric prefix with an exponential number. With this approach kilo- refers to \(10^{3}\) and milli- refers to \(10^{-3}\), so \(10^{3}/10^{-3}\) equals \(10^{6}\) (when dividing exponential numbers simply subtract the second exponent from the first), and thus:

\[ 2.4 \text{ kg} = 2.4 \times 10^{6} \text{ mg} = 2,400,000 \text{ mg} \]
Whether or not you represent your answer as an exponential number is up to you, either way the values are the same. To ensure that you’ve done the problem correctly, remember that any given distance, mass or volume should contain **more of a smaller unit** and **less of a larger unit**. This is simply common sense if you think about it. As you can see in the example above, there are a lot more of the smaller milligrams than there are the larger kilograms, even though both represent the exact same mass. So each time you do a metric conversion look at your answer to be sure that you have more of the smaller unit and less of the larger unit.

One more thing to remember is that a basic unit without a prefix (m, g or l) is one or \(10^0\) of that unit. Here are a couple more examples just to be sure everything is clear:

\[
\begin{align*}
643 \text{ m} &= \underline{\text{____}} \text{ km} & 1 \text{ divided by } 1000 \text{ (kilo-) } &= 0.001 \times 643 = \underline{0.643 \text{ km}} \\
50 \text{ ml} &= \underline{\text{____}} \text{ l} & 10^{-3} \text{ (milli-) divided by } 10^0 &= 10^{-3} \times 50 = \underline{5.0 \times 10^{-2} \text{ l}}
\end{align*}
\]

**Exercise 2E – Metric Conversions**

Complete the metric conversions on your worksheet.
Exercise 1A – Assessing hypotheses

Circle YES if you think a hypothesis is good (i.e., testable) as written, and NO if you think it is not. If you choose NO, indicate how you would change the hypothesis to make it a good one.

1. Students who own laptops have higher GPAs.  
   Good hypothesis?  
   YES or NO

2. Murders occur more often during a full moon.  
   Good hypothesis?  
   YES or NO

3. Cats are happier when you pet them.  
   Good hypothesis?  
   YES or NO

4. Sea level will be higher in 100 years than it is today.  
   Good hypothesis?  
   YES or NO

Exercise 1B – Paper basketball experiment

State your hypothesis:

In the table below, record the number of shots made at each distance (out of 10) for each person:

<table>
<thead>
<tr>
<th>Name</th>
<th>0 cm</th>
<th>____ cm</th>
<th>____ cm</th>
<th>____ cm</th>
</tr>
</thead>
<tbody>
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</tr>
</tbody>
</table>

What is your control in this experiment?

What is the dependent variable? On which axis of your graph should it be plotted?

What is the independent variable? On which axis of your graph should it be plotted?

Is your independent variable continuous or discrete?

Based on your answer to the question above, should you plot your data on a line or bar graph?
Graph the data for each member of your group below:

State your conclusion below addressing whether or not the data support your original hypothesis:

**Exercise 1C (optional) – A game of “Purble Shop”**

Fill in the table below as your group progresses through a game of Purble Shop. Indicate the number of “right color, right feature” and “right color, wrong feature” for each guess, and write down any conclusions your group makes based on all results up to that point:

<table>
<thead>
<tr>
<th>guess #</th>
<th>right color, right feature</th>
<th>right color, wrong feature</th>
<th>conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<tr>
<td>8</td>
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</tr>
</tbody>
</table>

Describe how you applied the Scientific Method during this exercise.
**Exercise 2A – Measurement of distance**

Laboratory width: _________ m
Laboratory length: _________ m

Calculate approximate area: width _____ m x length _____ m = _________ m²

Paper width: _______ cm
Paper length: _______ cm

Calculate approximate area: width _____ cm x length _____ cm = _________ cm²

Paper hole diameter: ________ mm

Your height: _______ cm, which is equal to _______ m

*Indicate which metric unit of length you would use to measure the following:*

length of a fork __________
width of a plant cell __________

size of a small pea __________
length of your car __________

height of a refrigerator __________
distance to the beach __________

diameter of an apple __________
size of a dust particle __________

**Exercise 2B – Measurement of volume**

Volume of fluid in Beaker A = ____________ ml

Volume of fluid in Test Tube B = ____________ ml

**Exercise 2C – Measurement of mass**

Mass of Graduated Cylinder = ____________ g

Mass of Graduated Cylinder with 50 ml of water = ____________ g

Mass of 50 ml of water (difference of the two numbers above): ____________ g

Difference between your measurement and actual weight of 50 ml of water (50 g): ______

Mass of Large Paper Clip = ____________ g
**Exercise 2D – Measurement of temperature**

Ambient temperature in lab _____ °C  
Ice water _____ °C  
Boiling water _____ °C

*Convert the following temperatures using the formulas on page 10 of the lab exercises:*

Mild temperature:  
72 °F = _______ °C  
Body temperature  
98.6 °F = _______ °C

Cold day  
10 °C = _______ °F  
Very hot day  
34 °C = _______ °F

**Exercise 2E (optional) – Converting from decimal notation to exponential notation**

*Convert the following decimal numbers to exponential numbers:*

186,000  = ____________  
32.9  = ____________  
700.02  = ____________

**Exercise 2F (optional) – Converting from exponential notation to decimal notation**

*Convert the following exponential numbers to decimal numbers:*

3.7 \times 10^3  = ____________  
1.01 \times 10^7  = ____________  
4.0103 \times 10^{-1}  = ____________

**Exercise 2G – Metric conversions**

*Convert the following measurements to the indicated unit:*

335.9 g = _________________ kg  
0.00939 μl = _________________ ml  
456.82 ng = _________________ μg  
20 megabytes = __________ kilobytes  
8 megabase pairs (mbp) = __________ kbp  
95 °C = _________________ °F  
20