THE METRIC SYSTEM

Objectives

1. Convert measurements between different metric units.
    - kilo (k) = 1000 x base unit
    - base unit = 1 x base unit
    - centi (c) = 0.01 x base unit
    - milli (m) = 0.001 x base unit
    - micro (μ) = 0.000001 x base unit
    - nano (n) = 0.000000001 x base unit

2. Determine what metric units to use when measuring mass, volume, temperature, and length.

3. Accurately measure mass, volume, and length.

4. Determine average body temperature, typical room temperature, and freezing and boiling points of water (in Celsius).

5. Collect data and construct graphical representations of data using a line graph.

Case Study: "Island Adventure"

You are a budding marine biologist. This summer you applied to go on a month-long expedition to explore local marine life on an island in the South Pacific. In the acceptance letter, you are reminded that all measurements made during this trip must be in metric units. As you research different units, you learn that the metric system is the standard system of measurement in most of the world and in all scientific fields.

In this lab, you will review the different units of scientific measurement, and practice converting among them.

Metric Conversions

The metric system is a system of measurements that uses the base units of meter for length, liter for volume, and gram for mass. The metric units are:

- Length or distance = meter (m)
- Mass = gram (g)
- Volume = liter (L)

All units of length in the metric system are derived from meter as the base unit. Conversion between units of length in the metric system are based on factors of ten and moving the decimal point to the right or to the left. The units to the right of the base unit are smaller than the base unit. As we move to the right, each unit is 10 times smaller or

one-tenth of the unit to its left. The units to the left of the base unit are bigger than the base unit. As we move to the left, each unit is 10 times greater than the unit to its right. A prefix is a group of letters added before the base unit. The prefix “centi-“ means one hundredth. A centimeter is one hundredth of a meter. The prefix ‘kilo’ is a thousand times the base unit. Conversion between units of length in the metric system involves moving the decimal point to the right or to the left. The prefixes have the same meanings whether they are attached to the units of length (meter), mass (gram), or volume (liter).

The table below contains ways to help you to convert among the different units you will be working with in lab (**Table 1**). Meter (m), liter (L), and gram (g) are defined as “base units” and thus do not use a prefix. The prefixes are in increments (powers) of ten. As you move to the right of the base unit, the subdivisions become 10x smaller, and those to the left of the base unit become 10x larger.

To make a measurement into a smaller unit, move the decimal to the right. This effectively makes the number larger. Similarly, measurement values get larger as you move to the left. To help you remember the order of units on the table you can use the following mnemonic.

“King Henry Doesn’t Usually Drink Chocolate Milk”

King is kilo, Henry is hecto, Doesn’t is deca, Usually is the base unit,
Drink is deci, Chocolate is centi, and Milk is milli

Table 1: Prefixes for the metric system units of measurements

When moving to the RIGHT, move the decimal point to the RIGHT

King	Henry	Doesn’t	Usually	Drink	Chocolate	Milk
Kilo (k_)	**Hecto (h-)**	**Deca/Deka (da_)**	**Base Unit**	**Deci (d_)**	**Centi (c_)**	**Milli (m_)**
0.001 km	0.01 hm	0.1 dam	1 meter	10 dm	100 cm	1,000 mm
1,000 times **larger** than the base unit	100 times **larger** than base unit	10 times **larger** than base unit	Base unit	10 times **smaller** than base unit	100 times **smaller** than base unit	1,000 times **smaller** than base unit

When moving to the LEFT, move the decimal point to the LEFT

Example 1:
1.0 centimeter (cm) equals how many millimeters (mm)?

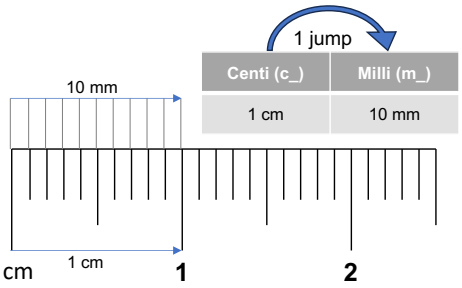


Figure 1: A centimeter ruler with millimeter markings

On a metric ruler, centimeters (cm) are indicated with whole numbers. The smaller lines between each centimeter represent millimeters (mm). One way observe this is to count the number of small lines from the start of the ruler to 1.0 cm (**Figure 1**). You should count ten little lines. Another way to do this conversion is to look at the chart and see how many columns are between the two units. To move from centimeters (cm) to millimeters (mm) you need to move one column to the right. This will equal moving the decimal one place to the right: 1.0 cm = 10 mm **(Table 1).**

Example 2:
1.0 meter (m) equals how many millimeters (mm)?

Millimeter (mm) is three columns to the right of a meter (m). For every column that you count, move the decimal place in the same direction the same number of places. To convert meters to millimeters you move three columns to the right. To convert 1.0 meter (m) to millimeters (mm) you will move the decimal three places to the right. Each time you move the decimal, add a zero to the number. Thus, 1.0 m = 1,000 mm

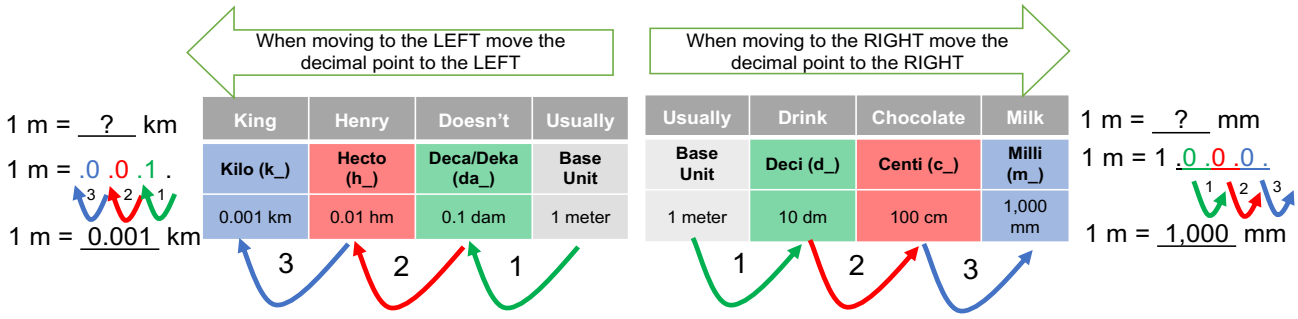


Figure 2: Conversion chart for metric units.

Example 3:
1.0 meter (m) equals how many kilometers (km)?

Consider the units in this example: for perspective, the length of the body is typically measured in meters (m) while the length between cities is measured in kilometers (km). Kilometers (km) are larger units than meters (m). Therefore, 1.0 meter (m) would be a fraction of a kilometer (km). The number of kilometers in one meter will therefore be a very small number.

Kilometers are three columns to the left of meters. You will therefore need to move the decimal point three places to the left. 1.0 meter (m) will thus equal 0.001 kilometers (km). The number got much smaller as you moved to the left on the chart, while the units got larger (**Figure 2**). Conversely, as you move to the right in the chart, the numbers will get bigger and the units will get smaller, such that 1.0 km = 1,000 m.

Example 4:
1.0 meter (m) equals how many micrometers (μm)?

How do you convert if the prefix is not between kilometers to millimeters? Easily! You can use the following chart and follow the rule that each prefix is based on the power of ten (**Table 2**).

A meter (m) is the base unit for length and is equal to 1.0×10^{0} which is one. Micrometers (μm) are 1.0×10^{-6}. The exponential power tells you how many places to move the decimal and the direction. Micrometers (μm) have a negative exponent and are much smaller than meters (m) and therefore you need to move the decimal to the right six places. (1.0 m = 1,000,000 μm)

Table 2: Conversion chart between metric units.

Metric Unit	Abbreviation	Description	Decimal	Scientific Notation
Meter	m	Base unit of length	1.0 m	1.0×10^{0}
Decimeter	dm	One-tenth of a meter	0.1 m	1.0×10^{-1}
Centimeter	cm	One-hundredth of a meter	0.01 m	1.0×10^{-2}
Millimeter	mm	One-thousandth of a meter	0.001 m	1.0×10^{-3}
Micrometer	μm	One-millionth of a meter	0.000001 m	1.0×10^{-6}

Example 5:
1.0 micrometer (μm) equals how many millimeters (mm)?

Micrometer (μm) is 1.0×10^{-6}, which means that you will move the decimal six places to the right from meters (m). Millimeter (mm) is 1.0×10^{-3}, which means that you will move the decimal three places to the right from meters. To calculate how many places to go from micrometer to millimeter, simply subtract the exponential numbers: 6 - 3 = 3. Since you are moving from micrometers to millimeters the number will get smaller because millimeters is a larger unit. You will need to move the decimal three places to the left. (1.0 μm = 0.001 mm)

Activity 1: Metric units for length

Background:
When learning about different species, range of length is frequently given to help properly identify a species. The following activity will describe the metric units for length and how to convert between smaller and larger metric units.

Procedure: (Work individually)

1. Practice converting metric units by filling out the chart below. Use the number in bold as your starting measurement. Fill out each row based on the bolded number. (Refer to **Table 1** for help.)

kilometer (km)	hectometer (hm)	decameter (dam)	meter (m)	decimeter (dm)	centimeter (cm)	millimeter (mm)
1 km						
						12 mm
			25 m			
	176 hm					

2. Have your instructor check and initial when you have completed the work.

Instructor's initials: _____

3. Measure the different parts of your body using metric units and practice converting:
    a. Length of your palm of your hand _____ cm = _____ (meter) m
    b. Width of your pointer finger _____ cm = _____ mm
    c. Width of your wrist _____ cm = _____ km
    d. Length of your shoe _____ cm = _____ μm
4. Look at the three colored pipe cleaners. Which one do you think is 10 cm? (Do not measure, just estimate for now.)
    a. Color of pipe cleaner that you think is 10 cm _____
5. Measure the 3 lengths of pipe cleaners in cm. Make sure to include the units.
    a. Green pipe cleaner _____
    b. Red pipe cleaner _____
    c. Blue pipe cleaner _____

6. Were you correct in your guess? If not, how could you have used some of the measurements of your hand to help you guess?

Activity 2: Measuring and estimating volume, mass, and temperature

Background:
Just as you practiced understanding the units for length (meters), now you will practice using the units for mass (grams) and volume (liters). We will also determine the range of temperatures in degrees Celsius (°C).

Procedure: (Work in pairs)

1. Use the scale to weigh one penny in grams and record the weight including the units. _____

2. How much do you think three pennies will weigh knowing what the one penny weighed? _____

3. Now weigh three pennies and record their mass in grams (g) _____

   Was your guess correct? _____

4. Fill a 250 mL beaker with 150 mL of water from the sink. This will be the water you use for the rest of the lab.

5. Measure 10 mL of water with a 25 mL graduated cylinder. Notice as you fill the cylinder the water looks curved at the surface. This is called the **meniscus** and is due to surface tension and adhesion of water molecules to the sides of the cylinder. Refer to the **Figure 3** on the right. When measuring liquids in a cylinder always get eye level with the meniscus and read the volume at the lowest level of the curve.

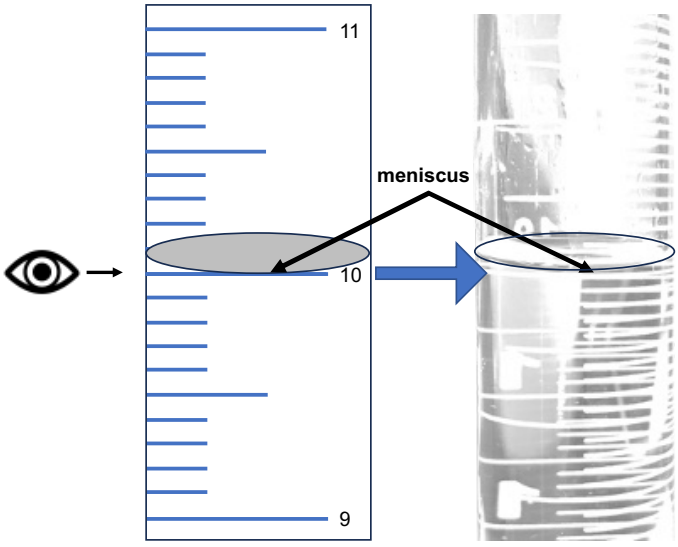


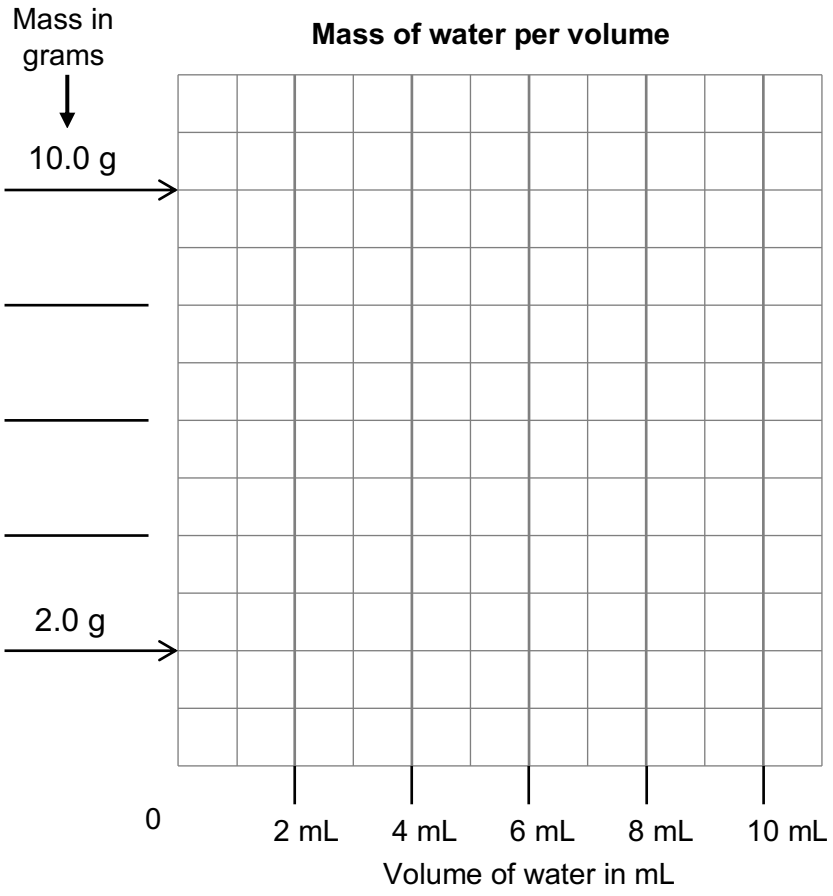
Figure 3: Visualization of the meniscus.

6. Place a weigh boat on the scale and press the "Zero" button. This is called "taring" the scale. Now fill the weigh boat with the 10 ml of water and record the weight in grams (g). _____

7. Dump the water out of the weigh boat back into the water beaker. Place the empty weigh boat on the scale and tare the scale. Use the 2 mL volumetric pipet with a regulator to remove 2 mL of water from the beaker of water. **Remember to not fill the pipet all the way to the top.** Place the water into the weigh boat and weigh the 2 mL of water on the scale. Continue to weigh increments of 2 mL until you reach 10 mL in the weigh boat. Record the measurements in grams (g) in the table below.

Volume of water (mL)	Mass of water (g)
2 mL	
4 mL	
6 mL	
8 mL	
10 mL	

8. Label the y-axis with equal intervals of possible masses of water starting at 0.0 g.
9. Now graph your results. Remember to **use a ruler** to draw a line that best incorporates all the points.
10. Do you see a pattern?



11. Erlenmeyer flask and beakers are **not** accurate for measuring liquids.
    a. Measure 10 mL of water in the 25 ml Erlenmeyer flask. Pour the water into the tared empty weigh boat and weigh the 10 mL of water. After recording the weight of the water, pour it back into the water beaker.

Mass of water from the Erlenmeyer flask _____.

    b. Measure 10 mL of water in the 50 mL beaker. Pour the water into the tared empty weigh boat and weigh the 10 mL of water. After recording the weight of the water, pour it back into the water beaker.

    c. Mass of water from the beaker _____.

    d. How close were these weights to your answer in question 6 above?

12. Practice estimating weight in proper metric units by looking at the three unknown bottles of sand. Put the three bottles in order of lightest to heaviest. Don't weigh them just yet but pick them up and feel how heavy they are.

    a. Order of bottles. (lightest first) _____

    b. How much do you think Bottle A weighs? _____

13. Weigh each of the bottles and record your measurements. (Don't forget units and to tare the scale before each new measurement.)

    a. Bottle A _____

    b. Bottle B _____

    c. Bottle C _____

14. Record the temperature of the following in degrees of Celsius (°C).

    a. Room temperature _____

    b. Boiling water temperature _____

    c. Water bath set to body temperature _____

    d. Ice bath temperature _____

15. Water should boil at 100°C and freeze at 0°C. How did your results in question 14 compare to the expected? If there was a difference, can you think of a reason why?

Activity 3: Putting it all together

Background:
Time to practice your newfound skills and see if you are ready to go out on an expedition to discover a new species!

Procedure: (Work in pairs)

1. Look at the sample of an unknown marine animal.
2. Record the following measurements of your unknown marine animal to the best of your ability and use the correct units.
    a. Length:_____
    b. Width:_____
    c. Weight:_____
3. Use complete sentences to describe this animal. You must include the three different measurements from question 2. Pick one additional measurement to include in your description.

4. When done with all the activities in lab, make sure to clean up your lab space and return all supplies used to the tray as seen in the picture on your tray and counter.

5. Before leaving lab, check that you have completed all items in the "**Lab Checkout**" list on the next page. You must have your instructor sign that you have completed all items on the list before leaving lab.

Name: _____ **Date:** _____

Lab Checkout: When you finish the lab, please clean up your lab space and put away your materials neatly in the tray. Please get your instructor's initials to check-out of lab.

- ❑ Lab bench clean, washed, and dried
- ❑ Glassware washed, dried, and in tray
- ❑ Place the graduated cylinders on their side in the tray
- ❑ Place the pennies back into the weigh boats
- ❑ Trays neatly put away

Instructor initials:_____ **% Completion of activities:** _____