# Making Measurements Using the Metric System

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OBJECTIVES:

1. Be able to identify and use the following pieces of laboratory equipment:
    a. Beam balance
    b. Pipettes and pipetting devices
    c. Graduated cylinders
    d. Meter sticks and metric rulers
    e. Thermometer
    f. Beakers
2. Identify the basic **metric units** that are used to measure:
    a. Length – (meter stick)
    b. Mass – (triple or quadruple beam balance)
    c. Volume – (pipette, graduated cylinder, beaker)
    d. Temperature – (lab thermometer)
3. Identify the commonly used metric prefixes.
4. Be able to perform metric conversions.

LABORATORY EQUIPMENT:

Human Physiology laboratory exercises may require you to use unfamiliar equipment. This lab will introduce you to the beam balance, pipettes and pipetting devices, meter sticks and metric rulers, graduated cylinders, beakers and Celsius thermometers.

The beam balance is used to precisely and accurately measure mass (or weight). Your lab instructor may ask you to **find the mass** of a given object or to measure out a specific quantity of a chemical. Follow these instructions to practice using the balance:

- Our balances have four beams, each of which has a sliding metal band on it. These are called riders. Adjust all of the riders so that they are in the zero position at the left. Now look at the pointer on the right. Does it match up with the horizontal line? If it does, then the balance is zeroed and ready to use. If the pointer is above or below the line, the balance is not zeroed, and must be adjusted. Turn the adjustment screw in the appropriate direction to bring the pointer to the line. Now you are ready to find the mass of your object.

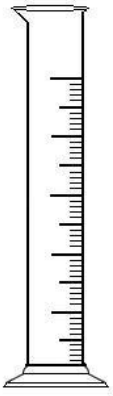
- If you are weighing a solid object, you may place it directly on the balance pan. If you are weighing a chemical, remember that chemicals are never placed directly onto the balance pan. Liquid chemicals should be placed in a

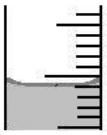
small flask or beaker, while solid chemicals should be placed in a plastic weigh boat.

- Look at the beam farthest from you. It measures masses between 0 and 400 grams, divided into 100-gram intervals. Start by moving the rider along that beam. Move it step by step to the right until the pointer drops below the horizontal line. Then move the rider one step to the left.
- Now move to the third beam. It measures masses between 0 and 100 grams, divided into 10-gram intervals. Slide the rider on that beam step by step to the right until the pointer drops. Move the rider one step to the left.
- Look at the second beam. It measures masses between 0 and 10 grams, divided into 1-gram intervals. Move that rider step by step to the right until the pointer drops. Move the rider one step to the left.
- Finally, move the rider on the closest beam step by step to the right until the pointer is even with the horizontal line. This beam measures masses between 0 and 1 gram, divided into intervals of tenths and hundredths of a gram.
- Add the masses indicated by the four riders to obtain the total mass. For example, 300 grams from the fourth beam + 40 grams from the third beam + 2 grams from the second beam + .58 grams from the first beam gives a total mass of 342.58 grams.

Pipettes are narrow, calibrated, hollow tubes with pointed tips. They are used for accurately and precisely measuring small volumes of liquids. Pipettes draw up liquid by suction, which may be provided by a device such as a pipette pump. You should NEVER pipette by mouth. Your instructor will give you instructions and have you practice using a pipette to measure specific volumes of water.

Graduated cylinders are also used to accurately and precisely measure volumes of liquid. They are calibrated glass (or plastic) cylinders. A liquid poured into a graduated cylinder will usually have a curve, or meniscus, at the top. Your instructor will give you instructions and have you practice using a graduated cylinder to measure specific volumes of water.



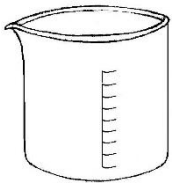


Meniscus

You are already familiar with using yardsticks and rulers to measure length in inches and yards. In the laboratory setting, you will use meter sticks, which are similar to yardsticks,

and metric rulers, which are marked in millimeters and centimeters instead of inches. Your instructor will have you **practice measuring the lengths** of specific objects.

The thermometers used in the laboratory probably look different from the ones you have used at home or at work. These are marked in degrees Celsius (°C) and can measure from 0 to 100 °C. Make sure that you are comfortable reading a Celsius thermometer.



Beakers are thin-walled glass vessels that have a lip for pouring. Although they have markings indicating volume on them, they should not be used for measuring volumes of liquid. They are neither accurate nor precise. Beakers are used for holding chemicals and/or mixing substances together.

THE METRIC SYSTEM:

If you grew up in a country other than the United States, you may already be comfortable using the metric system. If you were educated in the United States, you are probably used to measuring length in inches, yards, and miles; volume in cups, pints, and quarts; weight in ounces and pounds; and temperature in degrees Fahrenheit. In the laboratory, the metric system is used for all measurements. The metric system is based on established standards and uses the decimal system. In the metric system, the basic units are as follows:

Length – meter (m)
Volume – liter (l)
Mass – gram (g)
Temperature – degree Celsius (°C)

The meter may not be a convenient unit for measuring the distance between Rhode Island and Florida, or for measuring the height of a letter on this page. To form larger and smaller units, we add prefixes, or short names that precede metric units. A kilometer is 1000x larger than a meter, so it is useful in measuring long distances. A millimeter is 1000x smaller than a meter, so it is useful in measuring small quantities.

PREFIXES THAT ARE LARGER THAN THE BASIC UNIT

| Prefix | Abbreviation | Meaning | Numeric Equivalence |
|---|---|---|---|
| Kilo- | k | thousand | 1000 or $10^3$ |
| Hecto- | h | hundred | 100 or $10^2$ |
| Deca- | da | ten | 10 or $10^1$ |

PREFIXES THAT ARE SMALLER THAN THE BASIC UNIT

| Prefix | Abbreviation | Meaning | Numeric Equivalence |
|---|---|---|---|
| Deci- | d | tenth | 0.1 or $10^{-1}$ |
| Centi- | c | hundredth | 0.01 or $10^{-2}$ |

| | | | |
|---|---|---|---|
| Milli- | m | thousandth | 0.001 or ($10^{-3}$) |
| Micro | μ | millionth | 0.000001 or($10^{-6}$) |

A hectometer is 100 times larger than a meter, or 1 hectometer is equal to 100 meters. A centimeter is one hundredth of a meter, or there are 100 centimeters in 1 meter. You will need to be comfortable working with the various prefixes and converting one unit to another. Here is a mnemonic, or memory device, that might help you remember the prefixes:

| King | Hector | Died | by | Drinking | Chocolate | Milk | . | . | Maybe |
|---|---|---|---|---|---|---|---|---|---|
| Kilo- | Hecto- | Deca- | Basic unit | Deci- | Centi- | Milli- | | | Micro- |
| | | | meter liter gram | | | | | | |

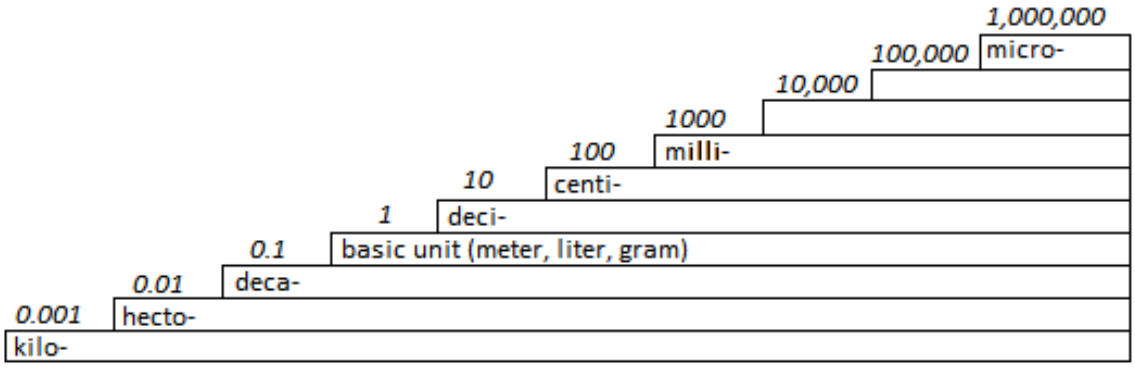
**In the spaces above express how many kilometers one meter equals, then how many hectometers on meter equals, and so on to how many micrometers there are in one meter**.

King Hector Died by Drinking Chocolate Milk . . Maybe.

(Note that there are two periods, each representing a decimal place, between "milk" and "maybe.")

To convert meters to kilometers, you need to move 3 columns to the left, dividing by 10 with each column. If we start with 3m, that would be 3m ÷ 10 ÷ 10 ÷ 10 = 0.003km. This is the same as moving the decimal point one place to the left with each column. To convert meters to millimeters, you need to move 3 columns to the right, multiplying by 10 each time. So, 3m x 10 x 10 x 10 = 3,000mm. This is the same as moving the decimal point one place to the right with each column.

Here is another way of looking at metric conversions. As you ascend the staircase, the units are getting progressively smaller – by a factor of 10 for each step. Therefore, your number gets larger, by a factor of ten, with each step.




Here are a few more metric facts that you should be comfortable with. One milliliter occupies the same volume as one cubic centimeter: 1 ml = 1 $cm^3$ or cc. When you work with the spectrophotometer, you will encounter an additional metric prefix: nano. Nano means billionth and is equivalent to $10^{-9}$ or 0.000000001. Wavelengths of light are measured in nanometers (nm).

Try the following metric conversions. **Please show your work.**

253 liters (3 sig figs) = _____ milliliters

0.05 liters (1 sig figs) = _____ kiloliters

53 milliliters (2 sig figs) = _____ microliters

53 milliliters (2 sig figs) = _____cubic centimeters

250 centimeters (2 sig figs)= _____ millimeters

60 decaliters (1 sig fig) = _____ liters

15 milligrams (2 sig figs) = _____ grams

43 kilograms (2 sig figs) = _____ grams

4 hectometers (1 sig fig) = _____ meters

5 grams (1 sig fig) = _____ mg

The metric system uses degrees to measure temperature, but degrees are based on the Celsius scale, not the Fahrenheit scale. The Celsius scale sets the freezing point of pure water at exactly 0 degrees, and the boiling point of pure water at sea level at exactly 100 degrees, so each degree in the Celsius scale represents a larger temperature change than a Fahrenheit degree does. You can use the following formulas to convert between the Celsius and Fahrenheit scales.

If you know the Fahrenheit temperature, use this formula:

$$^{o}C = (^{o}F - 32\ ^{o}F)\ (1\ ^{o}C / 1.8\ ^{o}F)$$

If you know the Celsius temperature, use this formula:

°F = [(X°C x (1.8°F/1°C)) + 32°F],

When you are using formulas like these, the order in which you perform the calculations is of utmost importance. You must follow the established order of operations. If you do not remember the order of operations, check the last chapter in this manual. The final chapter contains a review of all of the basic math that you will use in this physiology lab.

Complete the following table by determining the Celsius values for room temperature and normal body temperature. **Please show all your work and express the answers to the correct number of significant figures.**

| | Fahrenheit | Celsius |
|---|---|---|
| freezing point of water | 32 $^{0}$F | 0$^{o}$C |
| boiling point of water | 212 $^{o}$F | 100$^{o}$C |
| room temperature | 70$^{o}$F | |
| normal body temperature | 98.6$^{o}$F | |