The metric system

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Scientific data are always reported using metric system units of measurement. There are four basic metric measurement units:

- Length = meter (m)
- Volume = liter (L)
- Mass (weight) = gram (g)
- Temperature = ° Celsius (° C)

All four metric system basic units can be converted into larger or smaller "derived" units by simply by adding a prefix in front of the basic unit:

Derived unit prefixes:

- kilo (k) = Makes the basic unit 1000 times larger (10^3)
- deci (d) = Makes the basic unit 10 time smaller (10^{-1} or 1/10)
- centi (c) = Makes the basic unit 100 times smaller (10^{-2} or 1/100)
- milli (m) = Makes the basic unit 1000 times smaller (10^{-3} or 1/1000)
- micro (μ) = Makes the basic unit a million times smaller (10^{-6} or 1/1,000,000)

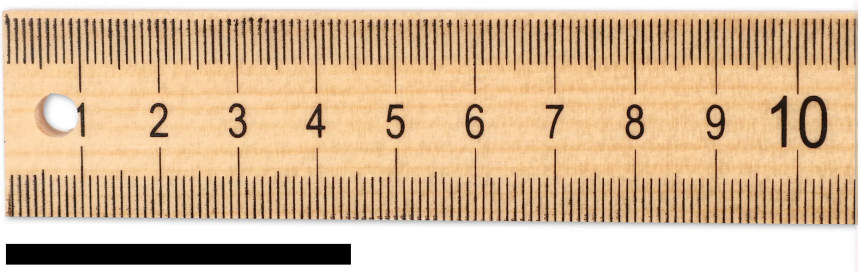
As an example, a person might weigh 63,000 grams. That same person also weighs 63 kilograms (kg) since each kilogram is equal to 1000 grams.

The major goals for this laboratory activity are that you (a) become familiar with the basic and derived metric units, (b) learn to mathematically convert between basic and derived metric units, and (c) learn to estimate the metric measurements of everyday objects.

A) Length

The basic unit of length in the metric system is the meter (m). A common derived unit for measuring small distances is the centimeter (cm). Each cm is 0.01 or 1/100 of a meter. Another derived unit for measuring small distances is the millimeter (mm), which is 0.001 or 1/1000 of a meter. For measuring large distances, the kilometer (km) (1000 meters) is often used.

Obtain a wooden meter stick (1 meter in length) and inspect its markings. The picture below shows one end of the meter stick.



The numbered graduations are centimeters. There are 100 centimeters total in the meter stick. The unnumbered tiny graduations on the meter stick are millimeters. There are 1000 millimeters in the meter stick. As an example of using these units, the black line above is 44 mm, 4.4 cm, and 0.044 m.

Spend a few minutes looking at the meter stick and its markings to memorize how big a meter, a centimeter, and a millimeter are. After you have memorized those length units, then estimate the sizes of the objects below. After you have recorded each estimate, measure the object and see how accurate your estimate was.

Object:	Estimate:	Measurement:
Width of door (left to right)	_____ m	_____ m
Width of chalkboard (left to right)	_____ m	_____ m
Length of a dollar bill	_____ cm	_____ cm
Width of your pen	_____ mm	_____ mm
Edge of a dime	_____ mm	_____ mm

Which of your fingernails is closest to 1 cm in width? _____ _____

B) Volume

The basic unit of volume in the metric system is the liter (L). The most common derived unit is the milliliter (mL) (0.001 or 1/1000 of a liter). The volume of a milliliter is equal to the volume of a cube 1 centimeter per side. (this is why the mL is often called the cubic centimeter (cc) in the medical field). Another derived volume unit is the microliter (μL) (0.000001 or 1/1,000,000 of a liter).

Obtain a 2 liter bottle and a 1 mL plastic cube. Fill the 2 liter bottle half way (to the black line). The volume of water in the half filled bottle is 1 liter.

Spend a few minutes looking at the liter of water and the milliliter cube to memorize how big a liter and a milliliter are. After you have memorized those volume units, then estimate the volumes of the objects on the next page. After you have recorded each estimate, measure the object's volume and see how accurate your estimate was.

How do you measure the actual volumes of the objects you have estimated?

- To measure the volume of a liquid, pour the liquid into a graduated cylinder, which is a cylinder with measurement marks called "graduations". In a graduated cylinder, the top of the liquid forms a slight curve, called a "meniscus". The volume of the liquid is the graduation closest to the bottom of the meniscus

- The volume of solid objects (like rocks, for example) can be measured using "Archimede's principle". This means measuring how much water the object displaces upward in a graduated cylinder. To measure the volume of a solid object using this method, first partially fill a graduated cylinder with water. Record the volume of water. Next, submerge the object completely under the water. The increase in the water's volume is equal to the object's volume.

Now estimate the volumes of the liquids and solid objects listed on the next page. After you have recorded each estimate, measure the volume and see how accurate your estimate was.

Object:	Estimate:	Measurement:
Water in the container on front desk (use large graduated cylinder to measure; refill the bottle when done)	_____ L	_____ L
Water in full coffee mug (use large graduated cylinder to measure)	_____ mL	_____ mL
Water in toothpaste cap (use small graduated cylinder to measure)	_____ mL	_____ mL
Smaller rock (use a large graduated cylinder and Archimedes principle to measure)	_____ cc	_____ cc
Larger rock (use a plastic 1 liter beaker and Archimedes principle to measure)	_____ mL	_____ mL

C) Mass (weight)

The basic unit of mass in the metric system is the gram (g). The most common derived unit is the milligram (mg) (0.001 or 1/1000 of a gram). For measuring large masses, the kilogram (kg) (1000 grams) is often used.

Obtain the same half-filled 2 liter bottle (containing 1 liter of water) and the same plastic cube that you used in section B of this handout. The mass of the cube is 1 gram. The mass of water in the half filled bottle is 1 kilogram. This is because **1 liter of water weighs 1 kilogram**. This is the same as saying **water weighs 1 gram per milliliter**.

Spend a few minutes holding the 1 kilogram of water and the 1 gram plastic cube to memorize how heavy 1 kilogram and 1 gram are. After you have memorized those mass units, then estimate the masses of the objects on the next page. After you have recorded each estimate, measure the object's mass and see how accurate your estimate was.

Masses are measured by using a scale (sometimes called a "balance"). Before you weigh anything on a scale, first place a container on the scale to hold the object. Next, press the tare button (labeled O/T on our scale) to reset the scale to zero grams. The scale may take a moment to zero itself.

(Be sure that the number zero has a “g” for grams after it). Lastly, place the object into the container on the scale. The scale will now show the object's weight in grams.

Estimate the masses of the objects below. After you have recorded each estimate, measure the object and see how accurate your estimate was.

Object:	Estimate:	Measurement:
Nickel	_____ g	_____ g
Penny	_____ g	_____ g
Paperclip	_____ g	_____ g
Butter knife	_____ g	_____ g
Smaller rock	_____ g	_____ g
Larger rock	_____ kg*	_____ kg*

*The scale weighs objects in grams. You will need to convert grams to kilograms for your answer to the large rock question).

Water in the container on front desk	_____ kg	_____ kg

(Don't use the scale. Instead, convert the volume of the container's water (that you measured in section (B)) from liters into kilograms. To do this conversion remember that 1 liter of water weighs 1 kilogram).

Your weight (kg)	_____ kg	_____ kg

(Don't use the scale. Instead, ask your instructor for a conversion factor from pounds to kilograms).

Density

If the mass of an object and the volume of the object are both known, the density of the object can be calculated. The formula for density is simply the object's mass (in grams) divided by its volume (in mL). In other words...

$$\text{Density of an object} = \frac{\text{grams}}{\text{milliliters}}$$

For example, a gold nugget that weighs 76 grams and that has a volume of 4 milliliters. The density of the gold is therefore:

(76 grams) / (4 milliliters) = 19 grams per milliliter

You have already measured the mass and the volume of the small and the large rocks. Using those measurements that you have already made, calculate the density of each rock.

Smaller rock = _____ g/mL

Larger rock = _____ g/mL

Would the density of these rocks be different if you had used a larger piece of the same rocks? _____

What is the density of water? _____ g/mL (hint: Re-read page 4).

D) Temperature

The basic unit of temperature in the metric system is the degree Celsius. (° C). There are no commonly derived units.

Here are some common temperatures in degrees Celsius.

- Ice water and the freezing point of water are 0 ° C
- Room temperature and tap water are about 20 ° C
- Normal body temperature is 37 ° C
- Water gets too painful to touch between 50 – 60 ° C
- Water boils at 100 ° C

Spend a few minutes looking at the temperatures listed above to memorize degrees Celsius. After you have memorized those temperatures then estimate the temperatures of the water in the four water baths on the back countertop by placing your finger in each bath for a few seconds. After you have recorded each estimate, measure the water's temperature using a thermometer to see how accurate your estimate was. **Don't look at the thermometers until after you have made your estimates.**

Waterbath:	Estimate:	Measurement:
Water in bath A	_____ ° C	_____ ° C
Water in bath B	_____ ° C	_____ ° C
Water in bath C	_____ ° C	_____ ° C
Water in bath D	_____ ° C	_____ ° C

E) Metric conversions

Convert the following values into the new units.

8 meters = _____ mm

22.1 ml = _____ l

10,900 cm = _____ m

0.0034 mg = _____ g

0.0087 l = _____ μl

660 g = _____ mg

789 cc = _____ l

0.490 l = _____ dl

0.98 kg = _____ mg

57 mm = _____ cm

3.2 dl = _____ ml.

349 ml = _____ μl

0.00003 m = _____ mm

4590 μl = _____ ml

How many grams does 73 ml of pure water weigh?

What is the volume of 0.23 kg of pure water?

Pure gold has a density of 19 g/ml. If you bought a "gold" ring and found it had a volume of 0.3 ml and that it weighed 5.7 grams, is it real gold?

Metric system "landmarks"

On quizzes and exams you may be asked to make metric estimations of objects, such as you did in sections A - D of this handout. Here are some metric system values of common objects. Keep these metric system "landmarks" in mind when you make metric system estimations:

Lengths:
• A standard door is about 1 meter wide and 2 meters tall.
• Your pinkie fingernail is about 1 centimeter wide
• The edge of a dime is about 1 millimeter wide

Volumes:
• A half-filled 2-liter soft drink bottle is 1 liter volume
• A coffee mug holds about 300 milliliters volume (about 1/3 of a liter)
• The cap of a toothpaste tube holds about 1 milliliter volume

Mass:
• A paperclip weighs about 1 gram
• A nickel weighs about 5 grams
• A butter knife (the non-sharp knives in your kitchen drawer) weighs about 100 grams
• A half-filled 2-liter soft drink bottle weighs about 1 kilogram
• An average sized adult weighs about 70 kilograms

Temperature:
• Ice water has a temperature of about 0 degrees C (freezing temperature)
• Room temperature is about 20 degrees C
• Body temperature is about 37 degrees C
• Boiling water is 100 degrees C