Metric System & Scientific Method

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Brief Historical Intro

The first standardized system of measurement, based on the decimal was proposed in France about 1670. However, it was not until 1791 that such a system was developed.

Designed during the French Revolution of the 1790's, the metric system brought order out of the conflicting and confusing traditional systems of weights and measures then being used in Europe. Prior to the introduction of the metric system, it was common for units of length, land area, and weight to vary, not just from one country to another but from one region to another within the same country. As the modern nations were gradually assembled from smaller kingdoms and principalities, confusion simply multiplied. Merchants, scientists, and educated people throughout Europe realized that a uniform system was needed, but it was only in the climate of a complete political upheaval that such a radical change could actually be considered.

It was called the "metric" system, based on the French word for measure. The driving force was the growing importance of weights in the sciences, especially chemistry. At that time, every country had their own system of weights and measures. England had three different systems just within its own borders!!

The Earth itself was selected as the measuring stick. The meter was defined to be one ten-millionth of the distance from the Equator to the North Pole. The liter was to be the volume of one cubic decimeter, and the kilogram was to be the weight of a liter of pure water. It didn't turn out quite like this, because the scientific methods of the time were not quite up to the task of measuring these quantities precisely, but the actual metric units come very close to the design.

Around 1850 a strong movement began among scientists, engineers, and business people in favor of a international system of weights and measures. The scientific and technical revolution was well underway and a global economy was developing. The need for uniformity in measurement was becoming obvious. Furthermore, the metric system was the only real choice available. The only possible competitor, the British Imperial system, was so closely tied to the British Empire it was not even acceptable to the Americans, let alone to non-English speakers.

Between 1850 and 1900 the metric system made rapid progress. It was adopted throughout continental Europe, in Latin America, and in many countries elsewhere. It became firmly established as a key part of the language of science.

The Units

The modern metric system has been renamed *Systeme International d'Unites* (International System of Units) and is denoted by the letters SI.

There are three major parts to the metric system: the base units, the prefixes and units built up from the base units. Here is a list of the base units that you should learn.

Physical Quantity	Name of SI unit	Symbol for SI unit	Example
length	meter	m	1m = ~39inches Height of a typical door handle
mass	kilogram	kg	1kg = 2.2lbs 1L of water = 1 kg
volume	liter	L	1L = ~1Qt A large fast food soda
temperature	Celsius	C	Water freezes at 0C and boils at 100C

In the International System of Units — SI — each physical quantity — length, mass, volume, etc. — is represented by a specific SI unit. Larger and smaller multiples of that unit are made by adding SI prefixes.

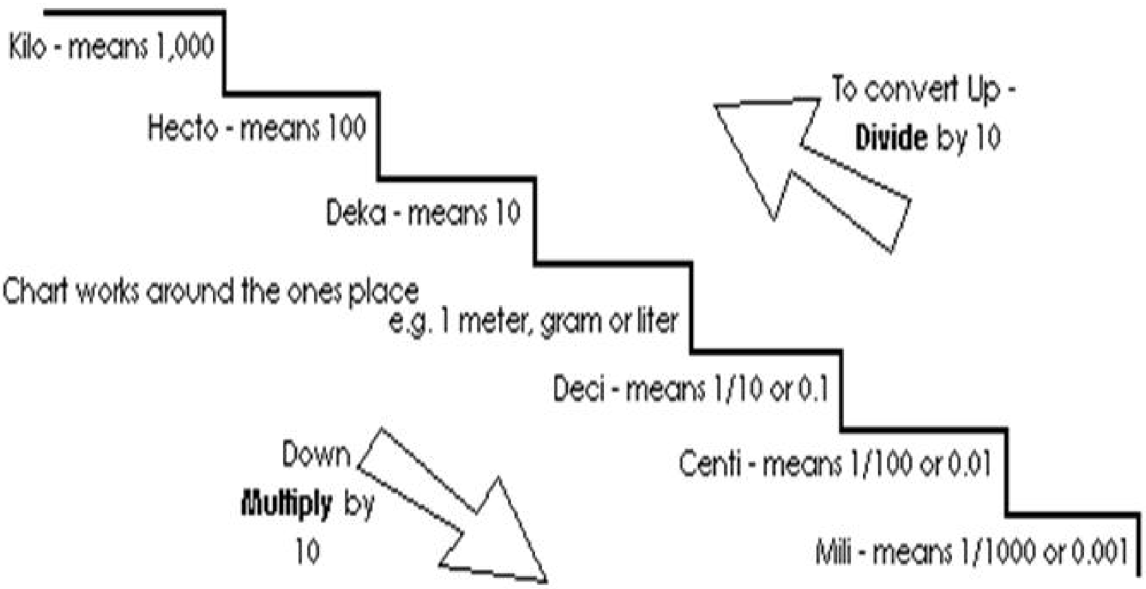
Commonly used metric system units and symbols

	Prefix	Symbol	Values		
Superunit	kilo	k	1000		10^3
	hecto	h	100		10^2
	deca	da	10		10
Unit	Meter	m			
	kilogram	kg			
	Liter	L			
Subunit	deci	d	0.1		10^{-1}
	centi	c	0.01		10^{-2}
	milli	m	0.001		10^{-3}
	micro	µ (u)*	0.000001		10^{-6}
	nano	n	.000000001		10^{-9}

Courtesy: US Metrics Association- http://lamar.colostate.edu/~hillger/common.html

Metric System Conversion Chart

This is the metric conversion stair chart. You basically take a place value chart turn it sideways and expand it so it looks like stairs. The Latin prefixes literally mean the number indicated. Meter, liter or gram can be used interchangeably.



You use this chart to convert metric measurements like this:

- **If you are measuring length use meter.**
- **If you are measuring dry weight use grams.**
- **If you are measuring liquid capacity use liter**

For every step upward on the chart you are dividing by 10 or moving the decimal one place to the left.

Pretend you are standing on the milli-gram step and to get to the 1-gram step you move up 3 steps dividing by 10 each time.

- move the decimal place one place to the left with each step

1000 milligrams = 1 gram.

When you move down the stairs you are multiplying by 10 for each step. So you are adding a zero to your original number and moving the decimal one place to the right with each step.

To convert 2 kilometers to meters you move 3 steps down on the chart so you add 3 zeros to the 2.

2 kilometers = 2000 meters

Complete the following:

36.87 g = ________ kg	2.38kg = ____________g	34.56kg = ______________g
36.97g = __________mg	2.38kg = ____________mg	34.56kg = ______________mg
1.7 cm = __________m	0.5cm = ____________mm	13.7m = ______________mm
24.68km = __________m	0.987m = ____________cm	124mm = _____________um
34.7cL = __________L	639mL = ___________uL	2.8L = ________________ul

Conversion Factors

From time to time, it may also be necessary to convert metric measurements into standard and visa versa. Here are the conversion factors.

1 kg = 2.2lbs

1g = 0.35oz

2.54 cm = 1 inch

1 km = 0.62 miles

1 liter = 1.06quarts

F = (C X 1.8) + 32

C = $\frac{F - 32}{1.8}$

12 in = 1 ft
3ft = 1 yd
5280ft = 1 mile

16oz = 1 lb
2000lb = 1 ton

8 oz = 1 cup
2 cup = 1 pint
2 pint = 1 quart
4 quart = 1 gallon

CONVERSIONS BETWEEN ANY TWO UNITS CAN BE ACCOMPLISHED QUITE EASILY USING THE FOLLOWING TECHNIQUE:

Units you have x (conversion factor) = units you want

Example:

You want to find out how many <u>centimeters</u> are in 7.0 <u>inches</u>.

Units you have = 7 inches
Units you want = ?? cm

STEP 1: you need a conversion factor for the <u>two units you're interested in,</u> centimeters and inches.

We know that 2.54cm = 1 inch

To use this information as a conversion factor, we have to re-write it to make it look a bit like a FRACTION

$$\frac{2.54\text{cm}}{1\text{ inch}} \quad \text{or} \quad \frac{1\text{ inch}}{2.54\text{cm}}$$

??? How do you know which units to put on top??

It depends on whether you're going from inches to cm or from cm to inches

STEP 2: Write out the problem as follows:

Always put the conversion factor so that the units on the top match the units you are trying to find out. To help you remember this rule, circle and draw an arrow to the units like below.

$$7.0\text{ inches} \times \frac{2.54\text{cm}}{1\text{ inch}} = \underline{\qquad\qquad}\text{ cm}$$

STEP 3: Perform the operation.

7 times 2.54 divided by 1 = 17.78cm

Complete the following:

36.87 lb = ________ kg

2.38kg = _____________lb

4.56oz = _______________g

36.97km = ________miles

34.56miles = _____________km

0.5cm = _____________inch

1.7 qt = __________L

13.7L = _______________qt

Conversions between Fahrenheit and Celsius temperatures are even simpler since the conversions are actually equations that you can plug your values into.

Recall that:

$$F = (C \times 1.8) + 32$$

$$C = \frac{F - 32}{1.8}$$

Example:
The boiling point of water is 100C = _________________ F

Put 100 in as the value for "C" and do the arithmetic as follows:

$$F = (100 \times 1.8) + 32 = 180 + 32 = 212F$$

Complete the following:

Average human body temperature is 98.6F = _____________C

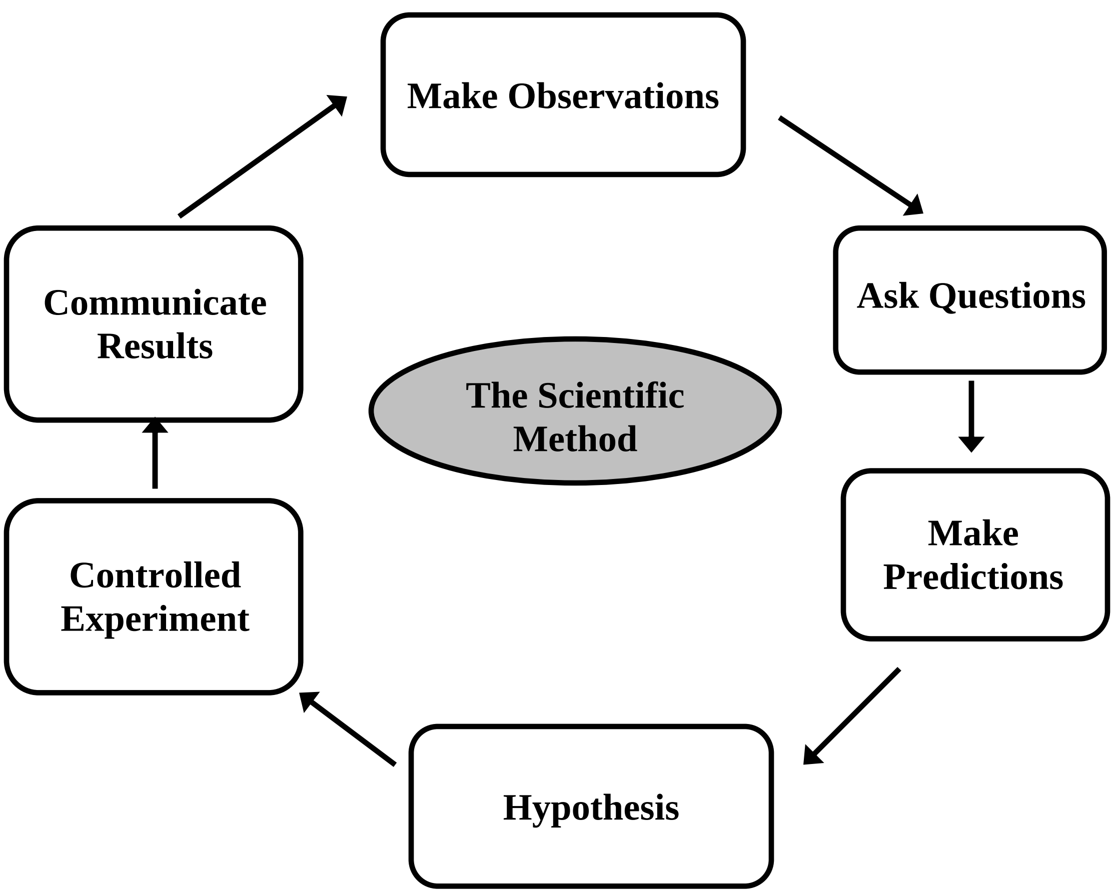
Typical room temp is 68F = ______________C

Freezing Point of water is 0C = ________________ F

The Scientific Method

The scientific method is a process by which researchers endeavor to answer questions and explain phenomena observed in nature. The process is somewhat circular in that the process gets repeated in order to find more and more complete explanations for observations and to find the relationships between all the parts of a system. The results of one experiment will often serve as the observations for another. Whether researchers are trying to discover how cancer tumors recruit new blood vessels or how arctic foxes find mates, they all apply the scientific method to their research.

The scientific process is applied to almost every research question from the simplest to the most complex. The steps are diagramed below. Study the diagram and be sure you know the steps in order.



MAKING OBSERVATIONS: The first step in the scientific process and perhaps the most critical. Learning to make detailed observations requires one to use all of the senses and to be alert to "obvious" characteristics of a subject. Good record keeping and good **measurement techniques** are also important. Observations also includes background research and observing the results of previous experiments. Since, *observation* and *measurement* are critical steps in the scientific process, there are some fields of study that do not lend themselves to "scientific" analysis. These include fields such as philosophy, sociology and literature in which the variables are measured subjectively. Also, fields in which one cannot see or measure the variables such as theology and astrology, cannot be studied scientifically.

ASKING QUESTIONS: Maybe, the most creative part of the scientific process. This is like a brainstorm at first. The idea is to "wonder". In other words, ask "why", "how" or "what if" questions.

MAKE PREDICTIONS: This part is where you make educated guesses about the answers to your questions.

WRITE HYPOTHESIS: This is really the first very formal part of a research project and often misunderstood. A hypothesis is a statement, not a question and **always ends with a period**. A hypothesis is a statement in which you describe a prediction in a way that it is testable.

CONDUCT A CONTROLLED EXPERIMENT: This is the fun part! Experimental design can be quite tricky to master. Scientists must design experiments that will test the hypothesis and answer the question posed without trying to answer too many questions at once. It is important to isolate the different parts of the system and investigate how each contributes without the input of the others. This requires identifying the variables and including controls.

The **variables** are the parts of the experiment that can change. For example, an experiment that tests whether the intensity of sunlight affects the rate of photosynthesis has two variables, the intensity of the sunlight and the amount of photosynthesis that occurs.

In experiments, one variable is called the **independent variable** and the others are called **dependant variables**. The independent variable is the one that the scientist controls and the dependant variables are the ones that the scientist measures. In the above example, the intensity of the sunlight is the independent variable. It is the variable the scientist will control and change by moving a grow light closer or further away from a plant. The dependant variable is the amount of photosynthesis that occurs. The scientist will measure it to see if the amount of photosynthesis changes when the light changes.

Controls are a very important part of any experiment. Scientists use controls to make sure that their results are not being affected by any other variables other than the independent variable (the one they are testing). In the experiment described here, one important control would be to make sure that the temperature of the plant does not change when the light changes. If the temperature changes, it might have an effect on photosynthesis and then the scientist wouldn't know whether it was the light or the heat that made the amount of photosynthesis change.

COMMUNICATE RESULTS: This is where researchers describe the experiment and its outcome to others. The report must include a description of the question, the observations that led to the question, some background information to familiarize the reader with the subject and the predictions of the researchers. The researchers must clearly state their hypothesis and describe what has led them to make their predictions. A thorough description of the experimental set-up is very important. It should be clear enough that anyone could reproduce the experiment by reading the report. Then the results must be reported in a clear and easy to understand format. Usually researchers use TABLES, GRAPHS and CHARTS to help others see the results more clearly.

Perhaps most importantly, the researchers then discuss what they think their results mean. In other words, did the experiment work? Was the hypothesis correct? Did anything go wrong that might have affected the experiment? If everything did go right and the hypothesis was correct, does it prove anything? If something went wrong, will you retry the experiment? In light of other information known about the subject, do your results make sense?

Complete the following:

1. List the steps of the scientific method in order (start with Observation)

2. Describe the independent and dependant variables.

3. What is an experimental control? Why is it important?

4. What fields of study are difficult or impossible to study scientifically? Why?