Weights & Measures (Metrology)

"*When you can measure what you are speaking about and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge of it is of a meager and unsatisfactory kind*." Lord Kelvin

>Measurements are made from observations, and all observations are made using our five senses.
-Our senses have limitations, and instruments have been invented and developed to expand our senses. [ex.'s; telescope, microscope, weighing scales, stethoscope, etc.]

A **measurement** is the process of making an observation more precise by providing a numerical value for whatever is being observed. It is an objective procedure of comparing an unknown value with a known "standard" relationship.
A measurement compares an unknown quantity with a known standard quantity.

A **standard** is an exact quantity people agree to use for comparisons. Standards are what measurements are compared to. [ex.'s; meter, foot, gram, pound, second, hour, mile]

* Measurements contain a number and a unit. [ex; 3.2 seconds]

What properties of the environment are measured?

>There are seven basic types of measurements ("base quantities"), all of which provide an interconnected and logical framework for measurements in science, industry, and commerce. They are as follows;

1) length (m) 2) mass (kg) 3) time (s) 4) temperature (K) 5) electric current (A) 6) luminousity (cd) 7) amount of substance (mol)

-The first 3 are known as the "**three fundamental units of measurement**" *or* "**basic dimensional quantities**," and all measurements contain at least one those three fundamental units directly or indirectly.

"**derived units**" ("derived quantities") are units obtained by combining two or more of the fundamental units.

ex.'s; speed = $^{\text{length}}/_{\text{time}}$ (m/s) volume = l x w x h (cm^3)

What "standard" units should be used?

>The earliest organized measuring systems were developed by the ancient Babylonians, Egyptians, and Sumerians around 3,000 B.C.E. parts of the body were used as measuring instruments and standards.
-Lengths were compared to the forearm, hand, finger, and foot.
-Time was referenced to the periods of motion of celestial bodies.
-Volume (capacity) was referenced to containers (clay or gourds).

>Separate measurement systems for specific uses were invented for various trades and occupations. With the rise and increase of international trade, countries needed to establish a system of measurement acceptable to all nations, but the lack of standardization between various systems prevented any single system from acceptance until the last two centuries.

"*What are the advantages and disadvantages of the two unit systems in use today?*"

Imperial ("customary")	Metric ("international") *Gk*. "metron" = a measure
>Values often derived from the anatomy of "ruling" people (and some foods). Original "standard" is gone! **>Uses "common fractions." ("vulgar fractions")** *Ltn*. "fractus" = broken numerator / denominator *or* dividend / divisor *Which is larger, and by how much?* $^3/_8$ *or* $^{11}/_{32}$ ----> (0.375 *vs*. 0.344) **>No "common multiplier."** Too many numbers to memorize. *ex*; 12 inches = 1 foot & 3 feet = 1 yard 5,280 feet = 1 mile & 16 ounces = 1 pound 128 fl. ounces = 1 gallon	**>Values derived from nature.** They are based on an unchanging entity....the earth! The meter is one ten-millionth of the distance from the equator to the poles (*quadrant*). [Eq. to pole is actually 10,001,887 m Close!] **>Uses "decimal" fractions.** *Ltn*. "decem" = 10 **>Uses 10 as the "common multiplier."** Since the decimal system is based on the unit of ten, we can benefit from the use of "exponetials" or "powers of ten." ex; 10^4 = 10,000 & 10^{-2} = 0.01 **>Uses SI "prefixes."** ex.'s; "syn" from *Gk*. = together mega-bucks, xero-graphy or prefix = "dry" & suffix = "writing," When we measure objects larger or smaller than 1.0, just add a prefix to the dimensional quantity. (ex's; centi-meter, milli-second, kilo-gram, milli-liter other examples: mega-phone, gigantic)

What are the "standard" units used in both systems?

	Imperial	**Metric**
length	foot (ft)	meter (m)
mass	*pound (lb)	kilogram (kg)
time	second (s)	second (s)
	foot-pound-second (**fps**)	*meter-kilogram-second* (**mks**)

* The "slug" is technically the proper unit for mass, whereas the pound (lb)[1] is a unit of force and *not* mass.
"Slug" is olde English, meaning "to slog" *or* "to hit." [1.0 slug = 14.6 kg & 1.0 kg = 0.0685 slug]

[1] The symbol for pound (lb) comes from the astrology sign of "Libra" the scales.

note! One can use the other metric unit system (cgs) when measuring in both centimeters and grams. It is more commonly used in the laboratory.

Never mix Imperial and Metric or MKS and CGS units! Convert first!

- Units are capitalized if derived from a proper name. [ex.'s; Newton, Kelvin, Ampere]
- In 1960 the General Conference of Weights and Measures recognizes the **MKS** units as the preferred system to use and adoptes the seven "base quantities." It is named the **SI** system.
  SI -----> Le **Systeme International** d'Unites

The aim of the metric system is to interrelate the units for the quantities; length, capacity, and mass.

- The metric unit for mass measured in kilograms, is related to the meter unit of length. A volume of 1.00 L (0.1 dm^3) of distilled water at 4˚C (at sea-level) has a mass of 1.00 kg.

Therefore, the kilogram unit of mass is derived from the meter and a physical property of pure water. The kilogram is used instead of the gram as the standard unit of mass because our sense of touch is not sensitive with small masses such as one gram. ["gram" *Gk*. = "gramma" ----> small weight]

*As 2005 the only non-metric countries are; 1) U.S.A. 2) Liberia 3) Myanmar (Burma)

*Current U.S. acceptance of metric units; 1) cameras (mm) 2) fluid sales (1 L & 2 L) 3) engine size (2.5 & 4.0 L)

*Imperial units used in our language; 1) "footage" for filming 2) "mileage" for fuel efficiency 3) "milestones" for accolades

How do we express measurements using proper "scientific notation?"

> Instead of writing out lengthy numbers, we can use a shorthand style called "**scientific notation**" or "**standard notation**" consisting of a coefficient, base, and exponent ex; [$1.4 \times 10^3 = 1{,}400$]

note! The coefficient should not be expressed as a value equal to or greater than the value ten (10.0).

*When very small or large numbers are involved in a measurement, the number is sometimes expressed as an "**order of magnitude**" rather than a more exact number.
An "order of magnitude" is the power of ten that is the closest approximation to the measured number, and one "order of magnitude" = 10 times larger or smaller.
ex; The closest star to the earth is 4×10^{13} km away. The order of magnitude closest to that value is 10^{13}.

"**significant figures**" (digits): A digit which is known to be reasonably trustworthy, and indicates the degree of accuracy that was made using an instrument.

ex: 2.16 = 3 significant digits

* The most significant digit in a number is the left-most significant one while the least significant digit is the right-most significant one.

How many digits can be read from the instrument?

-Never report a value more accurate than the instrument is capable of providing!

-No calculation should be made that is more accurate than the data recorded!

-Do not retain more than one estimated digit! ----> which is of course questionable

rounding off: A calculation cannot have more significant figures than the number of digits in the least significant figure used in the calculation.

ex; 2.41 x 2.225 = 5.36*(225)*

What if last digit to be dropped is a (5)? ----> Look to the number prior to it.

*If it is an odd number, then the (5) is rounded up. [ex: 4.775 = 4.78]

*If it is an even number, then the (5) is rounded down. [ex: 4.765 = 4.76]

multiplying & division:

ex; 2.2 x 0.36 x 3.12 = 2.47104 ----> 2.5 (because 2.2 has two significant figures)

ex; $^{2.5}/_{0.450}$ = 5.5555 ----> 5.6 (because 2.5 has two significant digits)

ex; $^{3.6}/_{4.2}$ = 0.85714 ----> 0.86

rule for zero's

1. All non-zero digits are significant.
2. Zero's used solely for spacing the decimal point are not significant. [0.12 = 2 significant digits]
3. All zeros which lie between two other significant digits are always significant. [4.509 = 4 significant digits]
4. Terminal zeros following the decimal point are always significant. [16.0 = 3 significant digits]
5. Zero's to the right of a non-zero digit are significant.

Errors in Measurements:

> All measurements have a limit of accuracy and are not exact. Therefore, a measurement should give an estimate of that error (or uncertainty).

> Since no observation is absolutely accurate, a conclusion should take into account errors in the experiment.

Classification of Errors:

- Errors that tend to make an observation high is called a "positive error," and one too low a "negative error."
- Two distinct kinds of error can enter into measurements;

random: Due to human error using an instrument, such as inaccurate estimation of distance between two fine lines, or the placement of equipment. [ex; slide meter stick across floor and mark wrong placement of the end of the stick, which adds up as one slides stick along floor.]

* Error is equally probable of being positive or negative.
* Errors from different measurements will give different values.

systematic: Due to imperfectly calibrated scale on instrument (flaw in equipment), or experimental procedure. However many times the experiment is done -----> error.