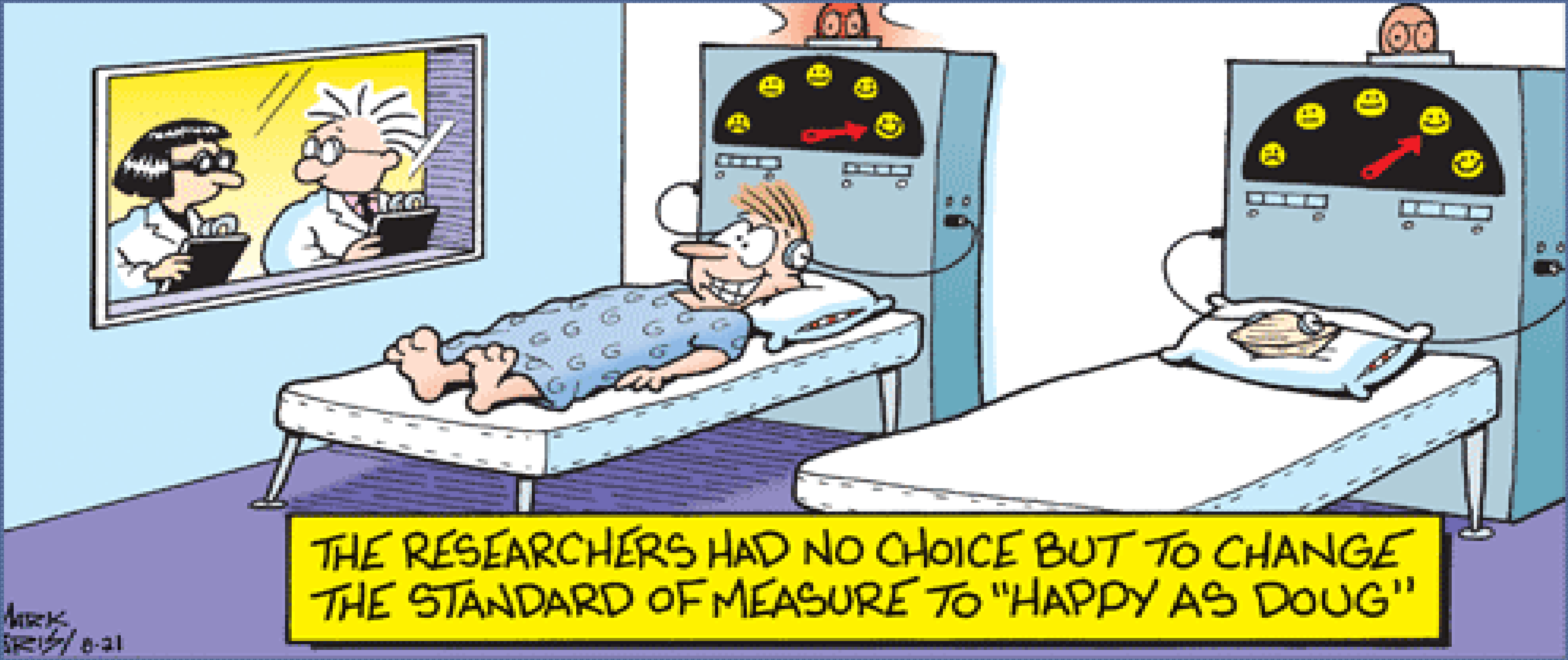
Measurement



Systems of Measurement

There are two major systems of measurement that are used in our everyday lives:

Metric

and

Imperial

[Systems of measurement intro video]

Imperial System of Measurement

- Based off of the old English units of measurement dating back to the 11th century.

- Most units of measure were based off of natural measurements
  - Ex. An inch used to be the width of an average man's thumb.

- Not used in science much since the units are based on standards that can change, and conversions between units are not so nice!

Imperial System of Measurement Con't.

Some of the Units used in the imperial system are:

Measurement	Examples of Units Used
Length/Distance	Inches, feet, yards, miles, fathoms, furlongs, nautical miles
Volume	Ounces, quarts, pints, gallons
Mass	Ounces, pounds, tons,
Temperature	Degrees Fahrenheit
Area	Acres

It is important to note that the American system is similar to the Imperial system, but some of the conversions are different.

http://www.youtube.com/watch?v=0iEYrWnyuJ0

The Metric System

- An internationally agreed upon set of units for measurement.
- Known as the SI system – Systemme International d'Units
- Started with the unit "meter" which comes from the Greek word "metron" meaning "measure".
- The original definition of the meter was "one ten-millionth of the distance from the north pole to the equator".
- Once the distance from the pole to the equator was calculated, a brass bar was cast to this length and used as the standard for the meter.

The Changing Meter

Over time this standard has changed (to increase the precision of the measurement), but the length has not:

Year	Definition of the meter
1793	1/10,000,000 of the distance from the pole to the equator
1795	Standard meter bar cast in Brass
1799	Standard meter bar cast in platinum
1889	Standard meter bar cast in platinum-iridium
1906	1,000,000/0.64384696 wavelengths of the red line of the cadmium spectrum
1960	1,650,763.73 wavelengths of radiation emitted during the transition between levels 2p10 and 5d5 of the krypton-86 atom.
1983	Length traveled by light in a vacuum during 1/299,792,458 of a second.

The Metric System Con't

- The metric system has only 7 units of measure called base units:

Type of Measure	Standard Unit	Symbol
length	meter	m
mass (weight)	kilogram	kg
temperature	degree Kelvin	K
time	second	s
electric current	ampere	A
amount of substance	mole	mol
luminous intensity	candela	cd

- The metric system takes these 7 base units and multiplies or divides them by factors of 10 to create new units.
- The new unit will have a prefix that tells you how it differs from the base unit

Prefixes Used in The Metric System:

Factors **ABOVE** the Base Unit

Multiplication Factor (Scientific Notation)	**Prefix**	**Symbol**
(10^{24})	yotta	Y
(10^{21})	zetta	Z
(10^{18})	exa	E
(10^{15})	peta	P
(10^{12})	tera	T
1 000 000 000 (10^{9})	giga	G
1 000 000 (10^{6})	mega	M
1000 (10^{3})	kilo	k
100 (10^{2})	hecto	h
10 (10^{1})	deka	da

Factors **BELOW** the Base Unit

Multiplication Factor (Scientific Notation)	**Prefix**	**Symbol**
0.1 (10^{-1})	deci	d
0.01 (10^{-2})	centi	c
0.001 (10^{-3})	milli	m
0.000 001 (10^{-6})	micro	μ
0.000 000 001 (10^{-9})	nano	n
(10^{-12})	pico	p
(10^{-15})	femto	f
(10^{-18})	atto	a
(10^{-21})	zepto	z
(10^{-24})	yocto	y

Unit Conversions

- Often in science, we need to convert between units. There are many different ways to do this.
- One way is called "Dimensional Analysis" or "Factor Labelling"

  → A way to cancel units so you end up with the units you want.

A bit of math review…

Multiply the following fractions:

$$\frac{2}{3} \times \frac{5}{2} = \frac{10}{6} = \frac{5}{3}$$

$$\frac{\frac{2}{3}}{\frac{5}{2}}$$

$$\frac{2}{3} \times \frac{3}{1} = \frac{6}{3} = 2$$

→ You should notice how certain numbers get cancelled out!

Unit Conversions Con't

- We can use this method to cancel any units we don't want, and end up with units we need.
- To do this we need to set up the proper ratios. It should look like this:

$$\text{Starting Units} \times \frac{\text{Desired Units}}{\text{Starting Units}} = \text{Desired Units}$$

Examples:

1. A car is travelling 60 km/hr. How far will it go in 2 hours?

$$2\,\text{hr} \times \frac{60\ \text{km}}{1\ \text{hr}} = 120\ \text{km}$$

2. How many seconds are there in 55 min?

$$55\,\text{min} \times \frac{60\ \text{sec}}{1\ \text{min}} = 3300\ \text{sec}$$

Unit Conversions Con't

- Sometimes we need to multiply by more than one ratio to get the units we want. You can do this using linking units:

$$\text{Starting Units} \times \frac{\text{Linking Units}}{\text{Starting Units}} \times \frac{\text{Desired Units}}{\text{Linking Units}} = \text{Desired Units}$$

Examples:

1. How many seconds are there in 3.7 hours?

$$3.7\ \text{hr} \times \frac{60\ \text{min}}{1\ \text{hr}} \times \frac{60\ \text{s}}{1\ \text{min}} = 13\,320\ \text{s}$$

2. Convert 100 km/hr to m/s.

$$\frac{100\ \text{km}}{1\ \text{hr}} \times \frac{1000\ \text{m}}{1\ \text{km}} \times \frac{1\ \text{hr}}{60\ \text{min}} \times \frac{1\ \text{min}}{60\ \text{s}} = 27.8\ \frac{\text{m}}{\text{s}}$$

3. Convert 15.2 nm to cm

$$15.2\ \text{nm} \times \frac{10^{-9}\ \text{m}}{1\ \text{nm}} \times \frac{1\ \text{cm}}{10^{-2}\ \text{m}} = 1.52 \times 10^{-6}\ \text{cm}$$

Unit Conversions Practice Questions…

Convert the following:

1. How many centimeters are in 6.00 inches? (1 in = 2.54 cm)

   15.24 cm

2. If it takes 2.5 minutes to complete a task, what is that same length of time in seconds?

   150 s

3. Express 24.0 cm in inches.

   9.45 in

4. If a container of water absorbs 3.4 cal of heat, what is the amount of energy absorbed (in joules)? (4.184 J = 1 cal)

   14.23 J

5. How many seconds are in 2.0 years?

   63,072,000 s

Metric Conversions

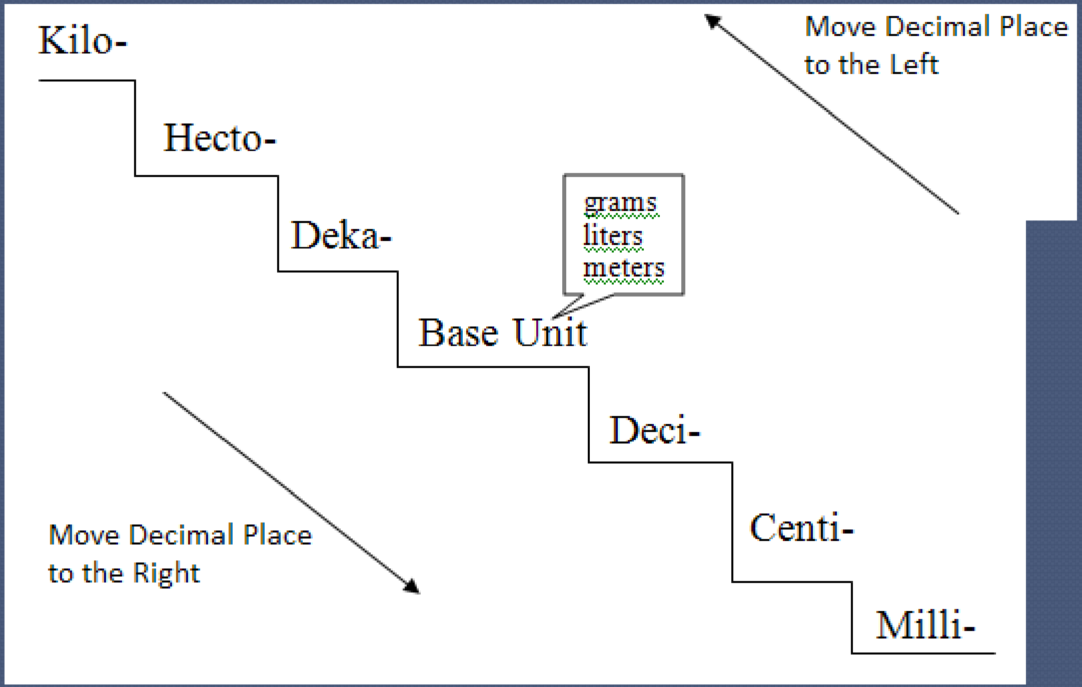
- Since the metric system deals with only factors of 10, there are some shortcuts that we can use to convert metric units.
- The most common metric prefixes that we will use are in the table below:

Factor	Prefix	Symbol
10^3	kilo-	k
10^{-1}	deci-	d
10^{-2}	centi-	c
10^{-3}	milli-	m
10^{-6}	micro-	μ
10^{-9}	nano-	n
10^{-12}	pico-	p

- Because everything is related by tens, we can simply move the decimal place to get from one unit to another.
- We will use the "stair method" to show this…

Metric Conversions

- We can set up a staircase that shows how the prefixes are related to one another:



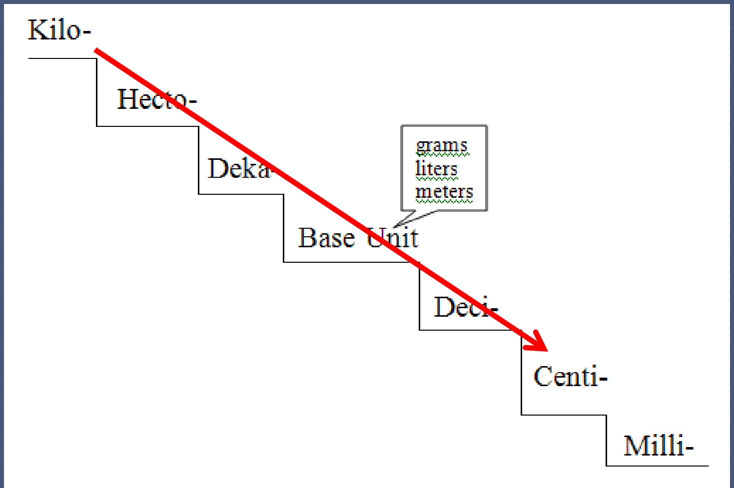
- Look at the prefix you have and count how many steps you need to get to the prefix you want.
- Then move the decimal that many steps and in the same direction to convert the number to the new unit.

[Example]

Metric Conversions

<u>Example:</u>

0.52 km to cm



- starting at Kilo it is 5 steps to the right to get to centi
- move the decimal 5 places to the right

Therefore: 0.52 km = 52000 cm

Metric Conversions

- We can also use the difference between the exponents for the prefixes to do our conversions…

<u>Example:</u>
Convert 52 μL to mL

→ 1μL = 10^{-6} L AND 1mL = 10^{-3} L

- The difference between the exponents is 3, so we need to move the decimal 3 places.
- Since the unit is getting bigger, we will need less of them

→ so our number should get smaller

Therefore: 52 μL = 0.052mL

Metric Conversions Practice Questions…

Convert the following:

1. 500 mL to L

   10^{-3} 10^{0} 0.500 L

2. 1600 m to km

   10^{0} 10^{3} 1.6 km

3. 5.5 cm to hm

   10^{-2} 10^{2} 0.00055 hm

4. 14 km to dam

   10^{3} 10^{1} 1400 dam

5. 1.5 kg to μg

   10^{3} 10^{-6} 1,500000,000 μg

   9 →

Significant Figures

Significant Figures

- When we are reporting measurements, it is important to be honest about the accuracy of our measurements.
  →if you weigh something on a scale that reads to 1 decimal place, you shouldn't state your measurement to three decimal places.
- This can also become an issue when using measurements to perform calculations.
  → Depending on how you round your answer, you will be saying something about the accuracy of the equipment used.

Significant Figures Con't…

Example:

You want to find the density of a liquid. You measured the mass on a balance and the volume in a graduated cylinder:

Mass = 15.52g Volume = 7.5 mL

The measurements suggest that the balance is accurate to 2 decimal places, and the cylinder is accurate to 1 decimal place.

I f you calculate the density (mass/volume), you get:

$$\text{Density} = 2.069\overline{3}\ \text{g/mL}$$

Your answer can only be as accurate as your LEAST accurate measurement (which would be to one decimal place), so this is where significant figures come in.

Determining the Number of Sig Figs

- Most measurements are comprised of digits that are known, and one digit that is estimated (the last digit).

- A buret will read to 1 decimal place (0.1), but if the measurement is between two of the graduations, your eye can approximate the next decimal place

  Example:
  You measure the volume of a liquid in a pipette to be 2.34 mL

  →The "2" and "3"" are KNOWN digits – read from the scale
  → The "4" is an ESTIMATED digit – read by your eye

  In this measurement, **all 3 digits are significant**!

Determining the Number of Sig Figs

- As we improve the sensitivity of the equipment used to make a measurement, the number of significant figures increases:

Postage Scale	3 ±1 g	→ 1 significant figure
Two-pan balance	2.53 ±0.01 g	→ 3 significant figures
Analytical balance	2.531 ±0.001 g	→ 4 significant figures

- When taking measurements, we must ensure that we are using the most accurate and precise equipment possible.

Rules for Counting Sig Figs:

1. **All non-zero digits are significant.**
   ex) 1245 → has 4 sig figs

2. **Zeros <u>WITHIN</u> a number are always significant.**
   ex) 4308 and 40.05 → both have 4 sig figs

3. **Zeros <u>BEFORE</u> a non-zero digit (leading zeros) are NOT significant.**
   ex) 0.003 → has 1 sig fig

4. **Trailing zeros after the decimal point are significant.**
   ex) 4.00 → has 3 sig figs

5. **Trailing zeros before the decimal point are significant only if the decimal point is shown.**
   ex) 1200. → has 4 sig figs
   1200 → has only 2 sig figs

Adding and Subtracting with Sig Figs:

When adding or subtracting measurements with different degrees of accuracy and precision, *the accuracy of the final answer can be no greater than the least accurate measurement.*

This principle can be translated into a simple rule for addition and subtraction:

For adding or subtracting, the answer cannot have more decimal places than the least accurate measurement.

150.0 g H_2O	→ one decimal place
+ 0.507 g salt	→ three decimal places
150.5 g solution	

→ Our least accurate measurement is accurate to one decimal place, so our answer can only go to one decimal place.

Multiplying and Dividing with Sig Figs:

The same principle governs the use of significant figures in multiplication and division:

→ the final result can be no more accurate than the least accurate measurement.

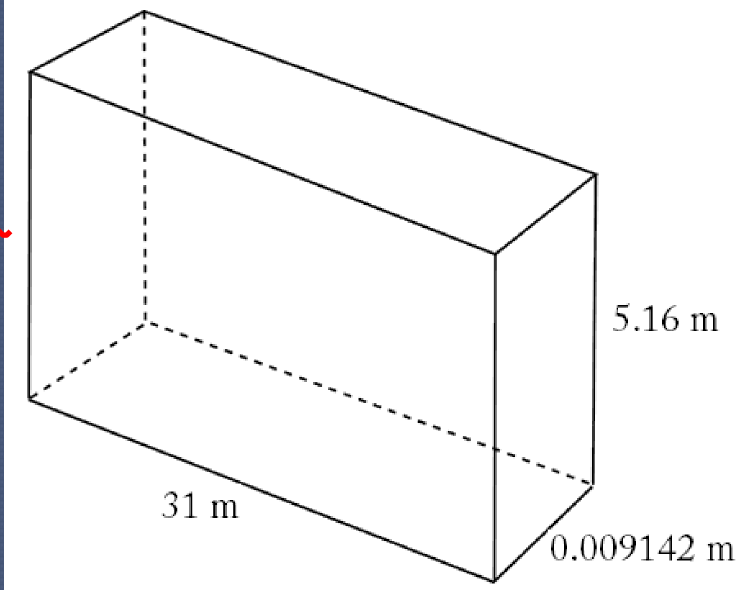
In this case, however, we count the significant figures in each measurement - not the number of decimal places:

When measurements are multiplied or divided, the answer can contain no more significant figures than the least accurate measurement.

Multiplying and Dividing with Sig Figs:

Example:

Find the volume of the cube to the right:



$V = l \times w \times h$

$V = (31m)(5.16m)(0.009142m)$

2 sig figs | 3 sig figs | 4 sig figs

1.4623 5432

$V = 1.462\ m^3$

→ but our answer must not have any more than 2 sig figs, so…

$V\ = 1.5\ m^3$ → **2 sig figs, and accurate to $0.1m^3$**