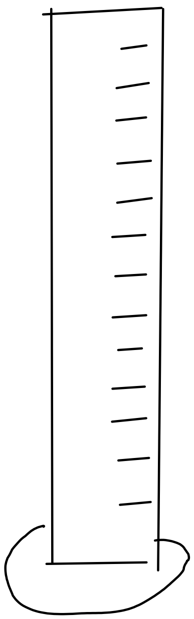
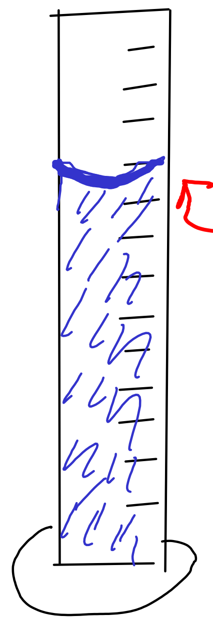
Measuring density

... of a liquid



1) Measure mass of empty cylinder

mass = 97.35 g



2) Fill cylinder and measure volume of liquid

volume = 25.3 mL

3) Measure mass of filled cylinder

mass = 130.55 g

4) Subtract to find mass of liquid

$$\begin{array}{r} 130.55\text{ g} \\ -\quad 97.35\text{ g} \\ \hline 33.20\text{ g} \end{array}$$

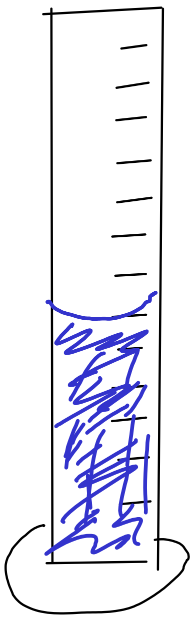
5) Density = mass liquid / volume liquid

$$\text{Density} = \frac{33.20\text{ g}}{25.3\text{ mL}} = \boxed{1.31\ \text{g/mL}}$$

...of an object

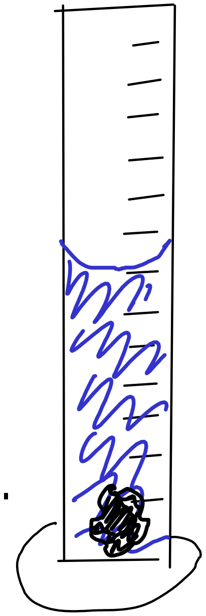
1) Measure mass of object

mass = 9.78 g



2) Partially fill cylinder with liquid, record volume.

volume = 25.0 mL



3) Put object into cylinder, record new volume

volume = 26.6 mL

4) Subtract to find volume of object

$$\begin{array}{r} 26.6 \text{ mL} \\ -\ 25.0 \text{ mL} \\ \hline 1.6 \text{ mL} \end{array}$$

5) Density = mass object / volume object

$$\text{Density} = \frac{9.78 \text{ g}}{1.6 \text{ mL}}$$

$$\boxed{= 6.1 \text{ g/mL}}$$

Converting from one unit to another

We will use the method of dimensional analysis, sometimes called the factor-label method.
... or, the "drag and drop" method!

Dimensional analysis uses conversion factors to change between one unit and another

What's a conversion factor? A simple equality.

Example

$$\boxed{12 \text{ in} = 1 \text{ ft}}$$

Conversion factors in metric

In the metric system, conversion factors between units may always be made from the metric prefixes!

For example, "kilo-" means 10^3

$$k = 10^3$$

so

$$kg = 10^3 g$$

$$km = 10^3 m$$

$$kL = 10^3 L$$

$$ks = 10^3 s$$

Just apply the prefix to the base unit!

How do we actually USE a conversion factor?

Convert 15.75 m to cm

$cm = 10^{-2} m$

$$15.75\ \cancel{m} \times \frac{cm}{10^{-2}\ \cancel{m}} = \boxed{1575\ cm}$$

* Similar to...

If X = 2, then

$$\frac{X}{2} = 1$$

15.75 / EE −2 .. on TI-83

* This fraction equals one, so multiplying by it does not change the VALUE of the number, only its UNITS!

Convert 0.01893 kg to g

$Kg = 10^{3} g$

$$0.01893\ \cancel{Kg} \times \frac{10^{3} g}{\cancel{Kg}} = \boxed{18.93\ g}$$

DRAG AND DROP

- Drag the part of the factor that contains the unit you want to get rid of (cancel out) to the BOTTOM.

- Then, drag the other half of the factor to the TOP

Convert 14500 mg to kg $\quad mg = 10^{-3} g \quad Kg = 10^{3} g$

$$14500\,m\cancel{g} \times \frac{10^{-3}\,\cancel{g}}{m\cancel{g}} \times \frac{Kg}{10^{3}\,\cancel{g}} = \boxed{0.0145\,Kg}$$

Tip: When constructing a metric conversion factor, always use units that don't have their own exponents (meters instead of square meters, etc.)

Convert 0.147 cm^2 to m^2 $\quad cm = 10^{-2} m$

$$0.147\,c\cancel{m}^{\cancel{2}} \times \frac{10^{-2}\,m}{c\cancel{m}} \times \frac{10^{-2}\,m}{c\cancel{m}} = \boxed{1.47 \times 10^{-5}\,m^2}$$

When converting squared or cubed units, use each factor two (squared) or three (cubed) times to cancel out the starting units. Remember ...

$cm^2 = cm \times cm$ and $cm^3 = cm \times cm \times cm$

... and it should make sense.

8.45 kg to μg

$Kg = 10^3 g \qquad \mu g = 10^{-6} g$

$$8.45\,K\cancel{g} \times \frac{10^3\,\cancel{g}}{K\cancel{g}} \times \frac{\mu g}{10^{-6}\,\cancel{g}} = \boxed{8.45 \times 10^9\,\mu g}$$

88100 kHz to MHz

$\boxed{Hz = s^{-1}\ (\text{frequency})}$

$KHz = 10^3 Hz \qquad MHz = 10^6 Hz$

$$88100\,K\cancel{Hz} \times \frac{10^3\,\cancel{Hz}}{K\cancel{Hz}} \times \frac{MHz}{10^6\,\cancel{Hz}} = \boxed{88.1\,MHz}$$

Convert 38.47 in to m, assuming 2.54 cm = 1 in

$2.54\,cm = in \qquad cm = 10^{-2}\,m$

$$38.47\,\cancel{in} \times \frac{2.54\,\cancel{cm}}{\cancel{in}} \times \frac{10^{-2}\,m}{\cancel{cm}} = \boxed{0.9771\,m}$$

Convert 12.48 km to in

$2.54\,cm = in \qquad cm = 10^{-2}\,m \qquad Km = 10^{3}\,m$

$$12.48\,\cancel{Km} \times \frac{10^{3}\,\cancel{m}}{\cancel{Km}} \times \frac{\cancel{cm}}{10^{-2}\,\cancel{m}} \times \frac{in}{2.54\,\cancel{cm}} = \boxed{491300\,in}$$

Accuracy and Precision

- two related concepts that you must understand when working with measured numbers!

Accuracy

- how close a measured number is to the CORRECT (or "true") value of what you are measuring
- "Is it right?"
- checked by comparing measurements against a STANDARD (a substance or object with known properties)

Precision

- how close a SET of measured numbers are to EACH OTHER
- "Can I reproduce this?"
- checked by repeated measurements

More on precison

Every measurement contains some amount of ERROR, or some amount of deviation from the true value of what is being measured.

RANDOM ERROR is the variability in a measurement that cannot be traced back to a single cause. Random errors cause measurements to fluctuate around the true value, but can be averaged out given enough measurements.

When reporting measurements, we want to indicate how much random error we think is present. How?

We'll go to the lab and measure the mass of a metal ring using an ANALYTICAL BALANCE: