DENSITY

- Density is a measure of the concentration of matter; of how much matter is present in a given space

- Density is defined as the MASS per unit VOLUME, or ...

$$\text{Density} = \frac{\text{mass}}{\text{Volume}}$$

What are the metric units of DENSITY?

mass: kilogram (kg)

volume: cubic meter (m^3)

So, density unit = $\boxed{\dfrac{kg}{m^3}}$

We don't typically measure mass in the lab in kilograms, or volume in cubic meters. We use smaller units.

In the lab, we typically measure masses as grams and volumes as milliliters, so the density unit we will use most often is:

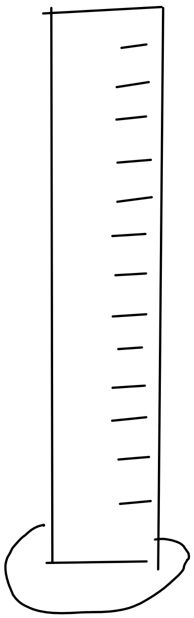
$$\boxed{\frac{g}{mL}}$$ same as $\frac{g}{cm^3}$

A useful density to remember:

$\boxed{\text{WATER at room temp: Density} = 1\ g/mL}$

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

$$\begin{array}{rl} 130.55 & \text{g} \\ -\ 97.35 & \text{g} \\ \hline 33.20 & \text{g} \end{array}$$

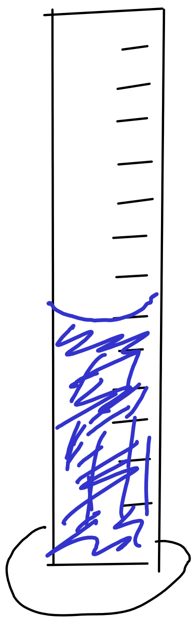
5) Density = mass liquid / volume liquid

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

...of an object

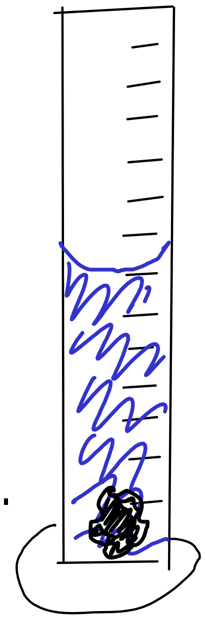
1) Measure mass of object

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

$$kg = 10^3 g$$

$$km = 10^3 m$$

$$ks = 10^3 s$$

$$kL = 10^3 L$$

Just apply the prefix to the base unit!

How do we actually USE a conversion factor?

$cm = 10^{-2} m$

DRAG AND DROP!

Convert 15.75 m to cm

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

Put what you want to cancel on the bottom, then ...

... put what it equals on the top!

Convert 0.01893 kg to g

$kg = 10^{3} g$

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

$mg = 10^{-3}g$ $\quad$ $kg = 10^{3}g$

Convert 14500 mg to kg

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

If you have TWO prefixes in your problem, you will apply TWO conversion factors in your solution!

Convert 0.147 mm to µm

micro-

$mm = 10^{-3}m$ $\quad$ $\mu m = 10^{-6}m$

$$0.147\,m\cancel{m} \times \frac{10^{-3}\cancel{m}}{m\cancel{m}} \times \frac{\mu m}{10^{-6}\cancel{m}} = \boxed{147\,\mu m}$$

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

2.54 cm = 1 in   cm = 10^{-2} m

$$38.47\ \cancel{in} \times \frac{2.54\ \cancel{cm}}{1\ \cancel{in}} \times \frac{10^{-2}\ m}{\cancel{cm}} = \boxed{0.9771\ m}$$

Convert 1.076 miles to inches

5280 ft = mi   12 in = ft

$$1.076\ \cancel{mi} \times \frac{5280\ \cancel{ft}}{\cancel{mi}} \times \frac{12\ in}{\cancel{ft}} = \boxed{68180\ in}$$

Even though English units are involved, we can solve this problem the same way we solved the previous problem where only metric units were used!

Even if you're unfamiliar with the metric units involved in a problem, you can still do conversions easily.

88100 kHz to MHz

kHz = 10^3 Hz   MHz = 10^6 Hz   Hz = $\frac{1}{s}$ (frequency)

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

0.004184 kJ to J

kJ = 10^3 J   J = energy

$$0.004184\ \cancel{kJ} \times \frac{10^3\ J}{\cancel{kJ}} = \boxed{4.184\ J}$$

Practical applications of dimensional analysis: Drug dosage

Example: A patient is ordered 40 mg of codeine phosphate by subcutaneous injection. 50 mg in 1 mL liquid is available. How much of this liquid should be adminstered?

This is a conversion factor. It equates the mass of drug to the volume of the solution containing the drug. We can use it the same way we wpuld use the other conversion factors we've worked with.

$$50 \text{ mg drug} = 1 \text{ mL}$$

$$40 \text{ mg drug} \times \frac{1 \text{ mL}}{50 \text{ mg drug}} = \boxed{0.8 \text{ mL}}$$

Mileage

A car (averaging 17.5 miles per gallon) is traveling 50 miles per hour. How many gallons of gas will be used on a trip that lasts 0.75 hours?

17.5 mi = gal   50 mi = hr

$$0.75\ \cancel{hr} \times \frac{50\ \cancel{mi}}{\cancel{hr}} \times \frac{gal}{17.5\ \cancel{mi}} = \boxed{2.1\ gal}$$

Accuracy and Precision

- two related concepts that you must understand wheh 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