Unit Equations:

A unit equation is exactly what it sounds like; an equation that gives a relationship between 2 or more units. For example, **1 foot = 12 inches** and **9.81 m = 1 s^2** are unit equations because they have an equal sign and 2 different units. While most of the unit equations that we will deal with in this class have only 2 units, it is important to note that there can be MORE than 2 units. One unit equation having 4 separate units, and one which we will be using this semester, is: **0.0821 atm•L = 1 mol•K** . Even though it has a bunch of different units, this is still going to act like any other unit equation. As stated above, these unit equations show the relationship between 2 more units and as such, they can be used to change one unit in the relationship to another one. The relationship **1 gallon = 4 quarts** can be used to convert back and forth between gallons and quarts. (NOTE: Some unit equations are always true, like 1 foot = 12 inches, which is true not matter what. Other unit equations are only true in certain situations, like 9.81 m = 1 s^2, which is only true on earth. We'll come back to this when we discuss sig figs of conversion factors.)

The metric system

Things get somewhat trickier when we start talking about unit equations based on the metric system, though the whole thing is laid out for us. The charts in both the book and that I handed out in lecture set up 10 different generic "unit equations". For example, the charts tell us that for kilo, **1 k = 1x10^3**. One problem with this is that there is only one unit, but we will let that go for now. If I want to talk about kilometers, I need to make the left side **1 km**, but remember that what I do to one side of an equation I must do to the other which means the other side must become **1x10^3 m**. This makes the unit equation **1 km = 1x10^3 m**. The same would be true if we wanted to talk about kiloliters. We take the generic "unit equation" **k = 1x10^3** and add liters to both giving **1 kL = 1x10^3 L**. Want to talk about microliters? Piece of cake! Take the generic "unit equation" for micro, **1 μ = 1x10^{-6}**, add seconds to both sides and viola! you have the unit equation **1 μs = 1x10^{-6} s**. This is how you work the metric system, you memorize the 10 generic "unit equations" from the tables, and then just add the unit you want to both sides! If you do this, you cannot make a mistake!

Practice: Please set up unit equations for each of the following metric relationships

a) Scoville (Sc) and kiloScoville (kSc)
b) mole (mol) and millimole (mmol)
c) megacalorie (Mcal) and calorie (cal)
d) farad (f) and picofarad (pf)
e) gigawatt (GW) and watt (W)
f) nanotesla (nT) and tesla (T)

Conversion Factors:

Once you are comfortable with unit equations, conversion factors are next. In fact the unit equations are the hard part! Once you have a unit equation down, it is as simple as putting the left side under the right side for the first one, and then the right side under the left side for the other. No tricks! You will always get two conversion factors from any unit equation. Going back to my example of a kilometer, the unit equation is **1 km = 1x10^3 m**. Moving the left side under the right side, we get $\frac{1\times10^3\,\mathbf{m}}{1\,\mathbf{km}}$ as the first conversion factor and moving the right side under the left side, we get $\frac{1\,\mathbf{km}}{1\times10^3\,\mathbf{m}}$ as the second conversion factor. We can then decide which conversion factor to use in our dimensional analysis. Another example I gave was **0.0821 atm•L = 1 mol•K** . To get the conversion factors from this, we go through the same process and we get $\frac{0.0821\ \mathbf{atm{\bullet}L}}{1\ \mathbf{mol{\bullet}K}}$ or $\frac{1\ \mathbf{mol{\bullet}K}}{0.0821\ \mathbf{atm{\bullet}L}}$.

Practice: Please give the 2 possible conversion factors for each of the following (the first 6 are from above)

a) Scoville (Sc) and kiloScoville (kSc)
b) mole (mol) and millimole (mmol)
c) megacalorie (Mcal) and calorie (cal)
d) farad (f) and picofarad (pf)
e) gigawatt (GW) and watt (W)
f) nanotesla (nT) and tesla (T)
g) 4.184 J = 1 g•1 °C (specific heat capacity of water)
h) 0.789 g = 1 mL (density of ethanol)
i) 1 mol•1 K = 8.314 J (one version of the gas constant)
j) 83 miles = 1 hour (the speed on my brother's ticket)

Sig Figs and Conversion Factors:

We know how to determine how many sig figs are in a number, but we need to clear up some stuff about conversion factors. First, recall that in general, the number "1" does NOT count towards sig figs; it is considered a counted number. So now, the final rule on sig figs. If all units in the conversion factor are 1) in the same system of measure, and 2) measure the same quality, then the conversion factor has infinite sig figs. If not, then count the number of sig figs in the conversion as you normally would. For example, **3 ft = 1 yard**. Both **feet** and **yard** are in the standard system and both measure distance. Therefore, the conversion factor $\frac{\mathbf{3\ ft}}{\mathbf{1\ yd}}$ infinite sig. figs. On your conversion sheet, you will see the unit equation **1 mL = 1 cm^3**. Both **mL** and **cm^3** are in the metric system and both measure volume. Because both conditions are met, the conversion $\frac{\mathbf{1\ mL}}{\mathbf{1\ cm^3}}$ also has infinite sig figs. Let's now look at two examples of when a conversion factor does NOT have infinite sig figs. For the metal iron, **7.87 g = 1 cm^3** at room temperature. This relationship between mass and volume is different for different materials and is called the density. Both **grams** and **cm^3** are in the metric system, but **grams** measures **mass** and **cm^3** measures **volume**. Because the two units do NOT measure the same quality, the conversion factor $\frac{\mathbf{7.87\ g}}{\mathbf{1\ cm^3}}$ does not have infinite sig figs, but rather has 3 sig figs. Another conversion is **1 stone = 6.350 kg**. **Stone** is a **standard** measure of mass and **kg** is a **metric** measure of mass, therefore the conversion $\frac{\mathbf{1\ stone}}{\mathbf{6.350\ kg}}$ would NOT have infinite sig figs (not the same system of measure) but would have 4 sig figs when used in a calculation.

Practice: For each of the following, state the system of measure for each unit, the quality measured by each unit, and then give the number of sig figs in the conversion factor.

a) 0.26420 L = 1 gal
b) 1 km = 1.09x10^3 yards
c) 1 L = 1x10^{-3} m^3
d) 0.3937 in = 1 cm
e) 5280 ft = 1 mile
f) 1 kg = 2.20 lb
g) 1x10^{-9} s = 1 ns
h) 1 hr = 60 min
i) 1 J = 0.2390 cal
j) 1 ML = 1x10^6 L

Using Conversion Factors:

Metric system:

Say I ask you to convert 0.00671 seconds (s) to milliseconds (ms). The first thing you need to do is decide which is the base unit and which is the prefixed unit. Hopefully, you knew that seconds are the base unit (no prefix) and milliseconds are the prefixed unit (milli is the prefix). Next, you need to write out the general "unit equation" for the prefix and then add the base unit.

General "unit equation" → **1 m = 1x10^{-3}**. Actual unit equation → **1ms = 1x10^{-3} s**.

(A way to check that you have the correct unit equation is to verify that there is a 1 in front of the prefix (**ms**) and a power of 10 in front of the base unit (**s**).) Now that you have the unit equations, you can write the two possible conversion factors:

$$\frac{1\ ms}{1\times10^{-3}\ s} \quad \textbf{or} \quad \frac{1\times10^{-3}\ s}{1\ ms}$$

Finally, decide which of the conversion factors to use so that units cancel out. We are starting with 0.00671 seconds, so we want seconds on the bottom to cancel.

$$0.00671\ \cancel{s} \times \frac{1\ ms}{1\times10^{-3}\ \cancel{s}} = 6.71\ ms$$

0.00671 has 3 sig figs. ms and s are both metric measures of time, so the conversion has infinite sig figs. Therefore, the answer as 3 sig figs.

Example: Convert 36.95 megawatts (MW) to watts (W)… (do we care what a watt is? NO!)

General "unit equation" → **1 M = 1x10^6**. Actual unit equation → **1MW = 1x10^6 W**.

$$\frac{1\ MW}{1\times10^{6}\ W} \quad \textbf{or} \quad \frac{1\times10^{6}\ W}{1\ MW} \quad \rightarrow \quad 36.95\ MW \times \frac{1\times10^{6}\ W}{1\ MW} = 3.695\times10^{7}\ W$$

Example: How many liters in 5.62×10^5 µL?

General "unit equation" → **1 µ = 1x10^{-6}**. Actual unit equation → **1 µL = 1x10^{-6} L**.

$$\frac{1\ \mu L}{1\times10^{-6}\ L} \ \textbf{or} \ \frac{1\times10^{-6}\ L}{1\ \mu L} \quad \rightarrow \quad 5.62\times10^{5}\ \mu L \times \frac{1\times10^{-6}\ L}{1\ \mu L} = 0.562\ L$$

Practice: Perform the following conversions (write out the generic "unit equations", unit equations, and both conversion factors for at least 6 of these):

a) 28.0 cm → m
b) 1000. m → km
c) 9.28 m → mm
d) 10.68 g →mg
e) 4.5 m → dm
f) 12 m → Mm
g) 23.6 kilojoules (kJ) to joules (J)
h) 1.6411×10^7 pg → g
i) 6.8×10^4 ng → g
j) 8.54 g → cg
k) 25.0 mL → L
l) 22.4 L → µL
m) 0.65 Gs → s
n) 5.5 kg → g
o) 0.468 TL → L
p) 9.0×10^5 µL → L

That's all fine and well, but what if you are asked to convert from one prefixed unit to another? It turns out it is essentially the same, but you need to make 2 steps instead of 1. WHEN CONVERTING BETWEEN TWO PREFIXED UNITS, ALWAYS CONVERT THE FIRST PREFIXED UNIT TO THE BASE UNIT AND THEN FROM THE BASE UNIT TO THE SECOND PREFIXED UNIT! Huh? Observe:

How many decigrams are in 739.22 centigrams?
First, write the conversion for centigrams to grams:

Generic unit equation → **1 c = 1x10^{-2}** unit equation → **1 cg = 1x10^{-2}g**

$$739.22\ cg \times \frac{1\times10^{-2}\ g}{1\ \ cg}$$

(notice that the 1 is still in front of the prefixed unit, good check!)

now write the conversion for the base unit to the second prefixed unit (dg) and answer:

generic unit equation → **1 d = 1x10^{-1}** unit equation → **1 dg = 1x10^{-1}g**

$$739.22\ cg \times \frac{1\times10^{-2}\ g}{1\ \ cg} \times \frac{1\ dg}{1\times10^{-1}\ g} = 73.922\ dg$$

(are sig figs correct? Why or why not?)

See? It is the same process, but with two steps instead of one. Just remember, ALWAYS convert to the base unit first!

Example: How many milliwatts (mW) are in 1.21 gigawatts (GW)? (again, don't worry about watts, I just wanted to say 1.21 gigawatts, and they are just units)

Generic unit equation → **1 G = 1x10^{9}** unit equation → **1 GW = 1x10^{9}W**
Generic unit equation → **1 m = 1x10^{-3}** unit equation → **1 mW = 1x10^{-3}W**

$$1.21\ GW \times \frac{1\times10^{9}\ W}{1\ \ GW} \times \frac{1\ mW}{1\times10^{-3}\ W} = 1.21\times10^{12}\ mW$$

Example: The Borh radius is 53 nanometers. What is that distance in cm?

$$53\ nm \times \frac{1\times10^{-9}\ m}{1\ \ nm} \times \frac{1\ cm}{1\times10^{-2}\ m} = 5.3\times10^{-6}\ cm$$

Okay, here are some for you to try (again, write out the generic "unit equations", unit equations, and both conversion factors for at least 6 of these):

1) 58216 microliters to dekaliters
2) 46.875 terabytes to kilobytes
3) How many femtoseconds in 22.16 milliseconds
4) If something has a mass of 3.78×10^{-2} megagrams, what is its mass in centigrams?
5) 650.89 Gm → pm
6) 249 cm → km
7) 45.14 dm → Mm
8) 570 kg → μg
9) 2383.7 Mg → mg
10) 39.46 μg → cg
11) 139.42 pL → nL
12) 5.23×10^{-4} TL → kL

Before I get much further in this "review", I want to remind you about conversions factors. A conversion fact is simply a way of changing from one unit to another. 1 in = 2.54 cm is a conversion factor because it allows you to convert from inches to centimeters or centimeters to inches. Densities can be thought of as conversion factors: 11.35 g per cm^3 is a conversion factor because it lets you convert from a volume (cm^3) to a mass (g) or vise versa. Anything with two or more units is just a conversion factor. You don't have to know what those units are or what they mean as long as the convert from one thing to another. Finally, I want to remind you that these conversion factors can be written in one of several ways:

2.54 cm = 1 in 2.54 cm per in $\frac{2.54\ cm}{1\ in}$ $2.54\ {}^{cm}\!/\!_{in}$

Each one of these is equivalent to the others and they are all the exact same conversion factor.

<u>Conversion between systems of measure</u>:
The main difference between this and the metric conversions is that you will not have to memorize these conversions; they will be given to you. (That should make it easier… maybe). So, how do you do this? Let's start off fairly easy and work our way up.

Example: How many liters in 43.125 gallons?

First thing you want to do on ANY conversion problem is write what you are given and what you are asked for. On a problem like this it may seem to be a waste of time, but as the problems get more complicated, it will be vital in order to keep track of what you are doing.

What is given? 43.125 gallons
What is asked for? Liters

Great, I know where to start, but where do I go from there? I need a conversion factor that will allow me to get from gallons to liters, so I look on my conversion sheet and see that 1 gal = 3.785 L. Looks good to me… I'll give it a try. Remember, that units only cancel if they are on opposite sides of the division bar.

$$43.125\ \boldsymbol{gal} \times \frac{3.785\ \boldsymbol{L}}{1\ \boldsymbol{gal}} = 163.228125\ \boldsymbol{L}$$

Cool, my answer ended up in L, which is exactly what I needed. Sig fig wise, L and gal both measure volume, but liters are metric and gallons are standard. This means that the conversion factor is NOT infinite and must be taken into account for sig figs. The starting value has 5 s.f. and the conversion has 4 s.f. so the answer must have 4 s.f. The final answer to this is **<u>163.2 L</u>**

If only all of the problems were that straight forward. So how do we deal with problems that are more complicated? In the last problem, we were able to find a direct conversion between gallons and liters. There will not always be a direct conversion, which is when we are really going to have to think.

Example: How many inches are in 0.018 m?

What is given? 0.018 m
What is asked for? inches

Since the 0.018 m is the only value given, we know that we must start there. So we go to our handy dandy conversion table and look for a conversion from meters to inches… and come up empty handed. What now? Now we need to use a little bit of intuition. We look at the conversion table a see that about the only conversion involving inches also involves cm. Can we work with that? Maybe, but in order to use that conversion, we must be in units of either inches or centimeters. We are starting in meters… what can be done? Hmmm, meter and centimeters… That is a metric conversion!! We can do that!

$$0.018\ m \times \frac{1\ cm}{1\times 10^{-2}\ m}$$

Now we are in centimeters and can use the cm to inch conversion!

$$0.018\ m \times \frac{1\ cm}{1\times 10^{-2}\ m} \times \frac{0.3937\ in}{1\ cm} = 0.70866\ in$$

I am in inches and that is what the question asked for! The starting value has 2 s.f., the first conversion has infinite s.f. (both are metric distances), and the second conversion has 4 s.f. (one is standard, one is metric) so the final answer of **0.71** in has 2 s.f.

Example: What is the volume in fluid ounce of a vat containing 0.02391 megaliters?

What is given? 0.023910 ML
What is asked for? fl. oz.

Again the only place to start is with 0.023910 ML, but again my conversion table has failed me; there is not a ML to fl. oz. conversion anywhere to be found. In fact, ML doesn't appear anywhere in my table, but I see fluid ounces in 2 places: 1 qt = 32 fl.oz. and 1 fl.oz. = 29.57 mL. Hmmm, ML and mL, I think I can do something about that! All I need to do is convert ML to mL, which is a prefix unit to prefix unit metric conversion! (remember, do this in 2 steps, 1st prefix to base, then base to 2nd prefix)

unit equation → **1 ML = 1x10^{6}L** unit equation → **1 mL = 1x10^{-3}L**

$$0.023910\ ML \times \frac{1\times 10^{6}\ L}{1\ ML} \times \frac{1\ mL}{1\times 10^{-3}\ L}$$

Now I am in mL and can use the 1 fl.oz. = 29.57 mL conversion

$$0.023910\ ML \times \frac{1\times 10^{6}\ L}{1\ ML} \times \frac{1\ mL}{1\times 10^{-3}\ L} \times \frac{1\ fl.oz.}{29.57\ mL} = 80858.97869\ fl.oz.$$

For sig figs, the starting value (which almost always counts for s.f.) has 5 s.f, the 1st and second conversions (each ahs two metric volumes) have infinite s.f., and the 3rd (metric and standard volumes) has 4 s.f. 4 is less than both 5 and infinity, so the answer, **8.086x10^{4} fl. oz.**, must have 4 s.f. (it must also be in scientific notation, why?)

These conversions are all about doing whatever it takes to get from one unit to another. Above, there was no meter to inch conversion, so we had to see what was available and sort of… build a bridge. This is what you need to practice. Some advice; the process is the same for every one of these so don't get wrapped up in each individual problem, but pay attention to overall thought process.

Practice: (use the "SI Units and Conversion Factors" table in your book, or the conversion table I gave you, to do these)

1) Convert 103 kg to ounces
2) What is the equivalent of 653 nm in angstroms?
3) How many liters are there in 6.375 pints
4) 0.75 tons is equal to how many kg?
5) How many atomic mass units (amu) are in 3.89266x10^{-17} pounds?
6) What is the distance in μm of 8.00 ft?
7) How many millimeters in a marathon (26.22 miles)
8) What is the volume in nL of 2.336 gallons?
9) Given that 1 mL = 0.789 g (for ethanol), convert 7.39x10^{7} m^{3} of ethanol to tons of ethanol

Percents:

Percent literally means "out of 100", so to say that something is 15 percent translates to "15 out of 100". A generic equation for percents looks like this: $\frac{\text{specific PART of a sample}}{\text{entire sample}} \times 100 = \%$. One of the hard parts about percentages is identifying what is the "part", and what makes up the "entire sample'. Here is an example: If 8.3% of the people in Sacramento are left-handed it means that 8.3 out of every 100 people are left-hand dominant. The specific part of the sample being discussed is left-handed people and the entire sample is the population of Sacramento. It takes some practice, but once you get the hang of identifying the part and the entire sample, percentages get much easier. Here are a couple more examples:

Example: Of the 29,011 students at CSUS in the Fall of 2009, 58.495% were female.

Specific part of the sample: female students
Entire sample: all 29,011 students at CSUS

Example: The letter "e" is the most common letter in the English language, accounting for roughly 12.479% of all letters in all the English words written in the world.

Specific part of the sample: The letter "e"
Entire sample: all letters written

Practice: Give it a try. I want you to try to identify the "part" and the "whole sample" in each of the following.
a) Selenium makes up 28.17% of the compound barium selenate.
b) Water is 11.2% hydrogen
c) A certain solution is 95% isopropyl alcohol
d) The other 5% of the above solution is water
e) Seawater is about 3.5% sodium chloride
f) Silicon makes up about 25.7% of the Earth's mass
g) The average human body is 2.9×10^{-4} % gold

Percents as conversion factors:

While there are times when you will have to use the equation given above when dealing with percentages, most of the time, you will be able to use them simply as conversion factors. Turning a percentage into a conversion factor is actually not all the tricky, and FAR easier than dealing with the metric system. If something is stated to 15%, then it is written as $\frac{15}{100}$. If something is 8.3%, then it is written as $\frac{8.3}{100}$. The trick comes with making sure that the units on the numbers is correct (remember, no naked numbers!) The units are always related to each other, so if the top units have something to do with grams, then the bottom units will also have something to do with grams. If the top units have to do with kL, then the bottom units will also have to do with kL. This is also where knowing the "part" and "whole" comes into play. For my example of left-handed people in Sacramento, it would look something like this: $\frac{\text{8.3 left handed people}}{\text{100 people}}$. Like any conversion factor, percentages can also be flipped upside down giving in this case: $\frac{\text{100 people}}{\text{8.3 left handed people}}$.

Example: Of the 29,011 students at CSUS in the Fall of 2009, 58.495% were female.

Conversion factors: $\frac{\text{58.495 females}}{\text{100 students}}$ or $\frac{\text{100 students}}{\text{58.495 females}}$

Example: The letter "e" is the most common letter in the English language, accounting for roughly 12.479% of all letters in all the English words written in the world.

Conversion factors: $\frac{\text{12.479 "e"s}}{\text{100 letters}}$ or $\frac{\text{100 letters}}{\text{12.479 "e"s}}$

Practice: Write the 2 possible conversion factors for each of the following. Be sure to include proper units.

a) Selenium makes up 28.17% of the compound barium selenate.
b) Water is 11.2% hydrogen
c) A certain solution is 95% isopropyl alcohol
d) The other 5% of the above solution is water
e) Seawater is about 3.5% sodium chloride
f) Silicon makes up about 25.7% of the Earth's mass
g) The average human body is $2.9\text{x}10^{-4}$ % gold

The nice thing here is that percentages, once turned into conversion factors, act exactly the same way as all the other conversion factors do. You make sure that units are going to cancel and away you go!

Example: Of the 29,011 students at CSUS in the Fall of 2009, 58.495% were female. How many females were there?

From above, we know that the conversion factors are: $\frac{58.495\text{ females}}{100\text{ students}}$ or $\frac{100\text{ students}}{58.495\text{ females}}$ so we set the problem up like this:

$$29,011\ \text{students} \times \frac{58.495\ \textbf{females}}{100\ \text{students}} = 16,970.\ \textbf{females}$$

Example: This review has approximately 1857 letters in it. If the letter "e" makes up 12.479% of all the letters, how many "e"s are there in this review?

From above, we know that the conversion factors are: $\frac{12.479\text{ "e"s}}{100\text{ letters}}$ or $\frac{100\text{ letters}}{12.479\text{ "e"s}}$ so we set the problem up like this:

$$1857\ \text{letters} \times \frac{58.495\ \textbf{"e"s}}{100\ \text{letters}} = 16,970.\ \textbf{"e"s}$$

Practice: Solve each of the following:

a) A sample of barium selenate weighs 56.113 grams. If selenium makes up 28.17% of the compound barium selenate, how many grams of selenium are in the sample?
b) Water is 11.2% hydrogen. If a bowl of water contains 1.44 kg of hydrogen, how many kg of water are there?
c) 750 mL of a certain solution is 95% isopropyl alcohol. How many mL of isopropyl alcohol does the solution contain?
d) Seawater is about 3.5% sodium chloride. How many m^3 of seawater contains 500.0 m^3 of sodium chloride?
e) Silicon makes up about 25.7% of the Earth's mass. If the Earth weighs about $5.9752\text{x}10^{24}$ kg, what is the mass of silicon available for making stuff?
f) The average human body is $2.9\text{x}10^{-4}$ % gold. If the average human weighs 2250 troy-ounces, how many troy-ounces of gold are in the human body? If the price of gold is $1257 per troy-ounce, how much is that gold worth?

<u>More Problems!</u>

1) What is my mass in lbs. if this morning I weighed 103,873 g? (1 kg = 2.20 lb.)
2) Gold is amazing stuff!! A 1.50 cm^3 piece of pure gold can be made into a single wire that stretches 82.21 km in length (roughly the distance from here to Stockton). How long would that wire be in nanometers (nm)
3) The speed of light is $2.998\text{x}10^{10}$ cm per second. What is the speed of light in miles per hour.
4) If a snail moves at 0.234 cm per second, how fast is the snail in furlongs per fortnight? (1 furlong = 660. feet and 1 fortnight = 14 days)
5) Lake Tahoe is the 2nd deepest lake in the United States and has a volume of 156 km^3. The Amazon River is the largest river in the world, with an average flow rate of $7.7351\text{x}10^6$ ft^3 per second. At that rate, how many days would it take for the Amazon River to fill Lake Tahoe?
6) Other than our own sun, the closest star to the Earth, Proxima Centauri, is about 4.22 light years away. The fastest man-made spacecraft, the Helios II deep space probe, travels at a speed of 70.2 km/s. If you were on the Helios II, how many years would it take you to get Proxima Centauri?
7) The standard London Gold Delivery Bar is 200.mm long, 80.0mm wide and 45.0mm tall. As of June 21, 2010, gold was selling for $1257 per troy-ounce. If gold weighs 19.3 grams per cm^3, how much is one London Gold Delivery Bar worth?

Remember, the metric system is built upon base units (grams, liters, meters, etc.) and prefixes which represent orders of magnitude (powers of 10) of those base units. In other words, a single "prefix unit" (such as *milli*gram) is equal to some order of magnitude of the base unit (such as gram). Below are the metric prefixes that you are responsible for and examples of unit equations and conversion factors of each. It does not matter what metric base unit the prefixes are being applied to, they always act in the same way.

Metric prefixes and exponents that you need to know.

Larger than the base unit ↑

Prefix	Symbol	Exponent	Unit equations	Conversion factors
tera	1 T =	$1x10^{12}$	1 Tfl = $1x10^{12}$ fl or $1x10^{12}$ fl = 1 Tfl	$\frac{1\,Tfl}{1\times10^{12}\,fl}$ or $\frac{1\times10^{12}\,fl}{1\,Tfl}$
giga	1 G =	$1x10^{9}$	1 GB = $1x10^{9}$ B or $1x10^{9}$ B = 1 GB	$\frac{1\,GB}{1\times10^{9}\,B}$ or $\frac{1\times10^{9}\,B}{1\,GB}$
mega	1 M =	$1x10^{6}$	1 MΩ = $1x10^{6}$ Ω or $1x10^{6}$ Ω = 1 MΩ	$\frac{1\,M\Omega}{1\times10^{6}\,\Omega}$ or $\frac{1\times10^{6}\,\Omega}{1\,M\Omega}$
kilo	1 k =	$1x10^{3}$	1 kJ = $1x10^{3}$ J or $1x10^{3}$ J = 1 kJ	$\frac{1\,kJ}{1\times10^{3}\,J}$ or $\frac{1\times10^{3}\,J}{1\,kJ}$

Each of these have positive exponents because each prefix is larger than the base unit (increasing orders of magnitude). Remember, the power of 10 is always written with the base unit whether it is on the top or the bottom of the ratio.

-- BASE UNIT --

Smaller than the base unit ↓

Prefix	Symbol	Exponent	Unit equations	Conversion factors
deci	1 d =	$1x10^{-1}$	1 dL = $1x10^{-1}$ L or $1x10^{-1}$ L = 1 dL	$\frac{1\,dL}{1\times10^{-1}\,L}$ or $\frac{1\times10^{-1}\,L}{1\,dL}$
centi	1 c =	$1x10^{-2}$	1 cPa = $1x10^{-2}$Pa or $1x10^{-2}$ Pa = 1 cPa	$\frac{1\,cPa}{1\times10^{-2}\,Pa}$ or $\frac{1\times10^{-2}\,Pa}{1\,cPa}$
milli	1 m =	$1x10^{-3}$	1 mA = $1x10^{-3}$ A or $1x10^{-3}$ A = 1 mA	$\frac{1\,mA}{1\times10^{-3}\,A}$ or $\frac{1\times10^{-3}\,A}{1\,mA}$
micro	1 μ =	$1x10^{-6}$	1 μg = $1x10^{-6}$ g or $1x10^{-6}$ g = 1 μg	$\frac{1\,\mu g}{1\times10^{-6}\,g}$ or $\frac{1\times10^{-6}\,g}{1\,\mu g}$
nano	1 n =	$1x10^{-9}$	1 nm = $1x10^{-9}$ m or $1x10^{-9}$ m = 1 nm	$\frac{1\,nm}{1\times10^{-9}\,m}$ or $\frac{1\times10^{-9}\,m}{1\,nm}$
pico	1 p =	$1x10^{-12}$	1 ps = $1x10^{-12}$ s or $1x10^{-12}$ s = 1 ps	$\frac{1\,ps}{1\times10^{-12}\,s}$ or $\frac{1\times10^{-12}\,s}{1\,ps}$

Each of these have negative exponents because each prefix is smaller than the base unit (decreasing orders of magnitude). Remember, the power of 10 is always written with the base unit whether it is on the top or the bottom of the ratio. The ratios can be "flipped" so that the appropriate unit is on the bottom of the ratio.

Can also be found on page 43 of your book

You are not responsible for many of the base units used in the above examples, but incase you are curious here they are:

fl = flop, computation per second; B = byte, information storage; Ω = ohm, electrical resistance; **J = Joule, energy**; **L = liter, volume**; Pa = Pascal, pressure; A = ampere, electrical current; **g = gram, mass**; **m = meter, length**; **s = second, time**

Any of these prefixes can be applied to any of these (and many many more) base units