Welcome to the EASE workshop series, given through the STEM Gateway program. First things first. If you want to do the survey electronically, here are the QR code and short URL. It is case sensitive. If you'd prefer to do a hard copy version, I'll pass them out at the end of the presentation. To get credit for attending, you'll hand in your assessment sheet, and show me the electronic confirmation, or hand in the paper evaluation, as you leave.

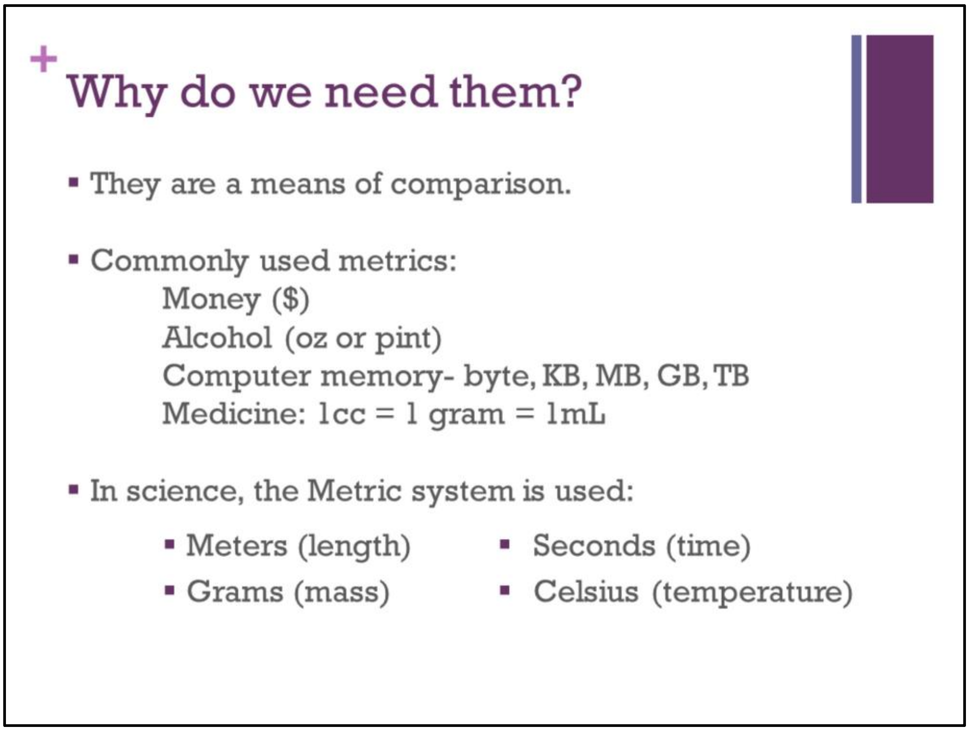
I also want to point out that this Power Point will also be available on the this site through the EASE Workshop series page, so you can always refer back to it at a later time if necessary.

What are Metrics?

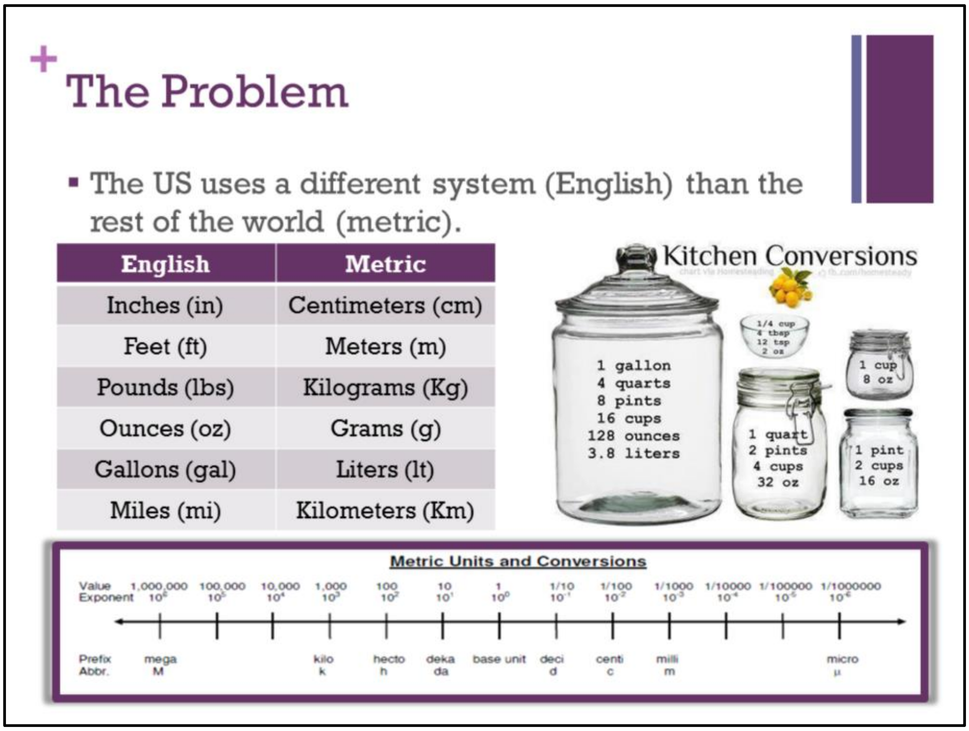
- A standard of measurement

Before we can talk about metrics, we need to figure out what it is. What do you think of when you hear the word metrics?

(*) The most simple definition is a standard of measurement.



So, why do we need metrics?
(*) They are a means of comparison. For example, the size of a house mouse at 15 grams or ½ oz, versus an elephant at 5,500 kg or 12 thousand pounds.
(*) There are a variety of different metrics, depending on what we are referring to. (go through slide)
(*) Lastly, they are largely used in science to take measurements of length, mass, time, temperature and more.



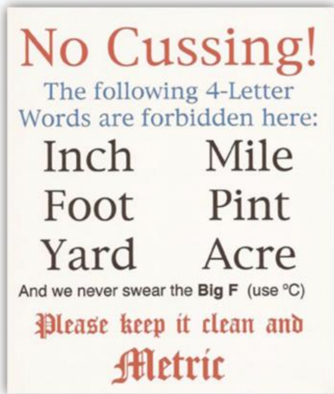
However, can you foresee any problems within metrics?
(*) The US uses an English system of measurement while the rest of the world, including the scientific community uses the metric system. So, take for a gallon jug, for example, in the US system is 1 gallon, 4 quarts, 8 pints, 16 cups or 128 ounces, but in metrics it is 3.8 liters.

The other common units are inches versus centimeters, feet versus meters, pounds versus kilograms, ounces versus grams, gallons versus liters, and miles versus kilometers.
(*) If you notice, in the English system, there is not noticeable relationship, inches, feet, and miles all measure distance or length. But, in the metric system it's centimeters, meters and kilometers, all based on meters, with the relationship that is easily visualized, like in this number line. Money is the ONLY English unit that is base 10, like the metric system.

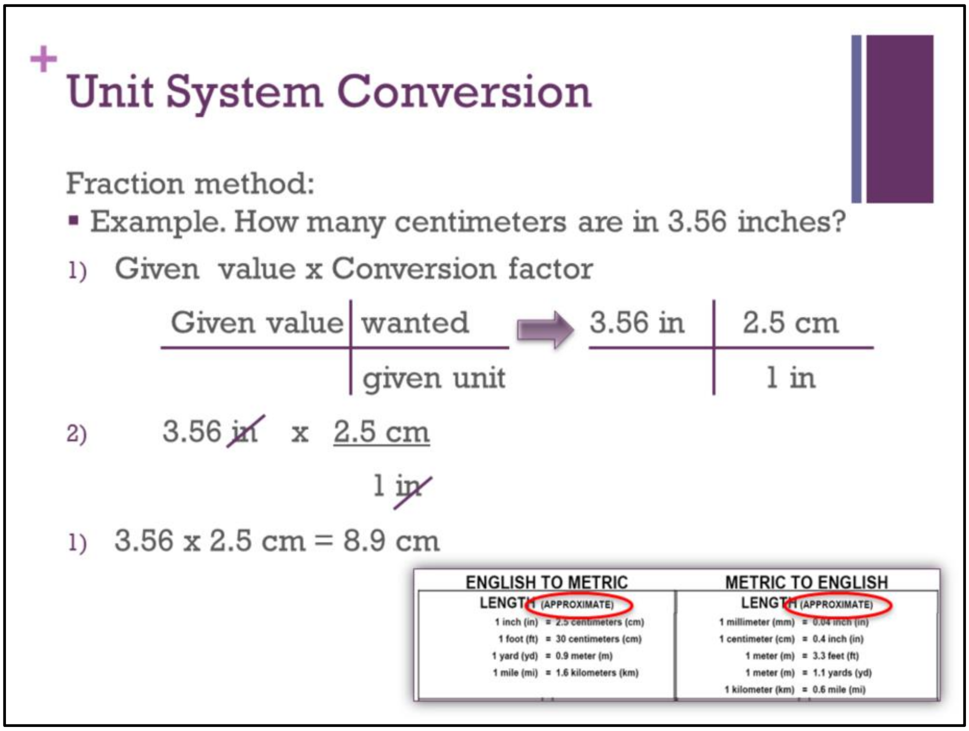
So, let's think about this. What happens if you read a recipe as Fahrenheit, but it's really listed as Celsius? If it results in a cooler oven, nothing will cook, if it's hotter, you can end up with bread looking like this, slightly raw in the center and burnt on the outside.
What about if you use too much or too little of an ingredient? If you were given an European recipe but read it as American? It can drastically change the results of your food.

+
The Solution

- Have science based on the metric system.
  - Universal across disciplines
  - Universal across geographic regions



What do you see as a possible solution within science to the difference between systems?
(*) Essentially, the scientists within the US ignore the national system and join the rest of the world in metrics. This allows a universal system between disciplines, as well as geographic regions. Even if we manage to get the entire country to switch over, we still need to know how to convert between the US system and the metric system, to at least transition.



To convert between systems, we'll go through how to use the fraction method. There are other methods out there, if this doesn't work for you. For the question: How many centimeters are in 3.56 inches…
(*) write the initial value. Don't forget to keep track of your units! It's very important, especially in this method. Then we find the relationship, and write it as a fraction, making sure the units can cancel out, that is, 2.5 cm on top and 1 in on the bottom,

Notice that the relationship says "approximate". You can use either relationship to do the problem, but you may see different results in the final answer. Both answers would be acceptable.

(*) so the inches can cancel out and end with just cm. then we do the math
(*) And end up with 3.56 x 2.5 giving us the same answer as before of 8.9 cm in 3.56 inches

Unit System Conversion

- You try: How many liters are in 2.64 pints?

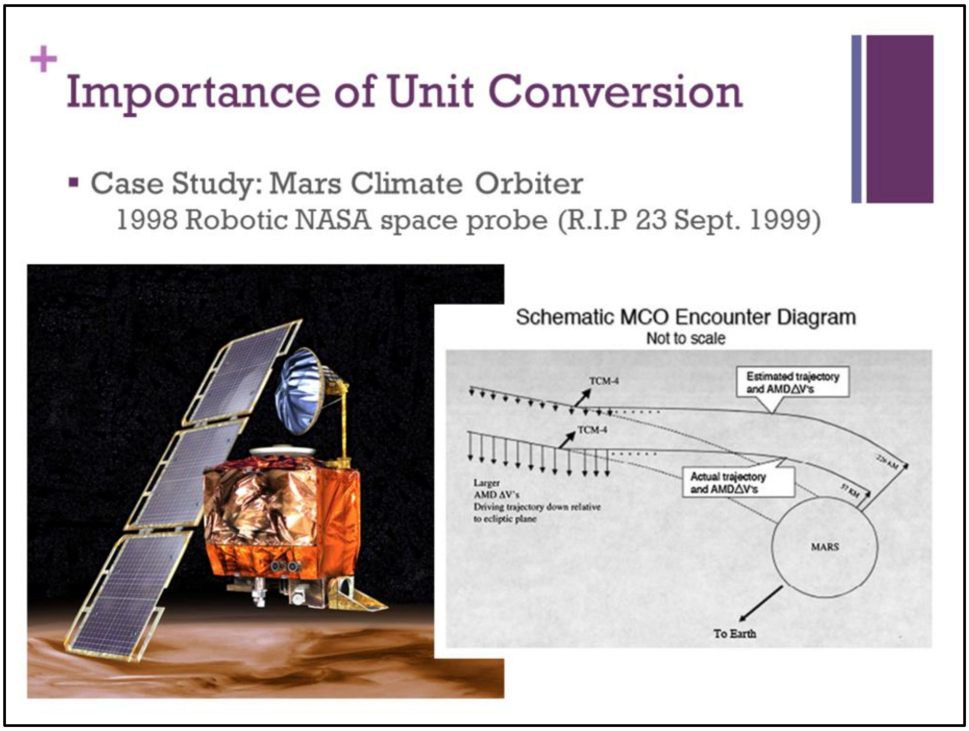
Given value	wanted
	given unit

Write your answer in the correct location on your assessment sheet.

VOLUME (APPROXIMATE)		
1 teaspoon (tsp)	=	5 milliliters (ml)
1 tablespoon (tbsp)	=	15 milliliters (ml)
1 fluid ounce (fl oz)	=	30 milliliters (ml)
1 cup (c)	=	0.24 liter (l)
1 pint (pt)	=	0.47 liter (l)
1 quart (qt)	=	0.96 liter (l)
1 gallon (gal)	=	3.8 liters (l)
1 cubic foot (cu ft, ft^3)	=	0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3)	=	0.76 cubic meter (m^3)

VOLUME (APPROXIMATE)		
1 milliliter (ml)	=	0.03 fluid ounce (fl oz)
1 liter (l)	=	2.1 pints (pt)
1 liter (l)	=	1.06 quarts (qt)
1 liter (l)	=	0.26 gallon (gal)
1 cubic meter (m^3)	=	36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3)	=	1.3 cubic yards (cu yd, yd^3)

Ok, now take a minute to do this one on your own and write your answer on your answer sheet. You are welcome to work or confer with your neighbor.

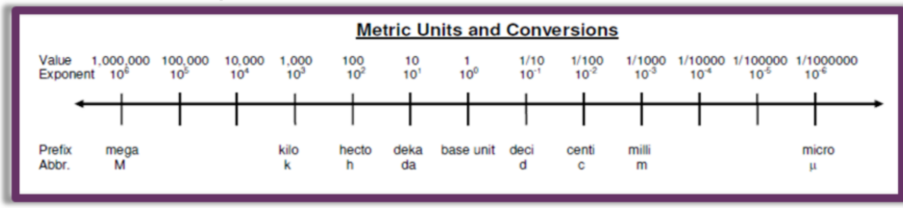


I just want to give you an example of why it is so important to both convert units correctly, but also indicate which units your numbers are in.

The Mars climate orbiter was sent out in 1998, but on September 23, 1999, communication with the spacecraft was lost. This is because the ground-based computer software produced output in pound-seconds instead of the contract specified metric units of newton-seconds. As a result, the spacecraft encountered Mars on a trajectory that brought it too close to the planet, causing it to pass through the upper atmosphere and disintegrate.

The prefixes you should know

Mega	M	1,000,000	10^6
kilo	K	1,000	10^3
hecto	H	100	10^2
deca	D	10	10^1
BASE (l, m, or g)		1	10^0
deci	d	0.1	10^{-1}
centi	c	0.01	10^{-2}
milli	m	0.001	10^{-3}
Micro	μ	0.000001	10^{-6}



If you are sticking with the universal metric system, you won't need to convert between systems, but may still have to convert with regards to magnitude. This is much easier, though. All we have to do is move decimal places! Each change in magnitude is a multiple of 10, rather than figuring out decimals. That said, you should become familiar with these prefixes.

+ How to remember these prefixes?

Kangaroos Hopping Down Big Driveways Carrying M & M's

King Henry Doesn't Usually Drink Chocolate Milk

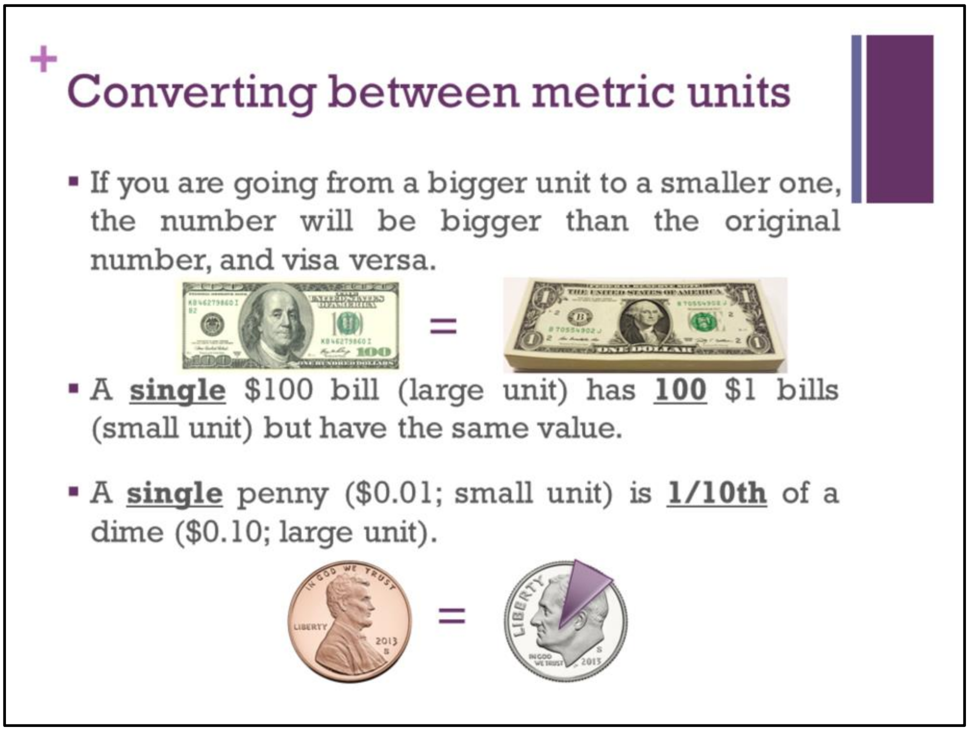
Kids Have Dropped (base/unit) Dead Converting Metrics

Kiss Her Daily Because Divorce Costs Money

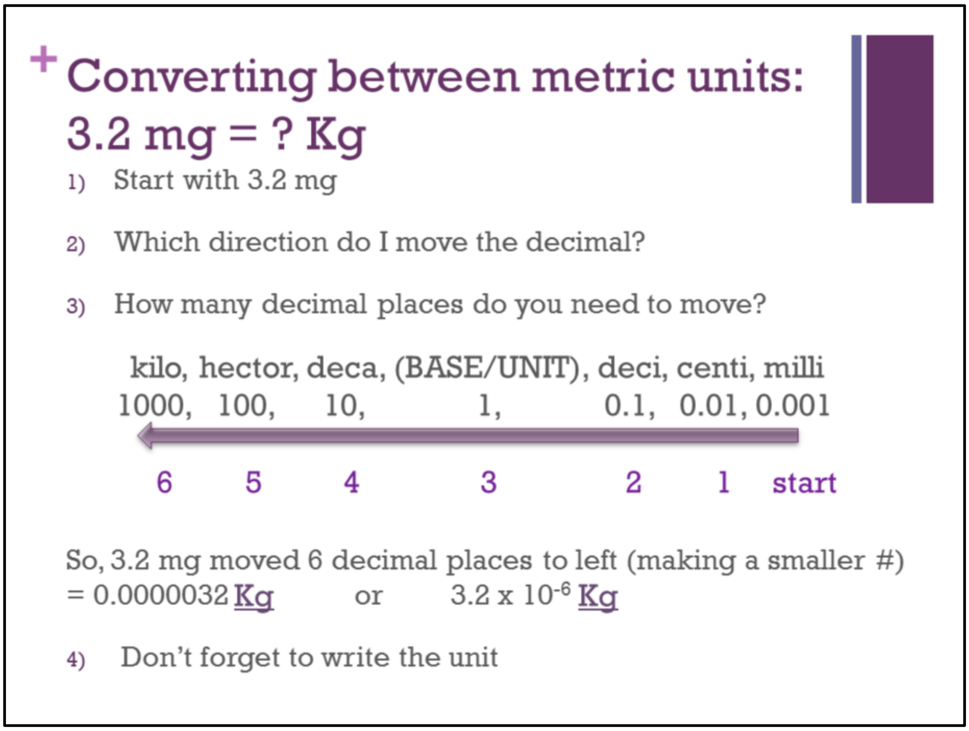
Kittens Hate Dogs But Do Chase Mice

kilo, hector, deca, (BASE/UNIT), deci, centi, milli

If you are not familiar with the prefixes, they can be tricky to keep track of, so mnemonics are often helpful. The first letter of each until size makes the first letter of each word. Here are a few different ones so you can pick which will help you remember the most. (read them). Don't forget about the base unit!



Now that you have a basic understanding of the prefixes and their relationships, let's go over how to convert across magnitude. Keep in mind, if you are going from a bigger unit to a smaller one, the number will be bigger than the original number, and visa versa. Small unit, big number, big unit, small number.
(*) Think of it this way. A single $100 bill is a large unit and has 100 $1 bills. A few large units or a lot of small units.
(*) Conversely, a single penny is only 1/10th a value of a dime.



Again, all you have to do is figure out which direction and how far to move the decimal place, but the number essentially stays the same.
For example. How many kg are in 3.2 mg?
(*) First ask which direction you need to move the decimal place.
(*) we are going from small unit to a large unit, so to the left.
(*) Next we determine how far to move the decimal place.
(*) Start at milli and move 1, 2, 3, 4, 5, 6 steps.
(*) That results in a smaller number. 3.2 mg has 0.0000032 kg (stumble on saying this to prove the point that this is not a functional form), or 3.2 x 10^-6 kg. Note the two forms of writing the answer because we'll come back to this in a minute.
(*) finally, make sure you don't forget your untis!

+
Now you try 4.79 kl = ? ml

- Convert: 4.79 kl = ? ml

Write your answer in the correct location on your assessment sheet.

kilo, hector, deca, (BASE/UNIT), deci, centi, milli
1000, 100, 10, 1, 0.1, 0.01, 0.001

Now it's your turn. Convert 4.79 hm into cm. Write your answer down on the answer sheet. Again, feel free to work with your neighbor.

It’s important to pay close attention to the units, not just the base unit, like before with pounds versus newtons or teaspoons versus milliliters.

A baby was given 5 times the prescribed dose of Zantac Syrup, a medication for reducing stomach acid production, until a doctor pointed out the error a month later. Fortunately, the child was not injured, although doctors say there was a risk of seizure or stroke had the incorrect dosing continued.

The doctor prescribed a dose of 0.75 milliliter twice a day, but the pharmacist labeled the bottle, “Give 3/4 teaspoonful twice a day.” A teaspoon is about 4.9 mL.

A similar problem could have occurred if the units were left off all together.

Scientific notation

- A way of handling very small or very large numbers.
- 1st number, decimal, rest of numbers x $10^{\#}$
- A POSITIVE exponent means the original number was large.

$$46{,}600{,}000 = 4.66 \times 10^{7}$$

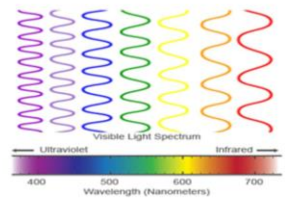
- A NEGATIVE exponent means the original number was small.

$$0.00053 = 5.3 \times 10^{-4}$$

So, remember before when I had two forms of the same number written down? The one with the 10 to a power is called scientific notation. We'll briefly go over this because it comes in to play in a minute when we discuss significant figures.
(*) We use this as a way to handle very small or very large numbers and avoid the difficulty in saying, reading, or transposing the values.
(*) the standard form is to have a single digit number, a decimal place, then all the other numbers, with a 10 to a power of x indicating the magnitude.
(*) When you see the exponent, a positive exponent means the number is large
(*) the 7 let's us know we were in the multimillions.
(*) opposite of this, a negative exponent means the number was small.
(*) the -4 means we are in the thousandths place.

Scientific notation

- Case Studies - Light
  - Shortest wavelength of visible light:
    4.0×10^{-7} m = 0.0000004 meter



  - Speed of Light:
    1.08×10^{9} km/hr =
    1,080,000,000 km per hour

A few real word examples when scientific notation is helpful are if we were looking at the global population, rather than writing out 7 billion, we can say 7 x 10^ 9, or for the size of a computer hard drive that is 4 GB, it’s 4 x 10^9, rather than writing out the number of bytes.

+

Scientific notation

- Now you try:

1) Approximate number of cells in the human body is 37,000,000,000,000 cells
2) Approximate size of a human skin cell is 0.00003 meters

Write your answers on your assessment sheet.

So, now it’s your turn, turn these two numbers into correct scientific notation. Write your answers on your answer sheet.

+ Accuracy

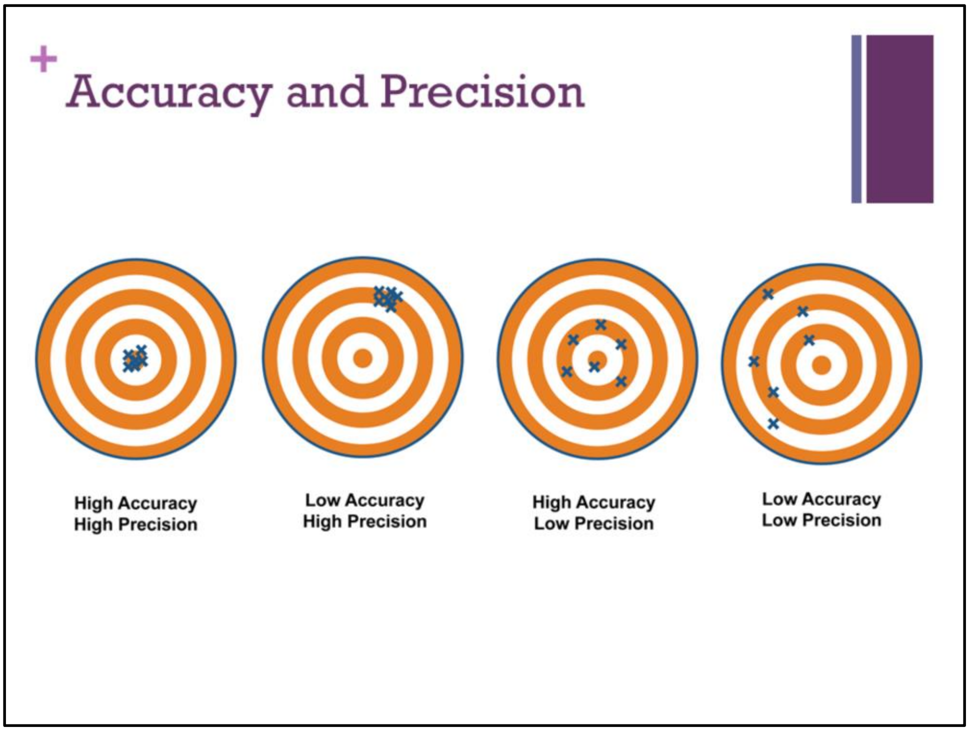
- Accuracy is how close is the measured value to the ACTUAL value.
- To determine accuracy, you must have an ACTUAL value, which can be in the form of:
  - Standard values
  - Known values

Now, we don’t want to have our numbers after the decimal run on and on. That is when the concepts of accuracy, precision and uncertainty come in.
(*) Accuracy is how close a given measurement is to the actual or known value.
(*) To determine accuracy, we have to have a reference or standard value which we can compare our measurement to.

Precision

- How close are the measured values TO EACH OTHER?
- Precision is independent of accuracy.

Related to that is precision.
(*) How close are the measured values to each other?
(*) This is independent of accuracy, which you'll see with a graphic in a minute.



Let’s look at the relationship of accuracy and precision a bit more
(*) Looking at this image, how would you describe the accuracy? High or low. And the precision?
(*) the accuracy was high, since we were looking at the x’s in relation to the central target point, and the precision is high, since all the x’s are clustered near each other.
(*) How about this one?
(*) the accuracy is low since they are not close to the target, but the precision is high since the value are close to each other.
(*) What would something with high accuracy and low precision look like?
(*) the x’s near the target, but spread out.
(*) and what about low accuracy and low precision?
(*) far from the central target and spread out.

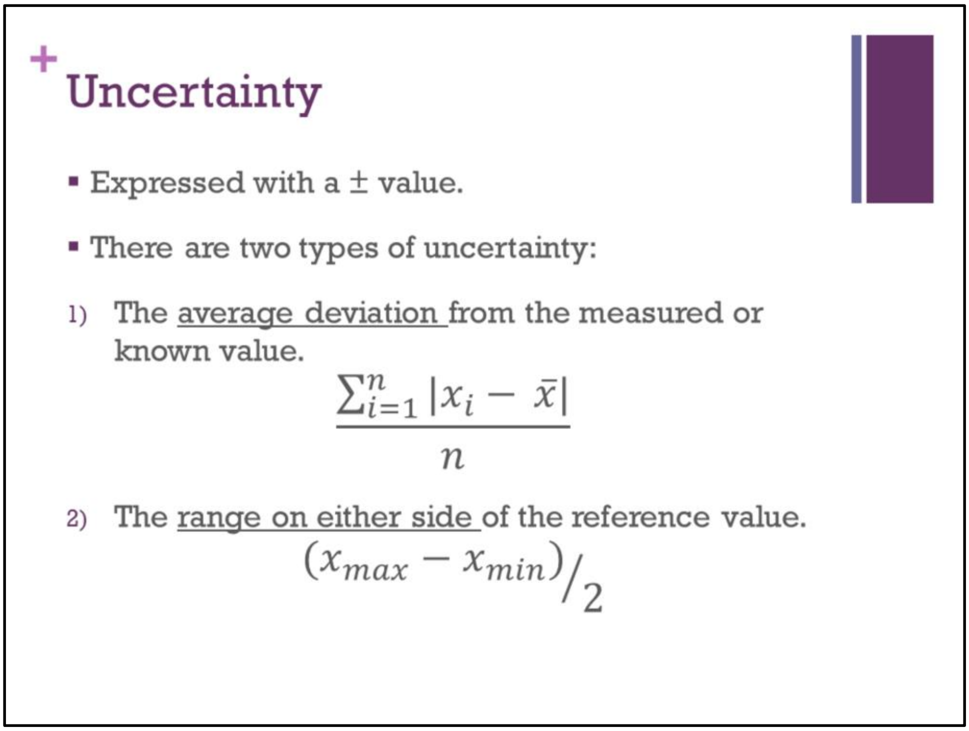
One last thing about this that I want to point out is that to determine if the accuracy or precision is statistically significant, you’d have to do additional tests on the data, which is not within the scope of this workshop.

Accuracy and Precision

- Case Study: Car manufacturers

For example, car manufacturers have to be both accurate and precise. If you see somebody with a car and decide THAT is the car you want, when you buy it, you expect that the one you purchase will be exactly, or close to it, like the one you saw, thus, car to car, must be very precise.

Then, when it comes to conforming to US Department of Transportation safety standards, they have to be very accurate.



Lastly, we have uncertainty.
(*) Uncertainty can be expressed with a range of values, a plus or minus.
(*) There are two main types of uncertainty:
(*) The average deviation from the measured or known value, calculated as the sum of the absolute value for each measurement minus the average, divided by the total number of measurements, or
(*) the range on either side of the reference value, the high value minus the low, divided by 2.

Let’s look at an example to see the difference of these two forms to help you understand it in context, rather than these abstract equations.

Uncertainty

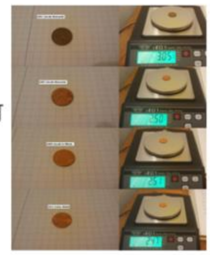
$$\frac{\sum_{i=1}^{n} |x_i - \bar{x}|}{n}$$

- Average Uncertainty Example.

A penny is measured on 6 different balances and results in these measurements:

- Deviations from the average: 0.011g, 0.004g, 0.001g, 0.005g, 0.001g, 0.001g
- Sum of the deviations: 0.023g
- Average deviation: (0.023g)/6 = 0.004g

Thus, the mass of the penny is: 3.121 ± 0.004 g



Mass (grams)
3.110
3.125
3.120
3.126
3.112
3.120
3.121 Average

A penny is measured on 6 different balances and results in these measurements.
(*) for average uncertainty we look at the deviation from the average for each measurement, that is, the absolute value of the first measurement of 3.110 minus the average, added to the absolute value of the second measurement minus the average, etc.
(*) Then, we sum this deviation
(*) and find the average of it.
(*) This gives us the mass of the penny of 3.121, the average value, plus or minus 0.004 g, the average uncertainty.

Uncertainty

$$(x_{max} - x_{min})/_2$$

- Range Uncertainty Example.

A penny is measured on 6 different balances and results in these measurements:

- The range of values is:

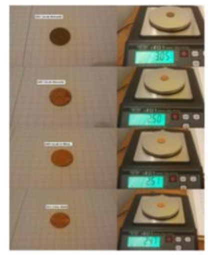
  Highest value – lowest value

  3.126 – 3.110 = 0.016 g

- Divided by 2 = 0.008 g

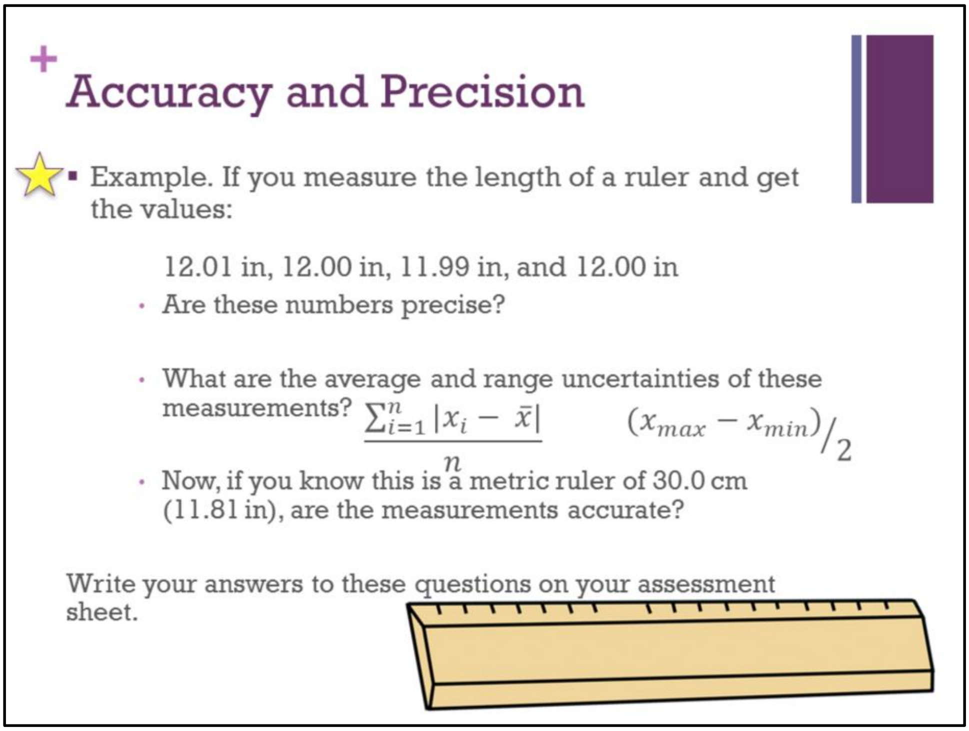
Thus, the mass of the penny is:

3.121 ± 0.008 g



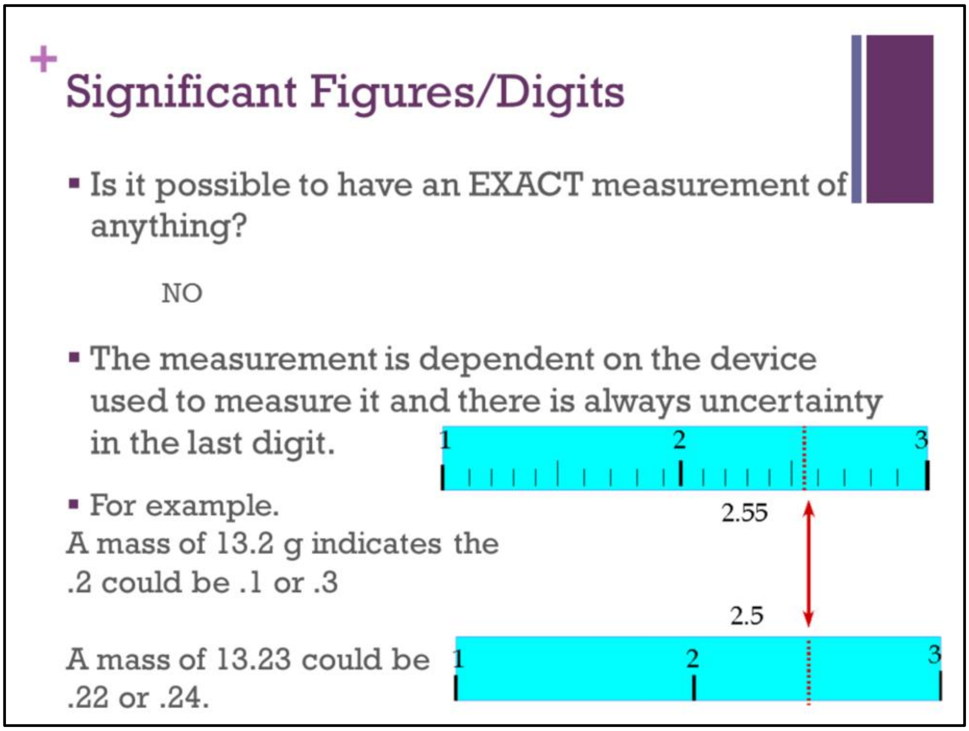
Mass (grams)
3.110
3.125
3.120
3.126
3.112
3.120
————
3.121 Average

Alternatively, we can look at the range of uncertainty
(*) by taking the lowest value away from the highest
(*) then dividing that by two
(*) resulting in the penny mass of 3.121 plus or minus 0.008 g.

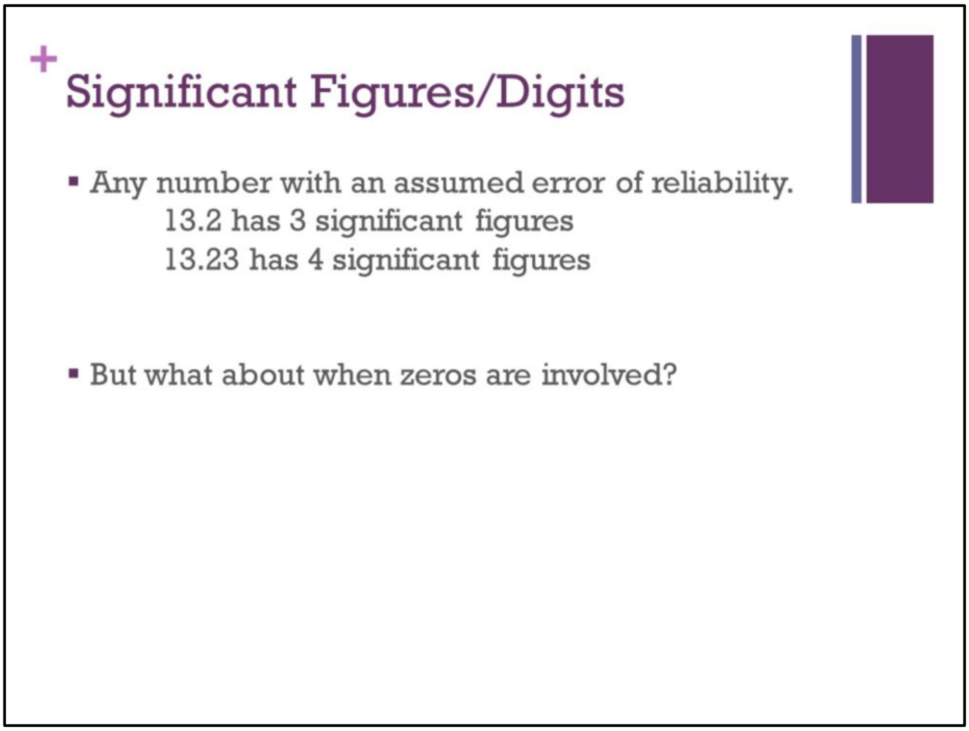


Let's put these concepts into practice. Imagine you measure a length of a ruler and get the values of 12.01, 12, 11.99, and 12 inches

(*) Are these numbers precise? What are the average and range of uncertainty of these measurements? What if I told you this was a metric ruler of 30 cm, thus 11.81 inches, are these measurements accurate? Make sure to write your answers on your paper.



Ok, now our last topic, significant figures or significant digits. To think about this, let's answer this question: Is it possible to have an exact measurement of anything?
(*) No
(*) There is always error as a result of the device we choose to measure with. We can always have smaller and smaller divisions, but at some point it becomes impractical and the last digit is always a guess, or the last digit is an uncertain figure, like you can see here with this image. If the device is only measuring by whole integers, we have to estimate the first decimal, where if we use the device that has marks for the 10ths, the second decimal is the uncertain figure.
(*) When you see a number of 13.2 g, this indicates that the 0.2 could be 0.1 or 0.3, but if we see 13.23, it could be 0.22 or 0.24. The more digits after the decimal, the more certain you are in the value, there is only a little space of uncertainty here (point to 2.55 image), and more here with 2.5 (show again), but it is never exact.

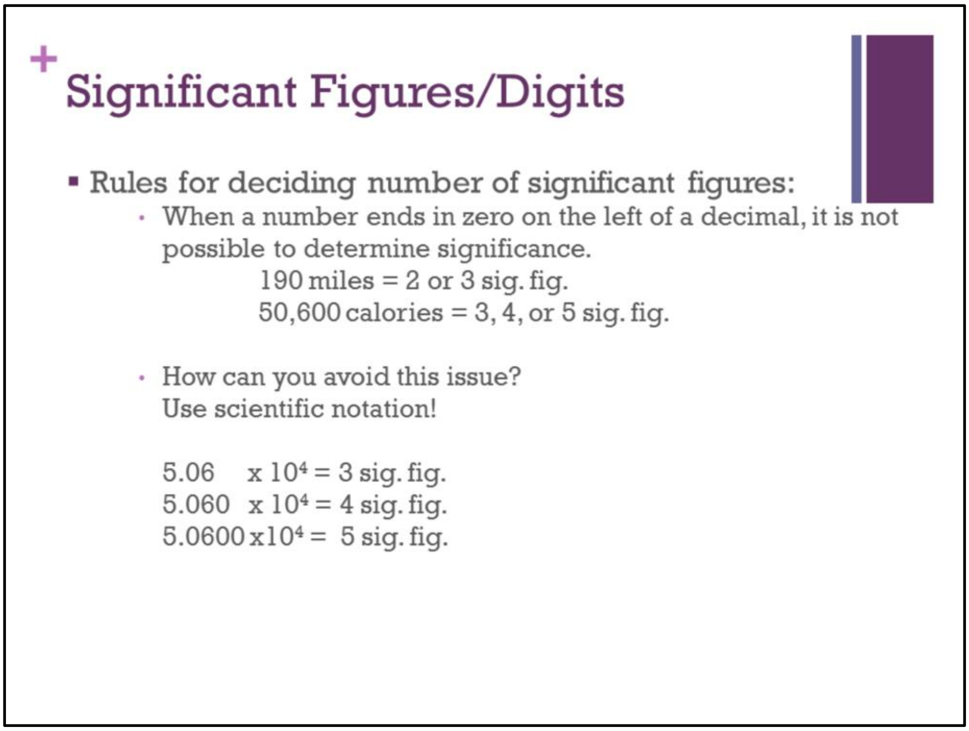


This means that any given number always has an assumed error of reliability, which we indicate with the use of significant figures.
(*) 13.2 has 3 significant figures, but
(*) 13.23 has 4. Those are pretty easy to count, but
(*) what if there is a zero involved? It get’s a little trickier, but is fairly intuitive.

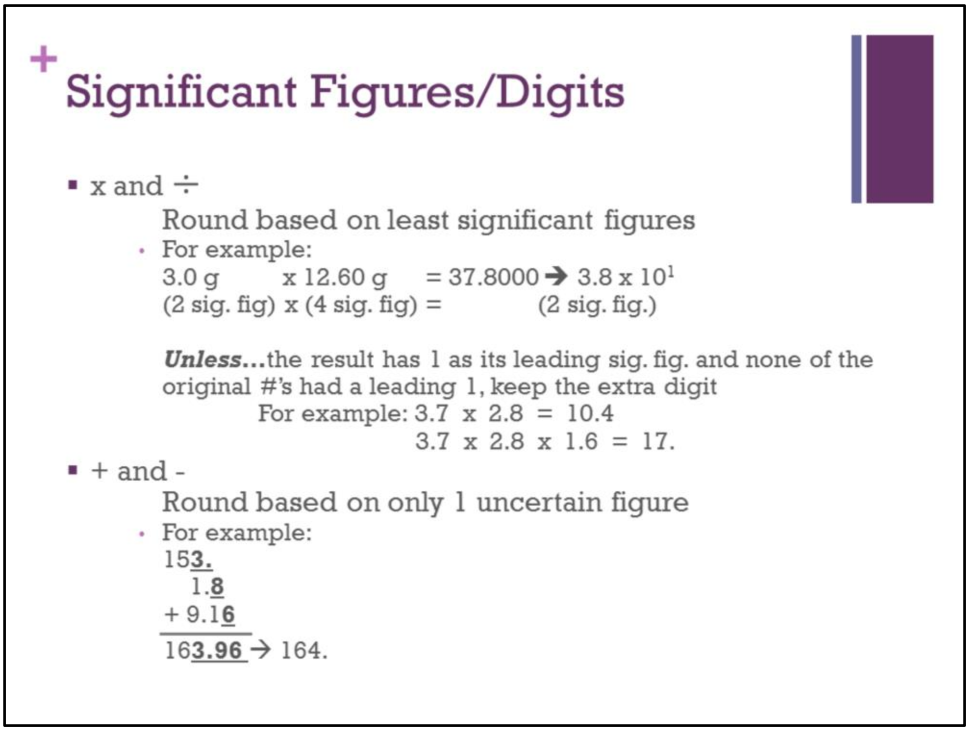
Significant Figures/Digits

- Rules for deciding number of significant figures:
  - All nonzero digits are significant
    - 1.234 g = 4 sig. fig.
    - 1.2 g = 2 sig. fig.
  - Zeros between nonzeros are always significant
    - 1002 kg = 4 sig. fig.
    - 3.01 mL = 3 sig. fig.
  - Leading zeros to the left of the first nonzero are NOT significant
    - 0.001 ^{0}C = 1 sig. fig.
    - 0.012 g = 2 sig. fig.
  - Trailing zeros to the right of the decimal point ARE significant
    - 0.0230 mL = 3 sig. fig.
    - 0.20 g = 2 sig. fig.
  - But…

So, to decide significant figures:
(*) any non-zero is counted as significant
(*) zeros in the middle of non-zero numbers always count
(*) If a zero is to the left of a number, they do not count, since they are just place holders, rather than indications of uncertainty.
(*) related to that, any zeros on the right of the decimal place do count.
(*) But



When a number ends in zero with no decimal place, we can't determine certainty. 190 miles could be 2 or 3 significant figures,
(*) and 50600 can be 3, 4 or 5.
(*) What can we do to avoid this problem? I'll give you a hint, you just learned about it in this workshop.
(*) You can use scientific notation! That forces there to be a decimal place and thus let's an outsider know how certain you are in your values.



The last thing we need to go over is dealing with calculations with varying levels of significant digits and uncertain figures.

(*) For multiplication and division, it is the "weakest link" approach. The final value is dependent on the fewest significant digits of the operators. For example, we have 2 significant figures times 4 significant figures, so our final answer has to be only 2 significant figures.

(*) the exception to this rule is if the calculation results in a leading "1", when no one's were in the original problem. In that case, we keep the extra digit. For example (go through them).

(*) For addition and subtraction, the answer can only have 1 uncertain figure, so if you look at the place for each uncertain figure, the answer can only have 1 of those (go through the example).

Significant Figures/Digits

- x and ÷ **AND** + and -
  1) Order of Operations
     (Please. Excuse. My/Dear. Aunt/ Sally)
  2) After EACH if
     a. Repeating the same operation – DO NOT round yet
     b. A different operation – MUST round first

If you encounter a problem that uses both multiplication/division AND addition/subtraction, you follow the order of operations, please excuse my dear aunt sally – parenthesis, exponent, multiplication and division, then additional and subtraction. After doing each step, if the next step is the same operation group, don't round yet, BUT, if it is a new group, you are switching from multiplication to addition, then round before you complete the next step.

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Significant Figures/Digits

- Rounding

1) If the digit to the right is 0 – 4, round down
   Example: 3.423 is rounded to:
   3.42, 3.4, or 3

2) If the digit to the right is 5 – 9, round up
   Example: 2.756 is rounded to:
   2.76, 2.8, or 3

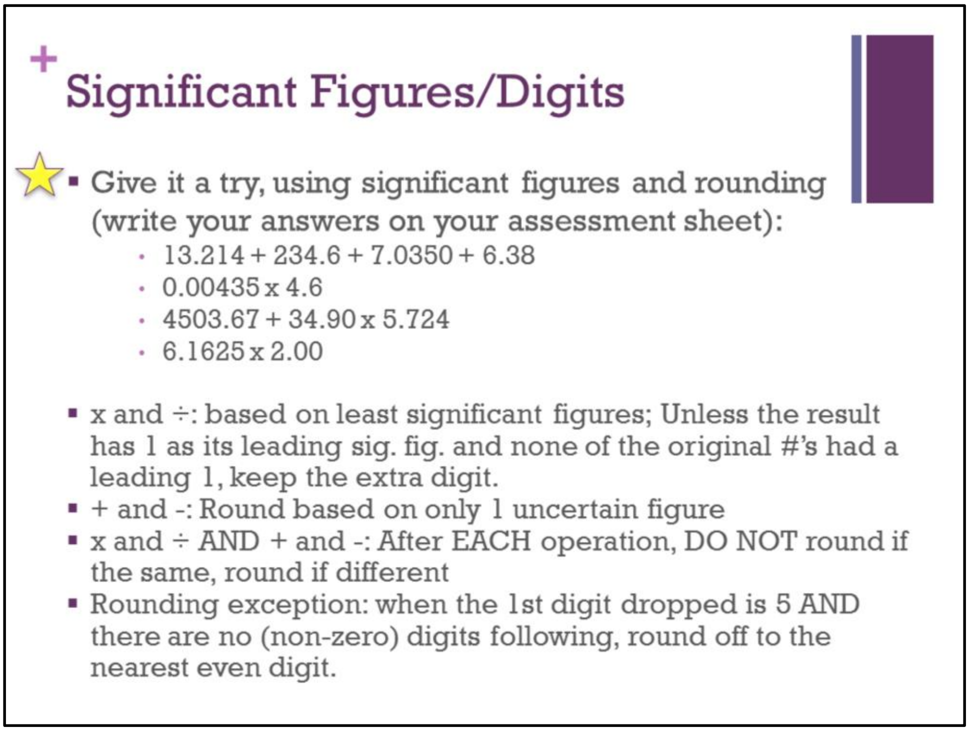
   a. Except when the 1st digit dropped is 5 AND there are no (non-zero) digits following, round off to the nearest even digit.
      Example: 2.315 and 2.325 are both 3.32

For rounding, as expected,
(*) if the digit to the right of what you need is 0 – 4, the number stays the same,
(*) and if it is 5 – 9 it goes up one, with one exception.
(*) If the first and only digit dropped is 5, then you round to the nearest even digit.
So, 2.315 and 2.325 both round to 3.32 because 315 is closer to 32 than it is to 30, and 325 is closer to 32 than it is to 34.

Significant Figures/Digits

- Case Study: Mortgage Interest
  - Initial Mortgage: $150,000.00
    - Interest = 3.94% vs. 3.9% per year
    - Over 30 years
  - 3.94% → $255,940
  - 3.9% → $254,701
  - Difference of $1,239

Case in point. If you purchase a house for 150k at an interest rate of 3.94% vs 3.9% per year, over the course of 30 years
(*) You'll pay a total of $255,940 with the 3.94% rate, but only $254,701 at the 3.9% rate
(*) A difference of $1,239, which could be invested to gain even more money!



Now it's your turn to figure out significant figures and rounding. Take a few minutes to figure these out and write the answer on your answer sheet. Feel free to confer with your neighbors or ask me any questions if you have them.

Also, Just to remind you, this presentation is available through the EASE website if you want to refer back to you.

Before you go, you need to complete our survey. If you can please do it electronically, that would be wonderful. Just show me the confirmation page when you hand in your assessment sheet. If you can not do it electronically, raise your hand and I will come by with paper copies.