Measurement

1. Handout: Condensed notes for Measurement Unit
2. Film: Measurement of Flouride Video Clip
3. **Homework:** Read article on the loss of the Mars Orbiter
4. Units/Scientific Notation
    1. Scientific Notation
        1. Used when expressing very large or very small numbers.
        2. Eliminates ambiguous numbers of significant digits (more on this later)
        3. Is written in the form such that the first number is greater than or equal to 1 and less than 10, and is multiplied by some factor of 10.
            * 1.04 x 10^6 would be equal to 1,040,000
            * 3.650 x 10^ -14 would be equal to 0.00000000000003650
            * you will see different forms for scientific notation but all of the following are equivalent
                o 2.4 x = 2.4 x 10^6 = 2.4 x 10+6 = 2.4 e+6
        4. Try this now on your calculator to see which form it uses to display scientific notation. You can see this by repeatedly multiplying or dividing some number by a very large number.
        5. To get some practice with converting numbers between "ordinary" decimal notation and scientific notation go to: http://janus.astro.umd.edu/astro/scinote/

2. Units:

Prefix	Symbol	Factor	Meaning	Prefix	Symbol	Factor	Meaning
yotta	Y	10^{24}	septillion	yocto	y	10^{-24}	septillionth
zetta	Z	10^{21}	sextilltion	zepto	z	10^{-21}	sextillionth
exa	E	10^{18}	quintillion	atto	a	10^{-18}	quintillionth
peta	P	10^{15}	quadrillion	femto	f	10^{-15}	quadrillionth
tera	T	10^{12}	trillion	pico	p	10^{-12}	trillionth
giga	G	10^{9}	billion	**nano**	**n**	$\mathbf{10^{-9}}$	**billionth**
mega	**M**	$\mathbf{10^{6}}$	**million**	**micro**	**µ**	$\mathbf{10^{-6}}$	**millionth**
kilo	**k**	$\mathbf{10^{3}}$	**thousand**	**milli**	**m**	$\mathbf{10^{-3}}$	**thousandth**
hecto	h	10^{2}	hundred	**centi**	**c**	$\mathbf{10^{-2}}$	**hundredth**
deca	da	10^{1}	ten	deci	d	10^{-1}	tenth

You should memorize the ones in bold. We will use them often.

Go to: http://www.wordwizz.com/pages/10exp27.htm or http://micro.magnet.fsu.edu/primer/java/scienceopticsu/powersof10/ to get a sense of the difference between these powers of ten.

2. We will be using metric units for all our measurements in this class so you should memorize the following:
   * length will be measured in meters (m) or centimeters (cm)
   * volume in centimeters (cm^3), milliliters (mL), or liters (L)
   * mass in grams (g) or kilograms (kg) – **Note: at no time will we be measuring the weight of any substance in this class, only its mass.**

5. Accuracy vs. Precision
   # Accuracy is how close a measurement or estimate is to the correct value.
   # Precision is how exact and reproducible a measurement or estimate is.

Notice that I stressed the fact that we are talking about measured or estimated data. Pure numbers like exact counts or numerically defined numbers have infinite precision and accuracy

1. If I count the number of people in this room to be 24 then that is perfectly accurate (assuming I counted correctly) and infinitely precise.
2. The equivalence 1 in = 2.54 cm is determined by definition. These numbers, when used in doing conversions would be considered to be both perfectly accurate and precise.

Below is a joke I found at
http://www.mpce.mq.edu.au/~malcolmt/measrmnt/sigfigs.htm

A group of Civil Engineers were at a conference being held in Central Australia. As part of the conference entertainment, they were taken on a tour of the famous rock, Uluru.

"This rock", announced the guide, "is 50,000,004 years old."
The engineers - always impressed by precision in measurement - were astounded.
"How do you know the age of the rock so precisely?" asked one of the group.
"Easy!", came the reply. "When I first came here, they told me it was 50 million years old. I've been working here for four years now."

Which below best describes the age of the rock given by the guide?

1. Correct accuracy
2. Correct precision
3. Both accuracy and precision are correct
4. Neither accuracy or precision are correct

Below is a data table produced by three groups of students who were measuring the mass of a paper clip which had a known mass of 1.0004g.

	Group 1	Group 2	Group 3	Group 4
	1.01 g	2.863287 g	10.13251 g	2.05 g
	1.03 g	2.754158 g	10.13258 g	0.23 g
	0.99 g	2.186357 g	10.13255 g	0.75 g
Average	**1.01 g**	**2.601267 g**	**10.13255 g**	**1.01 g**

Which of the above measurement(s) is represents a properly accurate and precise measurement of the mass of the paper clip

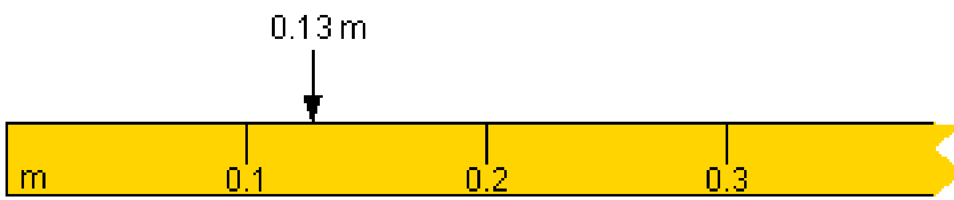
1. Group 1
2. Group 3
3. Group 4
4. Both Group 1 and Group 4

1. Notice that Group 1 had data that was precise (in terms of consistency) and the average was very close to the correct answer (accurate).
2. Group 2 had data that looks precise (many numerical digits of information). However, it is not very accurate. Notice that whatever instrument they are using to measure with really only gives measurements that are consistent to the tenths place. It makes no sense for them to record all the other digits. This answer should really be only

reported to one decimal place (2.6 g).

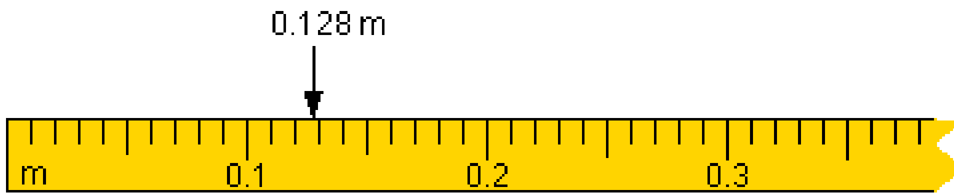
3. Group 3 had data that was very precise (both consistent and lots of digits) however it is not very accurate. What might cause this type of error in their data?
4. Group 4 looks like Group 1, but their answers are very different. Group 4's answer just happened to come out to the same as Group 2. Their data is all over the place (very imprecise).

6. Taking Precise Measurements
   1. **<u>Homework:</u>** Units, Precision, and Scientific Notation Sheet
   2. Lab: Measure various objects with different rulers, balances, and cylinders.
   3. Computer Lab: Practice taking measurements with correct precision.
   4. **<u>Homework:</u>** Rulers and Cylinders Practice
      1. Each measuring device has limits to its own precision.
      2. You can only estimate one digit between known markings.



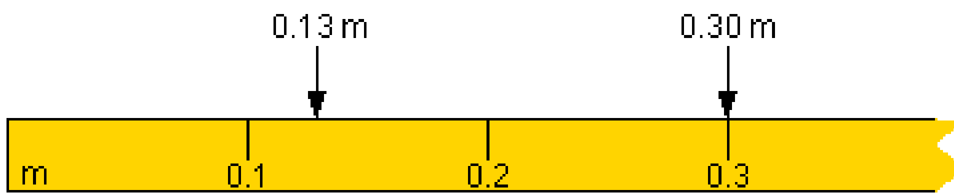
Because we know the arrow is between 0.1m and 0.2m we can estimate the next digit.

      3. On a more finely marked ruler we can get more precise measurements.

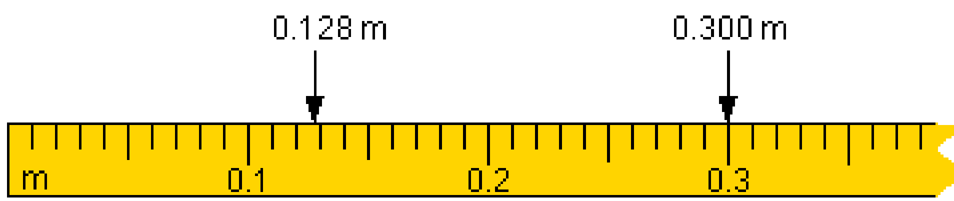


Now we know the mark is between 0.12m and 0.13m, so we can estimate one more digit.

4. If the arrow falls directly on one of the ruler lines then the measurement of that arrow should have the same precision as any other measurement on the ruler. You may have to add zeros to make this true.



Notice that the measurement is 0.30m, not 0.3m.



Again, notice that the number of digits (or precision) in the two measurements is the same.

7. Significant Digits
   1. Computer Lab: Practice Counting Significant Digits
   2. Computer Lab: Practice Calculating With Significant Digits
   3. **Homework:** Calculations with Significant Digits.
      1. All measurements have some limit to their precision. You can only be as precise as the instrument used to make the measurement.
      2. The digits which are considered significant are all the measured digits plus one estimated digit. How many significant digits were there in each of the measurements I made with the various rulers during the demonstration?
      3. Here are some rules to help determine how many significant digits are in a number

Rules for Counting Significant Digits:

- All non-zero digits and any zeros contained between non-zero digits count.

  300042 = 6 significant digits

- Leading zeros don't count.

  0.000034 = 2 significant digits

- Trailing zeros count if there is a decimal point.

  0.0002500 = 4 significant digits

- Trailing zeros may or may not count if there is no decimal point, so we go with the most conservative answer.

  190000 = 2 significant digits (could be up to 6)

4. In the last example, where the number 19000 has an ambiguous number of significant digits, scientific notation will clear up this problem. 11000 can be written several ways in scientific notation to indicate a certain amount of significant digits.

1.90×10^4	=	11000	and has 3 significant digits.
1.9×10^4	=	11000	and has 2 significant digits.
1.9000×10^4	=	11000	and has 5 significant digits.

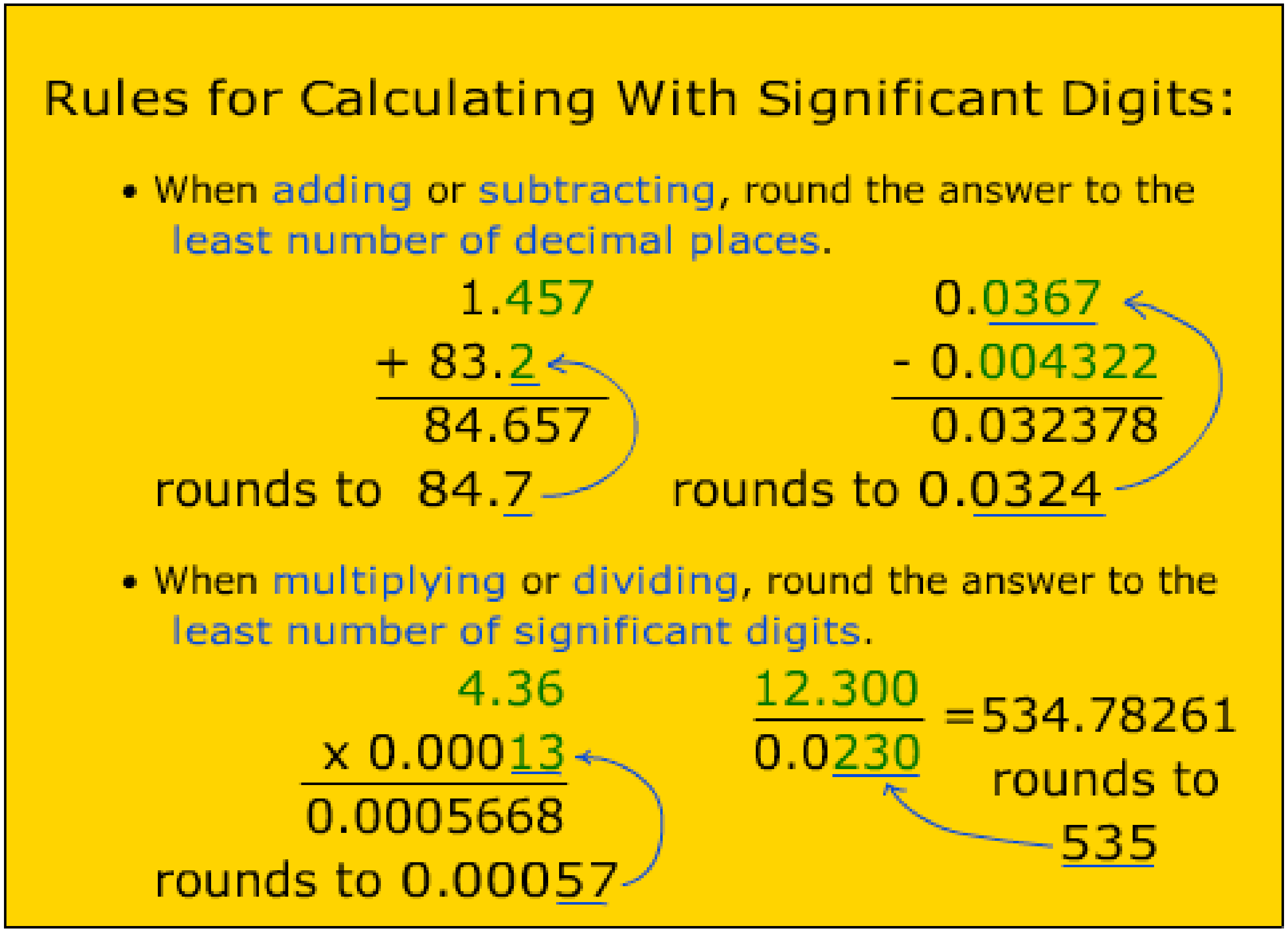
5. Try counting the significant digits in following set of numbers

3.456	5.000	10003
0.666	5.001	0.00300
5	0.005	314.000
10000	12000	10000.0
100321	90210	314000

For more significant digit practice use a Flash based significant figure problem generator.

6. Significant digits in calculations

1.



2. Addition and subtraction example:
   1. Let's say two measurements were take and they came out to 1.3 cm and 2.54 cm. The last digit of these measurements was estimated so 1.3 cm could be anything from 1.2 – 1.4 cm (or even broader), and 2.54 cm could be anything

from 2.53 – 2.55 cm (or even broader). Let's assume we will need to add these measurements together for a calculation.

2. The lowest possible right answer is: 1.2 cm + 2.53 cm = 3.73 cm
   The highest possible right answer is: 1.4 cm + 2.55 cm = 3.95 cm
3. Notice that the tenths place varies, so it doesn't make any sense to pretend we have any information about the hundredths place and should not report it. We should round this answer to the tenths place.
4. Using our original measurements we get:
   1.3 cm + 2.54 cm = 3.84 cm --- rounded to ---> 3.8 cm

3. Multiplication and division example:
   1. Let's assume we have the same two new measurements: 12 cm (implied range of 11 – 13 cm) and 1.33 cm (implied range of 1.32 – 1.34 cm). What if we needed to multiply them together to solve a problem.
   2. The lowest possible right answer is: 11 cm x 1.32 cm = 14.52 cm^2
      The highest possible right answer is: 13 cm x 1.34cm = 17.42 cm^2
   3. Notice that the ones place now varies and we really have no idea what the tenths or hundredths place would be, so we should round this answer to the ones place.
   4. Using our original measurements we get:
      12 cm +1.33 cm = 15.96 cm^2 --- rounded to ---> 16 cm^2
4. Try some practice problems for doing calculations significant digits.

8. Dimensional Analysis
   1. **<u>Homework:</u>** Label Factoring Practice Sheet
      1. Units in scientific calculations are extremely important. They can help you to determine

if you correctly solved a problem. They have meaning and should not be discarded, only to be tacked on (or not) to the final answer.

2. You can think of units (cm, m, g, ml, etc.) like algebraic variables (x, y, a, etc.)
3. All of the same operations that you can do with variables you can do with units (sometimes referred to as labels or dimensions). Consider the following:

a+a = Click here for answer.	1 cm + 1 cm = Click here for answer.
2a * 4a = Click here for answer.	2 cm * 4 cm = Click here for answer.
$\frac{12a^3}{4a}$ = Click here for answer.	$\frac{12\ cm^3}{4\ cm}$ = Click here for answer.
15a + 3b = Click here for answer.	15 cm + 3 sec = Click here for answer.

9. Density
    1. Density is the relationship between the mass of an substance the the amount of space that mass occupies.
    2. or Density is the ratio of mass to volume.
    3. Demo: Sample of Mercury
    4. Video: Raiders of the Lost Ark
    5. Using the measured density of gold to be 19.32 g/cm3, estimate the mass of the solid gold idol that Indiana Jones is tossing around in the first 10 minutes of this video.

1. Compuer Lab: Exploring Density
2. Lab: Density of Various Objects
3. **Homework:** Lab Questions from Density of Various Objects Lab
4. Handout: Putting Data in lab Format
5. Lab: Measuring the Thickness of Aluminum Foil: Given three different pieces of foil (generic standard foil, name brand standard foil, and name brand heavy duty foil) determine their

thicknesses. You should find at least 2 ways to determine this thickness using only a ruler, a balance, and anything else in your lab drawers. One method for determining the thickness must take into consideration the density of aluminum 2.70g/cm3.

6. **Homework:** Write up the Foil calculations in correct lab format and give a numerical conclusion about the thickness of each piece of foil.

10. Writing a Good Lab Report
    1. Handout: ClarisWorks spreadsheet tutorial.
    2. Handout: How to create proper graphs.
    3. Handout: Graphical Analysis software tutorial.
    4. Handout: Writing a Lab Report.
    5. Handout: Shorthand remarks I use when correcting your labs.
11. Lab: Measuring the Density of Coke vs. Diet Coke
    1. Homework: Type a full lab write up for the Coke vs. Diet Coke lab.
12. **Homework:** Review Practice Sheet