

Objective 1

Scientific measurement – represent uncertainty in measurement and calculations using sig figs, apply dimensional analysis (factor-label method) in conversions and calculations.

"I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the state of *Science*, whatever the matter may be."

-Lord Kelvin

How Big Is It? Size Is Measured In Different Units

Size of universe

measured in light years

Size of earth

24,000 mi circumference

Size of a yard stick

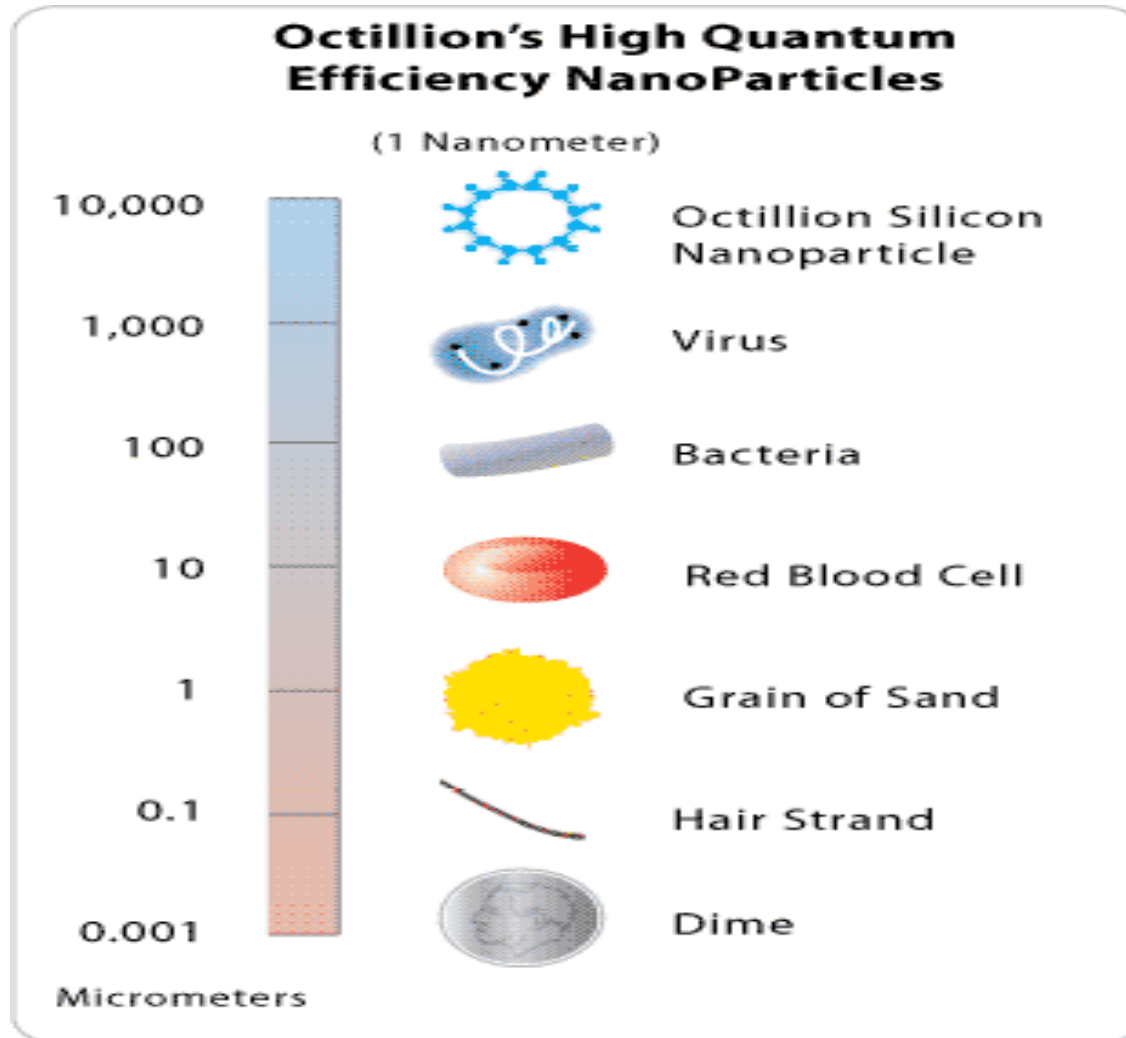
1 yd = 3 ft = 3.3 m

Size of cell

$10\ \mu\text{m} = 1 \times 10^{-5}\ \text{m}$

Size of H atom

$0.3\ \text{A} = 3 \times 10^{-10}\ \text{m}$



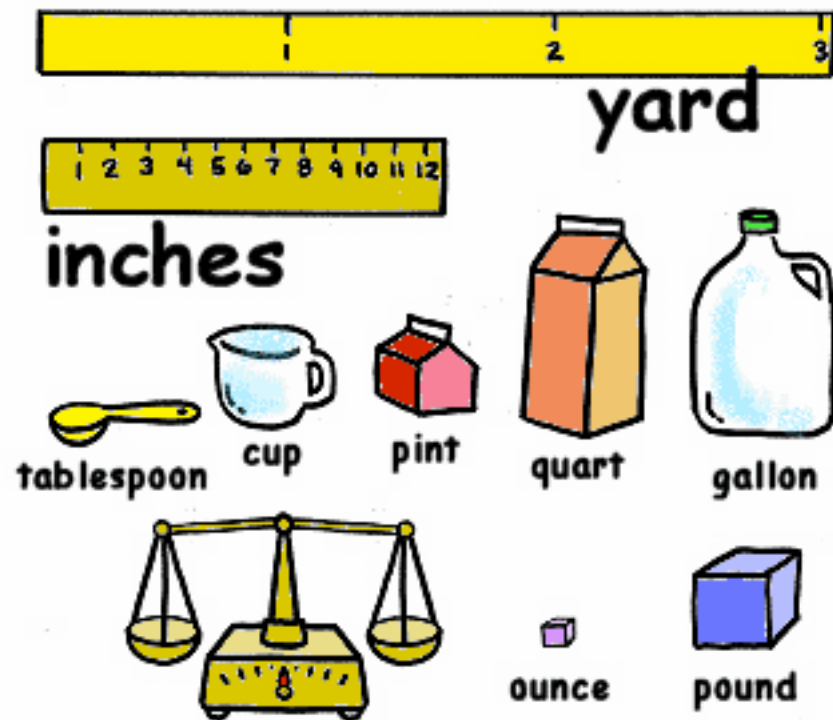
How Hot Is It?

	T, °C	T, K	T, °F
Center of Sun		1.5×10^7	2.7×10^7
Gold Melts	1067	1340	1953
(Ray Bradbury)	233		451
Water Boils	100	373	212
Room Temperature	25	298	78
Water Freezes	0	273	32
Dry Ice	-78	205	-108
Liquid Nitrogen boils	-196	77	-321
Helium Freezes	-272.05	0.95	-458
Bose-Einstein Condensate	-273	190 nK	
Absolute Zero	-273	0	-459

Fill in the blanks.

Are We There Yet?

10^{18} seconds	15 billion years	Age of Universe	Astrophysics
10^{14}	3 million years	Pliocene period	Geology
$10^{12} = 1$ Ts	32,000 years	Cro Magnon people	Geology
$10^{10} = 10$ Gs	300 years	White man in North America	
10^8	3 years	College degree	
$10^6 = 10$ Ms	12 days	Fortnight holiday	Chemistry
$10^4 = 10$ ks	3 hours	Chem 1A lab, GRE Exam	Chemistry
10^2	2 min	Soft boiled egg	Chemistry
10^0	1 sec	Blink of an eye	Chemistry
$10^{-2} = 10$ ms			Chemistry
$10^{-4} = 0.1$ ms			Chemistry
$10^{-6} = 1$ μ s		Intersystem crossing	Chemistry
$10^{-8} = 10$ ns		Intersystem crossing	Chemistry
$10^{-10} = 0.1$ ns		Internal conversion	Chemistry
$10^{-12} = 1$ ps		Internal conversion	Chemistry
10^{-13}		Period of vibration of atomic nuclei	Chemistry
$10^{-14} = 10$ fs			Physics



<http://mrskopari.weebly.com/measurement-and-data.html>

Every measurement has _____ associated with it.

The number of ***SIGNIFICANT FIGURES*** reflects the _____ in the measurement.

Objective: determine sig figs and uncertainty

16.00

represents a number used in chemistry. Include units.

Determine the number of significant figures in the number above.

a. 1 b. 2 c. 3 d. 4 e. 5 f. too many choices

What is the uncertainty in each number?

a. 5 b. ± 10 c. ± 1 d. ± 0.1

e. ± 0.01 f. ± 0.001

THE LAST SIG DIGIT IS THE UNCERTAIN DIGIT

Each number below represents a number used in chemistry or a conversion. Include units.

Determine the number of significant figures in the following numbers.

What is the uncertainty in each number?

a. 6.02×10^{23}

b. 0.6215

c. How many km are in 26.2 mi?

You want to measure 10 ml of water.
Would you use a 100 ml beaker or a 10 ml gc?

How would you report volume using sig figs?



- Volume:
- a. 10 ml
 - b. 10. ml
 - c. 10.0 ml
 - d. 10.00 ml



HINT: ID digit you know with certainty, guess next digit (the uncertain digit)

The Uncertainty in your Measurement is Determined by the Measuring Device

What is the uncertainty in each volume?

ID digit you know with certainty, guess next digit (the uncertain digit)



Uncertainty:

- a. ± 10 ml
- b. ± 1 ml
- c. ± 0.1 ml
- d. ± 0.01 ml



Each mark = 10 ml
Volume reported as 10. ml

Each mark = 0.1 ml
Volume reported as

The Uncertainty of a Measuring Device = Significant Figures

1. You measure 10 ml of a colorless liquid in a 50 ml graduated cylinder. Report the volume using the appropriate number of sig figs.

Hint: each line represents 1 ml

2. You see a volume reported as “10 ml”. Which volume measuring device was used?

- a. 250 ml Beaker
- b. 10 ml graduated cylinder
- c. 50 ml graduated cylinder

You want to measure 10 ml of water.

Would you use a 100 ml beaker or a 10 ml gc?

- Which volume measuring device do you think gives a more accurate measurement?
- Which volume measuring device do you think gives a more precise measurement?



DO THIS IN LAB!

Calibrate – correlate the readings of an instrument with those of a standard to check the instrument's accuracy.

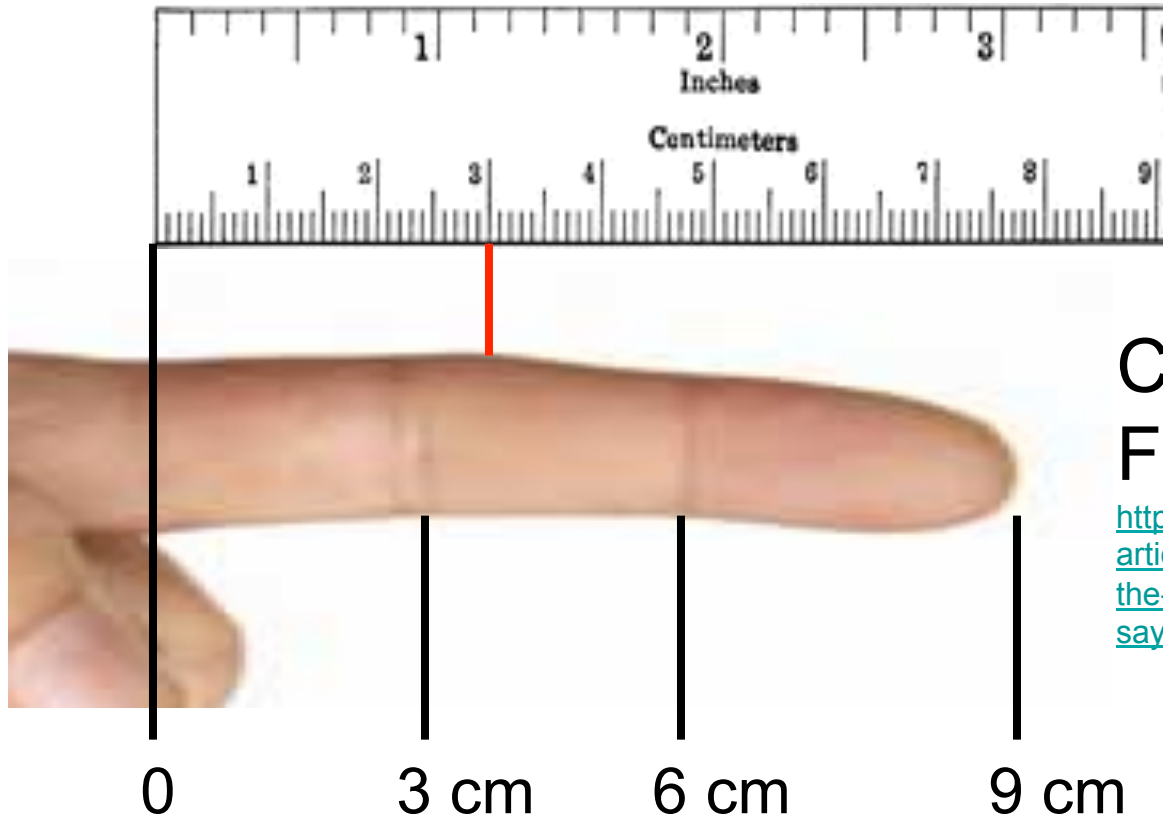
How would you calibrate your finger?

What instrument would you use as your standard?

How would you calibrate a beaker?

What instrument would you use as your standard?

Standard: ruler (http://etc.usf.edu/clipart/36400/36459/ruler1_36459.htm)



Calibrate:
Finger

<http://articles.mercola.com/sites/articles/archive/2010/12/21/what-the-length-of-your-index-finger-says-about-you.aspx>

3 cm line on ruler (standard) = 3.5 cm line on finger

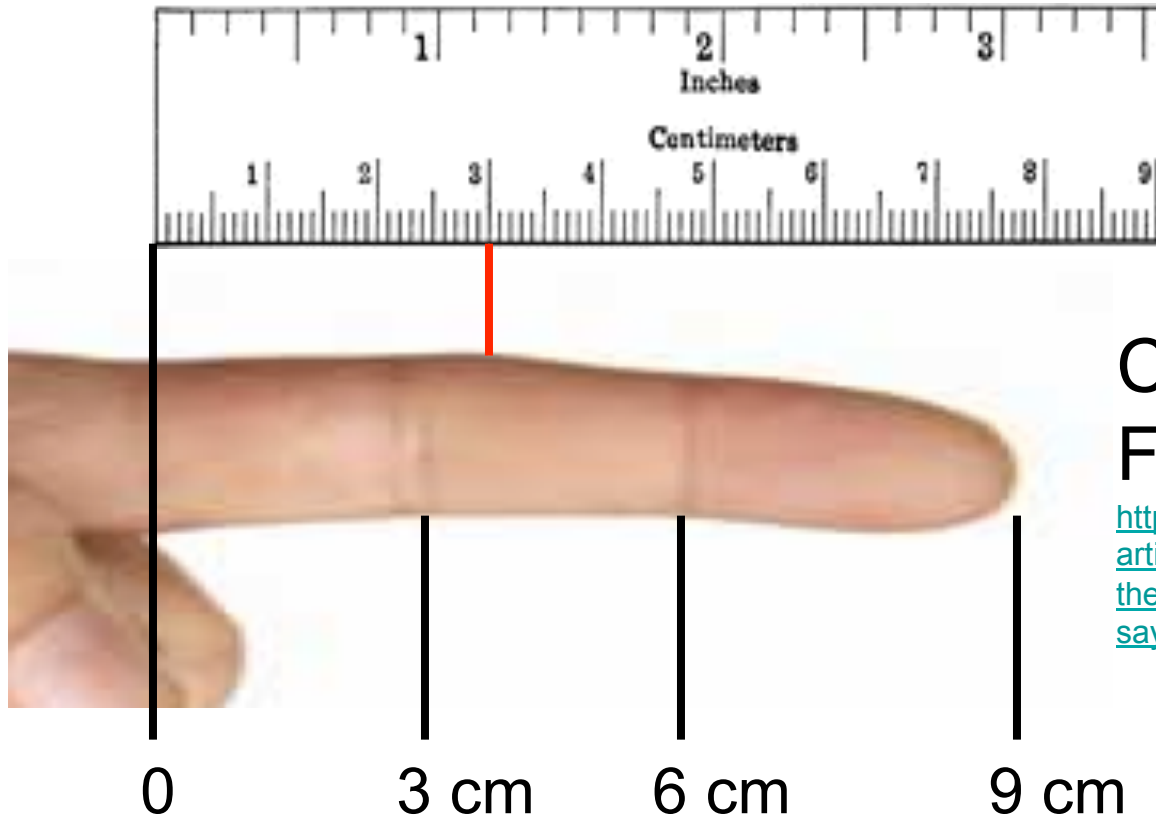
Difference = 0.5 cm (**relate to uncertainty**)

Using Finger gives a length _____ than true length.

a. higher

b. lower

Standard: ruler (http://etc.usf.edu/clipart/36400/36459/ruler1_36459.htm)



Calibrate:
Finger

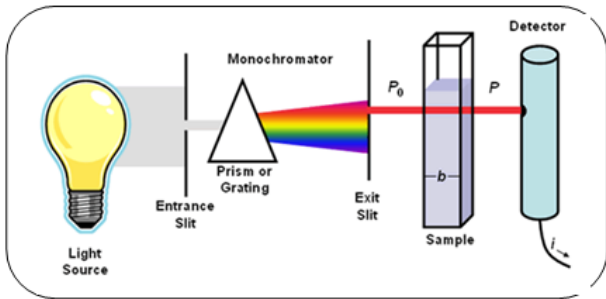
<http://articles.mercola.com/sites/articles/archive/2010/12/21/what-the-length-of-your-index-finger-says-about-you.aspx>

3 cm line on ruler (standard) = 3.5 cm line on finger
Using Finger gives a length higher than true length.

Using Finger leads to a Systematic Error and ___ Accuracy
a. good b. poor

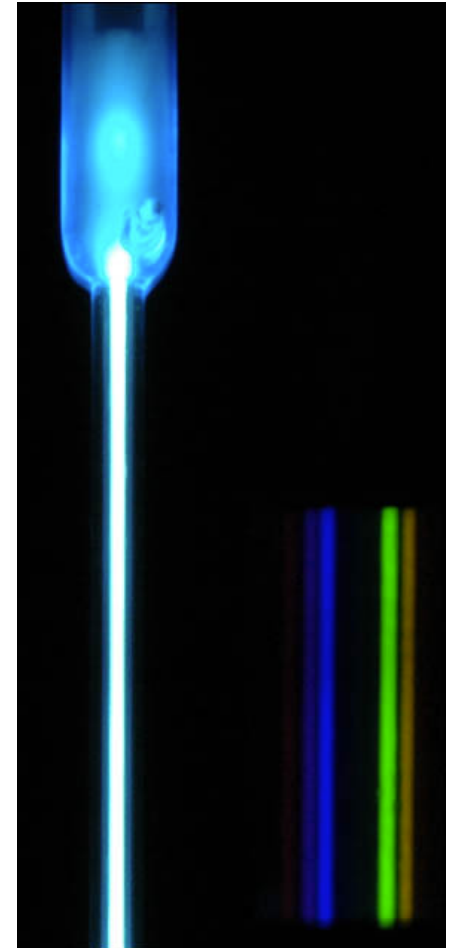
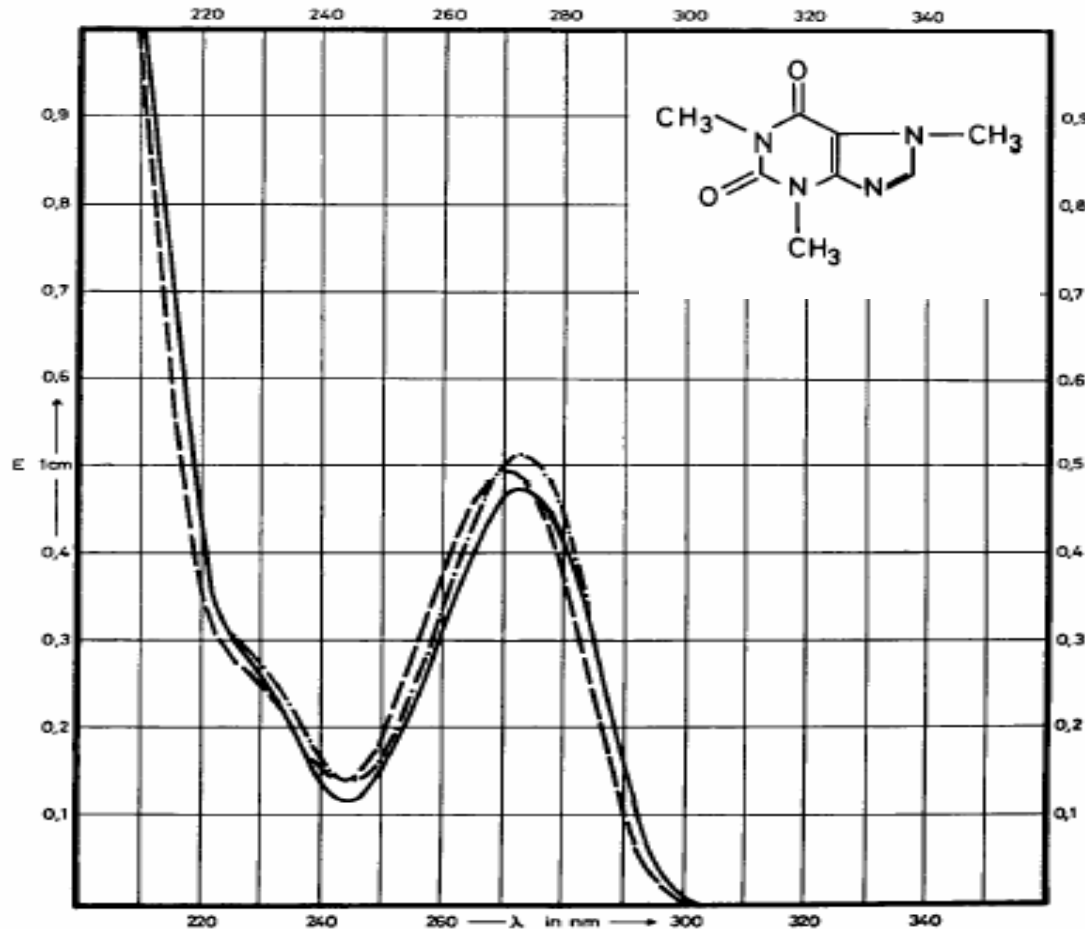
Calibrate light detector with Hg emission spectrum

GREEN line = 546.1 nm



<http://www.expertsmind.com/questions/absorbance-spectrophotometer-30118004.aspx>

caffeine



<http://hyperphysics.phy-astr.gsu.edu/hbase/quantum/atspect2.html>

Blood Glucose = 100 mg/dL (normal)

Pancreas secretes glucagon, insulin

Blood Glucose test – use a glucose test meter

Glucose -- glucose oxidase ---> gluconic acid (oxidation)
ferricyanide -- Gluconic acid ---> ferrocyanide (reduction)

Electric current is produced. Current \propto [glucose]

NEEDS TO BE CALIBRATED!



<http://www.diabetesforecast.org/2012/jul/anatomy-of-a-test-strip.html>

http://www.answers.com/Q/How_do_blood_glucose_meters_work

How Close You Are to the True Value is **Accuracy**

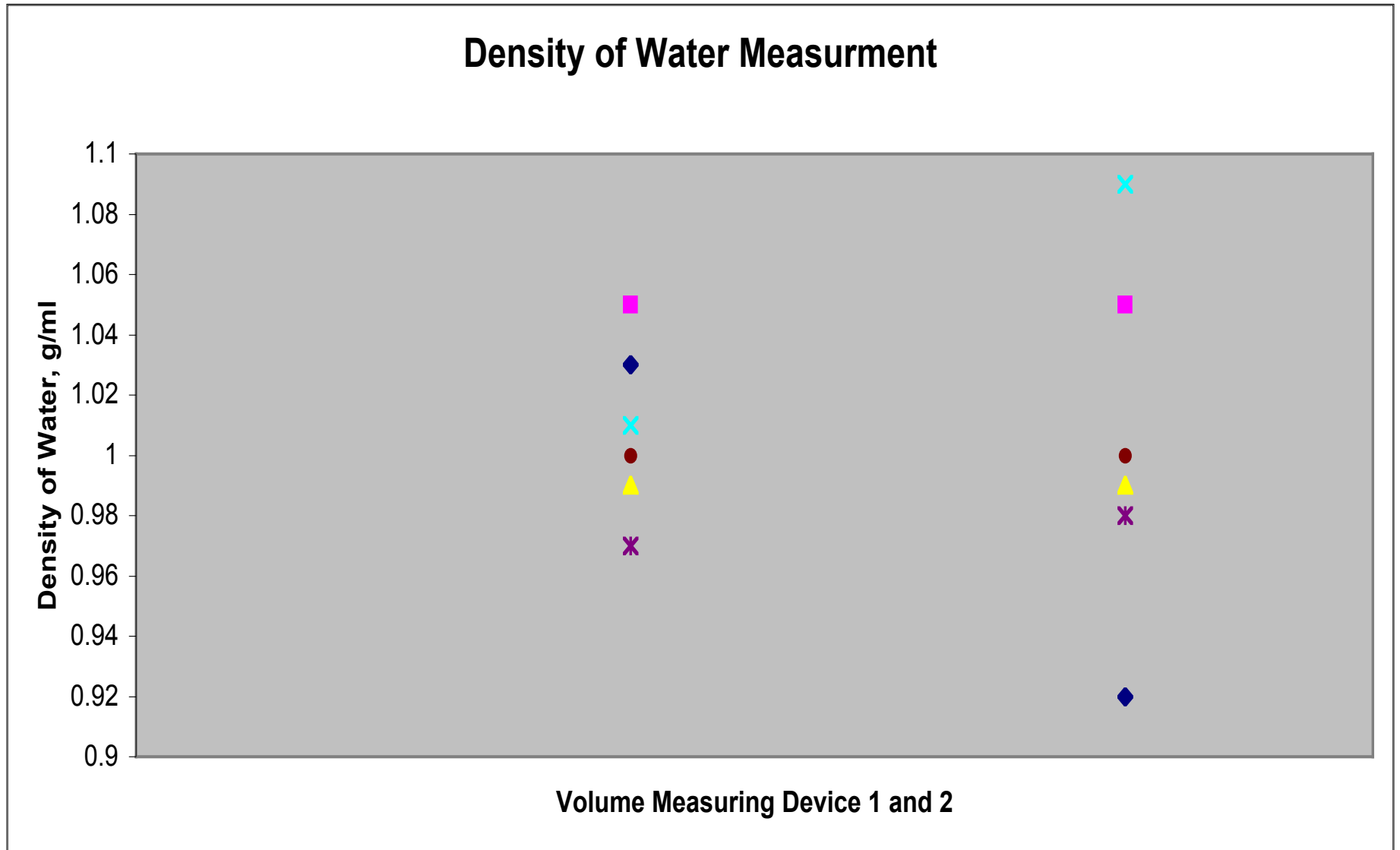
$$\% \text{ error} = \frac{(\text{true value} - \text{experimental value})}{\text{true value}} \times 100$$

How Close Your Results Are to Each Other is **Precision**

$$\% \text{ difference} = \frac{(\text{highest value} - \text{lowest value})}{\text{average}} \times 100$$

Does “scatter” refer to accuracy or precision?

Which set of data shows higher accuracy? Quantify accuracy.
Which set of data shows higher precision? Quantify precision.



Objective: *Use Sig Figs in Calculations*
Rounding Numbers

The **Uncertainty in a Measurement (Data) Must Be Reflected in a Calculation (Results)**

Use sig figs appropriately when you do calculations.

Add/Subtract = Look at # of Decimal Places

27.46 g	2 decimal places
+ 5.6 g	1 decimal place
<hr/>	
33.1 g	answer has 1 decimal place

Multiply/Divide = Look at # of Sig Figs

27.46 g	4 significant figures
÷ 5.6 ml	2 significant figures
<hr/>	
4.9 g/ml	answer has 2 significant figures

Objective: Use Sig Figs In Calculations – Rounding #'s

Example: Measure mass and volume to calculate density

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

Mass measuring device	Volume measuring device	Mass of beaker, g	Mass of beaker + water, g	Mass of water, g	Volume of water, ml	Density, g/ml
Pan balance	10 ml grad cyl			9.84	10.00	0.984
* Pan balance	100 ml beaker			9.84	10.	
Pan balance	50 ml grad cyl	26.78	35.99		10.0	

Calculate density for each trial using sig figs appropriately.

You have a job interview. The interviewer shows you data for a density of water experiment.

Mass of beaker, g	Mass of beaker + water, g	Volume of water, ml	Exp density of water at 23.5°C	True density of water at 23.5°C
78.23	87.98	10.0		0.9974

You are asked:

- Calculate the density of water. Use sig figs appropriately.
- Calculate % error and % difference.
- Based on the reported data, was a TBB or pan balance used to measure mass? Give reasons.
- Was a 10 ml transfer pipet, 50 ml graduated cylinder, or 50 ml beaker used to measure volume? Give reasons.
- How could you have gotten better results?

Objective: Use Sig Figs in Calculations - Rounding Numbers

The Uncertainty in a Measurement (Data) Must Be Reflected in a Calculation (Results). Use sig figs appropriately when you do calculations.

Add/Subtract = Look at # of Decimal Places

Mass of B + W	87.98 g	2 decimal places
Mass of B	<u>- 78.23 g</u>	2 decimal places
	9.75 g	answer has 2 decimal places

Multiply/Divide = Look at # of Sig Figs

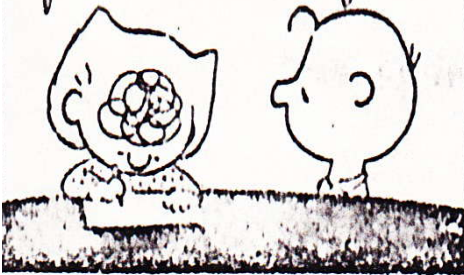
Mass of water	9.75 g	3 significant figures
Volume of water	<u>÷ 10.0 ml</u>	3 significant figures
density	0.975 g/ml	answer has 3 sig figures

Subtract: Round to 3 decimal places. **Divide:** use 2 s.f.

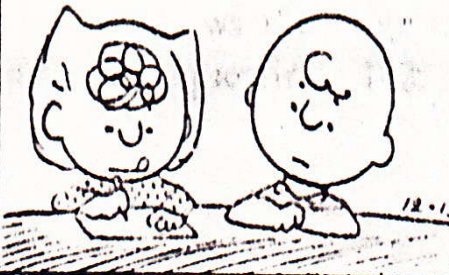
$$\% \text{ error} = \frac{(0.9974 - 0.975)}{0.9974} \times 100 = \frac{0.0224}{0.9974} \times 100 = 2.2\%$$

Divide: 4 sig figs. **Answer** has 2 sig figs.

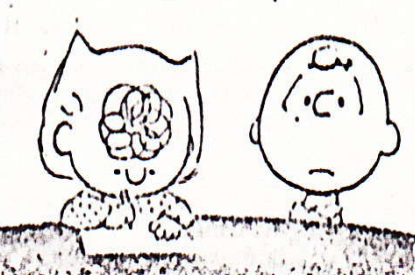
Ten milligrams equals one centigram.



Ten decigrams equals one gram.



Ten grams equals one grampa.



KEEP GOING... I CAN HARDLY WAIT TO SEE WHAT COMES NEXT...



Objective: Use Conversion Factors

Density is Used to:

- Identify Substances
- As a Conversion Factor (*ratio*)

Dimensional analysis (factor-label method).
Make sure units **cancel** out.

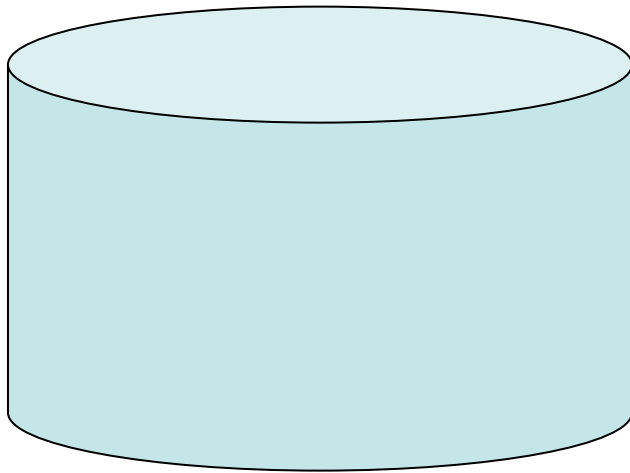
$$A \times \frac{b}{A} = b$$

$$240 \text{ g} \times \frac{\text{ml}}{0.79 \text{ g}} = 303.8 \text{ ml}$$

$$240 \text{ ml} \times \frac{0.79 \text{ g}}{\text{ml}} = 189.6 \text{ g}$$

You have 240 g of a colorless liquid. This liquid has a density of 0.79 g/ml.

Calculate the volume in ml of 240 g of this liquid.



$$m = 240 \text{ g}$$

$$V = ?$$



You have 1 cup (240 ml) of a colorless liquid. This liquid has a density of 0.79 g/ml.

- a. Is this liquid water? Give reasons.

- b. Calculate the mass of 1 cup of this liquid.

http://www.javapackaging.com/ccp0-catshow/Plastic_Cups.html

DO THIS IN LAB!

Measure the densities of regular soda and diet soda.



<https://sojo.net/articles/byu-students-pushing-caffeinated-sodas>



<http://thetrendguys.com/wp-content/uploads/2013/07/Diet-Sodas.jpg>

Are the densities the same?

If not, what ingredient accounts for the difference?
Use difference in densities to calculate mass of this ingredient.

The density of a liquid is 2.1 g/ml.
To 50.0 ml of this liquid, you add 7.0 g of salt (NaCl).
You stir to dissolve the salt.
The new volume of this solution is 51.3 ml.



http://www.javapackaging.com/ccp0-catshow/Plastic_Cups.html



<http://theshiksa.com/2012/06/04/salt-friend-or-foe/>

Calculate the density of this solution.

Objective: Use dimensional analysis to Convert from one unit to another

Tums contains CaCO_3 as its active ingredient
How much Ca is in a 550 mg CaCO_3 tablet?

1 tsp of salt (NaCl) has a mass of 6 g.
How much sodium is in 1 tsp of salt?

Scientific Measurement involves Error

Making a Measurement Using a Measuring Device

==> uncertainty (error) is shown with significant figures

Look at Lines in Measuring Device

==> the quantity shown in the line is certain

==> guess in between lines ==> uncertain digit

Calculation reflects uncertainty

add/subtract ==> look at decimal places

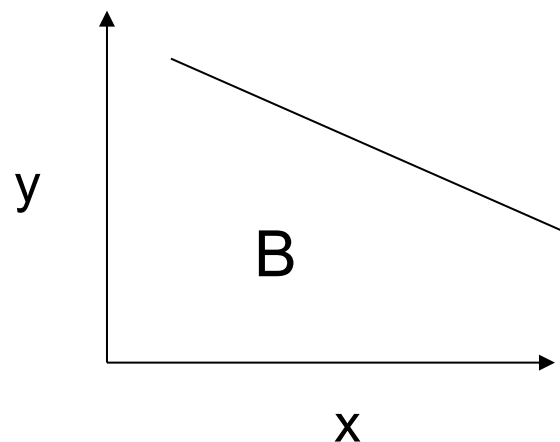
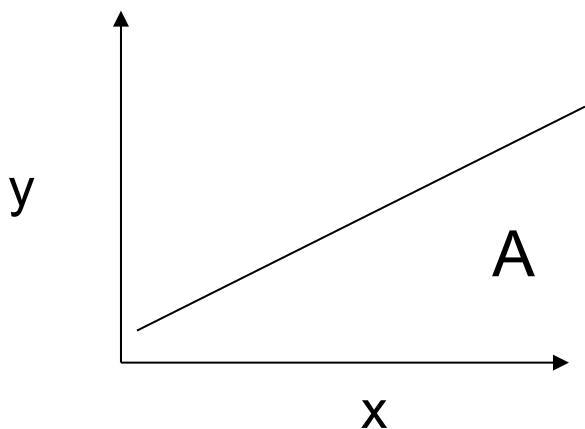
multiply/divide ==> look at sig figs

Conversion Factors and Dimensional Analysis

==> convert from one quantity to another

==> conversion factor is a ratio

Equations and graphs tell us which variables are directly proportional or inversely proportional.

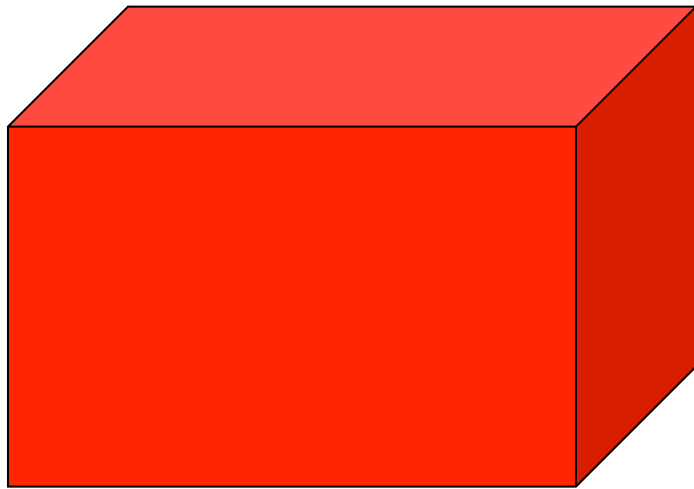


a. Which graph is directly proportional? A or B

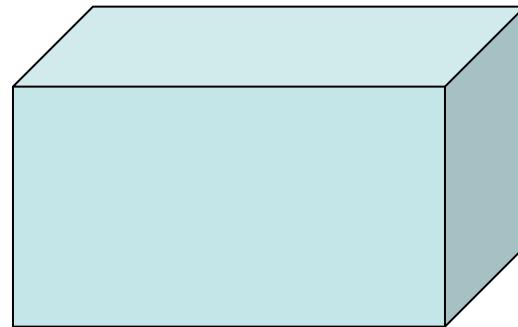
b. For this graph, as x decreases, what happens to y ?
increase decrease stay the same

Equations and graphs tell us which variables are directly proportional or inversely proportional.

A big cube and a small cube have the same mass.
Which cube is more dense? Why?



A



B



<http://www.clipartbest.com/dog-with-bone-clipart>

The museum guard proudly told the visitors that the dinosaur bones on display were “60,000,005 years old.” When asked how the age could be known so precisely, the guard said, “I don’t know how they do it, but when I started working here five years ago, they told me that the bones were 60 million years old.”

- John McGervey, “Probabilities in Everyday Life,” 1986

What is the uncertainty in the age of the dinosaur bones?



<http://www.digipac.ca/chemical/mtom/contents/chapter1/marsfacts.htm>

The distance from the earth to the moon is 0.25 million miles.

The distance between two H atoms in a H₂ molecule is 74 pm (1 pm = 1 picometer = 1×10^{-12} m).

Which measurement has the ***larger*** uncertainty?



http://nevada-outback-gems.com/prospect/gold_specimen/Gold_ores.htm

Very low grade gold ore deposits in Nevada are mined by the use of large steam shovels and trucks that can carry 125 tons of ore. The current price of gold is \$1,160 per ounce.

If the average grade of a gold deposit is 0.015 ounces of gold per ton of ore, what is the value of gold in one truckload of ore?

Nanoscience Is A Hot Topic. How Big Is A Nanometer?

$$1 \text{ nm} = 1 \times 10^{-9} \text{ m}$$

Human hair = 100,000 nm thick

e. Coli bacteria = 250 nm wide and 1,000 - 2,000 nm long

Visible light wavelength = 400 - 700 nm

Tobacco mosaic virus capsid = 18 nm x 300 nm

1 nm \cong 20 Hydrogen atoms \cong 3 Uranium atoms

How big is one H atom?

meijer healthy livingSM icons



Fat Free:

Less than 0.5g fat per serving.



Gluten Free:

Does not contain gluten, a protein that is naturally found in wheat, rye, barley, and oats, as well as a variety of other additives and fillers.



Heart Healthy:

Low in fat and less than 1g saturated fat, 480mg sodium and 20mg cholesterol per standard serving of an individual food. Contains at least 10% of the daily value of at least one of the following: vitamin A, C, calcium, protein or fiber.



High Fiber:

Diets rich in whole grain foods contain 51% or more whole grain ingredients by weight per recommended daily amount.



Lactose Free:

Does not contain lactose, the natural sugar found in milk.



Lean:

Less than 10g total fat, 4.5g or less saturated fat, and less than 95mg of cholesterol per 3-ounce serving of meat or fish.



Carb Conscious:

Foods that support a carb conscious diet.



Low Fat:

Less than 3g fat per serving of individual foods.



Low Sodium:

Less than 140mg sodium per serving of individual foods.



Natural:

Food that does not contain any additives, such as preservatives or artificial coloring.



Organic:

Food produced without synthetic fertilizers, pesticides, or chemical injections or additives, such as antibiotics or hormones.



Soy:

Has at least 6.25g of soy protein from soybeans or soybean by-products (soymilk, soybean oil, tofu, soy flour, tempeh, miso) and is low in fat, cholesterol and sodium.



Sugar Free:

Less than 0.5g sugar per serving. This includes both naturally occurring sugars, such as those found in milk and vegetables as well as added sugars.



Vegan:

No ingredients have been derived from animals, including meat, fish, dairy, eggs, honey, or anything made from these.

Information is also available online: Meijer.com/healthyliving

Salt (NaCl) tastes Good

RDA of sodium is 1500 mg per day.



<http://theshiksa.com/2012/06/04/salt-friend-or-foe/>



Campbell's new soup label design (right) is aimed at helping busy consumers more easily identify the variety of soup they want.

Campbell's Condensed Tomato Soup has 730 mg of sodium per $\frac{1}{2}$ cup. How many cups of Campbell's soup will meet the RDA?

<http://www.packagingnetwork.com/doc/campbell-soup-label-american-icon-gets-faceli-0001>

Fat Tastes Better

2 types: saturated (lard, butter) and unsaturated (veg oil).

Trans fat is a type of unsaturated fat.

RDA of saturated fats is 12 g/day (for 2,000 Cal/day diet)



http://www.eatingwell.com/nutrition_health/nutrition_news_information/butter_or_margarine_is_there_a_healthy_butter_substitute

Chipotle Chicken Burrito has 980 Cal and 18 g of saturated fat.

How many Chipotle Chicken Burritos will meet the RDA?



Fat Tastes Better

2 types: saturated (lard, butter) and unsaturated (veg oil).

Trans fat is a type of unsaturated fat.

RDA of saturated fats is 12 g/day (for 2,000 Cal/day diet)



Starbuck's Venti (20 oz.) White Chocolate Mocha with 2% milk and whipped cream has 580 Cal and 15 g of saturated fat.

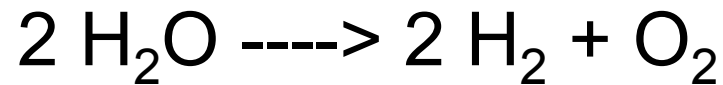
How many Starbuck's Venti (20 oz.) White Chocolate Mochas will meet the RDA?

How is a human body made?



If you have 13 A, how many H do you need?
What is the conversion factor?

Chemistry Conversions:



You electrolyze 200 moles of water. How much H_2 is produced?
What is the conversion factor?

Sig Figs Calculation

(quiz question from Fall 2000) The label on Skippy Peanut Butter gives the following nutrition information:

Serving Size = 2 Tbsp. (32 g)

Amount Per Serving	Calories 190	Calories from Fat 140
Total Fat 16 g		Cholesterol 0 mg
Sat. Fat. 3.5 g		Sodium 150 mg
Total Carbohydrates 7 g		
Dietary Fiber 2 g		Fat 9 cal/g
Sugars 3 g		Carbohydrates 4 cal/g
Protein 7 g		Protein 4 cal/g

- Based on the mass of fat, carbohydrates, and protein in one serving listed on the label, calculate the number of calories from fat, the number of calories from carbohydrates, and the number of calories from protein. Note that the label states that fats contain 9 cal/g, carbohydrates and proteins contain 4 cal/g. Show your work.
- Did the company report the total number of calories correctly on the label using significant figures? Give reasons.
- Did the company report the calories from fat correctly on the label using significant figures? Give reasons.