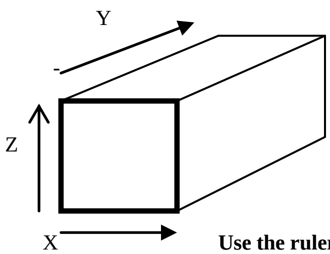
EXPERIMENT 1, Part 1: SOLIDS

Introduction: Volume can be measured directly with a volumetric device such as a graduated cylinder or calculated from dimensions if one has a regular geometric shape such as a cylinder or rectangular bar. Density is found by dividing mass by volume. In this experiment, the densities of a metal bar, metal cylinder and some irregular metal item are determined in units of **g/ cm^3**

Materials	**(optional – Vernier calipers)**
Metal piece of irregular shape, 50 mL graduated cylinder	
Ruler , metal bar and cylinder (obtained from instructor)	

Procedures. **Record all data in the notebook before you fill in the report sheet.**

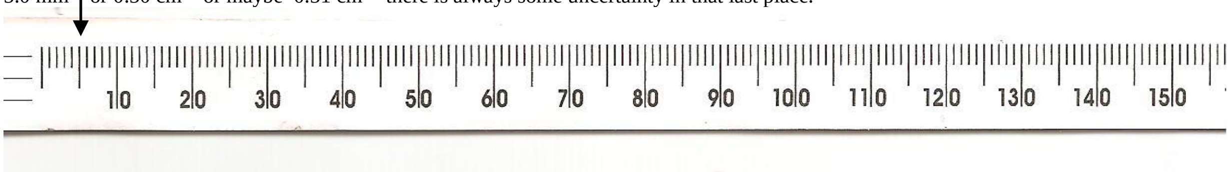
1. Measurements on a metal bar Record the code# Weigh the bar to 2 decimal places
Measure the length, height, and width of a metal bar Calculate the volume (in cm^3) from the three dimensions (length x width x height) to the appropriate number of significant figures.
Note – it doesn't matter which dimensions you call the length or width or height – just make sure you get the three x,y,z dimensions. All dimensions should be recorded to the nearest 0.01 cm.



A common mistake is to measure the length twice.
Make sure you measure the three (x, y, z) dimensions.

Use the ruler below – it should be sufficiently precise to obtain measurements to the nearest 0.5 mm (0.05 cm) or better. convert your readings in millimeters to centimeters !!! - Try to read the ruler as precisely as possible – even to the nearest 0.1 mm. If you think the object matches the mark exactly – record the first decimal as a 0 (mm) . ex: 5.0 mm or 0.50 cm

5.0 mm | or 0.50 cm or maybe 0.51 cm - there is always some uncertainty in that last place.



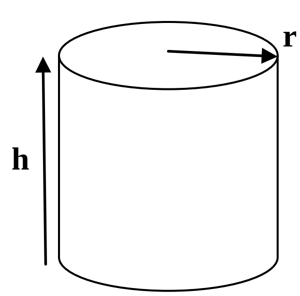
Weigh this same bar, to the nearest 0.01 g (2 decimal places). Now you can calculate the density of the metal, in g / cm^3 Consult the instructor for the true value and have your value signed and dated by the instructor in the notebook.

2. Measurements on a metal cylinder. Record the code # Weigh the cylinder to 2 decimal places
Determine the density of the metal object by measuring the diameter and the length of the cylinder to the nearest 0.01 cm . use the formula **$V = \pi r^2 h$**

Using the densities given in the Introduction to Measurements , (see the Los Angeles City College website). determine which metal you have (your choices are Al, Fe, Ni, Zn, Pb, Sn, Cu, Ag, Au, Pt, Cr, Brass (an alloy of mostly copper) Ti, Mn, Mg). Your instructor may confirm the identity of your metal's density after you complete part 3. . Determine the percent error in your density.

→ **r** the radius of a circle = ½ the diameter

h the height or length of the object.

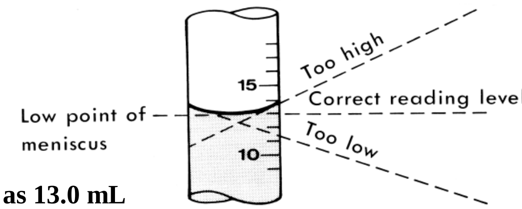


Record all measurements in units of centimeters (cm)

3. Volume by immersion. Using the same metal cylinder as in part 2, you can determine its volume by immersing it in a graduated cylinder which has been filled to the 25.0 mL mark with water. Actually – it doesn't have to be 25.0 mL – you can use any volume of water in the range of 20 – 30 mL as long as you record it to the nearset 0.1 mL. **Slide the metal very carefully into the grad cylinder at a shallow angle !!! Metal does break glass !!!.** To be sure you won't break the glass – tie a sewing thread to the object and control the rate at which the object is immersed by holding on to the thread. Read the new volume of the water in the cylinder. See instructions below on reading the grad cylinder to the nearest 0.1 mL.
Having determined the volume of the metal cylinder by displacement, you can now calculate its density in g/mL (1 mL = 1 cm^3) Get the true value and determine the % error

Some notes on volumetric readings

Water in a glass container forms a **meniscus**, a curved surface that is lower in the middle than at the edge. Volumetric laboratory equipment is calibrated to measure volume by sighting to the **bottom** of of the meniscus and read the value at eye level). In the example below, record the value to the nearest 0.1 mL; (you would read **13.0** mL).



read as 13.0 mL

4. Determination of density by Archimedes Principle. Over 2000 years ago, the Greek scientist Archimedes determined density of irregularly shaped objects by immersion. Grad cylinders were not available ! His principle states that the "apparent weight loss of an immersed object is equal to the mass of the displaced liquid." So if an object weighs 95 grams when not immersed, and 90 grams when immersed, then 5 grams of liquid were displaced. Using water as the liquid, whose density is close enough to 1.00 g/mL, we can say that 5.0 mL were displaced, thus the density is 95 g/ 5 mL . = 19 g/mL (close to the density of gold – which is what Archimedes was asked to determine by the king of Syracuse who was suspicious that his "gold" crown may not have been real gold).

Some irregular pieces of metal will be provided. Hang the metal piece on the hook and record the mass to the nearest 1 g. Spring scales are not so accurate , but 2 significant figures are obtainable.

Now raise a beaker about ¾ full of water such that the metal piece(s) are immersed. Record the mass on the spring scale now. Calculate the density of the metal. If a code # is provided, record it.

All work is to be done individually – no partners.

Hand in the copy sheet from the notebook at the end of the period. No copy sheet – no credit.

EXPERIMENT 1: Part 1 SOLIDS Report

Name: ______________________________
Section __________ Date ______________

Part 1: Data: metal bar **CODE #** ____________

height _________ length ________ width _______ mass: __________

volume and density calculations (show neat organized setup including all units)

Volume ______________ Density: ___________ True density: ____________

% error _____________________

Part 2: Data: cylinder **CODE #** _________

dimensions: diameter ______________

length__________________

mass: _______________________

Show set-up of volume and density calculations

Calculated values

volume : ______________

density : ______________

true density given by instructor

____

% error: _______________

Show set-up of % error calculation

Part 3. Volume of object by immersion (same metal cylinder as in part 2**)**

Volume of water without metal object: ____________________________

Volume of water with immersed metal ____________________________

Volume of metal object……………… ____________________________

Density of metal object …………….. ____________________________
(show setup of calculation)

% error ____________________________
(show setup
of calculation)

Part 4. Density by Archimedes' Principle.

Description of metal piece(s) record a code # if given. ____________________________

____

Mass of metal on the spring scale ____________________________

Mass of immersed metal ____________________________________

Volume of immersed metal __________________________________

Calculation of density. (show a neat detailed setup)

Density of irregular metal.

____

Questions and Conclusions

1. Compare the volumes of the metal object obtained in part 2 and 3 in this experiment. Which method, the measurement of dimensions, or the measurements of volume with a graduated cylinder, gives a better result? (compare the % error) Explain why one method gives a better result than the other.

2a) What is the densest element on the density chart (in the table in the Introduction to Measurements available on the website.) _________ (Note – don't confuse densities with atomic masses)

Densities of solid and liquid elements at 20°C are given in g / cm^3.
Densities of gases at 20°C are given in g/L (italic numbers).

gases' densities are given in Italics

H																	**He**
0.084																	*0.17*
Li	**Be**											**B**	**C**	**N**	**O**	**F**	**Ne**
0.53	1.85											2.46	3.51	*1.17*	*1.33*	*1.58*	*0.84*
Na	**Mg**											**Al**	**Si**	**P**	**S**	**Cl**	**Ar**
0.97	1.74											2.70	2.33	1.82	2.06	*2.95*	*1.66*
K	**Ca**	**Sc**	**Ti**	**V**	**Cr**	**Mn**	**Fe**	**Co**	**Ni**	**Cu**	**Zn**	**Ga**	**Ge**	**As**	**Se**	**Br**	**Kr**
0.86	1.54	2.99	4.51	6.09	7.14	7.44	7.87	8.89	8.91	8.92	7.14	5.91	5.32	5.72	4.82	3.14	*3.48*
Rb	**Sr**	**Y**	**Zr**	**Nb**	**Mo**	**Tc**	**Ru**	**Rh**	**Pd**	**Ag**	**Cd**	**In**	**Sn**	**Sb**	**Te**	**I**	**Xe**
1.53	2.63	4.47	6.51	8.58	10.28	11.49	12.45	12.41	12.02	10.49	8.64	7.31	7.29	6.69	6.25	4.94	*4.49*
Cs	**Ba**	**La**	**Hf**	**Ta**	**W**	**Re**	**Os**	**Ir**	**Pt**	**Au**	**Hg**	**Tl**	**Pb**	**Bi**	**Po**	**At**	**Rn**
1.90	3.65	6.16	13.31	16.68	19.26	21.03	22.61	22.65	21.45	19.32	13.55	11.85	11.34	9.80	9.20	--	*9.23*
Fr	**Ra**	**Ac**	**Rf**														
--	5.50	10.07	--														

Ce	**Pr**	**Nd**	**Pm**	**Sm**	**Eu**	**Gd**	**Tb**	**Dy**	**Ho**	**Er**	**Tm**	**Yb**	**Lu**	
6.77	6.48	7.00	7.22	7.54	5.25	7.89	8.25	8.56	8.78	9.05	9.32	6.97	9.84	
Th	**Pa**	**U**	**Np**	**Pu**	**Am**	**Cm**	**Bk**	**Cf**	**Es**	**Fm**	**Md**	**No**	**Lr**	
11.72	15.37	18.97	20.48	19.74	13.67	13.51	13.25	15.1	--	--	--	--	--	

b) If you have a coin made of this very dense element that weighs 100.0 g, and has a thickness of 4.00 mm, what would the diameter of the coin be, in cm ? ($V = \pi r^2 h$ h = 4.00 mm)

c) Looking at the metallic elements in the left ½ of the periodic table – is there a broad correlation between atomic masses and densities ? For example, compare copper, silver and gold. Then compare the densities of the elements ranging from Rb to Ag. What are the general trends ?

3. 12 karat gold contains 50% gold and 50% copper. What do you think the average density of 12 K gold should be (Hint, look up the densities of pure copper and pure 24 kt gold.)

4.a) Suppose you have a cion consisting of 22 kt gold alloyed with copper. What is the % composition of the coin ? (i.e. the % Au and the % Cu)

b) What would the density of the 22 kt coin be ?

the averaging formula is: $d_{alloy} = d_{Au}$ (% Au / 100) + d_{Cu} (% Cu / 100)

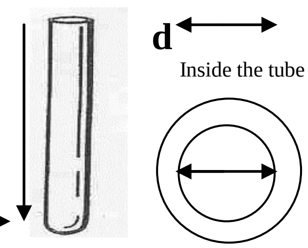
4. Consider the statement made by Archimedes that the apparent weight loss observed in an immersed object is equal to the mass of the displaced liquid. Do you think you would have found a different "weight loss" if you had used a different liquid, for example ethanol, with a density of 0.79 g/mL ? Calculate the weight lost if you immersed your metal object (part 4) in ethanol.

EXPERIMENT 1 part 2 VOLUMES & DENSITIES of LIQUIDS

Introduction: Volume can be measured directly with a volumetric device such as a graduated cylinder or calculated if one has a regular geometric shape such as a vial or test tube . Density is found by dividing mass by volume. In this experiment, the densities of water, or a salt solution, is determined and compared with values found in a table and graphed. Adding a solute such as salt increases the density of the solution in proportion to the amount of salt added . If water contains substantial amounts of salt, a person cannot sink since the density of the salt water is greater than the density of the person. Try drowning in the Great Salt Lake in Utah – you won't sink !!! **Work individually, with your own glassware**

Materials
two test tubes of different size , 50 mL graduated cylinder, ruler or calipers unknown salt solution

Procedures.



1. Determining the volumes of test tubes by two methods.

a) **Use the calipers** to measure inside **diameters** and lengths of two different test tubes to 2 decimal places (example: 1.30 or 1.35 cm) Measure the height to the beginning of the curvature with a ruler. The height measurement will be a bit imprecise – measure to the beginning of the curvature to the nearest 0.1 cm (ex 12.6 cm) a second . .. decimal place is not obtainable due to the curvature.

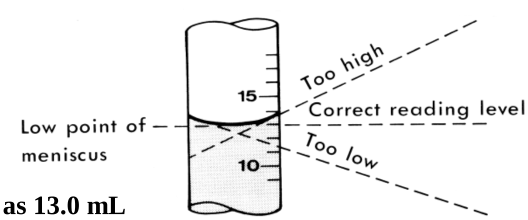
If all your test tubes are the same, borrow one of a different size.

Do not include the thickness of the glass in reading **d**

Calculate the volume using the formula $\mathbf{V = \pi r^2 h}$ (π = 3.14, r = the radius = ½ the diameter.) Round off your calculation to the appropriate number of significant figures. *Do the calculations in your notebook first, before writing them in the report sheet. Make sure your instructor signs the copy page in your notebook prior to leaving the lab.*

b) **Fill the same two test tubes (as in part 1a above) with water**. Separately pour the water from each tube into an empty 50.0 mL graduated cylinder. Measure the volume of the water from each test tube in the grad cylinder to **the nearest 0.1 mL**

Water in a glass container forms a concave "**meniscus".** Read the **bottom** of the meniscus at eye level). In the example below, record the value to the nearest 0.1 mL; (you would read **13.0** mL). Check the volume reading with the instructor



read as 13.0 mL

Compare the volumes obtained in part a by calculation with the volumes obtained in part b. Calculate the % error in each case. Use the value from part a) as the "accepted value" and the value from part b) as the "experimental value". (see formula next page)

$$\% \text{ error} = \frac{[\text{ experimental value} - \text{accepted value }]}{\text{accepted value}} \times 100$$

2. Measurements on water or salt solution. Record the solution's code # !!!!

Weigh a clean dry 50-mL graduated cylinder to 2 decimal places The instructor will either assign you a salt solution sample or tell you to use water. Pour water or a salt solution assigned by the instructor, into the cylinder . Read the volume in the cylinder **to the nearest 0.1 mL** Now weigh the cylinder with the liquid. **Don't spill liquid on the pan!**

Calculate the grams of liquid in the cylinder and the density of the liquid to 4 sig figs. There is a reason why you can "violate" the sig fig rules in this case, having to do with relative uncertainties. . If you were assigned water, you can find the value of the density of water at 20^{o}C in the CRC handbook and compare it with the value you obtained, and find the % error. If a salt solution was assigned, you will not have a density value for comparison – plot the densities vs % NaCl from the table given on the graph paper and then plot your salt solution's density on the line. Read the % NaCl off the x axis. Report this on the Report sheet

3. Make your own salt solution .

Take a clean dry 150 mL beaker and spatula to the balance room, and weigh your beaker.
Carefully weigh out somewhere between 3 and 5 grams NaCl into the beaker. Record the mass of the beaker with the salt to two decimal places.

Take the beaker with salt back to your station. Measure 30.0 mL of water as carefully as you can with your grad cylinder. Use your wash bottle to deliver the water to the cylinder, for greater precision to the 30.0 mL mark

Pour the 30.0 mL into your beaker containing salt and dissolve the salt. A stirring rod will be useful to mix the solution.

Very carefully, go and weigh the beaker with the salt solution you have prepared. You can calculate the grams of solution by difference. The percent of salt in the mixture is found simply:

$$\% = \frac{\text{g salt}}{\text{g solution}} \times 100$$

Finally: Carefully, without losing a drop, transfer the solution back into the graduated cylinder. Record the volume to the nearest 0.1 mL .

Now you can calculate the density of the solution. You are allowed to "cheat" a bit on the sig figs and record **4** sig figs in the density on the report sheet.

$$d = \frac{\text{g solution}}{\text{mL solution}}$$

Plot the calculated density of your solution on the graph that you previously used for the results in part 2. Maybe use a different color pencil to do this. Compare the % you read off the graph with the % you calculated from your grams of salt and solution.

Using the graph value as the "accepted value" compare it to your calculated "experimental" value to find a % error.

EXPT 1 part 2 Report Sheet **Name**: ______________________________

LIQUIDS: VOLUMES & DENSITIES Section __________ Date due ________

Date submitted ____________________

Part 1a: Test tube dimensions (show units) — Calculated values

test tube #	inside diameter (d)	height (h)	volume (cm^3)
1.	_________	________	___________
2.	_________	________	___________

Show the set-up of one volume calculation. *Watch your sig figs*

Part 1b: Data using the graduated cylinder (show units)

test tube #1 : volume __________ test tube # 2: volume: ___________

Part 2: Unknown NaCl solution — Code # ________

Show the units of your data and calculated values

mass of grad cylinder _______________g_

mass of cylinder with liquid : _______________g_

Calculate mass of liquid:
In the grad cylinder _______________g_

volume of liquid: ___________________
(mL)

density of liquid: _________________
(from your mass and volume)
Calculate this to **4** sig figs even though your data may not appear to warrant 4 sig figs. You will have three decimal places in the density

Show the setup of the density calculation here:

Plot the density of the unknown solution on the graph and find the **%** NaCl off the x axis.
Record the % NaCl here:

____

Part 3. Data & Calculations:

Mass of beaker : __________________ g

Mass of beaker with salt:__________________ g

Mass of salt by difference: ________________ g (this is between 3 and 5 grams)

Mass of salt solution with beaker _______________ (this includes the 30.0 mL water)

Mass of salt solution: __________________ g

Volume of salt solution __________________ (when solution is back in the cylinder)

Calculate the % NaCl in the solution:

Show setup and units:

___________ %

Calculate the density of the solution

-show setup and units

___________ g/mL

Find the % of NaCl off the graph (prelab exercise) and the plotted value of density (above)

__________ % NaCl

Calculate the % error (compare with the % calculated above)
(value off the graph)

___________% error

Show setup

Pre-lab graphing exercise. Obtain graph paper with 10 squares per inch

1. Set up the y axis along the vertical (long side) and the x axis along the horizontal (short) side Mark each ½ inch division (5 squares) starting with 0.990 at the x axis, 1.000 at the first ½ in Mark, 1.010 at the second ½ inch mark etc until you get to 1.119 at the top of the graph paper. Mark the x axis at each ½ inch mark (5 squares) starting with 0.0 , 2.0 at the first ½ in mark, 4.0 at the 2nd ½ inch mark (10 squares) etc up to 28 % at the end of the x axis.

2 Plot the densities of some of the salt solutions whose values are given the table 3 or 4 widely separated points are enough. Use a sharp pencil and draw a circle around each point

3. Draw a straight line with a ruler through the set of points.

% NaCl	d (g/mL)
0.0 %	0.998
3.0 %	1.020
7.0 %	1.049
9.0 %	1.063
14.0 %	1.101
18.0%	1.132
22.0 %	1.164

4. Find the slope of the line, using 2 new points (not plotted data)

The two points should be marked fairly far apart, in order to increase the # of sig figs. Use squares to outline the 2 new points so as to differentiate them from the data points in the table. Record the coordinates to the appropriate # of sig figs off the x and y axes.

Density (y_2 coordinate) _______________ Density (y_1 coordinate) __________________

% NaCl (x_2 coordinate) _______________ % NaCl (x_1 coordinate) __________________

Calculate the slope of the line : recall: $\frac{y_2 - y_1}{x_2 - x_1}$ = **m** the slope value in the equation of a straight line.

Show setup and watch your sig figs

m = ________________

5. Find "**b**" (the " y intercept) off your graph. This is the y value where the x value is 0.

b = _________________

6. Now write the equation of the straight line in the format y = mx + b using the values of slope and y intercept.

7. Using the equation of the line, predict the density of a 26.0 % NaCl solution. Show work
Does it match the extended line drawn from the plotted points ?

d = __________ g/mL

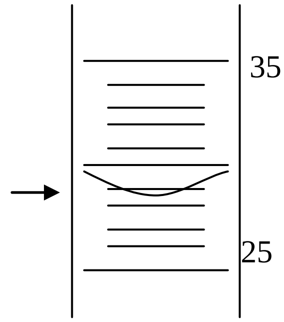
8. Look up the density of a 26.00 % NaCl solution from the CRC Handbook (D_{20}) __________

9. Calculate the % error in your value from the equation, compared to the accepted value.

Insert your graph here, after this page.

Questions

1. An empty graduated cylinder weighs 75.34 g.
It was filled to the extent shown in this partial segment of a graduated cylinder with a liquid called carbon tetrachloride (CCl_4). The density of CCl_4 is 1.61 g/mL How many grams does the cylinder weigh <u>together with</u> the CCl_4?



2. Compare the volumes of the test tubes obtained in part 1a and 1b in this experiment.
Which method, the measurement of dimensions, or of volume with a graduated cylinder, do you think gives a better result? Explain why.

3. There are only two liquid elements (at room temperature). What are they ? (use a textbook or a CRC Handbook for reference).

This table is the one given in the Introduction to Measurements appendix available on-line along with other useful information

Densities of solid and liquid elements at 20°C are given in g / cm^3.
Densities of gases at 20°C are given in g/L (italic numbers).

gases' densities are given in Italics

H																	**He**
0.084																	*0.17*
Li	**Be**											**B**	**C**	**N**	**O**	**F**	**Ne**
0.53	1.85											2.46	3.51	*1.17*	*1.33*	*1.58*	*0.84*
Na	**Mg**											**Al**	**Si**	**P**	**S**	**Cl**	**Ar**
0.97	1.74											2.70	2.33	1.82	2.06	*2.95*	*1.66*
K	**Ca**	**Sc**	**Ti**	**V**	**Cr**	**Mn**	**Fe**	**Co**	**Ni**	**Cu**	**Zn**	**Ga**	**Ge**	**As**	**Se**	**Br**	**Kr**
0.86	1.54	2.99	4.51	6.09	7.14	7.44	7.87	8.89	8.91	8.92	7.14	5.91	5.32	5.72	4.82	3.14	*3.48*
Rb	**Sr**	**Y**	**Zr**	**Nb**	**Mo**	**Tc**	**Ru**	**Rh**	**Pd**	**Ag**	**Cd**	**In**	**Sn**	**Sb**	**Te**	**I**	**Xe**
1.53	2.63	4.47	6.51	8.58	10.28	11.49	12.45	12.41	12.02	10.49	8.64	7.31	7.29	6.69	6.25	4.94	*4.49*
Cs	**Ba**	**La**	**Hf**	**Ta**	**W**	**Re**	**Os**	**Ir**	**Pt**	**Au**	**Hg**	**Tl**	**Pb**	**Bi**	**Po**	**At**	**Rn**
1.90	3.65	6.16	13.31	16.68	19.26	21.03	22.61	22.65	21.45	19.32	13.55	11.85	11.34	9.80	9.20	--	*9.23*
Fr	**Ra**	**Ac**	**Rf**														
--	5.50	10.07	--														

Ce	**Pr**	**Nd**	**Pm**	**Sm**	**Eu**	**Gd**	**Tb**	**Dy**	**Ho**	**Er**	**Tm**	**Yb**	**Lu**
6.77	6.48	7.00	7.22	7.54	5.25	7.89	8.25	8.56	8.78	9.05	9.32	6.97	9.84
Th	**Pa**	**U**	**Np**	**Pu**	**Am**	**Cm**	**Bk**	**Cf**	**Es**	**Fm**	**Md**	**No**	**Lr**
11.72	15.37	18.97	20.48	19.74	13.67	13.51	13.25	15.1	--	--	--	--	--