Lab #8: The Density of Various Materials

Every object in the Universe is made of various types of matter and this matter has mass and occupies space. All objects have a characteristic density, and objects made of a pure substance have a density determined by the laws of physics. You can determine what an object is made of by this characteristic density. This density depends on two factors: the number of protons and neutrons in the nucleus of each atom of the material, and the distance between atoms in the material. If either of these factors is changed, then the density changes. Notice in the list of elements in the table below that carbon is listed twice (first as graphite, second as diamond), and that the density of these two is not the same. This is so because in diamond the carbon atoms are more tightly packed, and that means a larger density than in graphite.

Astronomical objects are rarely made of one single substance, so knowing their density is not enough to determine their chemical composition. Nevertheless, out of the knowledge of the density of a planet, an asteroid, or a satellite, you can still make and educated guess and tell, with reasonable certainty, what it is composed of.

Recall, for your calculational work, that the density of an object is $density = {mass}/{volume}$. The volume of a cylinder is calculated as $V = \frac{\pi}{4} \times h \times d^2$, where *h=height,* and *d=diameter*.

In this laboratory you will be given objects made of unknown materials, you will measure the density of each of these, and determine what these objects are made of.

Name	**Symbol**	**Density** *g/cm³*	**Atomic/molecular mass**
Hydrogen	H_2	0.00009	2
Carbon (graphite)	C	2.1	12
Carbon (diamond)	C	3.5	12
Nitrogen	N_2	0.0012	28
Oxygen	O_2	0.0014	32
Magnesium	Mg	1.74	12
Aluminum	Al	2.70	13
Silicon	Si	2.33	14
Iron	Fe	7.87	26
Copper	Cu	8.96	29
Tungsten	W	19.3	74
Iridium	Ir	22.4	77
Gold	Au	19.3	79
Lead	Pb	11.4	82
Air	78% N_2 and 21% O_2	0.0012	28.4
Water	H_2O	1.00	10
Ice	H_2O	0.92	10
Quartz (in rock)	SiO_2	2.64	30
Basalt	mix	2.91	n/a
Limestone	$CaCO_3$	2.60	100
Plexi-glass	$C_5H_8O_2$	1.20	84
Carbon dioxide	CO_2	0.0021	44

How to use the vacuum pump:

Use the vacuum pump to suck out the air or gases from the cylinder. Your instructor should give you an illustration of how this is done:

(i) Attach the pump to the cylinder through a tube.

(ii) Open both facets, the one on the cylinder and the one on the pump.

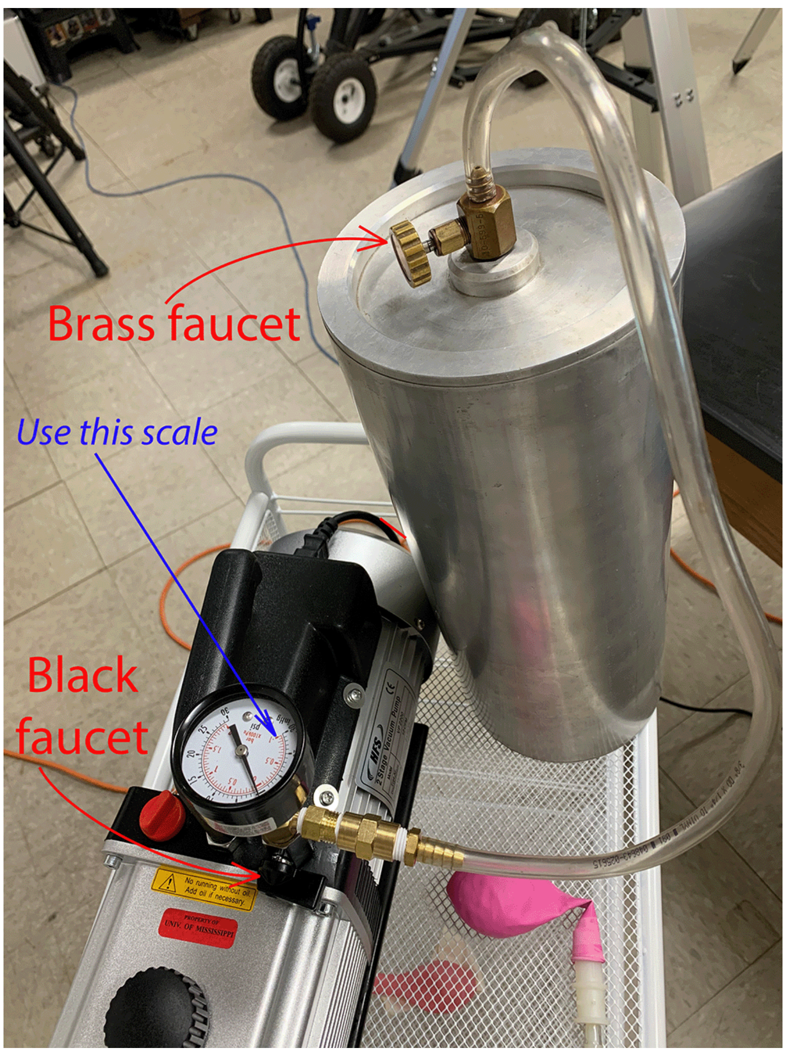
(iii) Run the pump for about one minute (you'll hear the pump running quiet and the steam disappearing).

(iv) Close the black faucet on the pump.

(v) Stop the pump.

(vi) Record the pressure from the gauge. Use the red scale, which is in bars. For your information, 1 bar approximately equals one atmospheric pressure. The reading goes from 1 bar down, so the reading should be negative, around -1 bar, when the cylinder is empty.

(vii) Close the brass faucet on the cylinder and remove the tube.



PROCEDURE AND LAB REPORT

Your name: _______________ Partner's name: _______________ Section: ___

Maximum two students may work together as partners!

Gases like air have their mass the same way as solids and liquids do; they are *not* massless nor weightless, only gases usually have smaller density (except when under large pressure like inside the San, for example). In the first two exercises you'll measure the density of air and of carbon dioxide. We have only three setups available; ***if*** all three are taken, do ***proceed with Exercise 3*** and on so as not to lose your lab time idly waiting.

Exercise 1. *The density of air:*

To get the measurement of the empty cylinder, we have one extra cylinder that has been taken apart, so you can get to its internal sizes. Take a measurement of the (inner) size of the cylinder. Your results are, diameter: _____ *cm*, height _____ *cm*. Calculate its volume: _____cm^3. Have your instructor check this number for you. (If this volume is incorrect, all your results will be wrong!)

Use the vacuum pump to suck out the air or gases from the cylinder. (For instructions, see the previous page.)

When measuring the mass of the cylinder, you'll need extreme precision, keeping one decimal in the mass. It is possible, but difficult, to read out the mass with this precision from the scales.

Record the pressure in the cylinder when emptied out: _____ *bars below atmospheric pressure*.
Measure the mass of the empty cylinder as precisely as you can: _____ *grams*.
Now, open the faucet on the cylinder, and weight about a minute for it to fill up with air. Re-weigh the cylinder with air inside, very precisely again: _____ *grams*. Calculate the density of air the same way as you did with the water. Mass of air: _____ *grams*, density: _____ g/cm^3. Compare this number to the number in the table; percent error: _____%. Do you think this is reasonable? _______ .

Exercise 2. *The density of CO_2:*

Empty out the cylinder of air/gases again, then fill the cylinder with carbon dioxide. You'll do this in two steps: first fill the balloon with CO_2, then attach the balloon to the aluminum cylinder using a needle valve. It may take more than one balloon's worth to fill up the cylinder.
Measure the density of carbon dioxide the same way as you did the density of air.
The mass of the CO_2-filled cylinder is _____ *grams*. Mass of CO_2: _____ *grams*; density: _____ g/cm^3. Compare this number to the number in the table; percent error: _____%. Do you think this is reasonable? _______ . Did you find the density of CO_2 to be more or less than the density of air? _______

Next, you'll measure the density of water, and a rock. You'll use the result to guess what type of rock this one is. (If a vacuum pump setup is available, do that first!)

Exercise 3. ***The density of water:***
Measure the mass of the empty plastic cylinder: _____ *grams*. Put *100 cm³* of water in the cylinder and measure its mass now: _____ *grams*. You conclude from this that the mass of *100 cm³* of water is _____ *grams*. Use these numbers to calculate your measured value of the density of water: _____ *g/ cm³*. What is the percent error in your measurement, _____%, and do you think this is reasonable? _______ .

Exercise 4. ***The density of your rock:***
Pour out some of the water from the cylinder and fill it back up to *60 cm³*. Measure its mass now: _____ *grams*. Next, add two pieces of rock. (Make sure the rock is completely immersed in the water, otherwise you have to start again with more than *60 cm³* of water.) Measure the new water level, _____ *cm³* , and the new total mass, _____ *grams*. You conclude from this that the mass of _____ *cm³* of rock is ______ *grams*; the density of the rock is _____ *g/ cm³*. What type of rock do you think this is? ____________ .

You can see that knowledge of the density of a material may help to guess what is, even when there might be more than one material (especially mixtures) with the same density.

Exercise 5. ***Several solid objects***
Now you will be determining the density (and identity) of several objects. As this involves a lot of computations and time may be limited, your lab instructor may cut these exercises down to fewer objects, and you may not have to finish all if time does not permit it. Be sure, however, to ***do Exercises 1, 2, and 6 before the end*** of the lab time.

Object #	**Metal?**	**Magne-tic?**	**Length** *[cm]*	**Width** *[cm]*	**Height/Dia-meter** *[cm]*	**Volume** *[cm³]*	**Mass** *[g]*	**Density** *[g/ cm³]*	**Made of …**

Do each of the elements below with each of the objects and put the results in the table above. Ask your instructor to give you a list of the objects you should select.

A. ***Metal? Magnetic?*** Touch a magnet to each object, inspect it, and record whether it looks and feels like metal and if it is attracted to a magnet. Answer Y/N.

B. ***Measure the mass*** of each object, using scales, and record it in the data sheet.

C. ***Measure the dimensions*** of each object with a ruler: length, width, and height or diameter.

D. ***Calculate the volume*** of each object. (The volume of a box is $length \times width \times height$.)

E. ***Calculate the density*** of each object. (Re-read the introduction above for a hint.)

F. ***What substance is it?***
Use the table to make an educated guess at what each of your objects is made of. In addition to the density values in the table, use common sense.

Exercise 6. ***An application to Solar System astronomy:***
In the table below we provide the densities of a few solar system objects. These have been measured using their strength of gravity. Use these densities and some common sense to tell what the composition of these objects must be: gas, ice, iron, rock, or maybe a mixture (if so, indicate what mixture).

	Earth	**Sun**	**Saturn**	**A comet**	**Moon**	**Pluto**
Density	5.5 g/cm^3	1.4 g/cm^3	0.8 g/cm^3	1.0 g/cm^3	3.1 g/cm^3	2.0 g/cm^3
Composition						

Hint: *Don't forget that gases are compressible, and the insides of the planets are much compressed!*