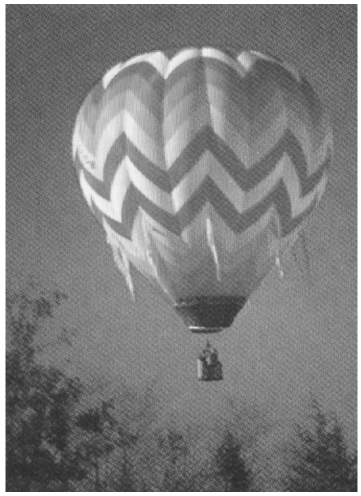
Name: ______________________________
Partners: ______________________________
____

PHYSICS 220 LAB #8: BUOYANCY AND IDEAL GAS LAW



The buoyant force that holds a hot air balloon aloft is the same thing that causes wood to float in water. The operation of balloon also uses the properties of air such as the increase of volume with temperature.

(Equipment: water containers, paper towels, blocks of wood with string, scale, force probe, pressure sensor, temperature sensor, tubing, ice, hot plate, boiling flask & stopper, syringe, computer, LabPro, 100-g mass)

OBJECTIVES

1. To understand and verify Archimedes' Principle which describes buoyant forces.
2. To experimentally verify some aspects of the Ideal-Gas Law.
3. To experimentally determine absolute zero.

PRE-LAB (to be completed before coming to lab)

Prior to coming to lab, read through this write-up and perform all the exercises labeled "**Pre-Lab**". You will also want to copy this work onto the back pages of the lab, which I will collect during the first 5 minutes of lab.

OVERVIEW

Archimedes' Principle states that an object partially or wholly immersed in fluid is buoyed up by a force equal to the weight of the displaced fluid. The density of a substance is its mass divided by its volume (ρ=M/V). Water's density is 1 g/cm^3 (1 cm^3 = 1 ml).

The Ideal-Gas Law is

$$PV = nRT = NkT,$$

where n is the number of moles of gas and N is the number of gas atoms or molecules. The relation between number of moles and number of molecules is

$$N = nN_A,$$

where $N_A = 6.02 \times 10^{23}$. The number of moles is the mass divided by the atomic or molecular mass. R=8314 J/kmol•K is the gas constant and k=1.38×10^{-23} J/K is Boltzmann's constant. This law describes the approximate behavior of gases that are far from condensation. The temperature used in it must always be expressed in kelvins. The temperature in kelvins is never negative because neither pressure nor volume can be negative. The lowest possible temperature is zero kelvin, which is known as absolute zero. The relation between the temperature in kelvins (T) and the temperature in degrees Celsius (T_C) is

$$T = T_C + 273.$$

The pressure in the law is the absolute pressure, not the gauge pressure ($P_G = P - P_a$). Recall that a pressure is a force divided by an area. Also, the relations between some common pressure units are:

$$1 \text{ atm} = 1.01 \times 10^5 \text{ Pa} = 76 \text{ cmHg} \qquad 1 \text{ Pa} = 1 \text{ N/m}^2$$

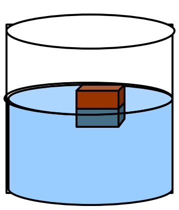
PART ONE: Buoyancy

1. **Floating Object**

   (a) **Computer Set-up:** Plug the Dual-Range Force Sensor into Channel 1 of the LabPro. Open Force Sensor in Physics Experiments / Physics 220-221/ Buoyancy.

   (b) To calibrate the force probe, select *Calibrate* from the **Experiment** menu and select CH1: Dual Range Force (N). Click Calibrate Now. For Reading 1, leave the probe unloaded, enter 0 N and hit Keep. For Reading 2, hang a 100-g mass from the probe and enter its weight: 0.98 N, then click **Keep**. Finally, hit **Done**.

   (c) **Pre-Lab:** Draw and label the forces on an object that is floating in water.



   (d) **Pre-Lab:** Write an equation which relates the forces in your diagram.

(e) Use the balance to measure the mass of the object which you will float.

m_{obj} = ________________ kg, w_{obj} = ________________ N

(f) Find the mass of an empty beaker.

m_{beaker} = ________________ kg, w_{beaker} = ________________ N

(g) Slowly lower the object into the water and catch the water that it displaces in the beaker. Be very careful that you do not splash out extra water. Measure the mass of the beaker and water and use that to determine the weight of the displaced water.

m_{total} = ________________ kg, w_{total} = ________________ N

w_{disp} = ________________ N

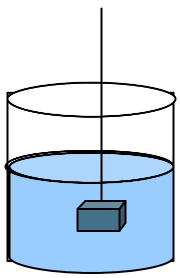
Question: What's the percent difference between the weight of the water displaced and the weight of the block?

Question: What's Archimedes' Principle, and do your measurements confirm it?

Before Continuing: Check with the instructor.

2. **Submerged Object**

(a) **Pre-Lab:** Draw and label the forces on an object that is hung by a string and submerged in water <u>without</u> touching the bottom.



(b) **Pre-Lab:** Write an equation which relates the forces in your diagram.

(c) Calibrate the force probe and do not forget to "Zero" the force probe before each measurement you make. Use the force probe to measure the weight of the object which you will submerge.

w_{obj} = ________________ N

(d) Empty and dry out the beaker. <u>Slowly</u> lower the object on a string into the water and catch the water that it displaces in the beaker. Measure the mass of the beaker and water and use that to determine the weight of the displaced water.

m_{total} = ________________ kg, w_{total} = ________________ N

w_{disp} = ________________ N

(e) Use the force probe to measure the tension of the string while the object is submerged in the water, but <u>not</u> touching the bottom.

T = ________________ N

Question: Do your measurements confirm Archimedes' Principle? Show the work you use to answer.

Question: What is the density of the submerged object? (Use your measurements and the density of water. Hint: How do the volume of the object and the volume of the displaced water compare?) Show your work.

PART TWO: Calibration of the Pressure Sensor

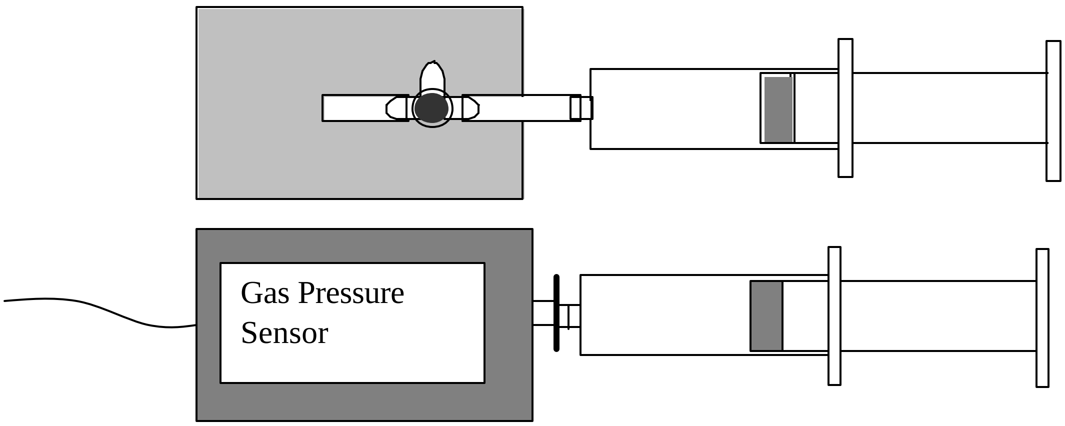
Before you can use the pressure sensor and temperature probe, you must calibrate them by entering readings for two known situations.

0. Unplug the force probe.
1. Plug the pressure sensor into Channel 1 and the thermometer into Channel 2.
2. Open Physics Experiments / Physics 220 – 221/ Ideal Gas / "Pressure-Temperature."
3. You'll need to calibrate the pressure sensor. Under the *Experiment* menu, select "Calibrate" and select just the pressure sensor. Hit "Calibrate Now." With the syringe completely pressed in, attach it to the pressure sensor. (Note: there are two models of pressure sensor, either the syringe screws directly onto the sensor or fits on a piece of tubing.) Hit "Calibrate Now." For the first calibration point, attach the larger of your two syringes and pull back on the plunger until the sensor reads 0 (or as close as you can get it). Then enter 0 kPa and hit "Keep." For the second calibration point, remove the syringe and allow the sensor to be exposed to atmospheric pressure; enter 101 kPa and hit "Keep." Finally, hit "Done."

PART THREE: Constant Temperature

For this part, you will work with air at room temperature. All changes in the volume of the syringe should be made slowly so that the temperature of the gas inside can readjust if necessary.

1. Un-attach the syringe from the gauge and pull it back to 20 cm^3. Then re-attach the syringe to the gauge. Do <u>not</u> squeeze the syringe so hard that the pressure goes above 6 times atmospheric pressure or you may damage the sensor. Gas is also likely to leak out of the syringe at very large pressures and you will be assuming the quantity of gas is constant.



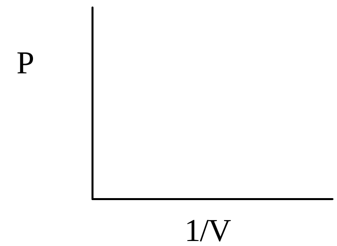
2. Record the room temperature in degrees Celsius.

T_C = ________

3. Slowly compress the air in the syringe and take readings of the pressure for five volumes, two smaller than 20 cm^3 and two larger. Note: without hitting "collect", you can just monitor the pressure reading in the bottom left of the program window. Also, calculate the inverse of the volume for each measurement.

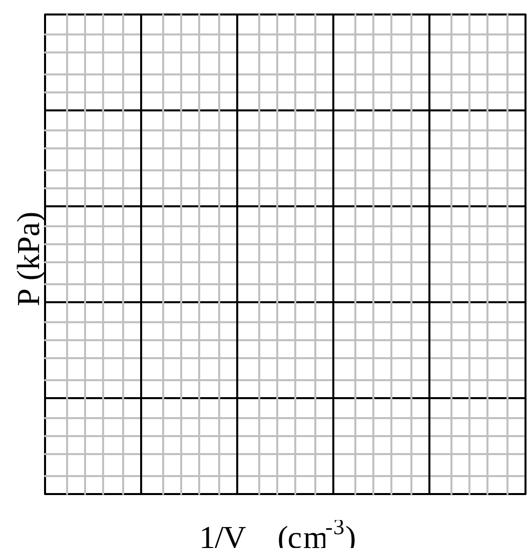
Volume (cm^3)	1/Volume (cm^{-3})	Pressure (kPa)

4. **Pre-Lab**: According to the Ideal Gas Law, sketch what you'd expect a plot of P vs. 1/V to look like.



5. **Pre-Lab:** In terms of N, k, and T, what does the Ideal Gas Law say the slope should be?

6. Plot the pressure vs. (1/volume) below. (Note: you can use LoggerPro to do this if, under the "Data" menu, you define a new data column and enter your 1/V values.)



Question: Does your data agree with the Ideal-Gas Law? Explain.

Calculate the Slope (you may wish to use LoggerPro or Excel).

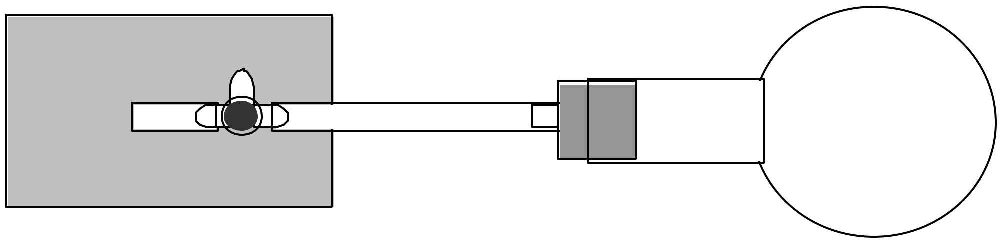
Question: How many molecules are inside the syringe? Show your work. (Note: you'll need to convert pressure, temperature, and volume into base SI units – Pa, K, and m^3).

Question: If you assume that all of the air is nitrogen molecules (molecular mass of 4.6×10^{-26} kg / molecule), what is the total mass of the gas inside the syringe? Show your work.

Question: If you very suddenly compressed a gas to half of its original volume, why could the pressure *more than* double?

PART FOUR: Constant Volume

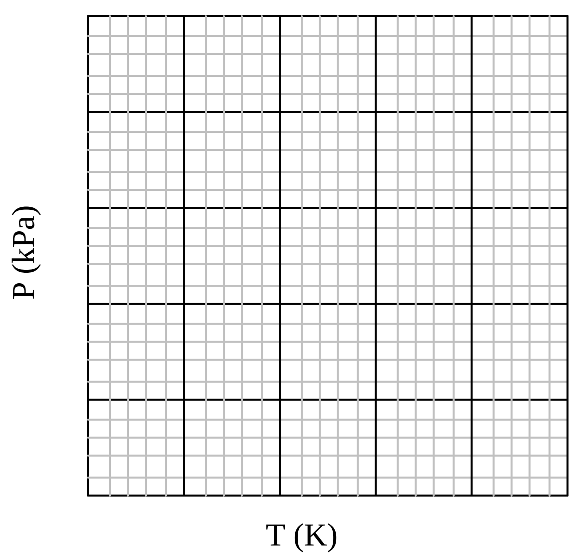
1. Attach the pressure sensor to a boiling flask filled with air as shown below.



2. In the "Pressure – Temperature" program, hit "Collect." There should now be a "Keep" button. Whenever you wish to record a data point, hit "Keep." When you've taken all your data points, hit "Stop."
3. Record temperature and pressure readings with the flask submerged in ice water and hot water in a beaker. In each case, allow at least 2 minutes for the gas in the flask to come into equilibrium with the water in the beaker.
4. Add a mixture of hot water and tap water and take another set of readings for a temperature between 320 and 340 K.
5. Record the room temperature and pressure readings on the first row in the table below.

Temp (K)	Pressure (kPa)

6. Plot pressure vs. temperature in <u>Kelvin</u> below.

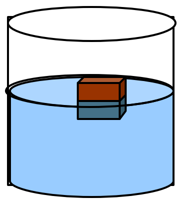


Questions: According to your data, at what pressure would the temperature be zero (what's your "Y-intercept")? (There is a "Linear Fit" button on the program's tool bar.) How does your value compare to the accepted value of absolute zero?

Pre-Lab #8 **Name:_______________**

Floating Object

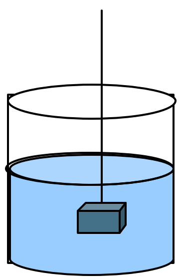
(a) **Pre-Lab:** Draw and label the forces on an object that is floating in water.



(b) **Pre-Lab:** Write an equation which relates the forces in your diagram.

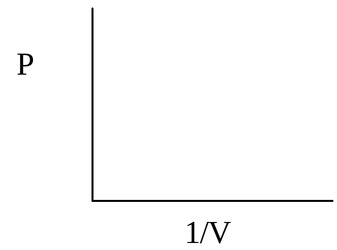
Submerged Object

(c) **Pre-Lab:** Draw and label the forces on an object that is hung by a string and submerged in water <u>without</u> touching the bottom.



(d) **Pre-Lab:** Write an equation which relates the forces in your diagram.

Pre-Lab: According to the Ideal Gas Law, sketch what you'd expect a plot of P vs. 1/V to look like.



Pre-Lab: In terms of N, k, and T, what does the Ideal Gas Law say the slope should be?