Engineering Physics – Mechanics Lab 10

The Ideal Gas Law

One of the most fundamental laws used in Thermal Physics and Chemistry is the Ideal Gas Law.

$$PV=nRT$$

where P is Pressure [kPa], V is Volume [m^3], n is the number of moles in the gas [mol], R is constant 8.314472 [m^3Pa/Kmol], and T is Temperature [K].

This law describes gases and the relationship between the Pressure, Volume and Temperature of a gas.

Please note that [cc] ≈ 1 cubic centimeter.

PLEASE READ ALL INSTRUCTIONS FOR EACH PART
BEFORE YOU ATTEMPT EACH PART!!

Part 1:
Construct a graph of Pressure (kPa) vs. Time and Temperature (K) vs. Time:

1. In Data Studio, set the sampling rate to 20Hz.
2. Disconnect the white plastic pressure coupler from the pressure sensor. Press the plunger of the syringe all the way in until the handle of the plunger bottoms out on the mechanical stop. Record this minimum volume as your final volume in Table 1. It should be close to 20 cc.
3. Set the plunger at 40 cc, and then re-connect the coupler to the sensor.
4. Start recording data, quickly compress the plunger all the way in and **KEEP IT COMPRESSED.** The plunger handle should be bottomed out against the mechanical stop.
5. Watch the graphs of pressure and temperature, and continue to hold the plunger in until the values are no longer changing. This should take about 10 seconds.
6. After the temperature and pressure have equalized, release the plunger. Again, watch the graphs and wait until the values are no longer changing.
7. Stop data collection.

Data Analysis:

1. Look at the Pressure vs. Time graph and highlight the beginning part before you compressed the air to obtain the initial Pressure (when the volume was at 40 cc and the Temperature was at room temperature). Record this in Table 1.
2. Look at the Pressure vs. Time graph, again, and highlight the portion just before you released the plunger. Record this as the final pressure in table 1. The volume is the volume that the plunger stopped at in step 2, and the temperature should be at room temperature at this point in your data collection.
3. Complete questions 1 through 4.
4. Highlight an area on the temperature graph at the beginning of the run before you compressed the air, as you did before. Record $P_{initial}$ and $T_{initial}$ in Table 2. Record the initial volume $V_{initial}$ (including V_0).

5. Look at the portion of your Temperature vs. Time graph when you compressed the plunger. Highlight the area on graph where the temperature peaks. Record the **peak** temperature (T_{final}) and the corresponding pressure (P_{final}) for that time in Table 2.
6. Record the volume V_{final} (including V_0) of the fully compressed plunger in Table 2.
7. Complete questions 5 through 8.

Part 2:

Procedure:

1. Add a digits display of temperature in DataStudio.
2. Disconnect the white plastic coupler from the pressure sensor. Set the plunger at 45 cc and the re-connect the coupler to the sensor.
3. Start recording data. Compress the plunger to 40 cc and hold it at this position. Watch the temperature on the digits display and wait until it has dropped down close to room temperature. Note the final (equilibrium) temperature. Each time you compress the air in this sequence, wait until the temperature returns back down close to this value.
4. Compress plunger to 35 cc and hold it at this position. Watch the temperature, and hold the plunger at 35 cc until the temperature has dropped to the value you noted in step 3. Do not release the plunger.
5. Compress the plunger to 30 cc, and wait until the temperature drops as before.
6. Repeat for 25 cc and 20 cc.
7. Stop recording data.

Data Analysis:

1. Compare your Temperature and Pressure graphs and determine when the plunger was at 40 cc. The values of temperature and pressure will become your equilibrium values. Record these in Table 3.
2. Repeat for all other volumes including the V_0 found in part 1. Pick a temperature as close to the equilibrium temperature as possible and record its corresponding pressure. Record these values in Table 3.
3. Calculate (1/P) for each of the volumes and record these values in Table 3.
4. Graph Volume vs. 1/Pressure in EXCEL.
5. Complete questions 1 through 3.

Part 3:

Adiabatic compression happens when a gas is compressed so quickly that all the work put into the compression goes into heating the gas, i.e. no heat escapes to the outside environment during compression.
For adiabatic compression the Pressure and Volume are related by:

$$\mathbf{P_{initial}\,(V_{initial})^{\gamma} = P_{final}\,(V_{final})^{\gamma}},$$

where γ is the ratio of specific heats, for air $\gamma \approx 1.40$.

1. Set the sample rate at 50Hz.
2. Disconnect the white plastic coupler from the pressure sensor. Set the plunger to 60 cc, and then re-connect the coupler to the sensor.

3. Start recording data. As quickly as possible, compress the plunger from 60 cc down to 20 cc. Do this in one quick motion, bottoming out the piston on the mechanical stop.
4. Stop recording data.

Data Analysis:

1. Use your Pressure and Temperature Graphs to find $P_{initial}$ and $T_{initial}$ before you compressed your syringe, also $V_{initial}$(including the V_0 from Part 1) and record them in Table 4.
2. Use the graph to find the “peak” temperature and the “peak” pressure. Record these in Table 4.
3. Complete questions 1 and 2.

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The Ideal Gas Law - Worksheet

Part1:
(a) Constant Temperature

Table 1:

	Volume (cc)	**Pressure (kPa)**
Initial	40.0	
Final		

1. The amount of air and the temperature in the syringe are the same at the initial point and the final point. the Ideal Gas Law reduces to In terms of $P_{initial}$, $V_{initial}$, P_{final}, and V_{final} what does the Ideal Gas Law reduce to?

2. The experimental error in this syringe is due to the unknown volume of the tubing. If we call this V_0, what will the equation from question (1) above look like in terms of $P_{initial}$, $V_{initial}$, P_{final}, and V_{final},?

3. Algebraically solve this equation for V_0 .

4. Using your values for $P_{initial}$, $V_{initial}$, P_{final}, and $P_{initial}$ calculate V_0.

CHECKPOINT 1:

(b) Varying Temperature

Table 2:

	Volume (cc)	Pressure (kPa)	Temperature (°C+273=K)
Initial			
Final			

5. Now only the amount of air is constant in Syringe. So (in terms of $P_{initial}$, $V_{initial}$, $T_{initial}$, P_{final}, V_{final}, and T_{final},) what does the Ideal Gas Law algebraically reduces to?

6. Now find the ratio of $P_{initial}$, $V_{initial}$, and $T_{initial}$ using your numbers from Table 2.

7. Now find the ratio of P_{final}, V_{final}, and T_{final} using your numbers from Table 2.

8. Find the percent difference between the ratios found in (6) and (7).

CHECKPOINT 2:

Part 2: Determining the Amount of Gas

Equilibrium Temperature (°C+273=K):_________________

Table 3:

Volume (cc)	**Pressure (kPa)**	**1/Pressure (1/kPa)**
$40 + V_0=$		

9. Have your lab instructor look at your graph. Then sketch your graph and include the slope of your best-fit line. Remember to label your axes, and title your graph.

10. Why do all the points seem to lie on a straight line?

11. The slope of your line is related to the Ideal Gas Law. How?

Slope =

12. Use the slope of your line to determine the number of moles in your syringe (pay attention to the units!!!).

CHECKPOINT 3:

Part 3: Adiabatic Compression

Table 3:

	Volume (cc)	Pressure (kPa)	Temperature(K)
Initial			
Final			

13. Use your values for $P_{initial}$, $V_{initial}$ and V_{final} to calculate the "peak pressure"(P_{final}).

14. Compare your "theoretical" peak pressure to the peak pressure you recorded in Table 3. Find the % difference. Should this be an adiabatic compression? Why or Why not?

CHECKPOINT 4: