Physics 124 Workshop Week Apr 17, 2017 – Thermo 3

I. Problem solving

1. One mole of a monatomic ideal gas is at an initial pressure $P_o$ and volume $V_o$. The P-V diagram below shows a reversible cyclic process $1 \to 2 \to 3 \to 4 \to 1$ etc. for which $P_1 = P_o$, $P_2 = 2.2P_o$, $P_3 = 1.1P_o$, $P_4 = P_o/2$.

![P-V diagram](image)

a) What is the change in internal energy in an isothermal process?

b) What is the work done by the gas when the volume does not change?

c) What is the heat added to the system when the volume does not change?

d) What is the work done by the gas in an isothermal process?

e) If $P_o = 10^5$ Pa and $V_o = 2 \times 10^{-2}$ m$^3$. What are the minimum and maximum temperatures?
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f) Complete this table for the reversible cycle displayed in Ia. (show your work below)

<table>
<thead>
<tr>
<th></th>
<th>ΔQ</th>
<th>ΔW</th>
<th>ΔU_{int}</th>
</tr>
</thead>
<tbody>
<tr>
<td>1→2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2→3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3→4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4→1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Complete cycle</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2. One mole of a monatomic ideal gas is at an initial pressure \( P_0 = 2 \times 10^5 \text{ Pa} \) and volume \( V_0 = 1.2 \times 10^{-2} \text{ m}^3 \). The P-V diagram below shows a reversible cyclic process \( 1 \rightarrow 2 \rightarrow 3 \rightarrow 4 \rightarrow 1 \) etc. for which \( P_1 = P_0, P_2 = 2P_0, P_3 = 2P_0, P_4 = P_0 \).

a) What are the temperatures at each point 1, 2, 3, 4?

b) Complete the table for this reversible cycle.

<table>
<thead>
<tr>
<th></th>
<th>( \Delta Q )</th>
<th>( \Delta W )</th>
<th>( \Delta U_{\text{int}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( 1 \rightarrow 2 )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( 2 \rightarrow 3 )</td>
<td></td>
<td></td>
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<tr>
<td>( 3 \rightarrow 4 )</td>
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<td></td>
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<tr>
<td>( 4 \rightarrow 1 )</td>
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<td></td>
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<tr>
<td>Complete cycle</td>
<td></td>
<td></td>
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</tbody>
</table>
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II. Simulation experience


1. Select “Temperature” under the Constant Parameter section. In the equation you wrote down in your prelab for the 1st Law of Thermodynamics, which quantity is directly related to temperature?

2. Type in “20” next to “Heavy Species” and hit Enter. This introduces 20 heavy gas particles into the box at a fixed temperature (which you can read off the thermometer). Observe the motion of the particles.

Now type in “20” next to “Light Species” and hit Enter. Observe the motion of these new, lighter gas particles that are at the same temperature as the heavy ones.

i) What do you notice is different about them (apart from having a lower mass)?

ii) Write down an equation that describes the quantity that you noticed was different between the two in terms of the mass of a gas particle, its temperature and any other constants that are needed. Show how you derive it.

3. Hit RESET. Select NONE as the Constant Parameter. Introduce 50 particles of the light species of gas. Add heat to it for a few seconds.

i) What happens to the temperature? What do you infer happens to the internal energy?

ii) Why did your adding heat cause the temperature to change? Explain using the first law equation and the internal energy equation.

4. Hit RESET. Select NONE as the Constant Parameter. Introduce 50 particles of the light species of gas. Now push on the left wall to make the box smaller (do this gently).

i) What happens to the temperature and consequently to the internal energy?

ii) Why did your pushing on the wall cause the temperature to change? Explain using the first law equation and the internal energy equation.
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iii) What would happen to the temperature if instead of you pushing the wall to make the box smaller, the gas pushed on the wall to make the box bigger? (this is a hypothetical situation and not modeled in the simulation).

5. Now that you have seen that temperature can be changed by two independent processes, can you think of a scenario where you add heat to a gas but its temperature does not change? What must happen for its temperature to stay constant?

   i) Add heat to increase the temperature. What happens to the pressure?

   ii) Draw a sketch of how the pressure changes with temperature. Use the ideal gas law equation to help you determine the shape.

7. Hit RESET. Keep TEMPERATURE constant and introduce 50 light particles. Let the readings settle down.
   i) Reduce the volume and let the readings settle again. What happened to the pressure?

   ii) Draw a sketch of how the pressure changes with volume. Use the ideal gas law equation to help you determine the shape.