EML 3002C Exam 1 **ME TOOLS THERMO** **9/28/20 3:30-4:45 pm**
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DO NOT WRITE ON THE BLUE TABLES. RETURN THE BLUE TABLES WITH YOUR EXAM. DO NOT STAPLE THE EXAM SHEETS TOGETHER. A letter-size formulae sheet, handwritten by you, may be used. Put your answers on the same sheet as the question. Use at least 5 significant digits in your computations and answers where possible. You must give the units of your answers. You must write clearly. Best possible answer for multiple choice. For questions asking a number, putting the clear correct formula(s) below the question might result in partial credit even if the answer is wrong. *Not following those requirements will result in reduced or no credit.*

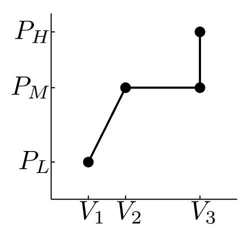
1. (5%) Suppose you would not have a compressed liquid table for water. In that case, you would take the specific volume of water at 40°C (about 100 F) and the humongous pressure of 5000 kPa (50 times the atmospheric pressure) to be 0.001008 m^3/kg. But you *do* have a compressed liquid table, so you can find the true number, 0.001006 m^3/kg. The error is 0.2 %.

2. (5%) If the molecules in an ideal gas have a "molecular" (molar) mass of 8, then the specific gas constant of that gas is 1.0393 kJ/kg K.

3. (5%) A manometer filled with mercury is at one end open to the ambient air pressure of 85 kPa and at the other end connected to a tank of helium at 250 kPa. The mercury below the end open to the ambient air stands 123.9 cm higher than below the other end.

4. (5%) Water in cylinder is pressurized to 250 kPa by the ambient pressure of 100 kPa and a heavy piston floating on the water. If the radius of the piston is 2 cm and gravity is standard, then the mass of the piston is 19.221 kg.

5. (5%) Write the expression for the work done in the shown process, in terms of V_1, V_2, V_3, P_L, P_M, and P_H. Use the standard formula for each process type from the class notes. It should be three different expressions in the same order as the graph.



$\frac{1}{2}(P_L + P_M)(V_2 - V_1) + P_M(V_3 - V_2) + 0$.

6. (5%) Suppose you have a 50/50 mixture of liquid and vapor pressurized by a heavy piston floating on top of it. To turn it into compressed liquid, (a) you can decrease the temperature just a bit; (b) you can decrease the temperature, but not just a bit; (c) you can reduce the volume just a bit. a

7. (5%) Given substance tables, what would be enough information to determine the temperature of the substance? (a) P, V; (b) P, m; (c) $P, \overline{n}$; (d) P, ρ; (e) V, m; (f) $V, \overline{n}$; (g) V, ρ; (h) v, m; (i) $v, \overline{n}$; (j) v, ρ? d.

8. (33%) A closed steel bottle with a volume of 0.3 m^3 holds 2 kg of water at a pressure of 100 kPa. Then the bottle is heated so that the temperature goes up to 200°C.

   (a) Construct the initial phase of the water in a very neat Pv-diagram, marking all lines and points used to do it with their values. State the phase. Do not put more info in the diagram than is needed to construct the phase.

   (b) What are the initial temperature and quality, if defined?

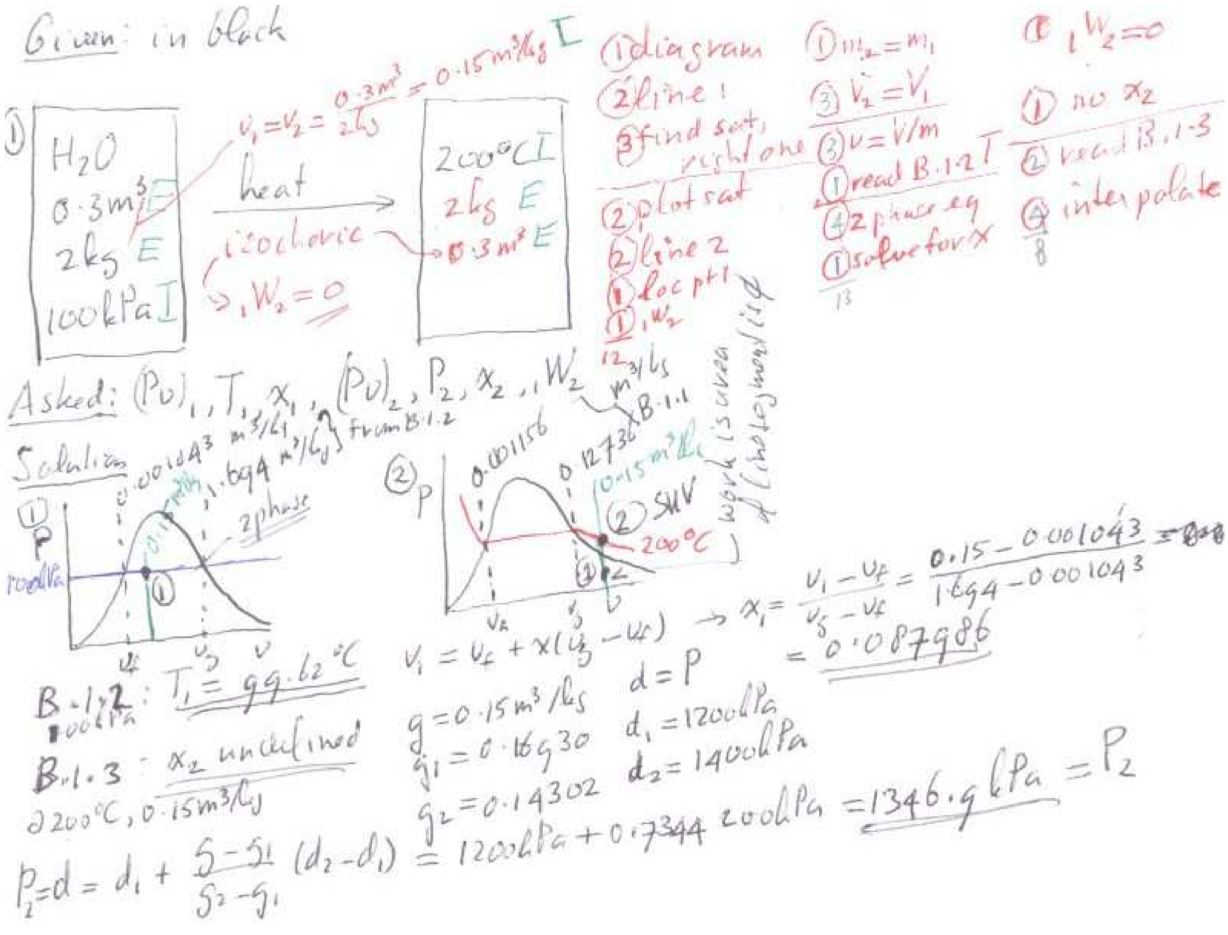
   (c) After finding enough info about the final state without assuming a phase, construct and state its phase in a second very neat Pv diagram, meeting the same conditions as the first. Also put the initial state in this second diagram, correctly located with respect to the constructed final state, and indicate the graphical work.

   (d) What is the final pressure and quality, if defined?

   (e) What is the work performed by the water during the heating?

Items are not equal credit. Remember, 5 significant digits throughout.

You must show the derivations and reasoning completely and correctly for full credit. You must give simplified units for your answers. Most accurate procedure only unless stated otherwise. Use at least 5 significant digits in your computations and answers. *Give the source of every number.*



9. (32%) A piston-cylinder combination contains 2 kg of air with a volume of 1.5 m^3 at the ambient temperature of 26.85°C. Then the piston is pushed down until the pressure reaches 2MPa. This is done so slowly that the process can be assumed to be isothermal.

   (a) What is the initial pressure? What is the final volume?

   (b) What is the work done by the air in the process?

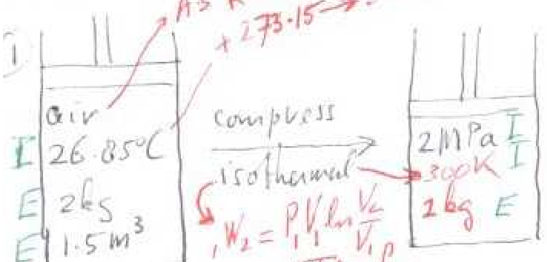
   (c) Air is mostly nitrogen gas. Will nitrogen be a good ideal gas, a mediocre one, or a horrible one under the conditions of this process. (To be a good ideal gas, it must be good at both the start and end of the process. If so, it can reasonably be assumed it is good during the entire process. For mediocre neither start nor end can be worse than mediocre.) Discuss each of the possible criteria for being an ideal gas for this case in detail first. Then give your conclusion whether the ideal gas assumption is good, mediocre, or horrible from that.

You must show the derivations and reasoning completely and correctly for full credit. You must give simplified units for your answers. Most accurate procedure only unless stated otherwise. Use at least 5 significant digits in your computations and answers. *Give the source of every number.*

Given: In black

A.5 $R = 0.287$ kJ/kg K

$+ 273.15 \to 300$ K



3 R from A.5
2 $m_2 = m_1$
4 $T_2 = T_1$
5 $PV = mRT$
2 find P_1 units
4 find V_2
20

6 work formulas
1 find work: units
2 criterion 1
2 criterion 2
1 conclusion
12

${}_1W_2 = mRT \ln \frac{P_1}{P_2}$

Asked: $P_1, V_2, {}_1W_2$, IG?

Solution: $P_1V_1 = mRT_1$ $\quad P_1\, 1.5\,\text{m}^3 = 2\,\text{kg}\; 0.287 \frac{\text{kPa m}^3}{\text{kg K}}\; 300\,\text{K}$ $\quad P_1 = 114.8$ kPa

$P_1V_1 = P_2V_2 \to V_2 = V_1 \frac{P_1}{P_2} = 1.5\,\text{m}^3 \frac{114.8\,\text{kPa}}{2000\,\text{kPa}} = 0.0861\,\text{m}^3 = V_2$ (or use $P_2V_2 = mRT$)

${}_1W_2 = mRT \ln \frac{P_1}{P_2} = 2\,\text{kg}\; 0.287 \frac{\text{kJ}}{\text{kg K}}\; 300\,\text{K} \ln \frac{114.8}{2000} = -492.10\,\text{kJ} = {}_1W_2$

criterion 1: T well above T_c, like $T/T_c \geq 2$ $\quad \frac{T}{T_c} = \frac{300\,\text{K}}{126.2\,\text{K}} \approx 2.4$

$\to$ good IG throughout

criterion 2: P well below P_c, like $P/P_c < 0.2$ $\quad \frac{P}{P_c} = \frac{2000\,\text{kPa}}{3390\,\text{kPa}} \approx 0.6$ X

$\to$ not satisfied. But OK since $T > T_c$)

However, only one criterion needs to be satisfied $\to$ Good I.G