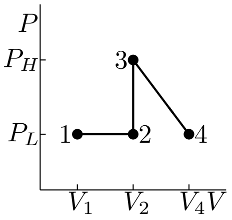
EML 3002 Exam 1 **ME TOOLS THERMO** **9/23/15 3:30-4:45 pm**
Page 1/3 Solutions (dommelen@eng.fsu.edu) series a

DO NOT WRITE ON THE BLUE TABLES. RETURN THE BLUE TABLES WITH YOUR EXAM. DO NOT STAPLE THE EXAM SHEETS TOGETHER. Put your answers on the same sheet as the question, Use at least 5 digits in your computations and answers where possible. You must give the units of your answers. You must write clearly. Encircle the right answer number in multiple choice. To correct, erase the wrong circle as well as you can and encircle the corrected answer number twice. 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%) Write the expression for the work done in the shown process, in terms of V_1, V_2, V_4 and the low and high pressures P_L and P_H. Use the standard formula for each process type:



$P_L(V_2 - V_1) + \frac{1}{2}(P_U + P_L)(V_4 - V_2)$

2. (5%) The absolute gas pressure inside a vessel is 120 kPa. A manometer filled with mercury measuring this pressure is at the other side open to the standard atmospheric pressure. The mercury in the leg connected to the vessel will stand *higher* by -14.023 cm.

3. (5%) A cylinder with a cross-sectional area of 5 cm^2 contains saturated water at 200kPa below a heavy floating piston. The ambient pressure is 100 kPa. The mass of the piston is 5.09858 kg.

4. (5%) Given substance tables and the pressure and number of moles, what would be enough additional information to determine the temperature:
   - [✓ (a)] m.
   - (b) V.
   - (c) ρ.

5. (5%) If you isothermally decrease the pressure of saturated liquid and of saturated vapor a bit,
   - (a) only saturated liquid will become superheated.
   - (b) only saturated vapor will become superheated.
   - [✓ (c)] both will become superheated.

6. (5%) The atmospheric pressure is 100 kPa, but if you dive about 10 m deep, the pressure increases by another 100 kPa. To get the water to boil there, you must heat it to 393.38 K.

7. (5%) The molar specific volume of ice at 0°C is 0.019646 m^3/kmol.

8. (33%) A piston cylinder configuration contains water, initially at 200 kPa, 1.7 m^3, and 0.85 m^3/kg. Then the water is compressed to 400 kPa in a process that is approximated as polytropic with n equal to 4/3.
   - (a) Construct the initial phase of the water in a very neat Tv-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 the initial mass? How many kg of that mass are in the vapor (saturated or superheated) phase?
   - (c) After finding enough info about the final state, construct and state its phase in a second Tv diagram, meeting the same conditions as the first.
   - (d) What is the final temperature? What is the final mass and how many kg are in the vapor phase?

   Items are not equal credit.

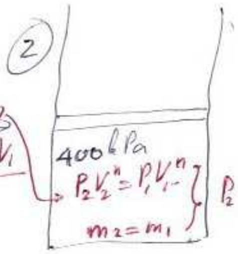
   You must show the derivations and reasoning completely and correctly for full credit. You must give simplified units for your answers. Most accurate procedure only unless stated otherwise. Use at least 5 significant digits in your computations and answers. *Give the source of every number.*

Given: In black

compress
polytropic $n = \frac{4}{3}$

$${}_1W_2 = \frac{P_2V_2 - P_1V_1}{1-n}$$

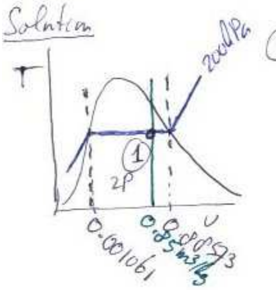
(NA)



$P_2 v_2^n = P_1 v_1^n$

Asked: Tv_1, T_1, m_1, m_{1vap}, Tv_2, T_2, ~~m_2~~

Solution



① is twophase

$T_1 = \underline{\underline{120.23 °C}}$

$v = v_f + x(v_g - v_f)$

$$0.85 \frac{m^3}{kg} = [0.001061 + x\underbrace{(0.88573 - 0.001061)}_{.88467}] \frac{m^3}{kg}$$

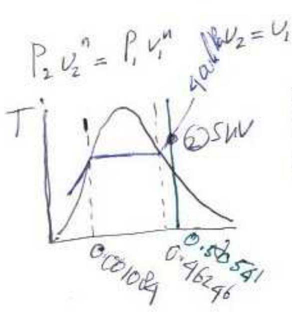
$$x = \frac{.85 - .001061}{.88467} = .95961$$

$$m_1 = \frac{V_1}{v_1} = \underline{\underline{2 kg}} \qquad m_{1v} = x m_1 = \underline{\underline{1.9192 kg}}$$

$P_2 v_2^n = P_1 v_1^n$

$$v_2 = v_1 \left(\frac{P_1}{P_2}\right)^{\frac{1}{n}} = v_1 \underbrace{\left(\frac{P_1}{P_2}\right)^{\frac{3}{4}}}_{.5946} = \underline{\underline{.50541 \frac{m^3}{kg}}}$$

$g = .50541$ $d = T$
$g_1 = .47084$ $d_1 = 150$
$g_2 = .53422$ $d_2 = 200$



$$\left[{}_1W_2 = \frac{P_2V_2 - P_1V_1}{1-n} = \frac{(P_2 v_2 - P_1 v_1) m}{1-n} \right.$$

$$= \frac{400 kPa\ 0.50541 \frac{m^3}{kg} - 200 kPa\ 0.85 \frac{m^3}{kg}\ 2 kg}{1 - \frac{4}{3}}$$

$$\left. = \underline{\underline{-192.904 kJ}} \right]$$

$$T_2 = d_1 + \frac{g - g_1}{g_2 - g_1}(d_2 - d_1)$$

$$= 150 + .54544 (50)$$

$$= \underline{\underline{177.27 °C}}$$

$m_2 = m_1 = \underline{\underline{2 kg, all vapor}}$

9. (32%) A piston-cylinder combination initially contains 3 m^3 of a hopefully good ideal gas at 6.85°C and 200 kPa. Then the substance is compressed slowly, isothermally, to 400 kPa. The substance has a, what the book calls molecular mass, of 50.

   (a) What are the specific gas constant and the initial mass?

   (b) What are the final mass and volume, and the work done *by* the gas during the compression.

   (c) List, following the book, the precise conditions that a substance is a good ideal gas. Suppose that the critical pressure is 4,000 kPa and the critical temperature is (i) 600 K; (ii) 300 K, and (iii) 150 K. Determine for each of these three cases whether following the book, we can be *sure* that the substance is a good ideal gas.

Items are not equal credit.

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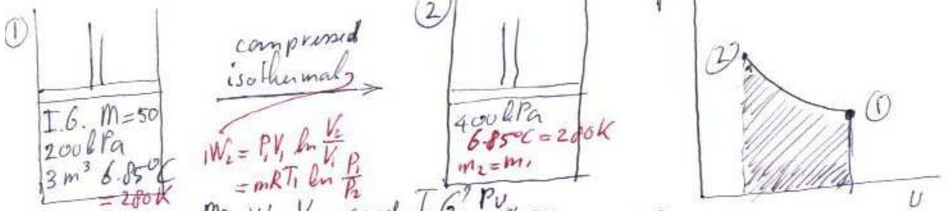
Given In black



$$ {}_1W_2 = P_1V_1 \ln\frac{V_2}{V_1} = mRT_1 \ln\frac{P_1}{P_2} $$

Asked R, m_1, m_2, W_2, V_2, good I.G.? P_v $_{1W_2,\,\text{proc}}$

Solution $R = \dfrac{\bar{R}_u}{M} = \dfrac{8.31451\,\frac{\text{kJ}}{\text{kmol K}}}{50\,\frac{\text{kg}}{\text{kmol}}} = \underline{\underline{0.1662902\,\frac{\text{kJ}}{\text{kg K}}}}$

$P_1V_1 = mRT_1$ $\quad 200\,\text{kPa}\ 3\,\text{m}^3 = m\ 0.16629\,\frac{\text{kJ}}{\text{kg K}}\ 280\,\text{K}$ $\quad m_1 = \underline{\underline{12.8865\,\text{kg}}} = m_2$

$${}_1W_2 = \underbrace{P_1V_1}_{600\,\text{kPa m}^3 = 600\,\text{kJ}} \underbrace{\ln\frac{V_2}{V_1} = mRT_1 \ln\frac{P_1}{P_2}}_{-.69315} = \underline{\underline{-415.89\,\text{kJ}}}$$

$P_2V_2 = m\,R\,T_2$

$400\,\text{kPa}\ V_2 = 12.8865\,\text{kg}\ 0.16629\,\frac{\text{kJ}}{\text{kg K}}\ 280\,\text{K}$

$\underline{\underline{V_2 = 1.5\,\text{m}^3}}$

either: 2) $P \ll P_c$ (like $0.1\,P_c$) <u>and</u> vapor

or: 1) $T \gg T_c$ (like $2T_c$)

$P = 0.1\,P_c$ $\quad T = 0.1\,T_c$: may not be vapor

$\left.\begin{array}{ll} P = 0.1\,P_c & T > T_c \\ P = 0.1\,P_c & T = 2T_c \end{array}\right\}$: good I.G. since cannot be liquid