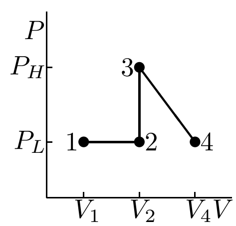
EML 3100 Exam 2 **THERMODYNAMICS** **2/28/08 11:45-1:00 pm**
Page 1/3 Solutions (dommelen@eng.fsu.edu) series a

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 many digits in your computation. 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%) The specific enthalpy of Helium is changing at a rate of 2kJ/kg-s. Its temperature is changing at a rate of <u>0.385</u> °C/s.

2. (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:



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

3. (5%) The specific heat at constant pressure of nitric oxide at 727°C equals <u>1.134</u> kJ/kg-K.

4. (5%) If a gas expands from 500 kPa and 2 m^3 to 100 kPa in a polytropic process with $n = 1.25$, the final volume is <u>7.248</u> m^3 and the work done by the gas is <u>1100.9</u> kPa.

5. (5%) If 100 m^3 of concrete cools down from 20°C to 15°C, it releases an amount of energy equal to <u>968</u> MJ.

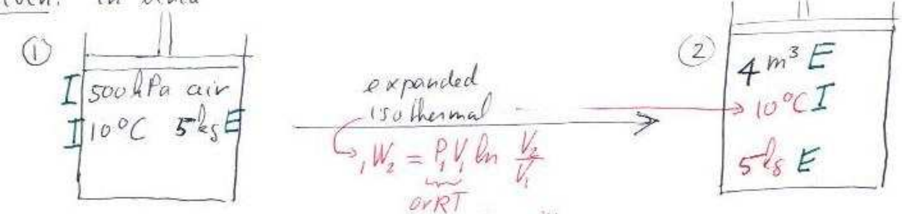
6. (5%) If the volume of 2 kg of a substance at atmospheric pressure is 3 m^3 and its internal energy is 120 kJ, then its specific enthalpy is <u>210</u> kJ/kg

7. (5%) A volume of 5 m^3 of air at 100 kPa and 300 K is expanding at a rate of .3 m^3/s. The rate at which work is being done by the air is <u>30</u> kW.

8. (32%) A cylinder contains 5 kg of air at 500 kPa and 10°C. The air is now isothermally expanded to a volume of 4 m^3. Find
   - the final pressure,
   - the work done by the air,
   - the heat added to the air,
   - the final internal energy,
   - the errors if you used the specific heat of air at 25°C to answer the question.

   You must show the derivations and reasoning completely and correctly for full credit. You must give units for your answers. Most accurate procedure only unless stated otherwise.

Given: in black



Asked: P_2, ${}_1W_2$, ${}_1Q_2$, U_2 $\quad m(u_2-u_1) = {}_1Q_2 - {}_1W_2$

Solution A.5: $R = 0.287 \frac{kJ}{kg\,K}$ $\quad P_2V_2 = mRT_2$ $\quad P_2\, 4\,m^3 = 5\,kg\; 0.287 \frac{kJ}{kg\,K} (10+273)K$

$P_2 = \underline{101.53\ kPa}$. $\quad P_1V_1 = mRT_1$ $\quad 500\ kPa\ V_1 = 5\,kg\; 0.287\frac{kJ}{kg\,K}(10+273)K$

$V_1 = 0.81221\ m^3$ $\quad {}_1W_2 = 500\ kPa\ 0.81221\ m^3 \ln\left(\frac{4\ m^3}{.81221\ m^3}\right) = \underline{647.45\ kJ}$

Since $T_2 = T_1 \rightarrow u_2 = u_1 \rightarrow {}_1Q_2 = {}_1W_2 = \underline{647.45\ kJ}$

Table A 7.1 $\quad T = 283\ K$ $\quad T_1 = 280\ K$ $\quad u_1 = 200.02\ kJ/kg$
$T_2 = 290\ K$ $\quad u_2 = 207.19\ kJ/kg$

$u_1 = u_2 = 202.17\ \frac{kJ}{kg}$ $\quad U_2 = m u_2 = \underline{1010.855\ kJ}$

If using $u_2 - u_1 = c_v(T_2 - T_1)$, still $u_2 - u_1 = 0$. No difference.

(2) $T_2 = 10°C$ $\quad$ (5) ${}_1W_2 = P_1V_1 \ln\frac{V_2}{V_1}$ $\quad$ (2) T → K ~~(in Table A 7.1)~~
(2) $m_2 = 5\,kg$ $\quad$ (1) compute V_1 $\quad$ (3) interpolate in A.7.1
(5) $P_2V_2 = mRT_2$ $\quad$ (1) compute ${}_1W_2$ $\quad$ (1) $U_2 = m u_2$,
(2) $R = .287$ $\quad$ (5) 1st law ${}_1Q_2$
(1) compute P_2, units $\quad$ (2) $u_2 = u_1$ from A.7.1 (or $c_{v,ave}\Delta T$)

9. (33%) Water at 300°C and 10 kPa enters a condenser at a rate of 2 kg/s with a velocity of 200 m/s. It exits at the same pressure it entered with, at the same height, and with negligible kinetic energy. Heat is removed from the water in the condenser at the rate of 4000 kW.

   - Construct the phase of the entering water in the Pv-diagram.
   - Show using another Pv-diagram that the exiting water is 2-phase without assuming so in advance.
   - Find the exit temperature.
   - Find the exit quality to four digits accurate.
   - Find the required diameter of the entrance pipe in cm.

   You must construct all phases that are not given in the Pv-diagram, marking all lines and points used to do it with their values. Unambiguously number the phases in the diagram.

   You must show the derivations and reasoning completely and correctly for full credit. You must give units for your answers. Most accurate procedure only unless stated otherwise.

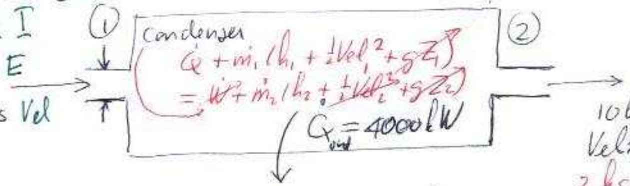
Given in black: no height difference between exit and entrance

H_2O 300 °C I

10 kPa I

2 kg/s E

200 m/s Vel



10 kPa I

Vel ≈ 0 Vel

2 kg/s E

Asked: ~~T_e, v_e~~, constant phase of ①, show ~~verify~~ phase of ② is saturated without assuming so in advance, T_e, x_e, D_1 in cm

Solution:

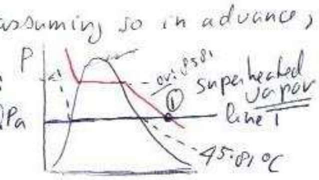


Table B.1.3 @ 10 kPa, 300 °C

$h_1 = 3076.51\ \frac{kJ}{kg}$ $\quad v_1 = 26.44508\ \frac{m^3}{kg}$

1st law: $-4000\ kW + 2\ kg/s\ (3076.51\ \frac{kJ}{kg} + \frac{1}{2}\ 200^2\ \frac{m^2}{s^2}\ \frac{1\ kJ/kg}{1000\ \frac{m^2}{s^2}})$

$= 2\ kg/s\ h_2 \rightarrow h_2 = 1096.51\ \frac{kJ}{kg}$

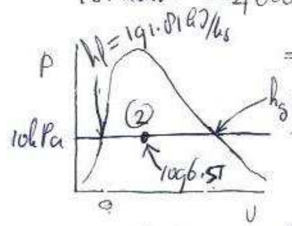


Diagram shows ② is 2 phase →

$T_2 = T_{s@10kPa} = \underline{45.81\ °C}$

$h = h_f + x(h_g - h_f) \qquad 1096.51 = 191.81\ \frac{kJ}{kg} + x\underbrace{(2584.63 - 191.81)}_{2392.82}\frac{kJ}{kg}$

$\underline{x = .378}$

$\dot{m}_1 = \frac{A_1\,Vel_1}{v_1} \qquad 2\ kg/s = \frac{\frac{\pi}{4}D_1^2\ 200\ m/s}{26.44508\ m^3/kg} \rightarrow D_1 = 0.5803\ m = \underline{58.03\ cm}$

phases: bubble diagrams ② $\quad h_1, v_1$ ② $\quad x_2$ ③

line 1 ② $\quad$ 1st law ⑤ $\quad D_1$ ③ — A = 1, in cm

sat value(s) ④ $\quad \dot{W} = 0$ ③

plot ② $\quad$ compute h_2 ① ← $\dot{m}_1 = \dot{m}_2$

line 2 ② $\quad T_2$ ②

identify ① ①