EML 3100 Exam 4 **THERMODYNAMICS** **4/26/06 3-5 pm**
Page 1/4 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. (3%) Which is poorest described thermodynamically as a control mass, normally speaking:

   [✓ (a)] A mixing chamber.
   (b) A covered pan while cooking.
   (c) A brick.

2. (3%) Starting with saturated water vapor, we increase its pressure reversibly adiabatically. Which is correct:

   [✓ (a)] Liquid water will not form and the temperature will increase.
   (b) Liquid water will form and the temperature will increase.
   (c) Liquid water will form and the temperature will decrease.

3. (3%) A heat engine that operates between an atmospheric temperature of 25°C and a sea water temperature of 5°C can extract no more than 0.06711 kJ of work from every kJ of heat removed from the atmosphere.

4. (3%) When the temperature of a 0.5 kg brick reduces from 127°C to the ambient temperature of 27°C, the entropy generated in the cool-down process is 0.0191 kJ/K

5. (3%) If air in a room is heating up at a rate of 0.2°C/s, its enthalpy increases by 0.2008 kJ/kg-s

6. (3%) Ignoring kinetic and potential energy, the work a pump must do to compress liquid water from 100 kPa to 200 kPa is about 0.1003 kJ/kg.

7. (3%) If a pressure cooker has an internal pressure of 250 kPa, then water in it will boil at 127.43 °C.

8. (3%) The specific heat at constant volume of acetylene at 400 K is 1.60206 kJ/kg-K

9. (3%) A gas with $C_p = 14$ and $C_v = 10$ expands reversibly adiabatically from 100 kPa and 27°C to 50 kPa. The final temperature is -26.9 °C.

10. (3%) Ignoring kinetic and potential energy, the work a turbine produces in which air expands reversibly at a constant temperature of 25°C from 1 MPa to 100 kPa is 196.93 kJ/kg.

11. (35%) Superheated water vapor enters a turbine at 1000 kPa and 250°C. It exits at an ambient pressure of 100 kPa, with 0.8 kJ/kg-K higher specific entropy than it entered with. Also, 50 kJ/kg of heat comes out of the turbine through a surface that is at 127°C. Potential and kinetic energies of the entering and exiting streams can be ignored.

    (a) Show in a very neat, unambigous, pv diagram that the initial phase is indeed superheated vapor, marking all lines and points used to do it with their values. Label the state.

    (b) From the entering entropy, find the exiting entropy, and then construct the exiting phase in a very neat, unambigous, Ts diagram, marking all lines and points used to do it with their values. Also clearly and correctly show the process in the same Ts diagram, labelling both states. As what phase does the water come out?

    (c) Find the specific power produced by the turbine.

    (d) Find the specific entropy generated by irreversible effects inside the turbine.

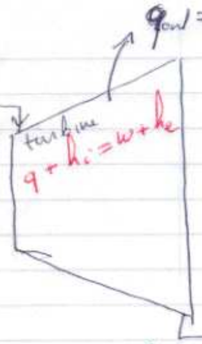
    (e) Show the ideal turbine process and the true turbine process in a single, very neat Ts diagram, marking all lines and points used to construct these processes with their values.

    (f) If the ideal turbine produces 429.18 kJ/kg of power, what is the isentropic efficiency of the turbine? Comment on the designer of the turbine.

    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.

$q_{out} = 50 \text{ kJ/kg} = -q$
@ 400 K (= 127 + 273)

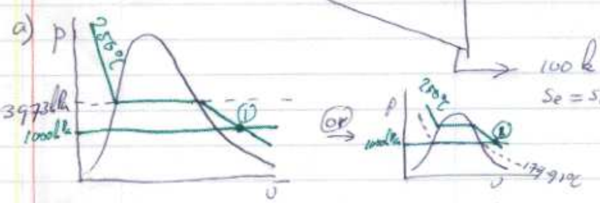
ⓣ1 H_2O, SHV
1000 kPa, 250 °C



100 kPa
$s_e = s_i + 0.8$ kJ/kg K

pv_1 ③
s_2 ③
Ts_2 ③
CM version −4 ← 1st law ⑥
interpolate h_e ③
w (units) ③
CM version −3 — 2nd law ⑤
s_{gen} (units) ③
process ③
η_T ③
(units = −1)

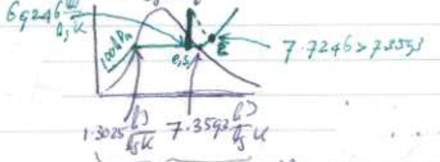
a)



b) B.1.3 @ 1000 kPa, 250 °C ⇒ $s_i = \boxed{6.9246} \frac{kJ}{kg\,K}$ $h_i = \boxed{2942.59} \frac{kJ}{kg}$

$s_2 = s_1 + 0.8 = \boxed{7.7246} \frac{kJ}{kg\,K}$ $p_2 = 100$ kPa

True turbine is SHV at exit
Ideal turbine has same entropy at exit as at entrance, so is 2phase



w
3 interpolate h_e
true

c) $q + h_i = w + h_e$ $-50 \frac{kJ}{kg} + 2942.59 = w + h_e$
h_e from B.1.3 @ 100kPa, s_e = 7.7246 interpolated:
$$h_e = 2776.38 + \frac{7.7246 - 7.6133}{7.8342 - 7.6133}(2875.27 - 2776.38) = 2826.20 \frac{kJ}{kg}$$
$\Big\}$ $w = 66.3844$ kJ/kg

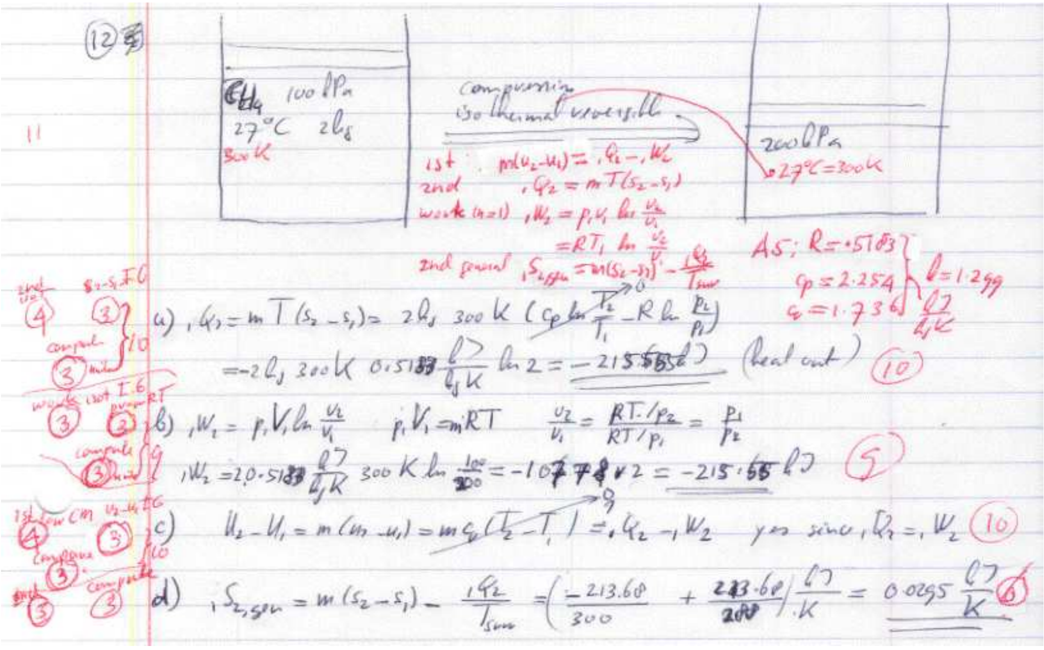
d) $s_e - s_i = \frac{q}{T} + s_{gen}$ $0.8 + \frac{50}{400} \frac{kJ/kg}{K} = 0.925 \frac{kJ}{kg\,K}$

e) See above in b.

f) $\eta_T = \frac{w}{w_s} = \frac{66.3844 \text{ kJ/kg}}{429.18 \text{ kJ/kg}} = 0.15$ Designer is incompetent

12. (35%) A piston/cylinder combination contains 2 kg of methane gas that is isothermally, reversibly compressed from 100 kPa and 27°C to 200 kPa. You may assume that its specific heat at constant pressure remains close to its room temperature value.
    (a) Find the heat that leaks out of the methane to the surroundings without using the first law.
    (b) Find the work done on the fluorine without using the first law.
    (c) Now demonstrate unambiguously that the first law is satisfied for the heat and work you found.
    (d) If the heat that leaks out ends up in a 15°C environment, what is the entropy generated by irreversible processes?

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.



⑫ 11

CH_4 100 kPa
27°C 2 kg
300 K

compressing
isothermal reversible

200 kPa
27°C = 300 K

1st $m(u_2-u_1) = {}_1Q_2 - {}_1W_2$
2nd ${}_1Q_2 = mT(s_2-s_1)$
work (n=1) ${}_1W_2 = p_1V_1 \ln \frac{V_2}{V_1}$
$= RT_1 \ln \frac{v_2}{v_1}$
2nd general ${}_1S_{2,gen} = m(s_2-s_1) - \frac{{}_1Q_2}{T_{surr}}$

A5; R = .5183, c_p = 2.254, c_v = 1.736, k = 1.299 kJ/kg K

2nd law ④ s_2-s_1 IG ③ compute ③ 10

a) ${}_1Q_2 = mT(s_2-s_1) = 2\text{ kg } 300\text{ K}\left(\cancel{c_p \ln\frac{T_2}{T_1}}^{\,0} - R\ln\frac{p_2}{p_1}\right)$

$= -2\text{ kg } 300\text{ K } 0.5183 \frac{\text{kJ}}{\text{kg K}} \ln 2 = \underline{-215.55\text{ kJ}}$ (heat out) ⑩

work isot I.6 ③ pv=mRT ② compute ③ 9

b) ${}_1W_2 = p_1V_1 \ln\frac{V_2}{V_1}$ $p_1V_1 = mRT$ $\frac{v_2}{v_1} = \frac{RT/p_2}{RT/p_1} = \frac{p_1}{p_2}$

${}_1W_2 = 2\cdot 0.5183 \frac{\text{kJ}}{\text{kg K}}\, 300\text{ K} \ln\frac{100}{200} = -107.78 \times 2 = \underline{-215.55\text{ kJ}}$ ⑤

1st law CM ④ u_2-u_1 IG ③ compare ③ 10

c) $U_2 - U_1 = m(u_2-u_1) = mc_v\cancel{(T_2-T_1)}^{\,0} = {}_1Q_2 - {}_1W_2$ yes since ${}_1Q_2 = {}_1W_2$ ⑩

2nd ③ compute ③

d) ${}_1S_{2,gen} = m(s_2-s_1) - \frac{{}_1Q_2}{T_{surr}} = \left(\frac{-213.60}{300} + \frac{213.60}{288}\right)\frac{\text{kJ}}{\text{K}} = \underline{0.0295\frac{\text{kJ}}{\text{K}}}$ ⑥