EML 3100 Exam 3 **THERMODYNAMICS** **4/15/10 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 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%) Superheated steam at 1 MPa and 185°C enters an adiabatic turbine and comes out as saturated vapor at 200°C.
   - [✓ (a)] No way!
   - (b) Lousy-quality, foreign-build turbine!
   - (c) Perfect US design!

2. (5%) If oxygen is reversibly adiabatically compressed from 100 kPa and 300 K to 800 kPa, and the specific heats are assumed to remain constant at their 25°C values, then the final temperature is 266.243 °C

3. (5%) If oxygen enters an insulated reversible compressor at 300 K and is compressed to 525 K, then the power requirement of the compressor is 207.195 kJ/kg. (Ignore potential and kinetic energy and assume constant specific heats.)

4. (5%) One of the following heat engines is possible, one does not satisfy the first law, and one does not satisfy the second law. Which is the one that is possible?
   - [✓ (a)] $W = 0$, $Q_H = 1$, $Q_L = 1$
   - (b) $W = 1$, $Q_H = 0$, $Q_L = 1$
   - (c) $W = 1$, $Q_H = 1$, $Q_L = 0$

5. (5%) A horizontal pump compresses a 0.3 kg/s low-velocity stream of engine oil from 100 kPa to 300 kPa. The power requirement of the pump can be ballparked to be at least 67.797 W.

6. (5%) As 2 L of engine oil is heated from 27°C to 127°C, its entropy increases by 0.9675 kJ/K.

7. (5%) If it is 27°C inside your house and –3°C outside, then a heat pump could be up to 10 times cheaper to operate than a resistance heater. (In terms of electricity).

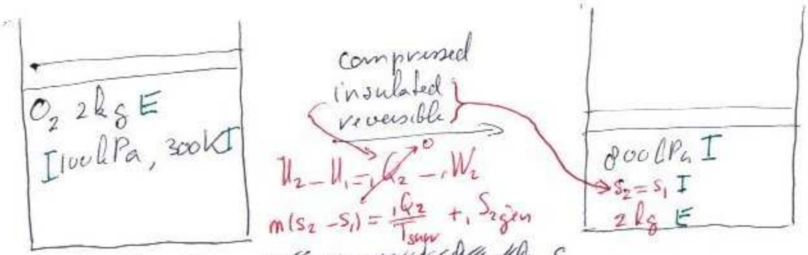
8. (32%) Two kg of oxygen initially at 100 kPa and 300 K in an insulated piston cylinder combination is reversibly compressed to 800 kPa.

   (a) What is the work done and heat added?

   (b) If the surroundings are at 25°C, then how much entropy is generated by this process in total?

   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 the maximum number of digits in your computations.

Given: In black. $T_{surr} = 25^\circ C$



$U_2 - U_1 = {}_1Q_2^{\,0} - {}_1W_2$

$m(s_2 - s_1) = \frac{{}_1Q_2}{T_{surr}} + {}_1S_{2gen}$

Asked: ${}_1W_2$, ${}_1Q_2$, ~~[illegible]~~ ${}_1S_{2gen}$

Solution: a) $s_2 - s_1 \overset{0}{=} s^o_{T_2} - s^o_{T_1} - R\ln(P_2/P_1)$

① $m_2 = m_1$ Table A.8 @ 300 K: $u_1 = 195.20\ \frac{kJ}{kg}$ $s^o_{T_1} = 6.4168\ \frac{kJ}{kgK}$

⑤ $s_2 = s_1$ $s^o_{T_2} = s^o_{T_1} + R\ln P_2/P_1 = 6.4168\ \frac{kJ}{kgK} + 0.2598\ \frac{kJ}{kgK}\ln\frac{800kPa}{100kPa}$

③ read A.8 $= \underline{6.957038}$

④ s formula ⊗ $s = s^o_{T_2} = 6.957038\ \frac{kJ}{kgK}$ $s_1 = 6.8969\ \frac{kJ}{kgK}$ $s_2 = 6.9903\ \frac{kJ}{kgK}$

① compute $s^o_{T_2}$ $d = u_2$ $d_1 = 331.72\ \frac{kJ}{kg}$ $d_2 = 367.7\ \frac{kJ}{kg}$

⑤ interpolate u ⊗ $u_2 = d_1 + \frac{s - s_1}{s_2 - s_1}(d_2 - d_1) = \underline{354.887}\ \frac{kJ}{kg}$

④ ${}_1Q_2 = 0$ → no ini -2 give specific -2

⑤ 1st law → ${}_1W_2 = m(u_1 - u_2) = 2kg\,(195.2 - 354.887)\ \frac{kJ}{kg} = \underline{-319.374\ kJ}$

① compute ${}_1W_2$ units! → no law: -1 ${}_1Q_2 = 0$ since adiabatic, ${}_1S_{2gen} = 0$ since $s_2 = s_1$ and ${}_1Q_2 = 0$

③ 2nd law, ... $P_2V_2 - P_1V_1$ with $n = k = 1.393$ from A.5. This assumes the ~~and Adiabatic reve~~ ... ~~Also PV = mRT~~ ... already [illegible]

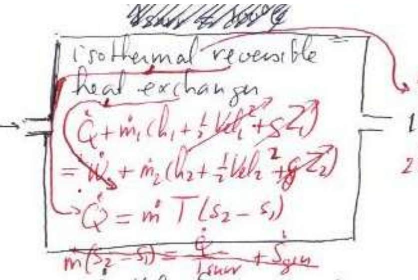
9. (33%) Water at 50°C and a specific entropy of 1 kJ/kg-K enters an isothermal internally reversible heat exchanger at a rate of 2 kg/s and negligible velocity. It exits at 10 kPa.
   (a) Construct the initial and final phases in *separate* Ts-diagrams. Mark all lines and points used to do it with their values. State the phase. Do not put more info in the diagram than is needed to construct the phases. Show the process as a fat line in the second diagram.
   (b) Find the heat added per unit time and the exit velocity.

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 the maximum number of digits in your computations.

Given: in Black:

H_2O 50°C $1\frac{kJ}{kgK}$

2 kg/s, Vel ~ 0

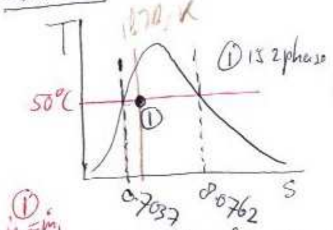


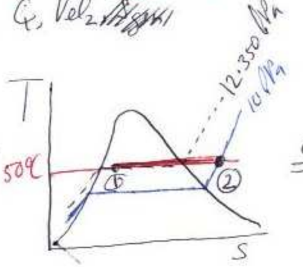
~~$\dot{m}(s_2-s_1)=\frac{\dot{Q}}{T_{surr}}+\dot{S}_{gen}$~~

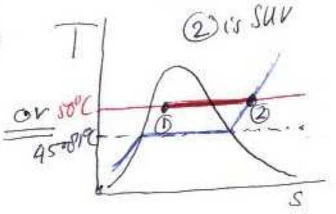
① diagram
② line 1
② find sat
② draw sat
② line 2
② ID
① proc
12

Asked $(Ts)_1$, $(Ts)_2$, proc, $\dot{Q}$, Vel_2

Solution







② $T_2=T_1$ ① $\dot{m}_2=\dot{m}_1$

B.1.1 @ 50°C $h_f = 209.31$ $h_{fg} = 2382.75$ $h_g = 2592.06\ \frac{kJ}{kg}$

② B-1.1 $s_f = 0.7037$ $s_{fg} = 7.3725$ $s_g = 8.0762\ \frac{kJ}{kgK}$

③ ① $s_1 = s_f + x s_{fg}$ $1 = 0.7037 + x\ 7.3725$ $x = .2963/7.3725 = 0.0401899$

formula find x

① find h $h_1 = h_f + x h_{fg} = 305.0725$ kJ/kg

③ B.1.3 B.1.3 @ 10 kPa, 50°C : $h_2 = 2592.56\ \frac{kJ}{kg}$ $s_2 = 8.1749\ \frac{kJ}{kgK}$

2nd law:

③ ① find $\dot{Q}$ 2nd $\dot{Q} = \dot{m}\,T(s_2-s_1) = 2\frac{kg}{s}\ \underbrace{(50+273)}_{323}K\ 7.1749\frac{kJ}{kgK} = \underline{\underline{4634.985\ kW}}$

1st law

③ 1st ① find Vel until $\frac{1}{2}Vel_2^2 = \frac{\dot{Q}}{\dot{m}} + h_1 - h_2 = 2317.5\frac{kJ}{kg} + 305.0725\frac{kJ}{kg} - 2592.56\frac{kJ}{kg}$

$= 30.00517\ \frac{kJ}{kg} = 30005.17\ \frac{m^2}{s^2}$ $\underline{\underline{Vel = 244.97\ m/s}}$