EML 3100 Exam 3 **THERMODYNAMICS** **4/16/15 11:00-12:15 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.*

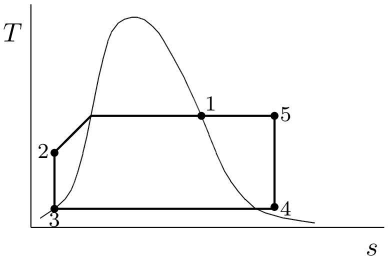
1. (5%) A reversible pump increases the pressure of 0.3 kg/s of engine oil from 100 kPa to 300 kPa. Ignoring potential and kinetic energy changes, the needed pumping power will be 67.797 W.

2. (5%) Which of the following heat engine data could be correct?
   [✓ 1.] $W = 0$, $Q_H = 5$, $Q_L = 5$.
   2. $W = 5$, $Q_H = 0$, $Q_L = 5$.
   3. $W = 5$, $Q_H = 5$, $Q_L = 0$.

3. (5%) Of the below processes, a total of 1 can be achieved in an insulated piston-cylinder combination:
   - Superheated water at 100 kPa and 150°C to saturated vapor at 50°C.
   - Superheated water at 100 kPa and 150°C to saturated vapor at 100°C.
   - Superheated water at 100 kPa and 150°C to saturated vapor at 150°C.

4. (5%) To compress 0.3 kg/s of argon in a reversible adiabatic compressor from 0.5 m^3/kg and 25°C to 200°C requires 27.305 kW of power.

5. (5%) *Neatly* draw the $T-s$ diagram for the reversible cycle described below. Label the states.
   - 1-2 Isobaric cooling from saturated vapor to compressed liquid.
   - 2-3 isentropic expansion to saturated liquid.
   - 3-4 constant temperature heating to superheated vapor.
   - 4-5 reversible adiabatic compression.
   - 5-1 isothermal cooling.



6. (5%) When 300 kg of brick cools down from 226.85°C to the ambient temperature of 26.85°C, the heat released by the brick will be 50.4 MJ and the entropy generated in the complete system will be 39.272 kJ/K.

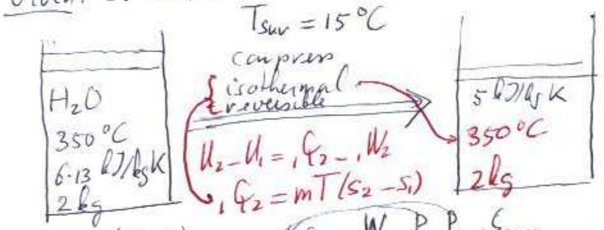
7. (5%) It is -5°C outside and 25°C inside your house. To add 4 kW of heat to your house with an A/C acting as a heat pump will require at least 0.40248 kW of electricity.

8. (33%) A piston-cylinder combination contains 2kg of water initially at 350°C with an entropy of 6.13 kJ/kg K (note units). The water is now isothermally and reversibly compressed until the entropy becomes 5 kJ/kg K.
   (a) Construct the initial phase in very neat Ts and Pv-diagrams. Mark all lines and points used to do it with their values. State the phase. Do not put more info in the diagrams than is needed to construct the phase.
   (b) Construct the final phase in the same two diagrams the same way. Also show the process as a fat line in the diagrams. Also show and label the process work and heat graphically in the diagrams.
   (c) Find the initial and final pressures, the heat added to the water and the work needed to compress the water.
   (d) Assuming that the heat transfer is with a surroundings at 15°C, what is the entropy generated in the entire system?

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:

$T_{sur} = 15°C$



$U_2 - U_1 = {}_1Q_2 - {}_1W_2$

${}_1Q_2 = mT(s_2 - s_1)$

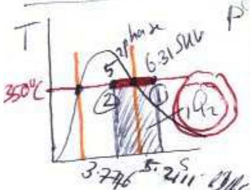
Asked: $(Ts, Pv)_{1,2,proc}, {}_1Q_2, {}_1W_2, P_1, P_2, {}_1S_{2gen}$

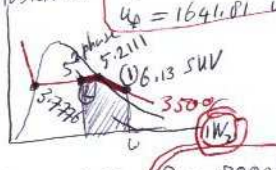
Solution B.1.1 @ 350°C (16514 kPa)

$s_f = 3.7776$ $s_{fg} = 1.4336$ $s_g = 5.2111$ kJ/kg K

($h_f = 1670.54$ $h_{fg} = 893.38$ $h_g = 2563.92$ kJ/kg)

$u_f = 1641.81$ $u_{fg} = 776.58$ $u_g = 2418.39$ kJ/kg





① is SUV

② is 2phase $P_2 = 16,514$ kPa

kJ/kg K

B.1.3 @ 350°C and 6.13 kJ/kg K: $P_1 = 8000$ kPa $u_1 = 2747.67$ ($h_1 = 2987.3$ kJ/kg)

$u_2 = u_f + x\,u_{fg}$ $u_2 = 2303.90$

B.1.1 @ 350°C $s = s_{f2} + x_2\, s_{fg2}$: $x_2 = .85274$

${}_1Q_2 = mT(s_2 - s_1) = 2\,\text{kg}\,(350 + 273.15)\,\text{K}\,(5 - 6.13)\frac{\text{kJ}}{\text{kg K}} = -1408.32\ \text{kJ} = {}_1Q_2$ added to water < 0

4.03

${}_1W_2 = {}_1Q_2 + m(u_1 - u_2) = -1408.32\ \text{kJ} + 2\,\text{kg}\,\underbrace{(2747.67 - 2303.90)}_{443.69}\,\text{kJ/kg}$ → 887.38

${}_1W_2 = -520.939\ \text{kJ} = -W_{compress}$

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

${}_1S_{2gen} = 2\,\text{kg}\,(5 - 6.13)\frac{\text{kJ}}{\text{kg K}} + \frac{1408.32\ \text{kJ}}{15 + 273.15} = 2.6274\ \text{kJ/K} = {}_1S_{2gen}$

9. (32%) Carbon dioxide at 320 K and 0.2 m^3/kg enters a adiabatic, horizontal, nozzle at negligible velocity. It exits the nozzle at 200 K. The flow can be assumed to be reversible.
    1. Find the initial and final pressures. Most accurate only!
    2. Find the exit velocity.
    3. Using only table A.5, and no polytropic formulae, what would the final pressure be?

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

CO_2 320 K I ①

0.2 m³/kg I

Vel Vel~0 →

well insulated

reversible

②

$\cancel{q} + h_1 + \frac{1}{2}\cancel{Vel_1^2} + g\cancel{z_1} = \cancel{w} + h_2 + \frac{1}{2}Vel_2^2 + \cancel{g z_2}$

no moving parts

horizontal

200 K I

$s_2 = s_1$ I

Asked: P_1, Vel_2, P_2

Solution: $P_1 v_1 = RT_1$ $\quad P_1\, 0.2\,\frac{m^3}{kg} = \overset{A8}{\downarrow}0.1889\,\frac{kJ}{kg\,K}\, 320\,K$ $\quad \boxed{P_1 = 302.24\text{ kPa}}$

$(u_1 = 171.332)$

$h_1 = 231.788\,\frac{kJ}{kg}$

$s^o_{T_1} = 4.91674\,\frac{kJ}{kg\,K}$

200 K $\quad (u_2 = 97.49)$

$h_2 = 135.28\,\frac{kJ}{kg}$

$s^o_{T_2} = 4.5435\,\frac{kJ}{kg\,K}$

A8: $g = 320\,K$ $\quad g_1 = 300\,K$ $\quad g_2 = 350\,K$

$d = h_1$ $\quad d_1 = 214.38$ $\quad d_2 = 257.90\,\frac{kJ}{kg}$

$d = s^o_{T_1}$ $\quad d_1 = 4.\overset{8631}{\cancel{997}}2$ $\quad d_2 = 4.9972$

$\frac{1}{2}Vel_2^2 = h_1 - h_2 = 96.508\,\frac{kJ}{kg} = 96508\,\frac{m^2}{s^2} \rightarrow \boxed{Vel_2 = 439.33\,m/s}$

$\times 2$: 193016

$\cancel{s_2 - s_1}^{\,0} = s^o_{T_2} - s^o_{T_1} - R\ln\frac{P_2}{P_1}$ $\quad P_2 = P_1 e^{\frac{4.5439 - 4.91674}{0.1889}} = 302.24\text{ kPa}\ e^{-1.97374}$

$= 302.24\text{ kPa}\ 0.138935 = \boxed{41.992\text{ kPa}}$

A5: $\cancel{s_2 - s_1}^{\,0} = c_p \ln\frac{T_2}{T_1} - R\ln\frac{P_2}{P_1}$ or $\frac{P_2}{P_1} = \left(\frac{T_2}{T_1}\right)^{\frac{n}{n-1}} = \left(\frac{200}{320}\right)^{\frac{1.289}{.289}} = \boxed{37.148\text{ kPa}}$