EML 3100 Exam 3 **THERMODYNAMICS** **4/17/14 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.*

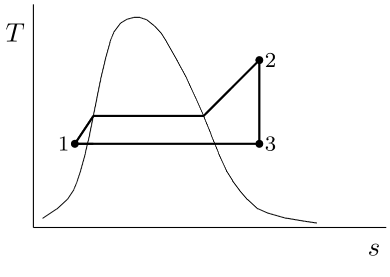
1. (5%) Which of the following heat pump data could be correct?
    1. $Q_H = 0$, $Q_L = 4$, $W = 4$
    [✓ 2.] $Q_H = 4$, $Q_L = 0$, $W = 4$
    3. $Q_H = 4$, $Q_L = 4$, $W = 0$

2. (5%) An inventor has submitted a device that involves adiabatic expansion of superheated water at 1 MPa and 200°C to saturated vapor at 100°C. You as patent examiner
    1. reject the device out of hand.
    2. consider it with unbelief.
    [✓ 3.] look for other potential problems.

3. (5%) Isentropic compression of helium from 100 kPa and 26.85°C to 150 kPa will produce a final temperature of 79.691 °C.

4. (5%) *Neatly* draw the $T - s$ diagram for the reversible cycle described below. Label the states.

- 1-2 Isobaric heating from compressed liquid to superheated vapor.
- 2-3 reversible adiabatic expansion.
- 4-1 isothermal cooling



5. (5%) A reversible pump increases the pressure of 0.02 kg/s of mercury from 100 kPa to 2 MPa. Ignoring potential and kinetic energy changes, the needed pumping power will be 2.80236 W.

6. (5%) When 3 kg of mercury cools down from 600 K to the ambient temperature of 300 K, the heat released by the mercury will be 125.1 kJ and the entropy generated in the complete system will be 0.12796 kJ/K.

7. (5%) It is -10°C outside and 23°C inside your house. An A/C acting as a heat pump will need at least 0.11143 kW of electricity for each kW of heat added to your house.

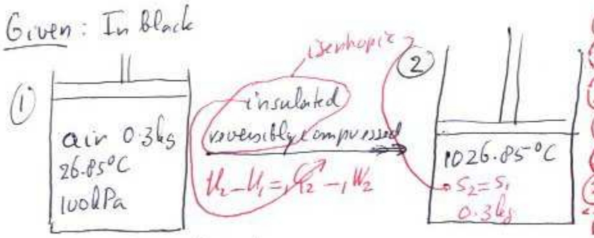
8. (33%) An insulated piston-cylinder combination contains 0.3 kg of air at 26.85°C and 100 kPa. The air is now reversibly compressed until the temperature becomes 1026.85°C.

   (a) Find the final pressure and volume and the work needed.

   (b) Assuming (incorrectly) that the air specific heat values are constant at their 300 K values, what would the appropriate work formula say about the work?

   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



① $m_2 = m_1$
④ $s_2 = s_1$ (2)
4 s formula (2)
① find R
③ read A-17
② compute P_2 units!
15

④ $PV = mRT$
① compute V_2, units!
5
⑤ 1st law $Q=0$
③ ① compute, W_2, units
9
④ work formula

Asked: $P_2, V_2, {}_1W_2, ({}_1W_2)_{cc}$

Solution: air is in A-17, must be used

table A-2a air $R = 0.287 \frac{kJ}{kg\,K}$

table A-17 300 K = 26.85 + 273.15 $s_1^o = 1.70203 \frac{kJ}{kg\,K}$ $u_1 = 214.07$ kJ/kg

$$\cancel{s_2 - s_1}^{0} = s_2^o - s_1^o - R \ln \frac{P_2}{P_1}$$

Table A-17 @ 1026.85 + 273.15 = 1300 K $s_2^o = 3.27345$ $u_2 = 1022.82$

$$R \ln \frac{P_2}{P_1} = s_2^o - s_1^o \qquad \ln \frac{P_2}{P_1} = \frac{s_2^o - s_1^o}{R} = \frac{3.27345 - 1.70203}{0.287} \frac{kJ/kg\,K}{kJ/kg\,K} = 5.47533$$

$$P_2 = P_1 e^{5.47533} = \boxed{23,873 \text{ kPa}}$$

$$P_2 V_2 = m R T_2 \qquad 23873 \text{ kPa}\ V_2 = 0.3 \text{ kg}\ 0.287 \frac{kJ}{kg\,K}\ 1300\text{ K} \qquad \boxed{V_2 = 0.0046886 \text{ m}^3}$$

$$ {}_1W_2 = U_1 - U_2 = m(u_1 - u_2) = 0.3 \text{ kg}\ \underbrace{(214.07 - 1022.82)}_{808.75} \frac{kJ}{kg} = \boxed{-242.625 \text{ kJ}}$$

64.221 − 306.864

b) at 300 K, air from A-2(a) $k = 1.4 = n$

$$ {}_1W_2 = \frac{P_2V_2 - P_1V_1}{1-n} = \frac{mR(T_2 - T_1)}{1-n} = \frac{.3\text{ kg}\ 0.287 \frac{kJ}{kg}}{-0.4} = \boxed{-215.25 \text{ kJ}}$$

$(1300)^{\frac{1.4}{.4}}$ 16,673 kPa

9. (32%) Water enters a reversible isothermal heat exchanger at 100°C with a (specific) entropy of 2.5 kJ/kg K with negligible velocity. In the heat exchanger, 2,000 kJ/kg of (specific) heat is added to the water. This may give a non negligible *exit* velocity.
   1. Construct the initial phase in a very neat Ts-diagram. Mark all lines and points used to do it with their values. State the initial phase. Do not put more info in the diagram than is needed to construct the phases.
   2. Find enough exit variables to construct the exit state.
   3. Actually construct the exit state, in the same diagram used before. Also show the process line as a fat line.
   4. Find the exit velocity.

   Be sure to use at least 5 significant digits everywhere.

   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.

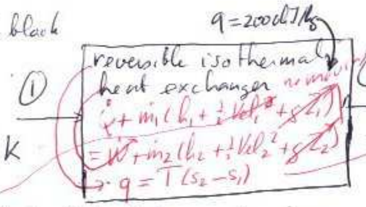
Given: In black

H_2O

T 100°C

I 2.5 kJ/kg K

$Vel_1 \sim 0$



$T_2 = T_1 = 100°C$

$s_2 = s_1 + \frac{q}{T}$

① diagram
① line 1
① find sat
① plot sat
① line 2
① ID
① process
$\frac{7}{7}$

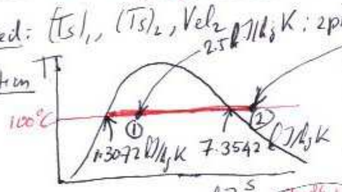
④ 2phase formulae
② find x_1
① read A-4
$\frac{7}{7}$

④ h out formula
② find s_2
① read A-6
④ interpolate
$\frac{11}{11}$

(5 1st law $\dot{W}=0$
② find Vel, units
$\frac{7}{7}$

Asked: $(Ts)_1$, $(Ts)_2$, Vel_2

Solution



Use A-4: $s_1 = s_f + x_1 s_{fg}$

$x_1 = \frac{s_1 - s_f}{s_{fg}} = \frac{2.5 - 1.3072}{6.047} = \boxed{.19725 = x_1}$

$h_1 = h_f + x h_{fg} = 419.17 + .19725\underbrace{(2675.6 - 419.17)}_{2256.43}$

$\boxed{= 864.26 \text{ kJ/kg}}$

$s_2 = \left(2.5 + \frac{2000}{100 + 273.15}\right)\frac{\text{kJ}}{\text{kg K}} = \boxed{\overset{7.86197}{7.85977}}$ use A-6 since SHV

$s = 7.85977$ $s_1 = 8.4489$ $s_2 = 7.6953$ $d = d_1 + \frac{s - s_1}{\underbrace{s_2 - s_1}_{.7817}}(d_2 - d_1) = \boxed{\overset{2684.37}{2683.5} \frac{\text{kJ}}{\text{kg}} = h_2}$

$d = h_2$ $d_1 = 2687.5$ $d_2 = 2682.4$

First law on specific basis $q + h_1 = h_2 + \frac{1}{2}Vel_2^2$

$Vel_2^2 = 2\underbrace{(2000 + 864.25 - 2683.5)}_{180.74}\frac{\text{kJ}}{\text{kg}}\frac{1000 \text{ m}^2/\text{s}^2}{1 \text{ kJ/kg}} = 361,485 \frac{\text{m}^2}{\text{s}^2}$

$Vel_2 = \boxed{601.23 \text{ m/s}}$