EML 3100 Exam 4 **THERMODYNAMICS** **4/27/11 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 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. (3%) The following list contains a total of 2 control volumes:

   (a) A mixing chamber.
   (b) A nozzle.
   (c) A rigid container.

2. (3%) You have compressed liquid in a well-insulated piston-cylinder combination. Now you want to get the liquid to boil in a reversible process.

   (a) That is not possible.
   [✓ (b)] You have to decrease the temperature.
   (c) You have to increase the temperature.

3. (3%) An adiabatic piston-cylinder combination contains 3 kg acetylene at 10°C and 200 kPa. It is being compressed at a rate of 0.7 m^3/s. The rate of temperature increase is 33.816 °C/s.

4. (3%) Liquid bismuth must be compressed by a pump from 100 kPa to 1MPa. Ignoring kinetic and potential energy changes, the specific work required to do so is at least 89.641 J/kg to 5 significant digits. (Note the units.)

5. (3%) If the temperature of 2 m^3 of common brick changes from 10°C to 100°C, its entropy changes by 834.64 kJ/K.

6. (3%) What heat engine is *possible*:

   [✓ (a)] $W = 0$, $Q_H = 5$, $Q_L = 5$
   (b) $W = 5$, $Q_H = 0$, $Q_L = 5$
   (c) $W = 5$, $Q_H = 5$, $Q_L = 0$

7. (3%) Acetylene at 10°C and 200 kPa flows through an isothermal compressor at a rate of 3 kg/s. The compressor compresses it to 800 kPa. The power requirement of the compressor is at least 376 kW.

8. (3%) You throw 2 kg of 100°C aluminum into 5 kg of water at 25°C. Ignoring heat conduction with the surroundings, the final temperature will be 30.947 °C.

9. (3%) The kitchen is at 25°C and 100 kPa. Water boils inside a pressure cooker pressurized to 125 kPa gage. The water temperature is 124 °C.

10. (3%) To produce an amount of ice cubes in a 25°C kitchen requires that 800 kJ is removed from the 0 °C water. The electricity required to do this is at least 67.08 kJ.

11. (35%) Water enters a reversible isothermal turbine at 200 °C and 0.1 m^3/kg. It exits at 400 kPa with the same velocity as it entered.

    (a) Construct the initial phase in a very neat Ts diagram, marking all lines and points used to do it with their values. Do not put more info in the diagram than is needed to construct the phase. State the phase.

    (b) Construct the final phase in a very neat Pv diagram in the same way. State the phase. Show the process in the diagram.

    (c) Find the specific heat added to the water and the specific work produced by the turbine.

    (d) If the heat originates from a surroundings at 26.85°C, then what is the generated specific entropy in the complete system? Comment on your answer.

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.

Given: in block $T_{surr} = 26.85°$

H_2O:
I 200°C
I 0.1 m³/kg
no extensives

turbine
isothermal reversible

200°C I
400 kPa I

$\dot{Q} + \dot{m}_1(h_1 + \cancel{\tfrac12 V_1^2} + \cancel{gz_1}) = \dot{W} + \dot{m}_2(h_2 + \cancel{\tfrac12 V_2^2} + \cancel{gz_2})$ $(\dot{m}_2 = \dot{m}_1)$ $\rightarrow q + h_1 = w + h_2$

$q = T(s_2 - s_1)$

$\dot{S}_{gen} = \dot{m}(s_2 - s_1) - \frac{\dot{Q}}{T_{surr}}$ $\rightarrow S_{gen} = s_2 - s_1 - \frac{q}{T_{surr}}$

① diagram
② line 1
② find sat right ones
② plot sat
② line 2 relation
② ID
① proc
—
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① Read B.1.1
② Read B.1.3
④ 2phase formulae
① find x, h_1, s_1
④ $q = T(s_2 - s_1)$
② use K, find quantities
④ 1st law
① find w, units!
② 2nd law
① find s_{gen}, units!
① comment
—
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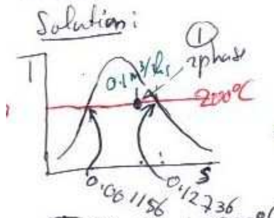
Asked: Ts_1, Pv_2, proc, q, s_{gen}

Solution:



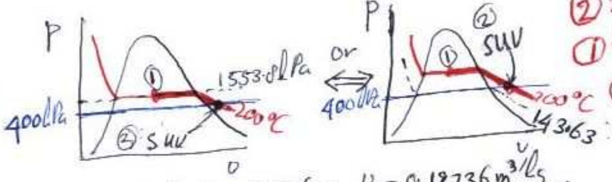


Table B.1.1 @ 200°C $v_f = 0.001156$ $v_{fg} = 0.12620$ $v_g = 0.12736$ m³/kg

$h_f = 852.43$ $h_{fg} = 1940.75$ $h_g = 2793.18$ kJ/kg

$s_f = 2.3308$ $s_{fg} = 4.1014$ $s_g = 6.4322$ kJ/kg K

$x_1 = \frac{v - v_f}{v_{fg}} = .78323$ $h_1 = 2372.49$ kJ/kg $s_1 = 5.54315$ kJ/kg K

.78321 2372.44 5.54305

Table B.1.3 @ 200°C, 400 kPa: $h_2 = 2860.51$ kJ/kg $s_2 = 7.1706$ kJ/kg K

$q = T(s_2 - s_1) = 473.15\text{ K}(7.1706 - 5.54315)\text{ kJ/kg K} = \cancel{770.027}$ kJ/kg
769.78

$w = q + h_1 - h_2 = (770.027 + 2372.49 - 2860.51)$ kJ/kg $= \underline{282.01}$ kJ/kg

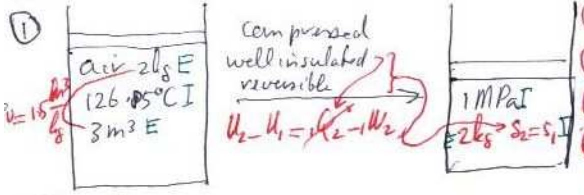
$s_{gen} = s_2 - s_1 - q/T_{surr} = 7.1706 - 5.54315 - 770.027/(26.85 + 273.15)$

$= \underline{-0.9393 \text{ kJ/kg K}}$ That is wrong, Must be positive.

12. (35%) A well-insulated piston-cylinder combination contains 2 kg of air at 126.85°C and 3 m^3. The air is compressed to 1 MPa in a process that can be taken to be reversible. Find the work done in the compression. Do *not* use $h = u + Pv$ or $H = U + PV$.

    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.

Given: In black



① Read A.5 R
② Read A.7.1
⑤ $P_1V_1 = mRT_1$
② find P_1 units! K
① $m_2 = m_1$
"

⑤ $s_2 = s_1$
④ entropy formula
② know can interpolate
④ interpolate
⑤ 1st law
③ $Q = 0$
① compute W, units!

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Asked: ${}_1W_2$

Solution: $s_2 - s_1 = 0 = s^o_{T_2} - s^o_{T_1} - R\ln P_2/P_1$ $\quad P_1V_1 = mRT_1$ $\quad P_1\,3\mathrm{m}^3 = 2\mathrm{kg}\;0.287\frac{\mathrm{kJ}}{\mathrm{kgK}}(126.85+273.15)\mathrm{K}$

$P_1 = 76.53$ kPa $\quad$ Table A.7.1 @ 400K: $u_1 = 286.49$ kJ/kg $\quad s^o_{T_1} = 7.15926$ kJ/kgK

$0 = s^o_{T_2} - 7.15926\frac{\mathrm{kJ}}{\mathrm{kgK}} - 0.287\frac{\mathrm{kJ}}{\mathrm{kgK}}\ln\frac{1000\mathrm{kPa}}{76.5333}$ $\quad s^o_{T_2} = 7.896858295$ kJ/kgK

$\mathcal{S} = s^o_{T_2} = 7.89686$ $\quad \mathcal{S}_1 = 7.88514$ $\quad \mathcal{S}_2 = 7.95207$ kJ/kgK $\quad \frac{\mathcal{S}-\mathcal{S}_1}{\mathcal{S}_2-\mathcal{S}_1} = .175$

$d = u$ $\quad d_1 = 592.58$ $\quad d_2 = 633.42$ kJ/kg

$u_2 = 599.730$ kJ/kg

$${}_1W_2 = -(U_2 - U_1) = m(u_1 - u_2) = 2\mathrm{kg}\,(286.49 - 599.73)\frac{\mathrm{kJ}}{\mathrm{kg}} = \underline{\underline{-626.48\ \mathrm{kJ}}}$$