EML 3100 Exam 2 **THERMODYNAMICS** **3/3/15 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%) The specific heat at constant volume of nitrogen at 900 K is 0.85262 kJ/kg-K.

2. (5%) If you add 50 kJ of heat to 2 L of benzene initially at 10°C, its final temperature will be 26.536 °C.

3. (5%) If helium at 300 K has an enthalpy of 800 kJ/kg, then its internal energy is 176.87 kJ/kg.

4. (5%) For an ideal gas, of the nine quantities $C_p, C_v, H, P, \rho, T, u, V, PV$, 4 depend on temperature only (not, say, also on pressure and/or mass).

5. (5%) A piston-cylinder configuration holds 0.3 kg of helium currently at 50 kPa and 400K. The volume is decreasing at a rate of 3 L/s and 0.2 kW of heat leaks out the helium. The temperature of the helium is changing at a rate of -0.053486 °C/s.

6. (5%) If you compute the enthalpy change of nitrogen between 300 and 1500 K using the room temperature specific heat, the result will be in error by 118.63 kJ/kg.

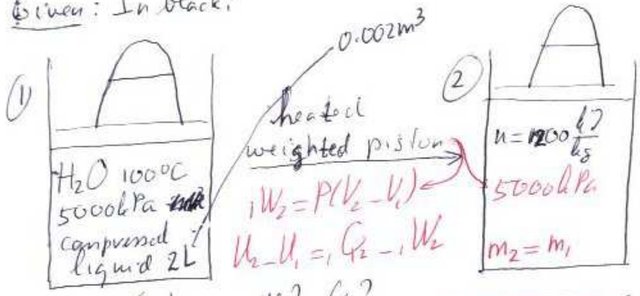
7. (5%) Heat is added to 3 kg of brass at a rate of 0.5 kW. The temperature of the brass is increasing at a rate of 0.4386 °C/s.

8. (33%) A weighted-piston/cylinder combination initially holds 2 L of compressed liquid water at 100°C and 5000 kPa. Then the water is heated until the internal energy becomes 1200 kJ/kg.

   - Construct the final phase in a very neat Tv-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.
   - What is the work done by the water and the heat added to it, to 5 significant digits?

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:



$_1W_2 = P(V_2 - V_1)$

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

~~1 Diagram~~
~~1 line 1~~
~~2 find sat v_f u_{fg}~~
~~1 plot sat~~
~~1 line 2 val~~
~~1 ID~~
7

Read B.1.4
~~Find m~~
~~$P_2 = P_1$~~
~~Read B.1.2~~
~~2 phase formulae~~
~~find x, v_2~~
~~work formula~~
~~find, W_2 unit~~

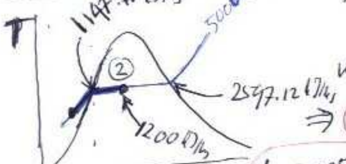
$m = \frac{V_1}{v_1} = \frac{.002\text{m}^3}{.001041\ \text{m}^3/\text{kg}} = \boxed{1.9212\ \text{kg}}$

Asked: $(Tv)_{2,\text{proc}}$, $_1W_2$?, $_1Q_2$?

Solution: B.1.4 @ 5000 kPa, 100°C: $\boxed{v_1 = 0.001041\ \frac{\text{m}^3}{\text{kg}}}$ $\boxed{u_1 = 417.50}$ $(h_1 = 422.71)\ \frac{\text{kJ}}{\text{kg}}$

B.1.2 @ 5000 kPa $v_f = 0.001286$ $v_{fg} = 0.03815$ $v_g = 0.03944\ \frac{\text{m}^3}{\text{kg}}$

$u_f = 1147.78$ $u_{fg} = 1449.34$ $u_g = 2597.12$ kJ/kg



$u = u_f + x u_{fg}$ $1200\ \frac{\text{kJ}}{\text{kg}} = (1147.78 + x\ 1449.34)\ \text{kJ/kg}$

$\Rightarrow \boxed{x = 0.03603}$ $v_2 = v_f + x v_{fg} = \boxed{0.0026605\ \frac{\text{m}^3}{\text{kg}}}$

$\boxed{V_2 = 0.0051114}$

$_1W_2 = P\underbrace{(V_2 - V_1)}_{m(v_2 - v_1)} = 5000\ \text{kPa}\ 1.9212\ \text{kg}\ (0.0026605 - 0.001041)\ \frac{\text{m}^3}{\text{kg}}$

$= \boxed{15.557\ \text{kJ}}$ $\boxed{U_2 = 2305.4 \quad U_1 = 802.1\ \text{kJ}}$

$_1Q_2 = U_2 - U_1 + {}_1W_2 = m(u_2 - u_1) + {}_1W_2 = \underbrace{1.9212\ \text{kg}\ (1200 - 417.5)\ \frac{\text{kJ}}{\text{kg}}}_{1503.34} + 15.557\ \text{kJ}$

$= \boxed{1,518.9\ \text{kJ}}$

1 Diagram
1 line 1
2 find sat
1 plot sat
1 line 2 val
1 ID

② Read B.1.4 u_1, v_1
③ Find m
5

② $P_2 = P_1$
① Read B.1.2
④ 2 phase formulae
② find x, v_2, units
2x×1
9

④ Work formula → heads mV
① Find, W_2, units
⑥ 1st law (h: -3) ($m_1 = m_2$)
① Find, Q_2 units
12
h = 1700: -3

9. (32%) A 0.2 kg/s flow of nitrogen at 0.9 m^3/kg and 26.85°C enters a compressor at a speed of 300 m/s. The nitrogen exits the compressor at 30 MPa with an enthalpy of 1700 kJ/kg and negligible velocity. During the transit through the compressor, 9 kW of heat leaks *out* of the nitrogen to the surroundings.

   - What is the entrance pressure and pipe diameter?
   - What is the exit temperature?
   - Find the work required by the compressor to at least 5 significant digits accuracy.

   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.*

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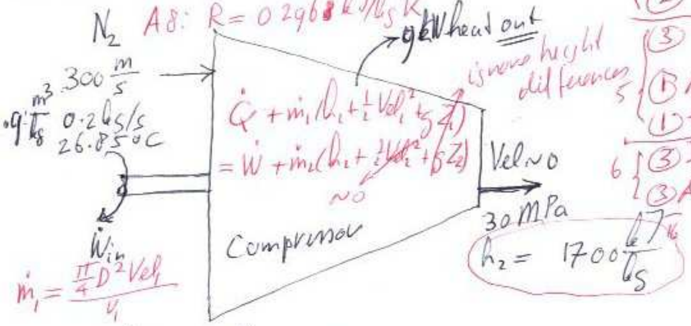

5 { ③ $Pv = RT$
② find P, units

5 { ③ $\dot m = \frac{A\,Vel}{v}$
① $A = \frac{\pi}{4}D^2$
① find D, units

6 { ③ Interpolation
③ Apply to T3 −1

② $\dot m_1 = \dot m_2$ in 1st
⑤ First law
② Clean up
③ $\dot Q = -9\,kW$ (sign 2)
② Read h_1, ~~h_2~~ in A8 −2
② find $\dot W$: units
no loss −2
16

Asked $\dot W$, D_1, T_2, P_1

Solution A8: $h_1 = 311.67\ \frac{kJ}{kg}$ $\quad P_1 v_1 = RT_1 \quad P_1 = 0.2968\ \frac{kJ}{kg\,K}\ 300\,K / .9\ \frac{m^3}{kg}$ kPa m³

$P_1 = 98.933\ kPa$

98.88 at 273 98.966 if 26.95

$D_1^2 = \frac{4}{\pi}\frac{\dot m_1 v_1}{Vel_1} = \frac{4}{\pi}\ \frac{0.2\ kg/s\ \ .9\ \frac{m^3}{kg}}{300\ m/s} = .00076394\ m^2$

$D_1 = ~~0.027640~~\ m = 2.7640\ cm$

1st law $\quad \dot W = \dot Q + \dot m(h_1 - h_2 + \frac12 Vel_1^2)$

$= -9\,kW + 0.2\ \frac{kg}{s}\ (311.67 - 1700 \overset{kJ/kg}{} + \overbrace{\frac12 (300\ \frac{m}{s})^2\ \frac{1\ kJ/kg}{1000\ m^2/s^2}}^{45})$

-1343.33

-286666

$\dot W = -277.66\ kW$

$g = 1700 \quad g_1 = 1680.7 \quad g_2 = 1805.6\ kJ/kg$

$d = T \quad d_1 = 1500\,K \quad d_2 = 1600\,K$

$T_2 = d_1 + \frac{g - g_1}{g_2 - g_1}(d_2 - d_1) = 1500\,K + \frac{1700 - 1680.7}{1805.6 - 1680.7}(1600 - 1500)K$

$T_2 = 1515.5\,K$