EML 3100 Exam 2 **THERMODYNAMICS** **3/4/14 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%) The specific heat at constant volume of ammonia at 1000 K is 2.8244 kJ/kg-K.

2. (5%) If 2 L of bronze cools down from 90°C to the room temperature of 20°C it releases 463.68 kJ of heat into the room.

3. (5%) If argon at 600 K has an enthalpy of 400 kJ/kg, then its internal energy is 275.14 kJ/kg.

4. (5%) If you know H and m for an ideal gas for which you have tables, then you can find
   1. P
   2. V
   [✓ 3.] T

5. (5%) A piston-cylinder configuration holds 0.3 kg of Argon currently at 100 kPa. The volume is expanding at a rate of 7 L/s and 0.2 kW of heat leaks into the argon from outside. The temperature is changing at a rate of 5.3384 °C/s.

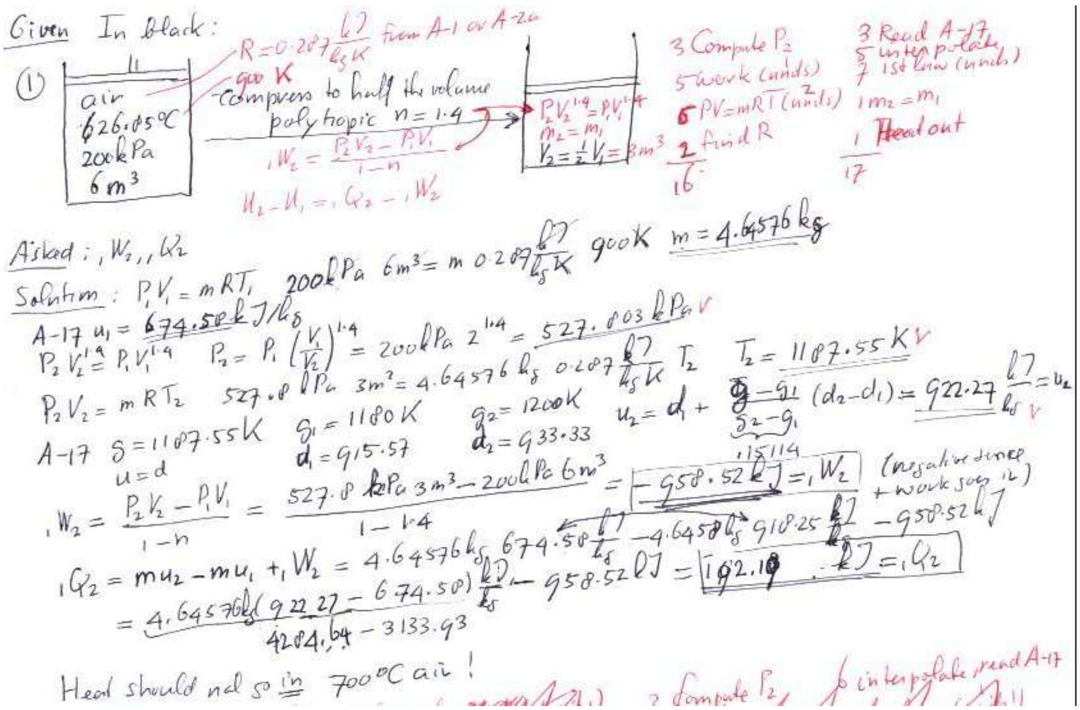
6. (5%) A 7 kg/s stream of steam at 1200°C and 800 kPa travels at a speed of 200 m/s through a pipe. The diameter of the pipe is 19.46 cm.

7. (5%) A weighted piston cylinder holds 2 kg of hot argon at 200 kPa and 600 °C that is cooling down at a rate of 3 °C/s. The heat leaking out to the surroundings is 3.1218 kW.

8. (33%) A piston-cylinder combination initially holds 6 m^3 of air at 626.85°C and 200 kPa. Then the air is compressed to half its original volume. I believe this will be a polytropic process with $n = 1.4$.

    - Under the given conditions, find the work that must be done on the air to compress it, and the heat transfer.
    - State any reason you can see to doubt my conclusion that the process will be polytropic with $n = 1.4$.

    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:

$R = 0.287 \frac{\text{kJ}}{\text{kg K}}$ from A-1 or A-2a

900 K

Compress to half the volume

polytropic $n = 1.4$

${}_1W_2 = \frac{P_2V_2 - P_1V_1}{1-n}$

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

3 Compute P_2
5 work (units)
6 $PV = mRT$ (units) 2
2 find R
$\frac{2}{16}$

3 Read A-17
5 interpolate
7 1st law (units)
1 $m_2 = m_1$
1 Heat out
$\frac{1}{17}$

Asked: ${}_1W_2$, ${}_1Q_2$

Solution: $P_1V_1 = mRT_1$ 200 kPa 6 m^3 = m 0.287 $\frac{\text{kJ}}{\text{kg K}}$ 900 K $\underline{\underline{m = 4.64576 \text{ kg}}}$

A-17 $u_1 = \underline{\underline{674.58 \text{ kJ/kg}}}$

$P_2V_2^{1.4} = P_1V_1^{1.4}$ $P_2 = P_1\left(\frac{V_1}{V_2}\right)^{1.4} = 200 \text{ kPa } 2^{1.4} = \underline{527.803 \text{ kPa}}$ ✓

$P_2V_2 = mRT_2$ 527.8 kPa 3 m^3 = 4.64576 kg 0.287 $\frac{\text{kJ}}{\text{kg K}}$ T_2 $T_2 = \underline{\underline{1187.55 \text{ K}}}$ ✓

A-17 $T = 1187.55$ K $T_1 = 1180$ K $T_2 = 1200$ K $u_2 = d_1 + \underbrace{\frac{T - T_1}{T_2 - T_1}}_{.15114}(d_2 - d_1) = \underline{\underline{922.27}} \frac{\text{kJ}}{\text{kg}} = u_2$ ✓

$u = d$ $d_1 = 915.57$ $d_2 = 933.33$

${}_1W_2 = \frac{P_2V_2 - P_1V_1}{1-n} = \frac{527.8 \text{ kPa } 3 \text{ m}^3 - 200 \text{ kPa } 6 \text{ m}^3}{1 - 1.4} = \boxed{-958.52 \text{ kJ} = {}_1W_2}$ (negative since + work goes in)

${}_1Q_2 = mu_2 - mu_1 + {}_1W_2 = 4.64576 \text{ kg } 674.58 \frac{\text{kJ}}{\text{kg}} - 4.6458 \text{ kg } 918.25 \frac{\text{kJ}}{\text{kg}} - 958.52 \text{ kJ}$

$= 4.64576 \text{ kg}(922.27 - 674.58) \frac{\text{kJ}}{\text{kg}} - 958.52 \text{ kJ} = \boxed{192.19 \text{ kJ} = {}_1Q_2}$

$= 4.64576 \text{ kg}(922.27 - 674.58)$

4284.64 − 3133.93

Heat should not go in 700°C air!

2 compute P_2 6 interpolate, read A-17

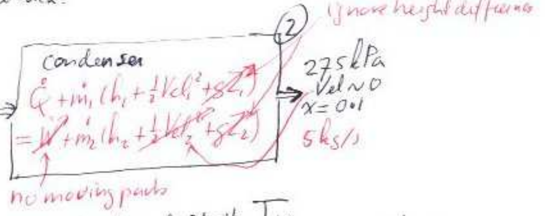
9. (32%) A 5 kg/s stream of water at 300 kPa and 200 °C enters a condenser at a speed of 300 m/s. The water exits the condenser at 275 kPa with negligible velocity. The condensation is incomplete; the exit quality is 10%.

    - Construct the initial 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.
    - Find the heat removed from the water 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.

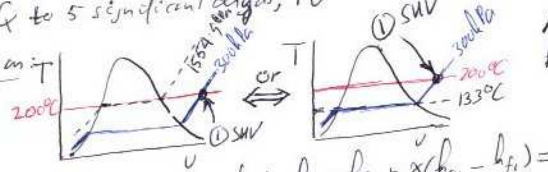
Given: In black:

H_2O ①
300 kPa
200 °C
5 kg/s
300 m/s



Asked $\dot Q$ to 5 significant digits, Tv

Solution:



A-6 @ 300 kPa = 0.3 MPa, 200 °C
$h_1 = 2865.9\ \frac{kJ}{kg}$ ~~$v_1 = 0.71643\ \frac{m^3}{kg}$~~

① is saturated as x exists: $h_1 = h_{f1} + x(h_{g1} - h_{f1}) = 548.86\ \frac{kJ}{kg} + 0.1\underbrace{(2720.9 - 548.86)}_{2172}\ \frac{kJ}{kg}$

$h_2 = 766.06\ \frac{kJ}{kg}$

1st law $\dot Q = \dot m(h_2 - h_1 - \frac12 Vel_1^2) = 5\ kg/s\,[\underbrace{(766.06 - 2865.9)}_{-2099.84}\ \frac{kJ}{kg} - \underbrace{\frac12\, 300^2\ \frac{m^2}{s^2}\ \frac{1\ kJ/kg}{1000\ m^2/s^2}}_{45}]$

~~2099.84~~ 10499.2 −2144.84 225

$\dot Q = -10724.2\ kJ/s = -10724.2\ kW$

8 1st law wrt d, knowledge it means $\dot W = P\dot V$: −3

1 diagram
1 line 1
2 find sat
1 plot sat
2 line 2
1 ID
$\overline{8}$

1 $\dot m_2 = \dot m_1$
3 look in SHV table
2 look in SAT table
6 sat h formula
$\overline{12}$

8 1st law
2 $\dot W = 0$
2 units
$\overline{12}$