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 many digits in your computation. 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 temperature of Helium is changing at a rate of 5°C/s. Its internal energy is changing at a rate of 15.578 kJ/kg-s.

2. (5%) To change the temperature of 0.5 kg of Helium that is kept at ambient pressure by 1000°C, we need to add 2.5963 MJ of heat.

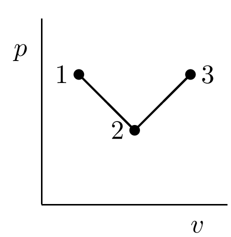
3. (5%) The specific heat of Xenon at constant pressure is 0.1583 kJ/kg-K. The specific heat at constant volume is 0.09498 kJ/kg-K.

4. (5%) If 27°C air isothermally expands from 2m^3 to 3m^3, the work done by the air is 34.91 kJ.

5. (5%) If the specific enthalpy of a substance at 2 bar of pressure is 400 kJ/kg and its specific volume is $0.5\ \text{m}^3/\text{kg}$, then its internal energy is 300 kJ/kg.

6. (5%) If 100 kJ of heat enters a 2 kg common brick, its temperature changes by 63.29 °C.

7. (5%) Write the expression for the work done from in the shown process, using numerical subscripts to identify the correct points of the quantities to use:



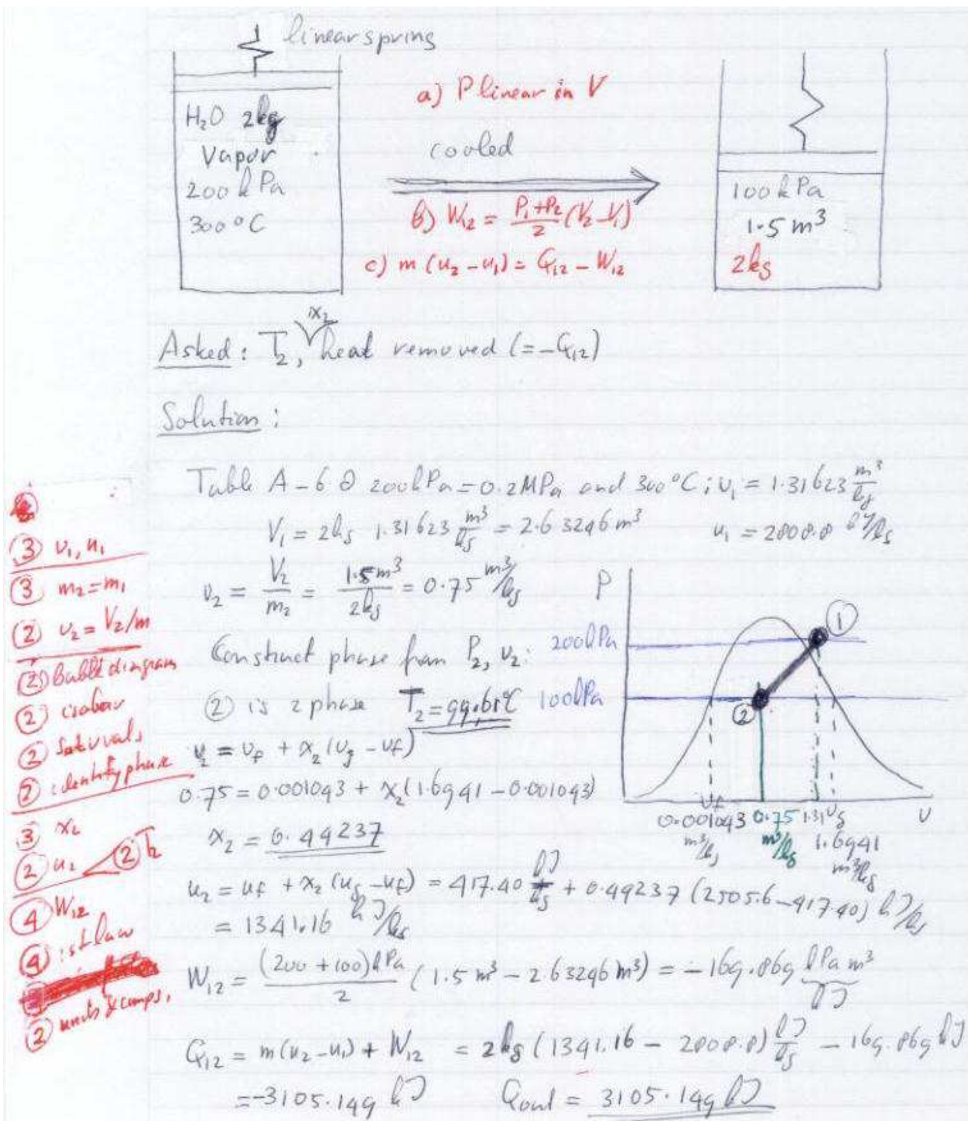
$\frac{1}{2}(P_1 + P_2)(V_2 - V_1) + \frac{1}{2}(P_2 + P_3)(V_3 - V_2)$

8. (33%) A cylinder contains 2 kg of water that is pressurized by a piston pushed down by a linear spring. Initially the water is in vapor form at 200 kPa and 300°C. The water is then cooled to 100 kPa, at which time the volume has been reduced to 1.5 m^3. Find the final temperature, quality if defined, and heat removed.

   You must construct all phases that are not given in the Pv-diagram, marking all lines and points used to do it with their values. Unambiguously number the phases in the diagram.

   Also show the process as a fat curve in the diagram.

   You must show the derivations and reasoning completely and correctly for full credit. You must give units for your answers. Most accurate procedure only unless stated otherwise.



linear spring

H_2O 2kg, Vapor, 200 kPa, 300 °C

a) P linear in V

cooled

b) $W_{12} = \frac{P_1+P_2}{2}(V_2-V_1)$

c) $m(u_2-u_1) = Q_{12} - W_{12}$

100 kPa, 1.5 m^3, 2kg

Asked: T_2, x_2, heat removed $(=-Q_{12})$

Solution:

Table A-6 @ 200 kPa = 0.2 MPa and 300 °C; $v_1 = 1.31623\ \frac{m^3}{kg}$, $u_1 = 2808.8$ kJ/kg

$V_1 = 2\,kg \cdot 1.31623\ \frac{m^3}{kg} = 2.63246\ m^3$

$v_2 = \frac{V_2}{m_2} = \frac{1.5\,m^3}{2\,kg} = 0.75\ m^3/kg$

Construct phase from P_2, v_2:

② is 2 phase $T_2 = 99.61$°C

$v_2 = v_f + x_2(v_g - v_f)$

$0.75 = 0.001043 + x_2(1.6941 - 0.001043)$

$x_2 = 0.44237$

$u_2 = u_f + x_2(u_g - u_f) = 417.40\ \frac{kJ}{kg} + 0.44237\,(2505.6 - 417.40)$ kJ/kg $= 1341.16$ kJ/kg

$W_{12} = \frac{(200+100)\,kPa}{2}(1.5\,m^3 - 2.63246\,m^3) = -169.869\ \frac{kPa\,m^3}{kJ}$

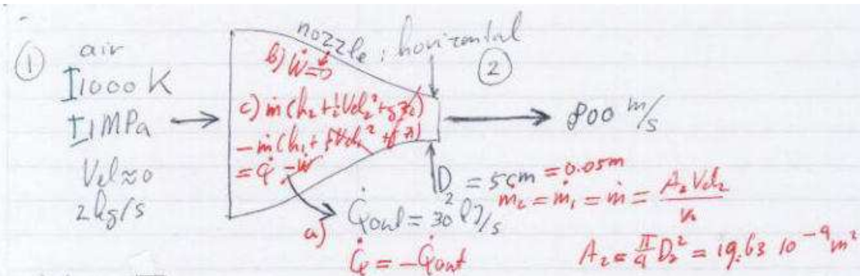
$Q_{12} = m(u_2-u_1) + W_{12} = 2\,kg\,(1341.16 - 2808.8)\ \frac{kJ}{kg} - 169.869$ kJ $= -3105.149$ kJ

$Q_{out} = 3105.149$ kJ

Grading: (3) v_1, u_1; (3) $m_2 = m_1$; (2) $v_2 = V_2/m$; (2) Bubble diagram; (2) isobar; (2) Sat. vals; (2) identify phase; (3) x_2; (2) u_2; (2) T_2; (4) W_{12}; (4) 1st law; (2) units & comps.

9. (32%) Air at 1000 K and 1 MPa enters a horizontal nozzle at a rate of 2 kg/s with negligible velocity. It exits at 800 m/s through an circular exit of diameter 5 cm. Heat is lost from the duct to the tune of 30 kJ/s. Find the temperature and specific volume of the exiting air.

   You must show the derivations and reasoning completely and correctly for full credit. You must give units for your answers. Most accurate procedure only unless stated otherwise.



$\dot m_2 = \dot m_1 = \dot m = \frac{A_2 Vel_2}{v_2}$

$A_2 = \frac{\pi}{4} D_2^2 = 19.63\ 10^{-4}\ m^2$

Asked: T_2, v_2,

Solution A-1: $R = 0.287$ kJ/kg K

No moving parts → $\dot W = 0$ $z_2 = z_1$ since horizontal

A-17: $h_1 = 1046.04$ kJ/kg

1st law: $2 \frac{kg}{s}\left(h_2 + \frac{1}{2} 800^2 \frac{m^2}{s^2} \frac{1\ kJ/kg}{1000\ m^2/s^2} - 1046.04 \frac{kJ}{kg}\right) = -30$ kJ/s

$h_2 = -\frac{1}{2} 800^2 \frac{m^2}{s^2} \frac{1\ kJ/kg}{1000\ m^2/s^2} + 1046.04 - 15 \frac{kJ}{kg}$

$= 711.04$ kJ/kg

Table A-17 @ $h = 711.04$ kJ/kg:

$s = 711.04$ kJ/kg $s_1 = 702.52$ kJ/kg $s_2 = 713.27$ kJ/kg

$d_1 = 690$ K $d_2 = 700$ K

$T_2 = d_1 + (d_2 - d_1)\frac{s - s_1}{s_2 - s_1} = 698$ K

$\dot m = \frac{A_2 Vel_2}{v_2}$ $v_2 = \frac{A_2 Vel_2}{\dot m} = \frac{\frac{\pi}{4} 0.05^2 m^2\ 800\ m/s}{2\ kg/s} = 0.7854 \frac{m^3}{kg}$

Grading: ④ $\dot m_2 = \dot m_1$ ④ $A_2 = \frac{\pi}{4} D_2^2$ ④ $v_2 = \frac{A_2 Vel_2}{\dot m}$ ④ 1st law ④ $\dot W = 0$ ④ h_1 from A-17 / h_2 to A-17 ④ solve for h_2: units!, $\dot Q$! ④ interpolate T_2