DO NOT WRITE ON THE BLUE TABLES. RETURN THE BLUE TABLES WITH YOUR EXAM. DO NOT STAPLE THE EXAM SHEETS TOGETHER. A letter-size formulae sheet, handwritten by you, may be used. Put your answers on the same sheet as the question. Use at least 5 significant 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 R-134a at 126.85°C equals 0.92175 kJ/kg K.

2. (5%) A piston-cylinder configuration contains 2 kg of R-134a at 25°C and 200 kPa that is expanding at a rate of 0.03 m^3/s, while 1 kW of heat leaks in. The rate of temperature increase of the R-134a is -3.2425 °C/s.

3. (5%) A house uses 2 m^3 of dry sand as a heat storage device. When this sand cools down from 40°C to 15°C, it releases 60 MJ of heat.

4. (5%) A rigid container contains 2 kg of helium. If its temperature changes from 20°C to 100°C, its enthalpy changes by 830.88 kJ.

5. (5%) An ideal gas with a molar mass of 12 kg/kmol has a temperature of 26.85°C and an internal energy of 300 kJ/kg. Its enthalpy is 507.86 kJ/kg.

6. (5%) A 2 kg/s stream of steam at 800 kPa and 200°C enters a turbine at a rate of 70 m/s. The diameter of the entrance pipe is 9.7404 cm.

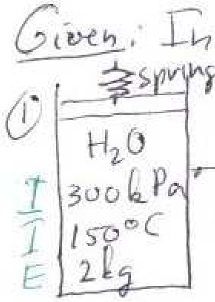
7. (5%) Given full substance tables on an ideal gas, what would enough info to find the pressure: (a) C_v, h; (b) C_v, T; (c) C_v, v; (d) h, T; (e) h, u; (f) T, u; (g) v, ρ; (h) V, m, ρ; (i) V, M, T; (j) V, R, T? c

8. (33%) A strong spring pressurizes 2 kg of 150°C water in a piston-cylinder combination to 300 kPa. The water is allowed to cool until the pressure has decreased to 125 kPa and the specific internal energy to 500 kJ/kg.

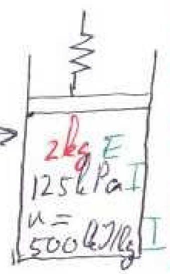
   - Construct the initial and final phases in a very neat *single Pv* diagram. Mark all lines and points used to do it with their values. Draw pressure first in both cases. Unambiguously number the states in the diagrams. Do not put more info in the diagrams than is needed to construct the phases. State the phases. Also show the work graphically in the diagram.
   - Find the final specific volume (remember, to 5 significant digits and that does not include leading zeros), the work done by the water and the heat that leaks out.

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



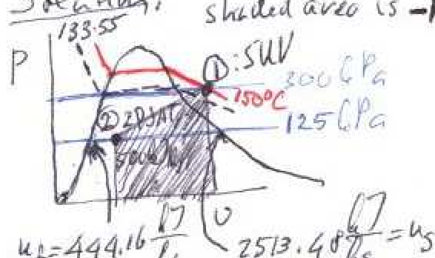
$U_2 - U_1 = {}_1Q_2 - {}_1W_2$



① diagram ① line 1 ○ find sat, right one ○ plot sat ○ line 2 rel ○ ID ○ work ○ Read B.1.3 u, v ○ Read B.1.1 2 phase formula u_2 v_2 find x_2 find v_2

Asked: $(Pv)_{1,2,w}$, P first, ${}_1W_2$, ${}_1Q_2$, v_2 (5 digits)

Solution: shaded area is $-{}_1W_2$



B.1.3 @ 300 kPa, 150°C: $v_1 = 0.63388\ \frac{m^3}{kg}$ $u_1 = 2570.79\ \frac{kJ}{kg}$

B.1.2 @ 125 kPa $u_f = 0.001048\ \frac{m^3}{kg}$ $v_{fg} = 1.37385$ $v_{fg} = 1.373852$

$v_g = 1.37490$

$u_f = 444.16\ \frac{kJ}{kg}$ $2513.48\ \frac{kJ}{kg} = u_g$

$x_2 = \frac{u - u_f}{u_g - u_f} = 0.026985$ $v_2 = 0.038121\ m^3/kg$

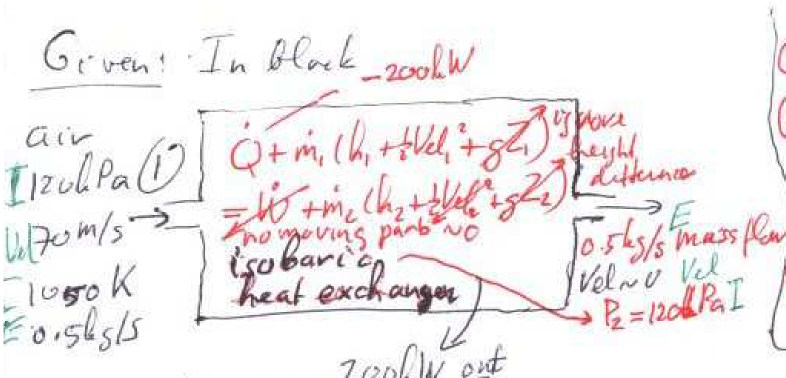
${}_1W_2 = \frac{P_1 + P_2}{2} m (v_2 - v_1) = \frac{300 + 125}{2}\ kPa\ 2 kg \times \frac{m^3}{kg} \times (0.038121 - 0.63388)$

${}_1W_2 = -253.19\ kJ$ $-253.19\ kJ$ work done by water

${}_1Q_2 = m(u_2 - u_1) + {}_1W_2 = -4394.8\ kJ$

9. (32%) A 0.5 kg/s stream of 120 kPa, 1050 K, air enters an isobaric heat exchanger at a velocity of 70 m/s. The air comes out with negligible velocity and 200 kW of heat leaks *out* of the heat exchanger. Find the volume of air that enters the heat exchanger per unit time, as well as the exit pressure and exit temperature in °C.

   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.*



(2) R
(5) $P_1v_1 = RT_1 \Rightarrow v$
(2) $\dot V_1 = \dot m_1 v_1$
(1) compute $\dot V_1$ units!
10

(5) 1st law
(1) $\dot W = 0$
(2) $\dot Q = -200$ kW
(1) $\dot m_2 = \dot m_1$
(3) h_1 from A.7.1
(2) find h_2, units!!
14

Know can
(2) Back interpolate T_2
(4) Do it
(2) $P_2 = P_1$
8

Asked: $\dot V_1$? P_2? T_2 in °C?

Solution: A.5: $R = 0.287\ \frac{kJ}{kg}$ $P_1v_1 = RT_1$ 120kPa $v_1 = 0.287\ \frac{kJ}{kg\,K}$ 1050K

$\Rightarrow v_1 = 2.5113\ m^3/kg$ $\dot V_1 = \dot m v_1 = 0.5\ \frac{kg}{s}\ 2.5113\ \frac{m^3}{kg} = \underline{1.2556\ m^3/s}$

1st law: $-200\ kW + 0.5\ \frac{kg}{s}\left(1103.48\ \frac{kJ}{kg} + \frac12 70^2 \frac{m^2}{s^2} \frac{1\ kJ/kg}{1000\ m^2/s^2}\right) = 0.5\ \frac{kg}{s} h_2$

2.45 kJ/kg; 1105.93

$h_2 = \underline{705.93\ kJ/kg}$

$g = 705.93$ " $g_1 = 692.12$ $g_2 = 713.56$ kJ/kg $d_1 = 680$ K $d_2 = 700$ K

$T_2 = d_1 + \frac{g - g_1}{g_2 - g_1}(d_2 - d_1) = 692.88$ K (0.64412)

$692.88\ K - 273.15 = \underline{419.73\ °C} = T_2$ $\underline{P_2 = 120\ kPa}$

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