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 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%) When 2 kg of aluminum cools down from 226.85°C to the ambient temperature of 26.85°C, the heat released by the alumimum will be ___360___ kJ and the entropy generated in the complete system will be ___0.28051___ kJ/K.

2. (5%) For each kJ of heat removed from a -10°C freezer in a 20°C, kitchen, at least ___0.114___ kJ of electricity is required.

3. (5%) A stream of argon enters a horizontal insulated reversible turbine and expands from 500 kPa and 300 K to 100 kPa at the exit. The final temperature will be ___157.56___ K and the power produced will be ___74.082___ kW/kg.

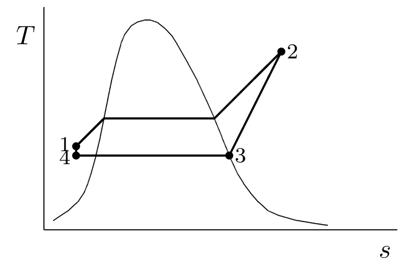
4. (5%) Superheated water at 100 kPa and 150°C can be changed to saturated vapor in an adiabatic piston cylinder combination as long as long as the final temperature ___is less than 80°C___.

5. (5%) To reversibly pressurize a 0.3 kg/s stream of liquid benzene from 100 kPa to 1200 kPa requires ___375.43___ W of electricity.

6. (5%) Of the following purported heat engines, case ___2___ violates the first law, and case ___3___ violates the second law:
   1. $W = 0$, $Q_H = 2$, $Q_L = 2$.
   2. $Q_H = 0$, $Q_L = 2$, $W = 2$.
   3. $Q_L = 0$, $W = 2$, $Q_H = 2$.

7. (5%) *Neatly* draw the $T - s$ diagram for the reversible cycle described below. Label the states.

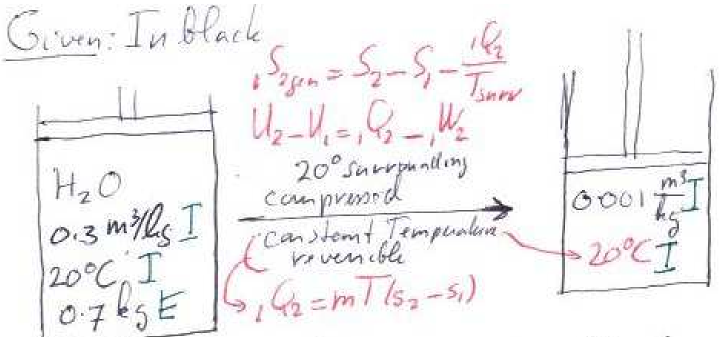
   - 1-2 Isobaric heating from compressed liquid to superheated vapor.
   - 2-3 isochoric pressure reduction to saturated vapor.
   - 3-4 isothermal cooling
   - 4-1 reversible adiabatic process



8. (33%) (In this question, you must compute accurate to 6, not 5, significant digits, where as always the first of those digits must be nonzero.) A piston-cylinder contains 0.7 kg of water at the ambient temperature of 20°C and specific volume 0.3 m^3/kg. Then the water is compressed to 0.001 m^3/kg. This is done reversibly and so slowly that the water stays at the ambient temperature.
   1. Construct both the initial and final phases together in a *single* very neat Ts diagram, and also in a *single* very neat Pv-diagram. Mark all lines and points used to do it with their values. Do not put more info in the diagrams than is needed to construct the phases. State each phase. Show the process line between the phases as a thick line and indicate the specific work and heat graphically if possible.
   2. Find the work done by the water on the piston and the heat that leaks out to the surroundings.
   3. Find the net entropy generated in the entire system. Comment on your result.

   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



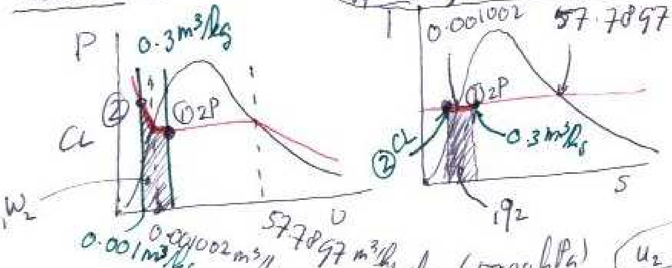
$_1S_{2\,gen} = S_2 - S_1 - \frac{_1Q_2}{T_{surr}}$

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

$_1Q_2 = mT(s_2 - s_1)$

Asked $(Pv)_{1,2,proc,w}$ $(Ts)_{1,2,proc,q}$, $_1Q_2$, $_1W_2$, $_1S_{2\,gen}$ (warn 6 sig digits pointered)

Solution B.1.1 @ 20°C: $s_f = 0.2966$, $v_f = 0.001002$, $u_f = 83.94$; $s_{fg} = 8.3706$, $v_{fg} = 57.7887$, $u_{fg} = 2318.98$; $s_g = 8.6671$, $v_g = 57.7897$, $u_g = 2402.91$



① $x_1 = \frac{v - v_f}{v_{fg}} = 0.00517398$ (real 0.005173898)

$u_1 = u_{f_1} + x_1 u_{fg_1} = 95.9304$ (95.93832)

$s_1 = s_{f_1} + x_1 s_{fg_1} = 0.339909$ kJ/kg K (.3399088)

B.1.4 @ 20°C, 0.001 m³/kg (= 5000 kPa): $u_2 = 83.64$ kJ/kg, $s_2 = 0.2955$ kJ/kg K

$_1Q_2 = mT(s_2 - s_1) = 0.7\text{ kg}\,(20 + 273.15)\text{ K}\,(0.2955 - 0.339909) = -9.11303\text{ kJ}$

205.205, −0.0444093

$_1W_2 = {_1Q_2} + m(u_1 - u_2) = -0.504165$ kJ

−13.01839

$_1S_{2\,gen} = m(s_2 - s_1) - \frac{_1Q_2}{T_{surr}} = 0.7\text{ kg}\,(0.2955 - 0.339909)\frac{\text{kJ}}{\text{kg K}} + \frac{9.11302}{20 + 273.15}\frac{\text{kJ}}{\text{K}} = 0\ \frac{\text{kJ}}{\text{K}}$

−0.0310866, 0.0310866

Entire process is isothermal reversible

9. (32%) Nitrogen at 3 MPa and 0.1484 m^3/kg enters an adiabatic and ideal turbine at a speed of 300 m/s. It leaves the turbine at 0.1 MPa with negligible velocity.

   (a) Find the specific work produced by this ideal turbine, and the heat that leaks out of the hot nitrogen to the surroundings.

   (b) If the true adiabatic turbine corresponding to the above ideal turbine has an turbine efficiency of 80%, find the true work produced. Also find two intensive quantities at the exit of the true turbine.

   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

$P_1 v_1 = R T_1$ $\quad 3000\,kPa\, 0.1484\,\frac{m^3}{kg} = 0.2968\,\frac{kJ}{kg\,K} T_1$

True turbine has $\eta_T = 0.8$

N_2

I 3 MPa

I 0.1484 m^3

Vel 300 m/s

ideal adiabatic turbine

reversible

$\dot Q + \dot m_1 (h_1 + \frac12 Vel_1^2 + g z_1) = \dot W + \dot m_2 (h_2 + \frac12 Vel_2^2 + g z_2)$

$\frac{1}{\dot m}$

$q + h_1 + \frac12 Vel_1^2 = w + h_2$

$s_2 = s_1$ I

$\dot m_1 = \dot m_2$??

0.1 MPa I

$Vel \approx 0$ Vel

Asked: v_1, q, w, 2 intensives for real true turbine

Solution: $q = 0$ $\quad$ A8 $1500\,K$ $\quad h_1 = 1680.7\,\frac{kJ}{kg}$ $\quad s^o_{T_1} = 8.6345\,kJ/kg\,K$ A8

$s_2 - s_1 = 0 = s^o_{T_2} - s^o_{T_1} - R \ln \frac{P_2}{P_1}$ $\quad s^o_{T_2} = s^o_{T_1} + R \ln \frac{P_2}{P_1} = \left[8.6345 + 0.2968 \ln \frac{0.1\,MPa}{3\,MPa}\right] \frac{kJ}{kg\,K}$

$s^o_{T_2} = 7.62502 = g$

$d = h_2$

$g_1 = 7.5741 \quad g_2 = 7.6606$

$d_1 = 627.24 \quad d_2 = 681.26\ kJ/kg$

$d = d_1 + \frac{g - g_1}{g_2 - g_1}(d_2 - d_1) = 659.04\,\frac{kJ}{kg} = h_{2s}$

1st law $\quad w_s = q^{0} + h_1 - h_{2s} + \frac12 Vel_1^2 = \underbrace{(1680.7 - 659.04)}_{1021.66}\frac{kJ}{kg} + \underbrace{\frac12 (300)^2 \frac{m^2}{s^2}\,\frac{1\,kJ/kg}{1000\,m^2/s^2}}_{45}$

$w_s = 1066.66\,kJ/kg$

True turbine: $w = 0.8 \cdot 1066.66\,\frac{kJ}{kg} = h_1 - h_2 + \frac12 Vel_1^2 = 1680.7\,\frac{kJ}{kg} - h_2 + 45\,\frac{kJ}{kg}$

$w = 0.8 \cdot 1066.66\,\frac{kJ}{kg} = 853.33\,\frac{kJ}{kg}$

$h_2 = 872.37\,\frac{kJ}{kg}$ $\quad P_2 = 0.1\,MPa$