EML 3100 Exam 3 **THERMODYNAMICS** **4/17/07 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 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%) Your air conditioning is set to an inside temperature of 25°C and it is 40°C outside. The A/C is removing heat at a rate of 4kW from your house. It will be using at least 0.201 kW of electricity.

2. (5%) One of the following heat engines is fine, one does not satisfy the first law, and one does not satisfy the second law. Which is the one that does not satisfy the second law?

   (a) $W = 0$, $Q_H = 0$, $Q_L = 0$
   (b) $W = 1$, $Q_H = 0$, $Q_L = 0$
   [✓ (c)] $W = 1$, $Q_H = 1$, $Q_L = 0$

3. (5%) What is the work done when air is compressed reversibly at constant temperature from 300 K and 100 kPa to 200 kPa? Ignoring kinetic end potential energy changes the work will be 59.68 kJ/kg

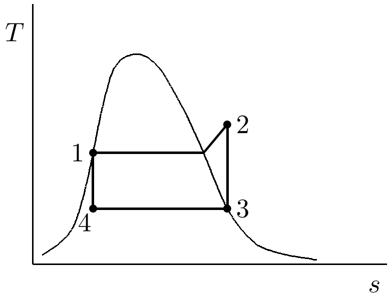
4. (5%) If you add 500 kJ of heat to 4 kg of marble at 27°C, you raise its temperature by 142 °C and its entropy by 1.364 kJ/K.

5. (5%) A heat engine with a thermal efficiency of 0.1 will require 10 kW of heat for each kW of power produced.

6. (5%) Liquid water is reversibly compressed at room temperature from 100 kPa to 500 kPa at a rate of 2 L/s. The required power will be 0.8 kW. Ignore kinetic and potential energy changes.

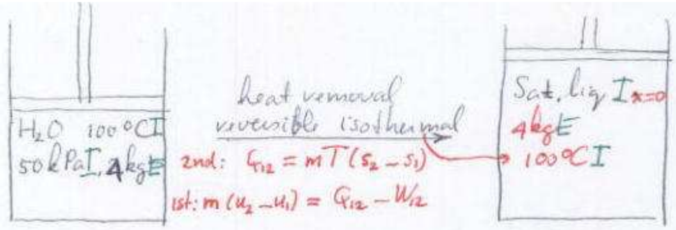
7. (5%) *Neatly* draw the $T - s$ diagram for the reversible cycle described below. Label each state and label the lowest and highest temperatures and entropies on the axes.

   - 1-2 isobaric heating from saturated liquid to somewhere in the middle of the superheated region;
   - 2-3 reversible adiabatic pressure reduction to saturated vapor;
   - 3-4 isothermal heat removal;
   - 4-1 isentropic process,



8. (33%) A piston cylinder device contains 4 kg of water at 100°C and 50 kPa. Heat is now removed from the water in a reversible way while maintaining the same temperature until the water turns into saturated liquid.
   - (a) Neatly construct the initial phase in the Ts-diagram, marking all lines and points used to do it with their values.
   - (b) Show the process in the Ts-diagram as a fat line, marking start as 1 and end as 2.
   - (c) Find the heat removed from the substance.
   - (d) Find the work done by the substance during the process.

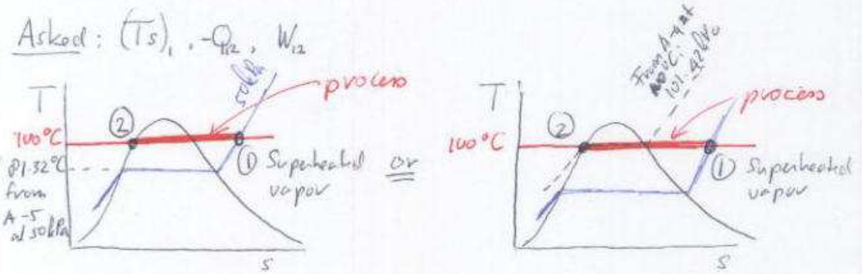
   You must show the derivations and reasoning completely and correctly for full credit. You must give units for your answers. Most accurate procedure only unless stated otherwise.



2nd: $Q_{12} = mT(s_2 - s_1)$

1st: $m(u_2 - u_1) = Q_{12} - W_{12}$

Asked: $(Ts)_1$, $-Q_{12}$, W_{12}



~~2nd law: $Q_{12} = mT(s_2 - s_1)$ — Table A-6 at 50 kPa, 100°C~~

Table A-6 at 50 kPa, 100°C: $u_1 = 2511.5 \frac{kJ}{kg}$ $s_1 = 7.6953 \frac{kJ}{kg\,K}$

Table A-4 @ 100°C: $u_2 = u_f = 419.06 \frac{kJ}{kg}$ $s_2 = s_f = 1.3072 \frac{kJ}{kg\,K}$

2nd law: $Q_{12} = mT(s_2 - s_1) = 4\,kg\,(100 + 273)K\,(1.3072 - 7.6953)\frac{kJ}{kg\,K}$

$= -9531\ kJ$ $\underline{\underline{+9531\ kJ\ \text{removed}}}$

1st law: $m(u_2 - u_1) = Q_{12} - W_{12}$

$4\,kg\,(419.06 - 2511.5)\frac{kJ}{kg} = -9531\ kJ - W_{12}$

$W_{12} = \underline{\underline{-1161.28\ kJ}}$

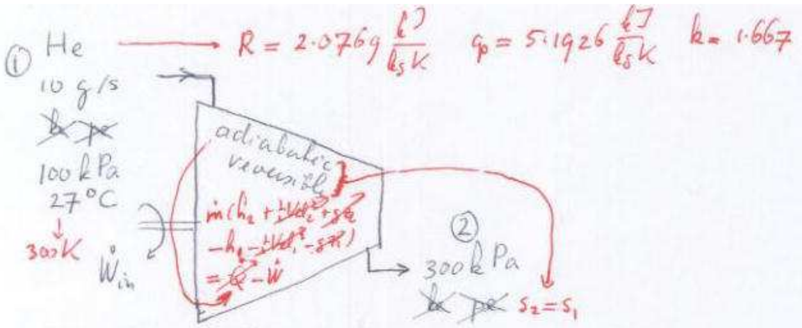
② isobar
② isotherm
② sat value
② process
⑦ 2nd law
⑦ 1st law
③ table values SHV
④ table values SAL
④ comps & units, sign of W

sign : -1 units -2

$s_g = 7.3542$
$u_g = 2506.0$

9. (32%) Helium is to be compressed from 100 kPa and 27°C to 300 kPa pressure at a rate of 10 g/s by a very well insulated compressor. All kinetic and potential energy can be neglected.
   (a) Compute the exit temperature and work required assuming that the process in the compressor is reversible.
   (b) After the compressor is actually installed and turned on, it turns out that it requires 10 kW of power to run it. What is the performance parameter called that is not quite perfect? What is its value?

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.



Asked: T_2? $\dot W_{in}$?

⑥ ID vars $c_p, R, k, \dot m$ as needed (−2 each)

Method 1:

⑤ formula and $s_2 = s_1$ $\quad s_2 - s_1 = 0 = c_p \ln\frac{T_2}{T_1} - R\ln\frac{P_2}{P_1}$

③ Use k

$c_p \ln T_2 = c_p \ln T_1 + R\ln\frac{P_2}{P_1}$ $\quad c_p, R$

③ solve $\quad \ln T_2 = \ln T_1 + \frac{R}{c_p}\ln\frac{P_2}{P_1}$

$T_2 = 465.54$ K

Method 2:

$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} = 1.552$ $\quad k$

$T_2 = 465.615$

Method 1:

⑤ formula and $\dot Q = 0$

$\dot W_{in} = \dot m(h_2 - h_1)$

$= \dot m c_p (T_2 - T_1)$ $\quad \overset{\dot m}{\frac{kg}{s}} \frac{kJ}{kg\,K} K$

$= 8.5950 \frac{kJ}{s}$

Method 2:

$\dot W_{in} = \dot m \frac{kRT_1}{k-1}\left(\left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} - 1\right)$ $\quad \dot m, R \quad \frac{kg}{s}\frac{kJ}{kg\,K}K$

$= 8.5966 \frac{kJ}{s}$

① solve

② units

② 5 sig figs

Actual work: 10 kW

② The isentropic compressor efficiency is

③ $\eta_c = \frac{8.60}{10} = 86\%$