EML 3100 Exam 3 **THERMODYNAMICS** **4/13/06 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 3 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%) If your kitchen is at 25°C and your freezer is at -5°C, then to remove 100 W of heat from the freezer compartment requires at least 11.19 W of electricity.

2. (5%) Which of the following refrigeration cycles does not satisfy the second law of thermo:

   (a) $W = 1$, $Q_H = 2$, $Q_L = 1$
   [✓ (b)] $W = 0$, $Q_H = 1$, $Q_L = 1$
   (c) $W = -1$, $Q_H = -2$, $Q_L = -1$

3. (5%) To compress 3 kg of air at 300 K until its temperature increases to 400 K in a polytropic process with $n = 1.3$ requires 287 kJ of work.

4. (5%) If 1 L of glycerine at 25 °C is heated up to 100 °C, its increase in entropy is 0.6845 kJ/K.

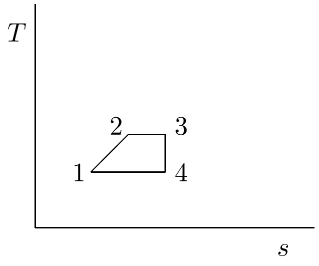
5. (5%) If the thermal efficiency of your car is 0.3, and you want to get 170 metric hp out of your engine, then the fuel you must burn must produce 416.78 kW of heat.

6. (5%) In an adiabatic process, superheated water vapor changes from 200 kPa and 250 °C to 100 kPa and 150°C. It can be said that this process

   (a) Obeys the second law of thermodynamics.
   [✓ (b)] Violates the second law of thermodynamics.
   (c) Is reversible.

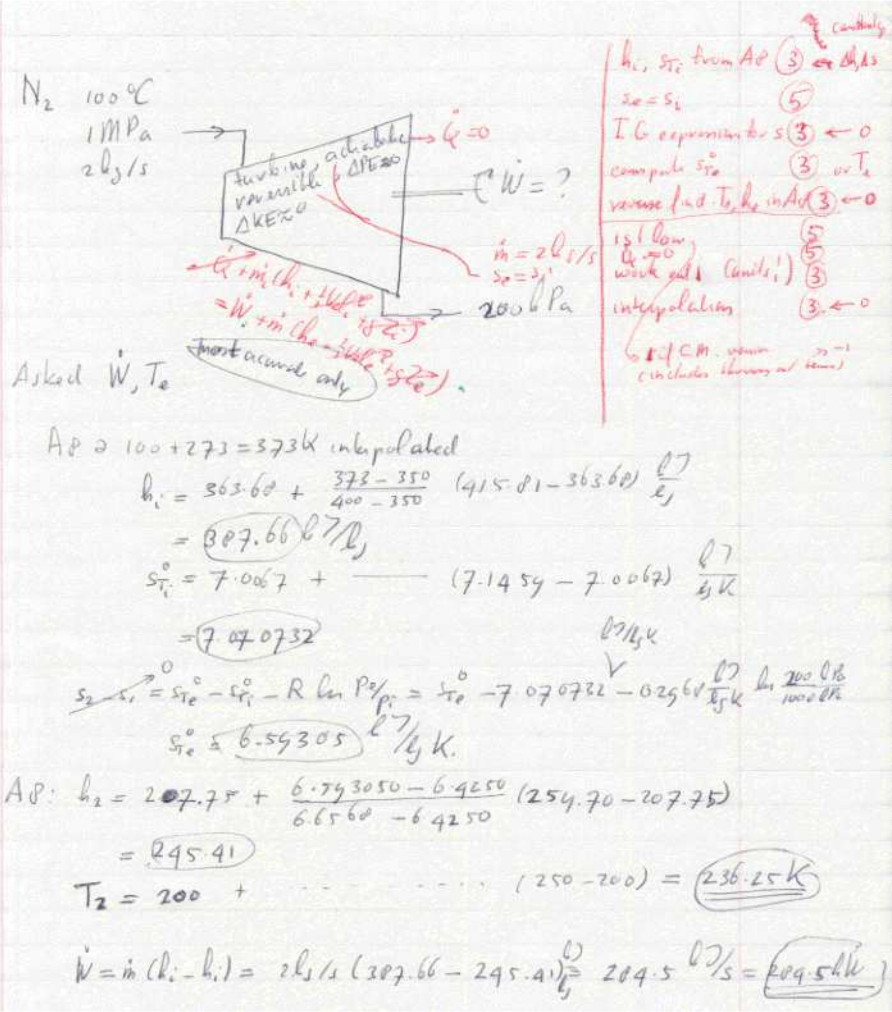
7. (5%) *Neatly* draw the $T - s$ diagram for the reversible cycle described below. Label each state and label the lowest and highest temperatures and entropies on the axes. Assume an ideal gas as a working fluid:

   - 1-2 isobaric increase in temperature;
   - 1-2 polytropic heat addition with n=1;
   - 3-4 reversible adiabatic temperature reduction;
   - 4-1 isothermal process



8. (33%) Nitrogen at 100°C and 1 Mpa enters an adiabatic, reversible turbine at a rate of 2 kg/s. It exits the turbine at 200 kPa. What is the work produced and the exit temperature? Most accurate answer *only*. Ignore height and kinetic energy differences between entrance and exit.

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



N_2 100°C
1 MPa
2 kg/s

turbine, adiabatic
reversible, ΔPE≈0
ΔKE≈0

$\dot Q = 0$

$\dot W = ?$

$\dot m = 2$ kg/s
$s_e = s_i$

200 kPa

$\dot Q + \dot m(h_i + \frac{1}{2}v_i^2 + gz_i) = \dot W + \dot m(h_e + \frac{1}{2}v_e^2 + gz_e)$.

~~most~~ accurate only

Asked $\dot W$, T_e

carefully

h_i, s°_{Ti} from A8 ③ ← Δh, Δs

$s_e = s_i$ ⑤

IG expression for s ③ ← 0

compute s°_{Te} ③ or T_e

reverse find T_e, h_e in A8 ③ ← 0

1st law ⑤

$\dot Q = 0$ ⑤

work out (units!) ③

interpolation ③ ← 0

-1 if CM. [illegible] -1
(includes [illegible])

A8 @ 100+273=373K interpolated

$$h_i = 363.60 + \frac{373-350}{400-350}(415.81-363.60)\ \frac{kJ}{kg}$$

$$= \boxed{387.66}\ kJ/kg$$

$$s^\circ_{T_i} = 7.0067 + \text{———}\ (7.1459 - 7.0067)\ \frac{kJ}{kgK}$$

$$= \boxed{7.070732}$$

$$\overset{0}{\cancel{s_2 - s_1}} = s^\circ_{Te} - s^\circ_{Ti} - R\ln P_e/P_i = s^\circ_{Te} - 7.070732 - 0.2968\ \frac{kJ}{kgK}\ln\frac{200\ kPa}{1000\ kPa}$$

kJ/kgK

$$s^\circ_{Te} = \boxed{6.59305}\ kJ/kg\,K.$$

$$\text{A8: } h_2 = 207.75 + \frac{6.593050 - 6.4250}{6.6560 - 6.4250}(254.70 - 207.75)$$

$$= \boxed{245.41}$$

$$T_2 = 200 + \cdots\cdots (250 - 200) = \boxed{236.25\,K}$$

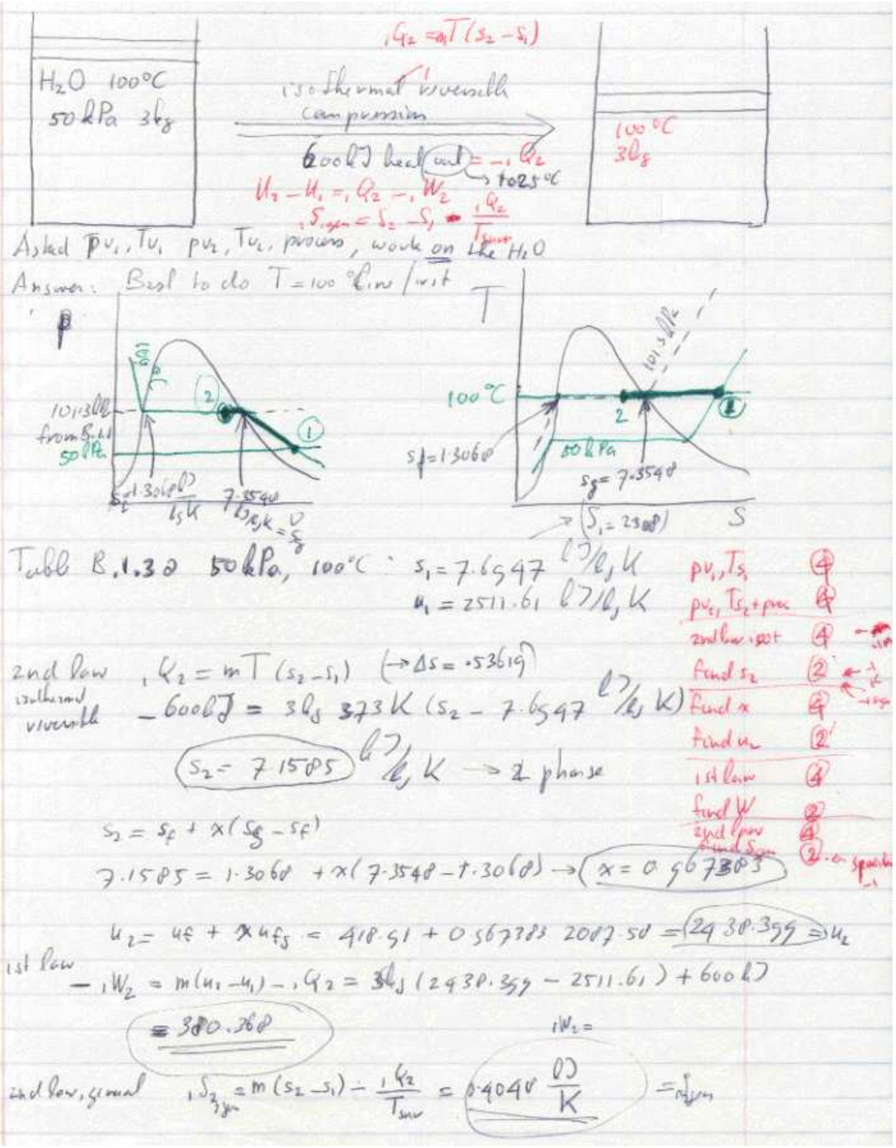
$$\dot W = \dot m(h_i - h_e) = 2\,kg/s\,(387.66 - 245.41)\frac{kJ}{kg} = 284.5\ kJ/s = \boxed{284.5\,kW}$$

9. (32%) If we isothermally and reversibly compress 3 kg of water, initially at 100°C and 50 kPa, and 600 kJ of heat is *removed* in the process, what is the work done to compress the water? If the surroundings are at 25°C, what is the total entropy generated by irreversible effects?

   You must construct all phases that are not given both in the *pv*- and *Ts*-diagrams, marking all lines 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. Most accurate procedure only unless stated otherwise.



$_1Q_2 = mT(s_2 - s_1)$

600 kJ heat out $= -{}_1Q_2$

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

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

Asked pv₁, Tv₁, pv₂, Tv₂, process, work on the H₂O

Answer: Best to do T = 100°C line first

Table B.1.3 50 kPa, 100°C: $s_1 = 7.6947$ kJ/kg K

$u_1 = 2511.61$ kJ/kg K

2nd law isothermal reversible $\quad {}_1Q_2 = mT(s_2 - s_1)$ $(\to \Delta s = .53619)$

$-600\text{ kJ} = 3\text{ kg}\ 373\text{ K}\ (s_2 - 7.6947\text{ kJ/kg K})$

$\boxed{s_2 = 7.1585}$ kJ/kg K → 2 phase

$s_2 = s_f + x(s_g - s_f)$

$7.1585 = 1.3068 + x(7.3548 - 1.3068) \to \boxed{x = 0.967383}$

$u_2 = u_f + x u_{fg} = 418.91 + 0.567383\ 2087.58 = \boxed{2438.359} = u_2$

1st law $\quad -{}_1W_2 = m(u_2 - u_1) - {}_1Q_2 = 3\text{ kg}\ (2438.359 - 2511.61) + 600\text{ kJ}$

$\boxed{= 380.268}$ $= {}_1W_2$

2nd law, general $\quad {}_1S_{2\,gen} = m(s_2 - s_1) - \frac{_1Q_2}{T_{surr}} = \boxed{0.4040\ \frac{\text{kJ}}{\text{K}}} = S_{gen}$

pv₁, Ts₁ ④
pv₂, Ts₂ + proc ④
2nd law, isot ④
find s₂ ②
find x ④
find u₂ ②
1st law ④
find W ②
2nd law ④
find S_gen ②