Solutions to Spring 2004-2 Thermodynamics 105:

1) Solution:
1a): This is a steady flow problem. The enthalpy change in stream 1 should be equal to the enthalpy change in stream 2

(h1(w)-h2(w)) x mass flow rate of water =
Mass flow rate of air x (h2(air)-h1(air)= 29x 1 (T2-T1) = 29x T2

Stream 1: 29 * 1 * (T_mix - 0^oC)
For air ΔH=29 * 1 * 99.63 = 2889.27 kJoules
For steam 2889.27= 18 * (h1(w)-h2(2)) → h2(w)= 2514.98 KJ/Kg
From steam table → quality = 0.929

1b) The entropy lost by stream 1 should equal the entropy gained by stream 2, an ideal heat engine , e. g. Carnot engine does not generate entropy

Entropy change of stream 2 (air) is integral of (Cp/T) dT = 29 * 1* ln(373/273) = 29*0.312 = 9.05 kJ/K-min= entropy change of the air.

Stream 1 still at 99.63C , some of the steam condenses, with entropy change: DeltaS_fg=6.04 kJ/(kg-K)
Thus: 9.05=18* 6.04 kJ/(kg-K) * (1-x)
means that steam quality is x=0.916

We now compute power by enthalpy balance: 18 * DeltaH_fg * (1-x) with x=0.916
=> 3382 kJ/min = 56.4kW while air enthalpy change is same as part 1. 2889.27 kJ/min

Power is 3382-2889 ~ 482kJ/min ~ 8 kW

Note that slightly more steam condenses in Part 1b (8.3%) compared to Part 1b. (7%).

2) Solution

A) Work = Heat * thermal efficiency
   Thermal efficiency = $(1- 1/8^{(1.4-1)})$ =56.47%
   Work= 750 kJ x 0.5647= 423.5 k J

B) Heat = 750kJ x (mass of air with turbo-charger)/mass of air without turbo-charger
   Work = Heat x thermal efficiency (same as it only depends on compression ratio)

   Mass of air with turbo-charger / mass of air without turbo-charger
   = (V_cylinder /v)_with turbo / (V_cylinder /v)_without turbo
   = v_without turbo / v_without turbo
   = (T/P) without turbo / (T/P)_with turbo

(using isentropic relation $(T_2/T_1)= (P_2/P_1)$ (k-1)/k
T_with turbo= 300K * (120kPa/100kP) $^{(1.4-1)/1.4}$ = 316K)
= (300 K / 100kPa) /(316K /120 kPa) = 1.139

The amount of mass in the cylinder at BDC is increased by a factor of 1.139

Work = =750kJ x 1.139 x 0.5647= 482.4 kJ

3) 1st law -> $U_f=U_i$ -> $m_1u_1+m_2u_2= Mu_3$-> $T_3=(T_2+T_1)/2$
Entropy change for partition 1 to final state
$\Delta S_{3-1}=M/2[C \ln (T_3/T_1)]$

Entropy change for partition 2 to final state
$\Delta S_{3-2}=M/2[C \ln (T_3/T_2)]$

$\Delta S= \Delta S_{3-1}+\Delta S_{3-2}= M/2[C \ln (T_3/T_1) +C \ln (T_3/T_2)]$
$= MC/2 \ln \{ T_3/T_1 * T_3/T_2\}$
$= MC \ln \{ T3/ (T1*T2)^{0.5}\}= MC \ln \{ (T_2+T_1)/ [2(T_1*T_2)^{0.5}] \}$

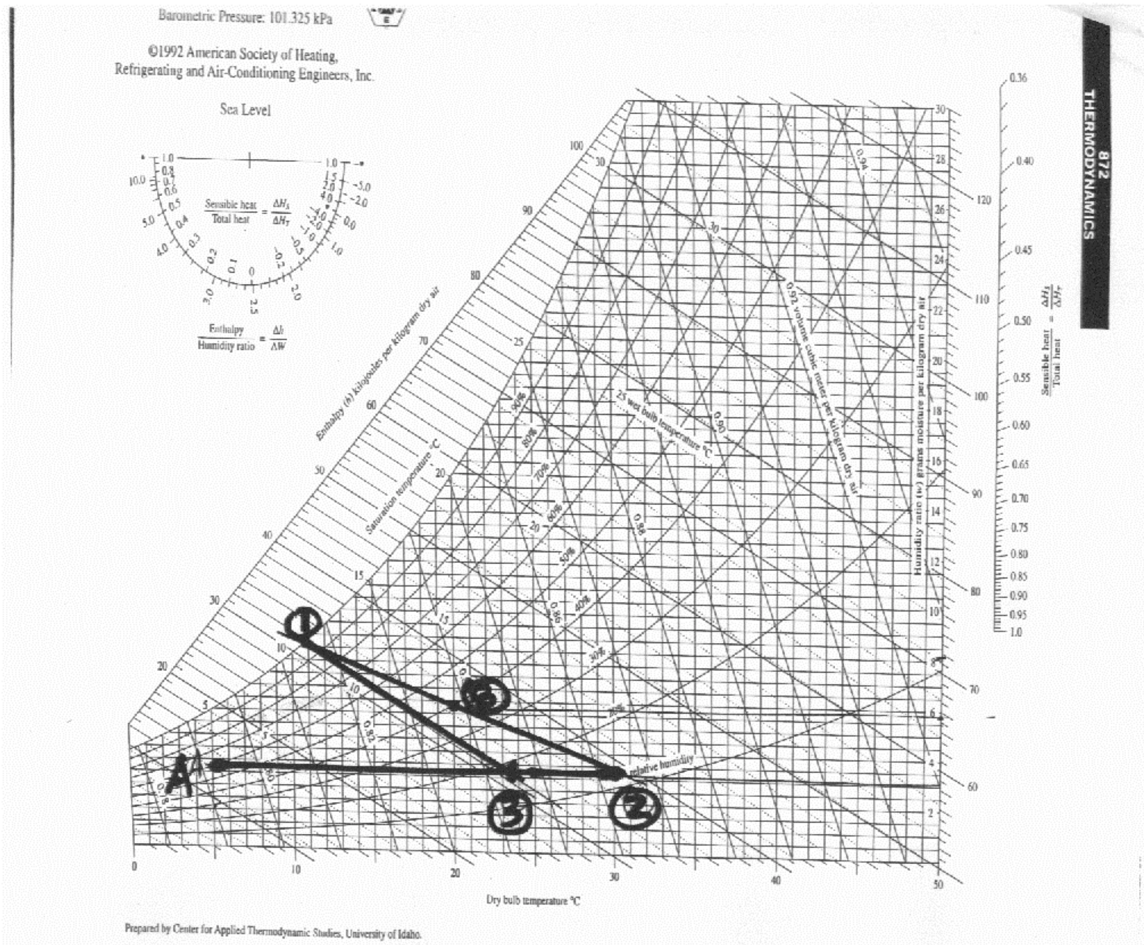
4) At the inlet pg1=0.8721 kga →
W1= 0.622*ϕPg1/(p-*ϕPg1) = 0.0040951 kgH2/Kg dry air
At the exit, Pg2(T=65^{o}C) = 25.03 kPa.
Now ϕ2=w2p2/(0.622+w2)/Pg2 = 0.13065 → 13.06%

5) solution:

from the psychrometric chart state 2: w2=3.4x10^{-3} kg/kg
by connecting the final point B to state 2 crossing the saturated state (state 1), we have w1~8x10^{-3}, wB=5.5x10^{-3} kg/kg,

a) the temperature at state 3 is obtained from state 1 (saturation point) following the constant enthalpy line until intersecting with the horizontal line (that connects state A and 2) → T3~ 23.5 ^{o}C

b) The mass flow rate ratio ma1/ma2= (wB-w2)/(w1-wB)~0.96



6) By connecting a line with the two points in the psychrometric chart, we find the line intersects the saturation line; therefore condensation will occur during mixing.

7) From the R134-a tables:

State 3: saturated liquid P=1.0164MPa, h3=105.3 kJ/kg,

State 3a: compressed liquid -> ha=98.05kJ/kg

State 4a: saturated vapor→ h4a=235.31 kJ/kg

State 4: constant enthalpy throttling → h4=h3

Control volume analysis for the subcooler→ h1-h4a= h3a-h3

h1= 265.76 ; from superheated table→ v1~ 0.1627 m3/kg

2) mass flow rate of R134-a = 1.2 m3/min / v1 = 7.38 kg/min = 0.123 kg/s
3) QL rate= 7.38 kg/min (235.31-98.05) KJ/kg= 1012.97 kJ/min = 16.88 kW
4) Work required by the compressor:

s1= s2 ~ 1.04 kJ/kg-K

p2=1.0164 Mpa→ use the superheated table at 1.0MPa

h2~ 313.2 kJ/kg

Wcompressor= 7.38 kg/min x (313.6-265.76) kJ/kg =442.8 kJ/min ~ 7.38 kW

COP= QL/Wcompressor= 16.88/7.38 = 2.29

8) Solution:

For gas turbine cycle, $P_2=P_3$, and $P_4=P_1$, we have the following relation

$(T_2/T_1)=(P_2/P_1)^{(k-1)/k} =(P_3/P_4)^{(k-1)/k}=(T_3/T_4)$.

When $T_2=T_4$, we have

$T_1T_3= T_2 x\ T_2$

With given $T_3/T_1=3$ the above equation gives

$3\ T_1\ x\ T_1= T_2xT_2$ -> $T_2/T_1=(3)^{1/2}$

Using the isentropic relation,

$P_2/P_1= (T_2/T_1)^{k/(k-1)} = 6.8$