ME 105 Thermodynamics Sec 2 Final 5/18/04
8 Problems (100 points)

#1) (15 points) Assume you have two streams. Stream 1 contains saturated steam (water vapor with quality=100%) at 100kPa (T=99.63°C) at a mass flow rate of 18 kg/min. Stream 2 is air at P=100 kPa and T_2= 0°C with a flow rate of 29 kg/min. Assume that the air has a constant specific heat of Cp= 1.0 kJ/(kg-K).

1a) (5 points) If heat is transferred from the steam to the air until both air and steam (which will now have liquid water in it) are at same temperature at 99.63°C. Determine the quality of steam at state 2.

1b) (10 points) If a heat engine is placed between stream 1 and stream 2, what is the maximum power than can be generated when both streams reach 99.63°C? (hint: the maximum power is produced when both streams undergo reversible processes and the net change of entropy for the system is zero.)

#2) (15 points) Considering an ideal Otto cycle with a compression ratio of 8, determine the following.

2a) (5 points) At the beginning of the compression process, ambient air at 100kPa and 300K is drawn into engine cylinder. During the constant-volume heat addition process, 750kJ of heat is transferred to the air. Determine the amount of net work produced per cycle.

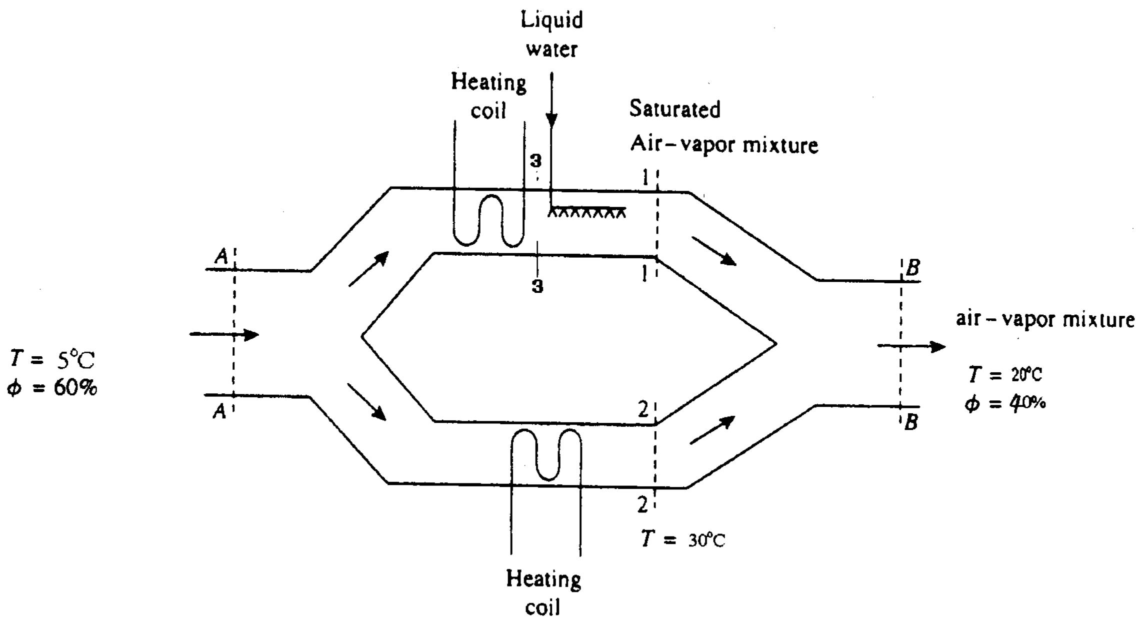
2b) (10 points) The Otto cycle in part (2a) is now modified by adding a turbo-charger to boost the air pressure at the beginning of compression process. Ambient air at 100kPa and 300K is compressed isentropically by the turbo-charger to 120kPa before entering the engine cylinder. Assuming that the heat transferred to the air during the constant-volume heat addition process is linearly proportional to the mass of air that is drawn into the engine cylinder at the beginning of compression process, determine the amount of net work produced per cycle with the turbo-charger.

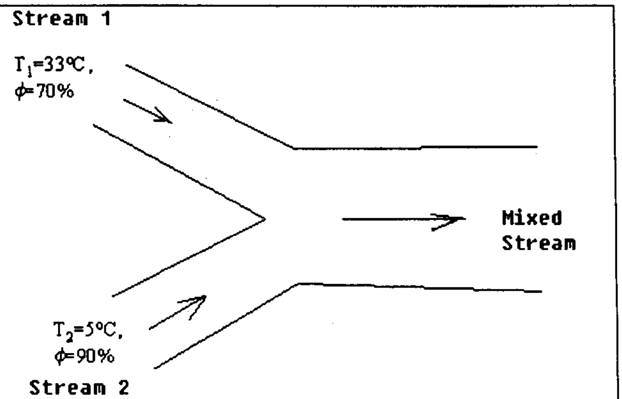
#3) (10 points) An isolated system contains liquid with a total mass of M. Initially, the system is divided into two partitions of equal mass with temperatures at T_1 and T_2 respectively. The two partitions are allowed to mix thoroughly and reach a final equilibrium state. The liquid is incompressible with a constant specific heat, C. Determine the total generation of entropy for this system in terms of C, M, T_1, and T_2.

#4) (5 points) Atmospheric air at 100kPa, 5°C and 75% relative humidity enters an air compressor and exits at 65°C and 500kPa. With the help of analytic expressions and steam tables, determine the relative humidity at the compressor exit.

#5) (20 points) In a heating and ventilating system, fresh air at ambient pressure is taken in at 5°C, 60% relative humidity (see figure below). The air is split into two streams. One stream is heated and humidified to saturation, while the other stream is simply heated. The two streams are then mixed to obtain the desired final state of 20°C and 40% relative humidity. Using the attached psychrometric chart,

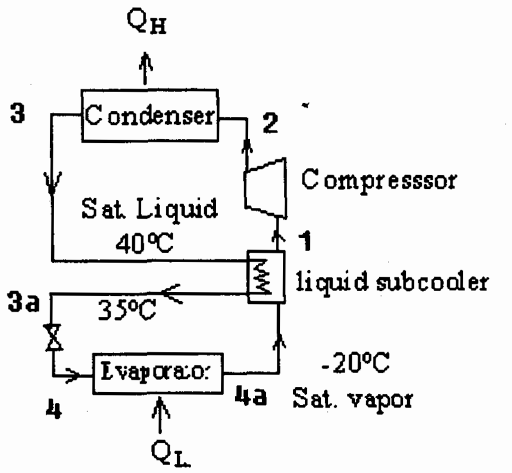
a) (5 points) estimate the temperature to which the first stream is heated (state 3) if the second stream is heated to 30°C. (5 points) Show your procedures on the chart and mark states A, B, 1,2 and 3;
b) (10 points) estimate the ratio of mass fractions of the two streams, $\dot{m}_{a1} / \dot{m}_{a2}$. (must show your procedures)



#6) (5 points) Two moisture streams mix as shown in the right sketch. Stream 1 contains air at 33°C with relative humidity at 70%; stream 2 is 5°C with relative humidity at 90%. Determine whether or not condensation of water will occur during the mixing.	

#7) (15 points) A vapor-compression refrigeration cycle shown on the left includes a liquid subcooler. Refrigerant R134-a is used and the subcooler cools the saturated liquid from 40°C to 35°C while receiving saturated vapor at –20°C. Pressure drops in all components are assumed negligible. Compression of the refrigerant is handled by a compressor with an adiabatic efficiency of 80%. The volumetric flow rate at the inlet of compression is 1.2 m^3/min.

a) (5 points) Determine the mass flow rate of the refrigerant,
b) (5 points) the rate of heat absorbed by the evaporator, and
c) (5 points) COP



#8) (15 points) A gas-turbine engine is equipped with a regenerator which can be switched on and off. To keep the thermal efficiency as high as possible, determine the pressure ratio (P_2/P_1) beyond which the regenerator should be switched off as the compressor exit temperature (T_2) exceeds the turbine exit temperature (T_4). The ratio between the turbine inlet temperature (T_3) and the compressor inlet temperautre (T_1) is 3, i.e., $T_3/T_1=3$. An ideal cycle is assumed with $C_p/C_v=k=1.4$ and $(T_2/T_1)=(P_2/P_1)^{(k-1)/k}$ for an isentropic process between state 1 and state 2.

State 1: Compressor Inlet
State 2: Compressor Exit
State 3: Turbine Inlet
State 4: Turbine Exit