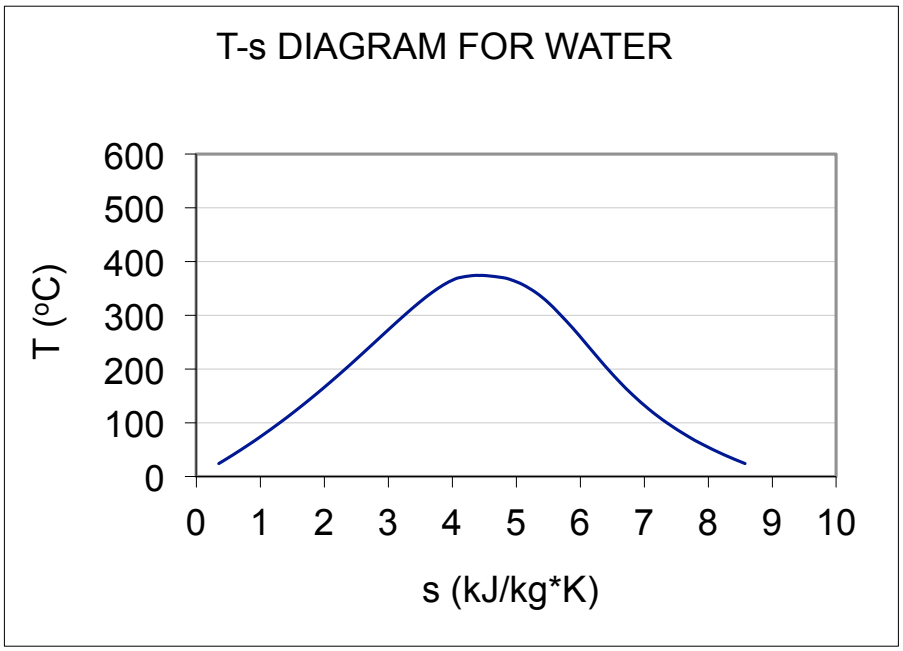
AREN 2110: Thermodynamics
Spring 2011

HOMEWORK 11: Due Friday, April 22, 6 PM (9 problems, 40 points possible)

1. (6 points, 1 per part) A Rankine cycle has a fixed turbine inlet temperature and condenser pressure. If the boiler pressure is increased do the following increase, decrease or remain the same?:
    a. Pump work input
    b. Turbine work output
    c. Heat supplied
    d. Heat rejected
    e. Cycle efficiency
    f. Moisture content at turbine outlet.

2. (4 points, 2 per part) A Rankine cycle with refrigerant (R-134a) as the working fluid is to be used to produce work with heat added from a lower temperature source than a steam power cycle. The boiler pressure is 1.6 MPa and the condenser pressure is 0.4 MPa. The temperature of the R-134a at the turbine inlet is 80 ^{o}C, and the quality at the turbine outlet is 0.98. Calculate
    a. The mass flow rate of R-134a required to produce 750 kW power
    b. The thermal efficiency of the cycle

3. (5 points, 1 for a and 2 for b and c) Compare the efficiency and net work output of a Carnot heat engine and a Rankine cycle with steam as the working fluid. In both cases, steam enters the turbine at 5 MPa and as saturated vapor and the condenser pressure is 50 kPa. In the Rankine cycle the water at the condenser exit is saturated liquid. In the Carnot cycle, the boiler inlet state is saturated liquid.
    a. Draw the T-s diagram for both cycles.
    b. Calculate the efficiency and net work output for both cycles.
    c. Calculate the entropy generated in the surroundings for both cycles.



4. (6 points, 2 per part) R-134a enters the coils of the evaporator of a refrigeration system as a saturated liquid vapor mixture at a pressure of 160 kPa. The refrigerant absorbs 170 kJ of heat from the cooled space, which is maintained at – 5 ^{o}C and exits the evaporator as saturated vapor at the same pressure. Determine:

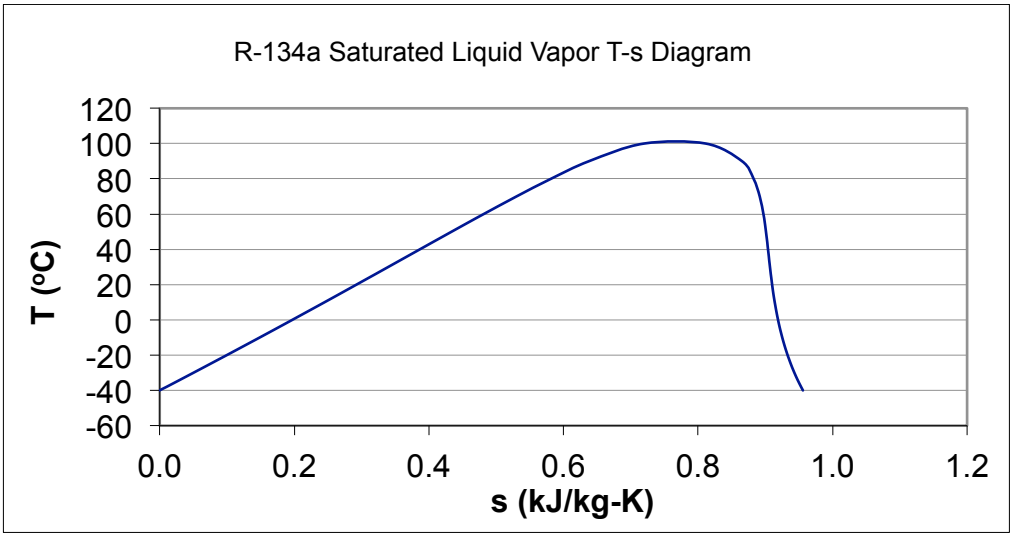
    a. The entropy change of the refrigerant
    b. The entropy change of the cooled space
    c. The total entropy change for the process

5. (5 points, 1 per part) A Rankine reheat cycle has water as the working fluid. The boiler pressure for the first turbine is 15 MPa, and the reheater pressure is 2 MPa. The condenser pressure is 100 kPa. The temperature of the steam is 450 ^{o}C at the entrance to both the high- and low-pressure turbines. The mass flow rate of steam is 1.74 kg/s. Determine:
    a. The power used by the pump
    b. The net power produced by the cycle
    c. The rate of heat transfer in the reheater
    d. The thermal efficiency of this system
    e. Compare the efficiency to a Rankine cycle without reheat with the boiler pressure at 15 MPa and the same turbine inlet temperature, condenser pressure and steam mass flow rate.

6. (4 points, 1 per part) An industrial refrigerator with R-134a is used to keep the cooled space at -30 ^{o}C. Heat is rejected to cooling water flowing at 0.25 kg/s that enters the condenser heat exchanger at 18 ^{o}C and leaves at 26 ^{o}C. The R-134a enters the condenser at 1.2 MPa and 65 ^{o}C and leaves at 42 ^{o}C. The R-134a at the compressor inlet is 60 kPa and -34 oC, and the compressor gains heat from the surroundings at a rate of 450 w. Determine
    a. A. The quality of the R-134a at the evaporator inlet.

b. The rate of cooling
c. The COP
d. The theoretical maximum cooling rate for the same power input to the compressor.

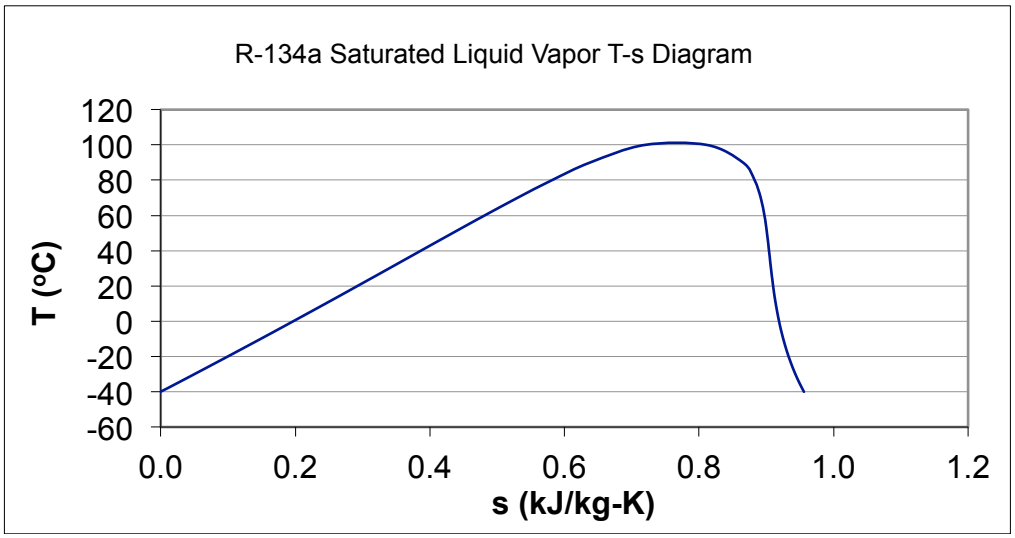
7. (3 points, 1 per part) A heat pump operates on the ideal vapor-compression refrigeration cycle with R-134a as the working fluid. This heat pump is used to keep a space at 25 ^{o}C by absorbing heat at a rate of 2.7 kw from geothermal water flowing through the evaporator heat exchanger. The evaporator operates at 20 ^{o}C, and the condenser pressure is 1.4 MPa. The compressor receives work at a rate of 20 kJ/kg.
    a. Show the process on a T-s diagram



    b. Determine the rate of heat transfer to the heated space.
    c. Determine the COP

8. (3 points) A water heater is operated using a heat pump that heats the water by removing heat from the room air and transferring it to the water. The heat pump has a COP of 3.4 and consumes 6 kw power. Determine if the heat pump can be used to cool the room for "free" by absorbing heat from the air in the room. The rate of heat gain in the house in summer is less than 45,000 kJ/hr.

9. (4 points, 1 per part) A Carnot refrigeration cycle uses R-134a as the working fluid. The maximum and minimum temperatures in the cycle are 30 ^{o}C and -20 ^{o}C, respectively. The quality of the R-134a at the inlet of the evaporator heat exchanger is 0.15 and 0.80 at the outlet.
    a. Show the process on the T-s diagram.
    b. Calculate the coefficient of performance.
    c. Find the condenser and evaporator pressures.
    d. Find the net work required.


R-134a Saturated Liquid Vapor T-s Diagram
T (°C)
120
100
80
60
40
20
0
-20
-40
-60
0.0
0.2
0.4
0.6
0.8
1.0
1.2
s (kJ/kg-K)