AREN 2110: Thermodynamics
Spring 2010

Homework 9: Due Friday, April 9, 6 PM

1. A Carnot heat engine receives heat at 750K and rejects the waste heat to a low temperature reservoir (sink) at 300K. All the work output of the heat engine is used to drive a Carnot refrigerator that removes heat from the cooled space at – 15 ^{o}C at a rate of 400 kJ/min and rejects it to the same sink at 300K. Determine

    a. The rate that heat must be supplied to the heat engine
    b. The total rate of heat rejected to the environment for the combined cycles

2. Calculate and plot the COP of a completely reversible refrigerator as a function of the temperature of the sink (HTR) up tp 500K, with the temperature of the source (LTR) fixed at 250K.

3. Work is entropy-free, and sometimes a claim is made that work will not change the entropy of a fluid passing through an adiabatic steady-flow system with a single inlet and outlet. Is this a valid claim? Why/Why not?

4. 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. Water at 10 ^{o}C and 81.4 percent quality is compressed isentropically in a closed system until the pressure reached 3 MPa. How much work does this process require in units of kJ/kg?

6. Using the relation $dS = \frac{\delta Q}{T}_{int\ rev}$ as the definition of entropy, calculate the change in the specific entropy, s, of R-134a as it is heated at a constant pressure of 200 kPa from a saturated liquid to a saturated vapor. Then use the property tables to verify your answer.

7. An adiabatic pump is to be used to compress saturated liquid water at 10 kPa to a pressure of 15 MPa in a reversible process. Compare the calculated work output in kJ/kg by three methods:
    a. Using entropy and enthalpy data from the compressed liquid water table (A-7)
    b. Inlet specific volume value and pressure values given
    c. Using average specific volume value from part a and pressure values given

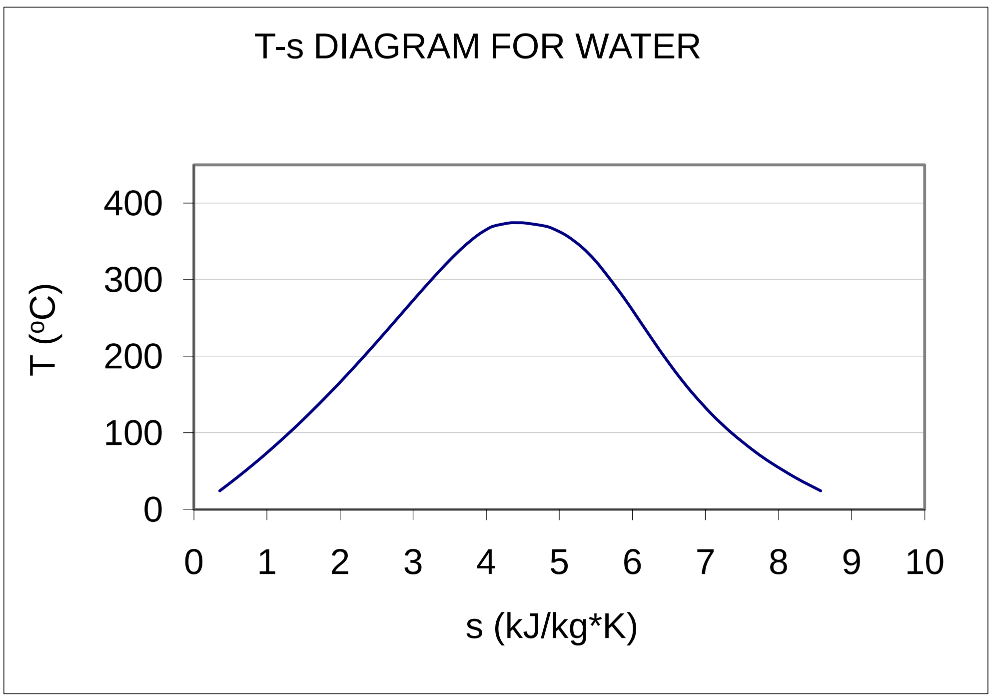
8. An ideal gas undergoes a process between two specified temperatures, first at constant pressure and then at constant volume. For which case will the ideal gas experience a larger entropy change? Justify your answer.

9. Air is compressed in a piston-cylinder device from 100 kPa and 17 ^{o}C to 800 kPa in a reversible adiabatic process. Determine the final temperature and the work done during this process assuming constant specific heat.

10. A piston-cylinder device contains 5 kg steam at 100 ^{o}C with a quality of 50%. The steam undergoes two processes:

   1→2 Heat is transferred to the steam in a reversible manner while the temperature is held constant until the steam is saturated vapor.
   2→3 The steam expands in an adiabatic reversible process until the pressure is 15 kPa.

   a. Show the process on the T-s diagram below



   b. Calculate the heat transferred to the steam in process 1→2
   c. Determine the work done by the steam in process 2→3 in kJ.

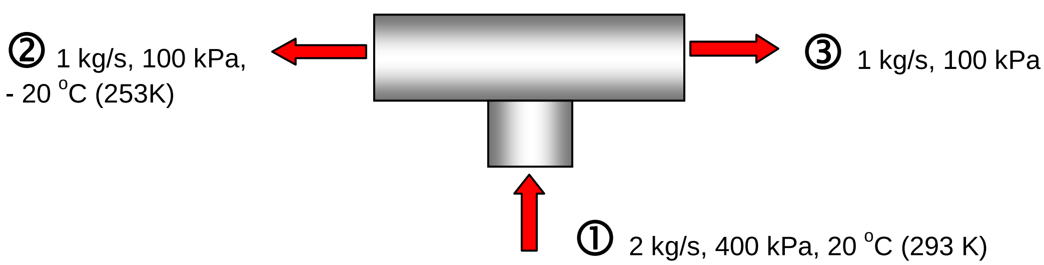
11. Air in a large building is kept warm by heating it with steam in a heat exchanger. Saturated water vapor enters the heat exchanger unit at 35 ^{o}C at a rate of 10,000 kg/hr and leaves as a saturated liquid at 30 ^{o}C. Air at 1-atm pressure enters the unit at 20 ^{o}C and leaves at 30 ^{o}C at the inlet pressure. What is the rate of entropy generation for this process?

12. Steam expands in a turbine steadily at a rate of 25,000 kg/hr. The steam enters the turbine at 6 MPa and 450 ^{o}C and leaves at 20 kPa as saturated vapor. If the power generated by the turbine is 4 MW, determine the rate of entropy generation for the process, assuming that the surrounding medium is at 25 ^{o}C.

13. Helium gas is throttled steadily from 500 kPa and 70 ^{o}C. Heat is lost from the helium at a rate of 2.5 kJ/kg to the surroundings at 25 oC and 100 kPa. If the entropy of the helium increases by 0.25 kJ/kg-K in the throttling valve, determine:

    a. The exit pressure and temperature of the helium
    b. The entropy generation during throttling

14. The vortex tube is a device that produces a low-temperature gas stream that is used for cooling manufactured parts. The device is well insulated, has no external work entering or leaving the system, and has no moving parts. For this particular device, air flows in at a mass flow rate of 2 kg/s, 4 atmospheres pressure and 20 ^{o}C (293 K). The air stream is split into two equal exit streams of 1 kg/s each, both at 1 atmosphere pressure, the cooling stream temperature is -20 ^{o}C (253 K).



a. What is the temperature of the exit air at point ③?

b. Does this process satisfy the second law of thermodynamics? Justify your answer.