AREN 2110: Thermodynamics
Spring 2011

HOMEWORK 7: Due Monday, March 14, 6 PM (11 problems, 35 points possible)

1. (5 points, 1 point per part) 997 kJ heat is added to a rigid tank containing 3 kg water of which 0.6 kg is vapor, at 150 kPa. The final pressure in the tank is 325 kPa.

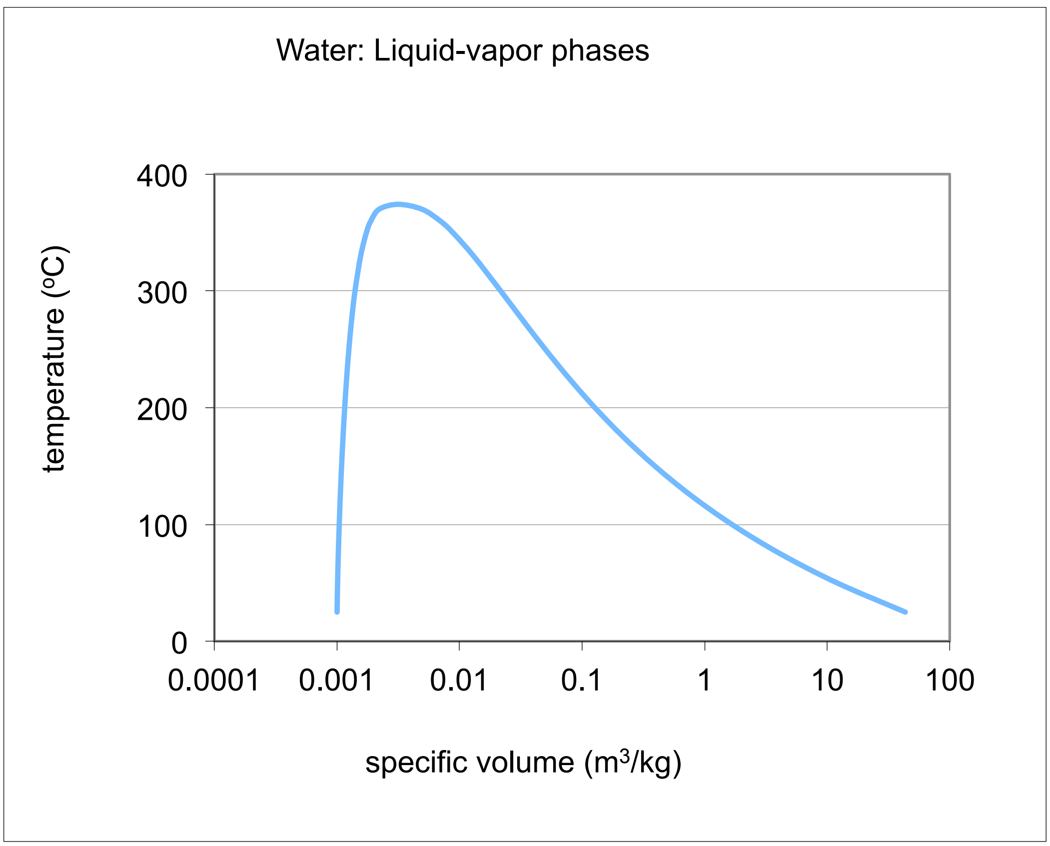
a) What is the final temperature?

b) What is the mass of water in the vapor phase after heat addition to the rigid tank?

c) If one boundary were movable to obtain an isobaric process, what would the final temperature be with the same heat addition?

d) What is the work done in the isobaric process?

e) Draw both processes on the T-v diagram below.



2. (3 points, 1 point per part) A rigid tank is divided into two parts by a barrier. At state 1, one part of the volume contains 0.02 m^3 saturated liquid refrigerant at 0.7 MPa and the other part is evacuated. Then the barrier is removed and the refrigerant fills the entire volume. The final pressure is 200 kPa and the final temperature is 30 ^{o}C.

a) What is the mass of refrigerant?

b) What is the total volume of the tank? (m^3)

c) What is the heat transfer?

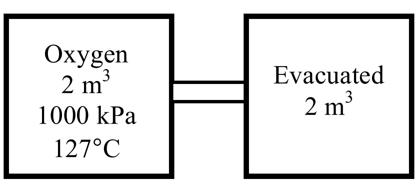
3. (3 points, 1 point per part) Suppose the expansion in the rigid tank in problem 2 occurred adiabatically with the same initial state, and the final pressure is also 200 kPa.

a) What is the final temperature of the R-134a?

b) What is the total volume of the tank (m^3)?

c) What is the mass of R-134a in the vapor phase (kg)?

4. (2 points, 1 point per part) Two very well insulated chambers, each 2 m^3, are connected by a valve. One chamber contains air at 1000 kPa and 127 ^{o}C. The second is evacuated. After the valve is opened the system comes to equilibrium



a) What is the final temperature of the air?

b) What is the final pressure of the air?

5. (4 points – 2 points per part)) Steam at 9 MPa and 600 oC passes through an adiabatic throttling valve, with the exit pressure = 400 kPa.

a) What is the temperature of the steam at the exit?
b) What is the ratio of outlet to inlet areas so that the change in kinetic energy of the steam is zero?

6. (4 points, 2 points per part) A room receives heat from warm outdoor air. To keep the room cool, an air conditioning system mixes chilled air at 5 ^{o}C with warm outdoor air at 34 ^{o}C in an adiabatic mixer before it enters the room. The pressure of both streams is 105 kPa. The room is maintained at 24 ^{o}C, which is the temperature of the air leaving the room to maintain steady-state conditions. The <u>volumetric flow rate</u> of cold air is 1.25 m^3/s, and the ratio of <u>mass flow rates</u> of hot-to-cold air is 1.6.

a) What is the temperature of the mixed air as it enters the room?
b) At what rate is the room gaining heat from the outside?

7. (2 points) Steam condenses on the outside of a 5-m long 3-cm diameter copper tube of a heat exchanger. The water enters the tube at 25 ^{o}C and exits at 35 ^{o}C. **What is the rate of condensation of the steam?**

8. (2 points) An adiabatic pump is designed to raise the pressure of 15 kg/s saturated liquid water at 25 kPa to 10 MPa.

a) What is the required power input?
b) What is the enthalpy of the water at the pump outlet?

9. (4 points – 2 per part) Steam at 3 MPa and 400 ^{o}C enters an adiabatic nozzle. The inlet velocity is 40 m/s. At the outlet, the pressure is 2.5 MPa and the velocity is 300 m/s.

a) What is the outlet temperature of the steam?
b) Find the ratio of the inlet to outlet areas

10. (3 points) Steam enters the condenser (adiabatic heat exchanger) of a power plant at a mass flow rate of 20,000 kg/hr, pressure of 20 kPa and a quality of 0.95. River water is circulated in the condenser at a rate such that the condensed steam is saturated liquid at the condenser outlet. Environmental regulations require that the maximum temperature increase of the discharged cooling water must be 10 oC. What is the mass flow rate of the cooling water?

11. (3 points) An two-stage adiabatic turbine operates with 20 kg/s steam entering the turbine at 12.5 MPa and 550 ^{o}C. The turbine outlet conditions at the end of the second stage are 100 kPa and 100 ^{o}C. In order to preheat feedwater to the boiler, 5% of the steam is removed after the first stage, at a pressure of 1 MPa and 200 ^{o}C . What is the total power output of the turbine?