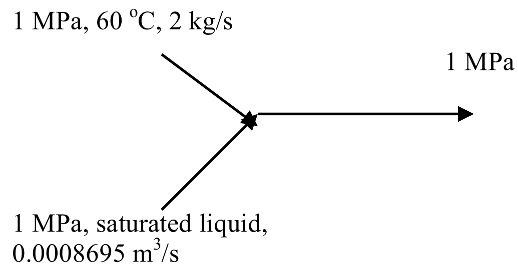
AREN 2110: Thermodynamics
Spring 2011

HOMEWORK 6: Due Friday, March 4, 6 PM (13 problems, 45 points possible)

1. (6 points: 1 per part) Refrigerant (R-134a) at a pressure of 1 MPa and 60 ^{o}C flows into a well-insulated mixing chamber at a rate of 2 kg/s. Saturated liquid R-134a at the same pressure enters the mixer at a rate of 0.0008695 m^3/s. Assume steady flow conditions.



a) What is the temperature of the refrigerant at the mixer outlet?

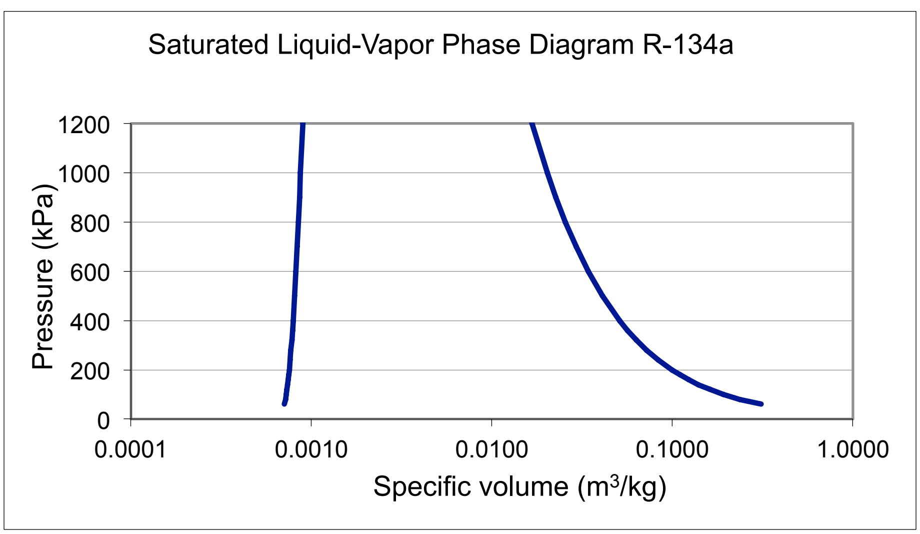
b) What is the percent liquid in the refrigerant at the mixer outlet?

c) After mixing, the refrigerant enters an adiabatic throttling valve that reduces the pressure to 200 kPa. What is the specific enthalpy of the refrigerant at the throttling valve outlet?

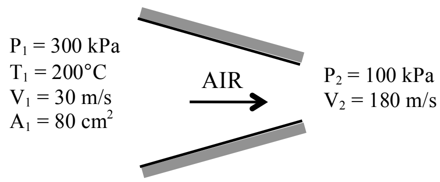
d) What is the temperature of the refrigerant at the throttling valve outlet?

e) What percent of the R-134a is liquid at the throttling valve outlet?

e) Draw the throttling valve process on the P-v diagram for refrigerant.

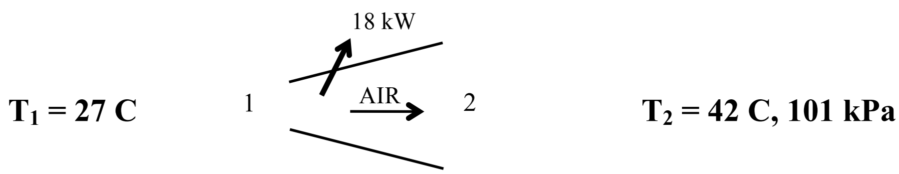


2. (3 points) Air is accelerated in an insulated nozzle from 30 m/s to 180 m/s under the following conditions:



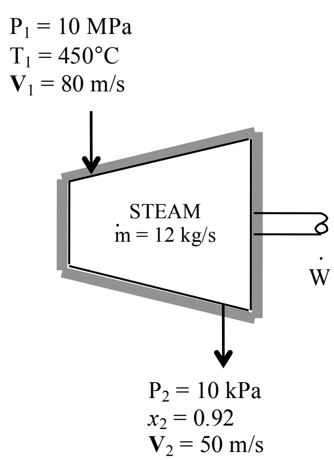
Estimate the mass flow rate, the exit temperature, and the exit area of the nozzle.

3. (2 points) Air at a mass flow rate of 2.5 kg/s is decelerated in a diffuser from 220 m/s, with $A_2/A_1 = 3$. The device loses 18 kW of heat during its steady state operations under the following conditions:

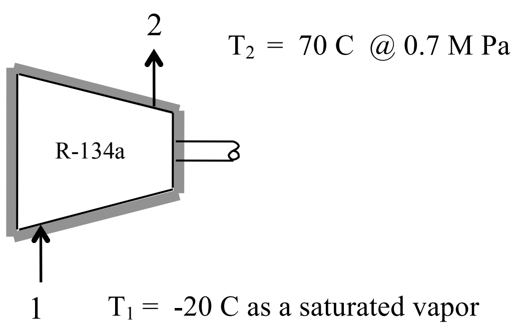


Determine the exit velocity and the inlet pressure of air.

4. (3 points) Steam expands in an insulated turbine at a flow rate of 1.2 kg/s. The change in kinetic energy, the power output, and the turbine inlet area are to be determined from the following conditions.



5. (2 points, 1 per part) Refrigerant-134a is compressed steadily by an insulated compressor at a mass flow rate of 1.2 kg/s. Determine the power input to the compressor and the volume flow rate of the refrigerant at the compressor inlet.

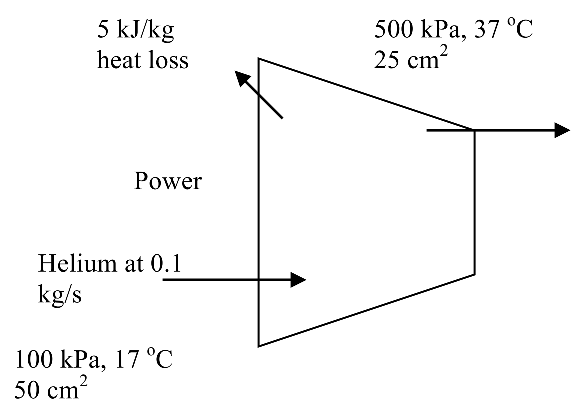


6. (3 points, one per part) Helium (He) enters a compressor at 100 kPa and 17 ^{o}C at a steady flow rate of 0.1 kg/s. The inlet area is 50 cm^2. Helium leaves the compressor at 500 kPa and 37 ^{o}C through a 25 cm^2 outlet. The compressor loses heat to the surroundings at a rate of 5 kJ/kg.

a) Calculate the volumetric flow rates of He at the inlet and outlet, in m^3/s?

b) Calculate the change in kinetic energy of the helium during compression, in kw.

c) What is the power required for compressing the helium, in kw? Use room temperature value for specific heat (300K).



7. (2 points) During the throttling process, the temperature of a fluid drops from 30 ^{o}C to – 20 ^{o}C (253K). Can this process occur adiabatically? Under what condition(s)?

8. (2 points) Steam enters an insulated nozzle at 200 kPa and 200 ^{o}C and leaves at 150 kPa and 150 ^{o}C. The inlet-to-outlet diameter ratio for the nozzle, D_1/D_2 = 1.80. Find the inlet and outlet velocities of the steam.

9. (2 points, 1 per part) A glass bottle washing facility uses a well-mixed hot water bath at 55 °C. The bottles enter the washer at a rate of 800 per minute at an ambient temperature of 20 °C and leave at the bath water temperature. Each bottle has a mass of 150 g and as it leaves the bath, takes 0.2 g water with it. Make up water with temperature of 15 °C is used to keep the mass of water in the bath constant. Assuming no heat loss from the outer surface of the bath tank, calculate:

a) The rate at which water must be supplied to maintain a constant mass of water
b) The rate at which heat must be supplied to maintain steady operation

10. (4 points. 1 per part) A car is left with its windows closed on a summer day and the interior air reaches a temperature of 60 °C.

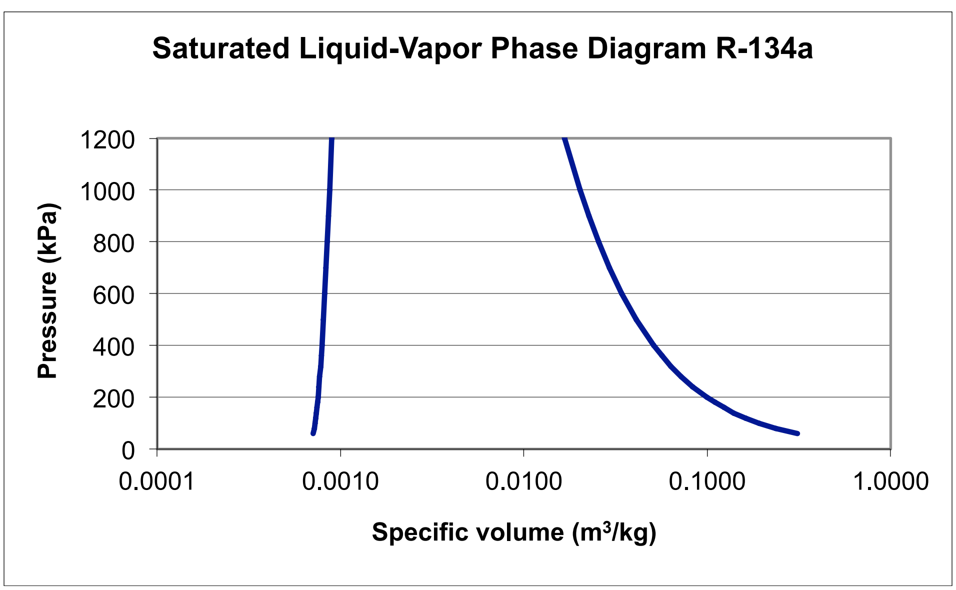
a) At what rate must heat be removed by an air conditioner in the car to bring the temperature to 22 °C in 5 minutes? Assume the windows remain closed during cooling. The volume of air in the car is 7 m^3, and the air pressure = 100 kPa. Solar radiation heats the car at the rate of 10 kJ/min and the air conditioner has a 100-w fan.

The air conditioner uses R-134a refrigerant as a working fluid. The car air is cooled by blowing it across tubes in a heat exchanger. The R-134a enters the heat exchanger pipes as a saturated mixture at 320 kPa and quality = 0.3 and exits the exchanger as saturated vapor at the same pressure.

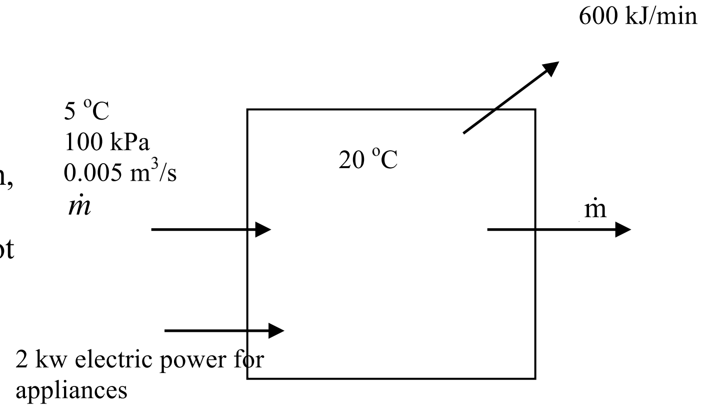
b) What mass flow rate of refrigerant is required to cool the car interior as for part a?

c) After evaporation in the heat exchanger, the saturated R-134a vapor is compressed to a pressure of 1 MPa and temperature = 50 °C in an adiabatic compressor. What is the power requirement for the compressor?

d) Graph the R-134a processes on a P-V diagram (below)



11. (7 points, 1 per part) A house kept at 20 °C loses 600 kJ/min heat during January when the average outside temperature is 5 °C. In addition, cold air infiltrates the house at a rate of 0.005 m^3/s. Since the mass of air in the house does not change, the house loses warm air to the outdoors at the same mass flow rate. Finally, appliances use 2 kw electricity which adds energy to the house.



a) What is the mass flow rate of infiltrating air?

b) At what rate must heat be added to keep the house at 20 °C?

12. (5 points, 1 per part) Heat for the house is provided from the **condenser** of a heat pump where heat is rejected as R-134a condenses at a constant pressure of 1 MPa from a vapor at 50 °C at the inlet to a saturated liquid at the outlet.

a) What is the temperature of the R-134a at the outlet?

b) What is the change in specific enthalpy (kJ/kg) of the R-134a during the condensation process?

c) Calculate the mass flow rate of R-134a required to keep the house at 20 °C.

d) The refrigerant leaves the condenser and enters a **throttling valve** where the pressure is reduced from 1 MPa to 200 kPa. What is the temperature of the R-134a at the throttling valve outlet? Justify your answer.

e) What is the vapor content of the refrigerant at the throttling valve outlet?

13. (4 points, 2 per part) Hot water is cooled by air flow in a well-insulated heat exchanger. The hot water inlet temperature is 80 °C, and the outlet temperature is 30 °C. Air flows to the air inlet at 800 m^3/min at a pressure of 100 kPa and a temperature of 27 °C. The exit air pressure is 95 kPa and temperature = 60 °C.

a) Find the mass flow rate of water that satisfies the conditions given.

b) Find the volumetric air flow rate at the air outlet.