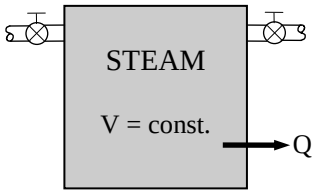
AREN 2110: Thermodynamics
Spring 2010

HOMEWORK 6: Due Friday, March 5, 6 PM

1. The radiator of a steam heating system has a volume of 0.02 m^3 is initially filled with 250 C steam at 300 kPa. The valves are closed, and the steam is then allowed to cool until the pressure drops to 100 kPa by transferring heat to the room. Determine the amount of heat transferred, and show the process on a *P-v* diagram.

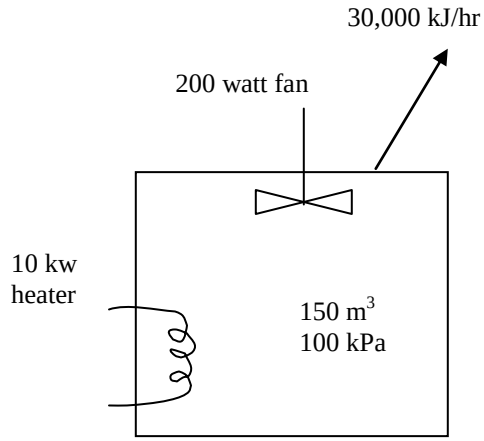


2. A room with volume = 150 m^3, pressure = 100 kPa loses an average of 30,000 kJ/hr of heat to the surroundings continuously during the winter. The house is heated by a 10 kw electric resistance heater. A 200-watt fan that runs all the time mixes the room air. During the day when no one is home, the thermostat is set to 15 ^oC. At 5 PM, the thermostat set point is increased to 22 ^oC and the room is kept at that temperature until 8 AM the next day. Use specific heat at room temperature (300K).

a) How long will it take to warm the room air from 15 to 22 ^oC?

b) How long will the resistance heater run between 5 PM and 8 AM the next day to keep the room at 22 ^oC? (Neglect time to warm room.)

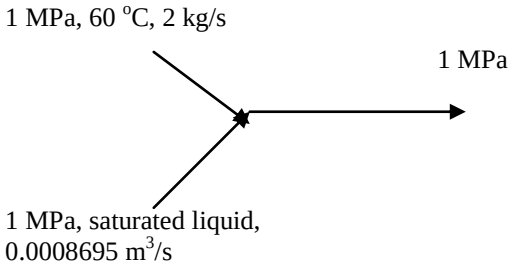
c) If the heater turns off at 8 AM, how long will it take the house to cool to 15 ^oC?



d) The homeowner is considering replacing the electric heater with a steam radiator. Steam enters the radiator at 200 kPa and 150 ^oC, and leaves as saturated liquid at the same pressure. What is the mass flow rate of steam required to keep the house at 22 ^oC from 5 PM to 8 AM?

3. 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?



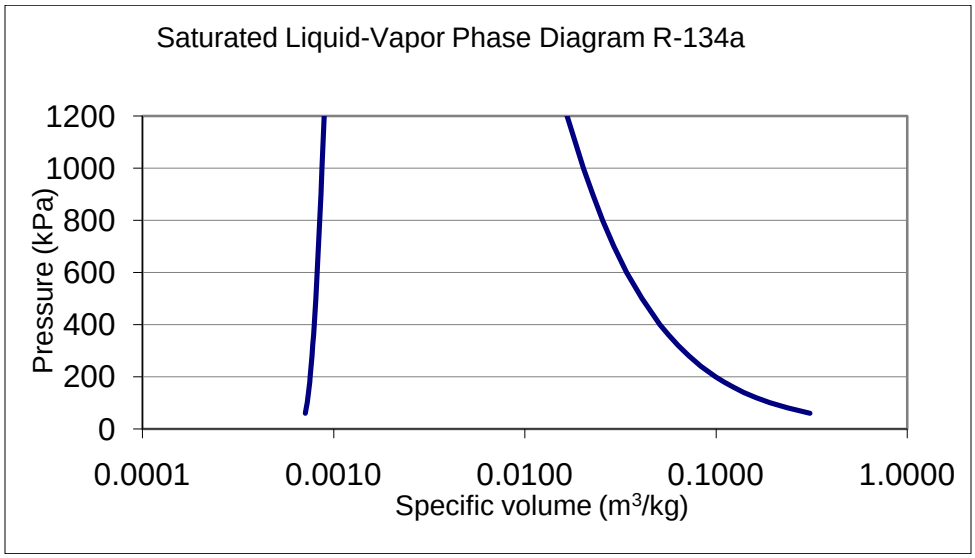
b) What is the percent liquid in the refrigerant at the mixer outlet?

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?

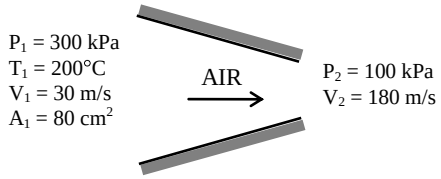
d) What is the temperature of the refrigerant at the throttling valve outlet?

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.

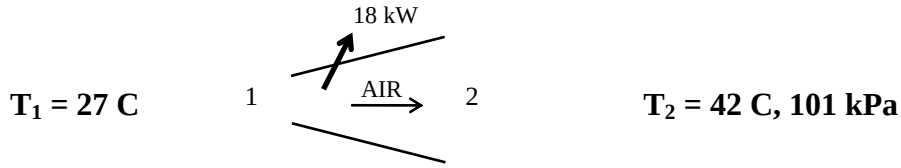


4. Air is accelerated in an insulated nozzle from 30 m/s to 180 m/s under the following conditions:



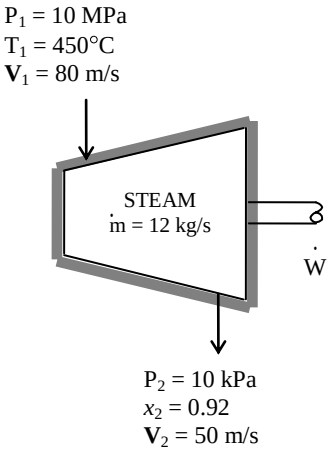
Estimate the mass flow rate, the exit temperature, and the exit area of the nozzle.

5. 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:

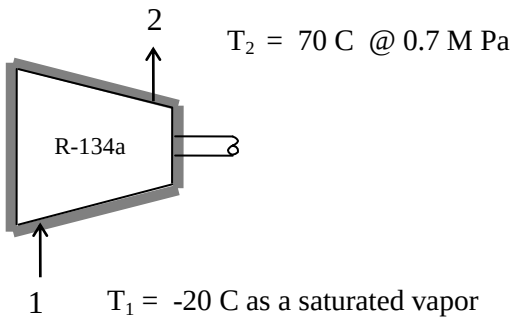


Determine the exit velocity and the inlet pressure of air.

6. 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.



7. 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.

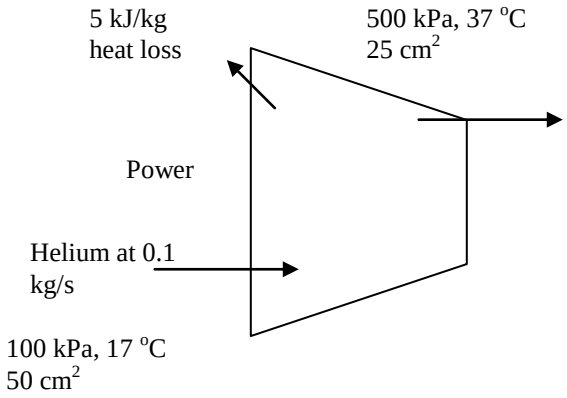


8. Helium (He) enters a compressor at 100 kPa and 17 ^{o}C at a steady flow rate of 0.1 kg/s. The inlet area is 50 cm^2. Helium leaves the compressor at 500 kPa and 37 ^{o}C through a 25 cm^2 outlet. The compressor loses heat to the surroundings at a rate of 5 kJ/kg.

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).



9. Argon is compressed in a piston-cylinder device polytropic process with n = 1.2 from 120 kPa and 30 ^{o}C to 1,200 kPa. Determine the work produced and the heat transferred during the compression process in units of kJ/kg.

10. 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)?

11. 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.

12. A glass bottle washing facility uses a well-mixed hot water bath at 55 ^{o}C. The bottles enter the washer at a rate of 800 per minute at an ambient temperature of 20 ^{o}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 ^{o}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

13. A car is left with its windows closed on a summer day and the interior air reaches a temperature of 60 ^{o}C.

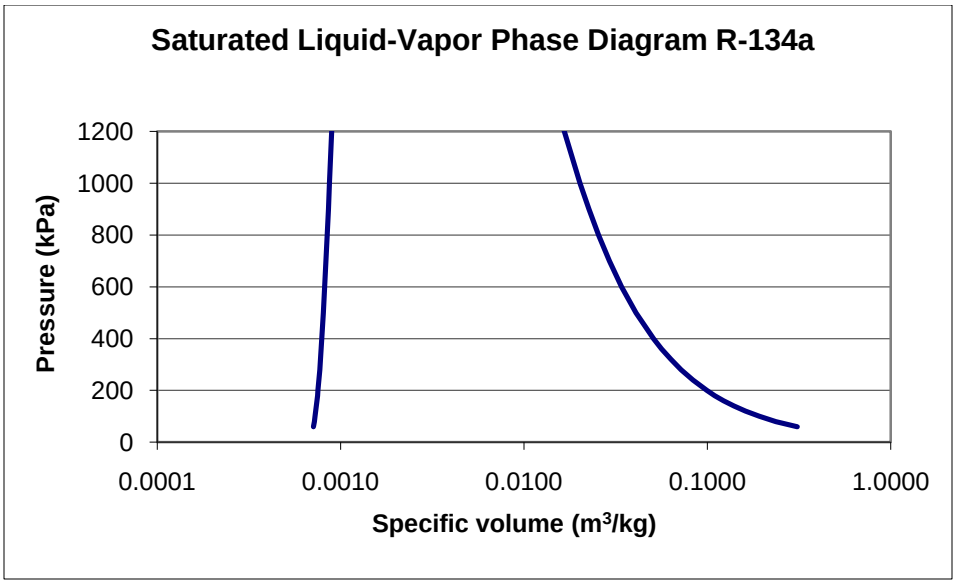
a) At what rate must heat be removed by an air conditioner in the car to bring the temperature to 22 ^{o}C in 5 minutes? Assume the windows remain closed during cooling. The volume of air in the car is 7 m^3, and the air pressure = 100 kPa. Solar radiation heats the car at the rate of 10 kJ/min and the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



14. A water heater consists of an insulated pipe 5-cm in diameter with an electric resistance heater inside. Cold water at 20 ^{o}C enters the heating section of the pipe at a constant flow rate of 30 L/min. The water is to be heated to 55 ^{o}C. Determine:

a) The power rating of the resistance heater
b) the average velocity of the water in the pipe