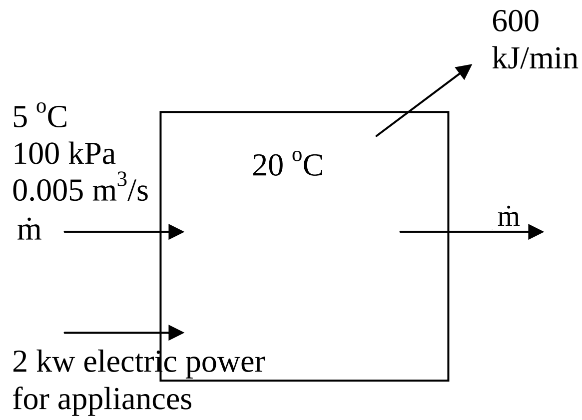
AREN 2110 Thermodynamics
Review Problems for Chapters 4 and 5 to be covered in Midterm 2

1. 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?

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.

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

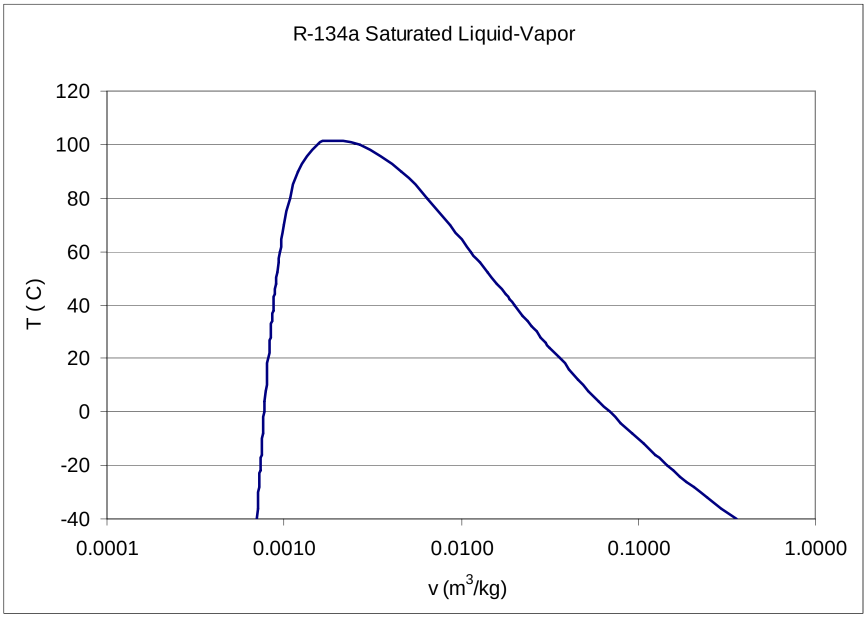
d) What is the change in specific enthalpy (kJ/kg) of the R-134a during the condensation process?

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

f) 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? <u>Justify your answer</u>.

g) What is the <u>vapor content</u> of the refrigerant at the throttling valve outlet?

h) Draw the **throttling and condenser process sequence** on the T–v diagram below.



2. Air flows through a **nozzle** operating at steady state with the following conditions:

   Inlet: 27 ^{o}C, 120 kPa, velocity = 200 m/s and inlet area = 0.04 m^2.
   Outlet: 60 kPa, velocity = 500 m/s.

a) What is the <u>mass flow rate of air</u> that satisfies these conditions?

b) <u>At what rate must heat be added (or removed)</u> to (or from) the nozzle to keep the process <u>isothermal</u>? Use the appropriate sign convention for heat.

c) Calculate the <u>outlet area of the nozzle</u>.

d) Does the volumetric flow rate of air at the nozzle inlet = the volumetric flow rate at the outlet? <u>Justify your answer</u>.

e) Air leaving the nozzle enters an **adiabatic compressor** and exits at a pressure of 200 kPa and specific volume = 1 m^3/kg. What is the temperature of the air at the compressor outlet?

e) Find the required power input for the compressor, assuming that kinetic energy changes can be neglected. (5)

f) What is the volumetric flow rate of air at the compressor outlet?

3. Air is expanded in a turbine from 0.25 m^3/kg with a pressure of 1 MPa to 1.0 m^3/kg and a pressure of 100 kPa at the turbine outlet. Heat loss from the turbine is 100 kw

a) What mass flow rate is required to generate 1 megawatt of power? Neglect the kinetic energy change.

b) The area of the turbine outlet equals 2-times the area of the inlet. Inlet area = 100 cm^2. Show that the kinetic energy change can be neglected.

c) If the turbine were well-insulated so no heat loss occurred, how much would the power output be increased given the same operating conditions as in part a?

4. A car is left with its windows closed on a summer day and the interior air reaches a temperature of 60 ^oC.

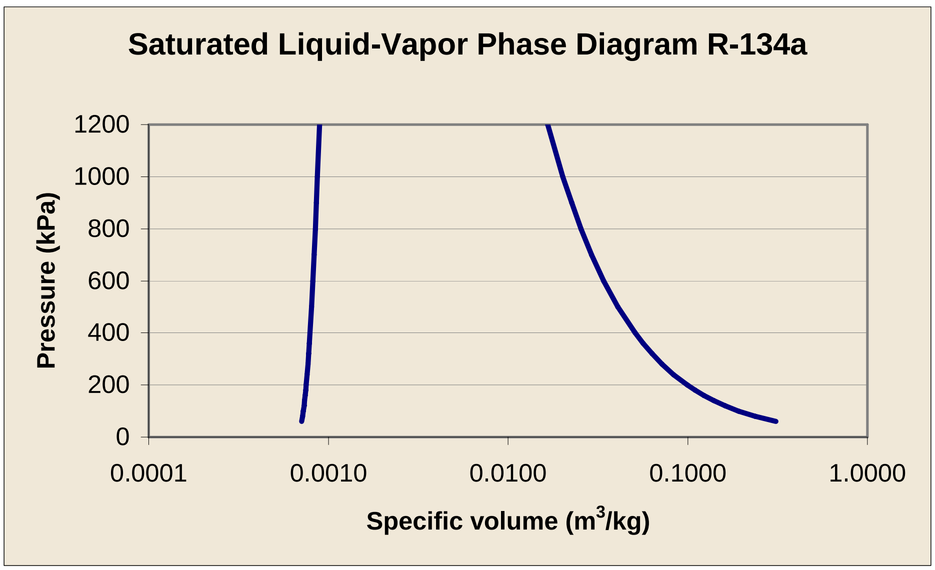
a) At what rate must heat be removed by an air conditioner in the car to bring the temperature to 22 ^oC in 5 minutes? Assume the windows remain closed during cooling. The volume of air in the car is 7 m^3, and the air pressure = 100 kPa. Solar radiation heats the car at the rate of 10 kJ/min and the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

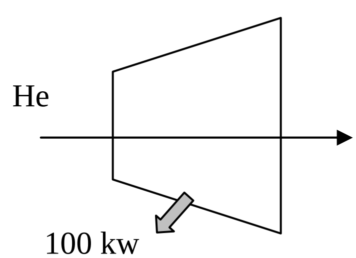
c) After evaporation in the heat exchanger, the saturated R-134a vapor is compressed to a pressure of 1 MPa and temperature = 50 ^oC in an adiabatic compressor. What is the power requirement for the compressor? (6 points)

d) Graph the process on a P-V diagram (below) (5 points)



5. Helium enters a diffuser with a velocity of 500 m/s, pressure = 100 kPa, and temperature = 50 ^oC. The diffuser inlet area is 0.1 m^2. The outlet temperature of the helium = 70 ^oC. Heat is lost from the diffuser at a rate of 100 kw.

a) What is the mass flow rate of helium for the conditions stated above?



b) What is the velocity of the helium at the diffuser outlet?

c) The outlet area = 0.2 m^2. What is the pressure of the helium at the outlet?

6. A device containing air is operated in a cycle described below with no work exchanges other than boundary work.

1 → 2: Isothermal compression, $V_1 = 3\ m^3$, $V_2 = 1\ m^3$, $P_1 = 100$ kPa
2 → 3: Isochoric heat loss, $P_3 = \frac{P_1}{2}\ m^3$
3 → 4: Isobaric expansion, $V_4 = 3\ m^3$
4 → 1: Isochoric heat addition, return to state 1

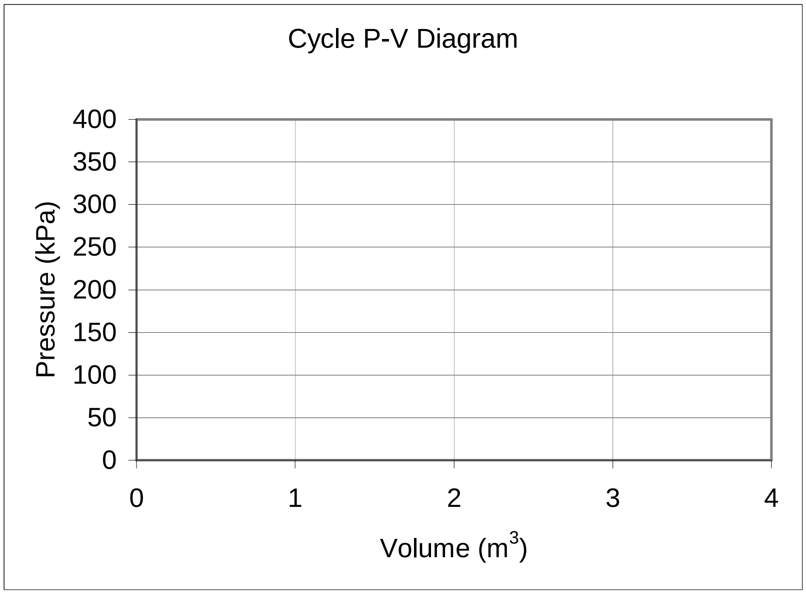
a) Find P_2

b) Find W_b for process 3 → 4

c) Find W_b for process 1 → 2

d) Find the net work for the cycle

e) Graph the process on the P-V diagram below



7. Helium, an ideal gas, is compressed in a closed system in an isothermal process. The initial volume of the gas is 8 m^3, the initial pressure is 100 kPa, and the initial temperature is 100 ^oC. During the compression, the volume decreases to 2 m^3 and the pressure increases to four times the initial value.

a) Find the equilibrium temperature of the helium after compression

b) Find the density of the helium after compression

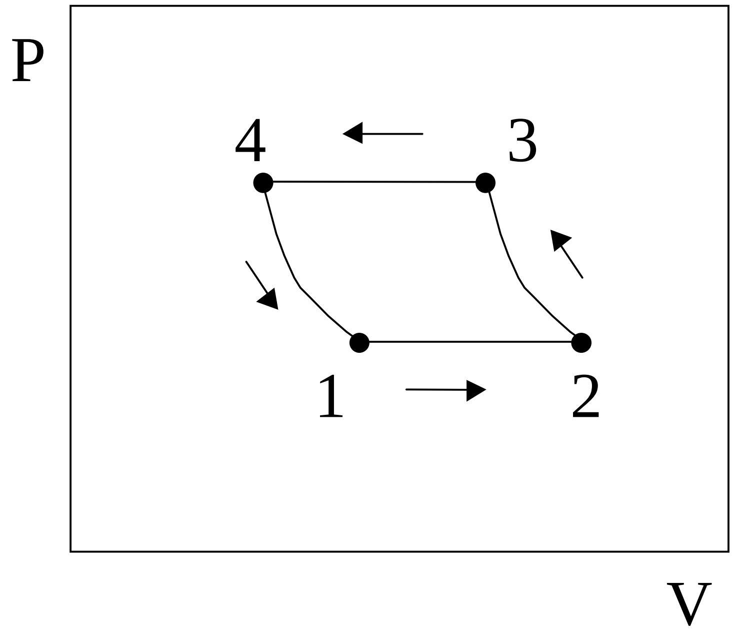
c) Find the boundary work during the compression process in kJ.

Now the helium is <u>expanded back to its initial volume in an isobaric</u> process.

d) Find the boundary work during the expansion process

e) Find the equilibrium temperature of the helium after expansion

8. Use the P-V diagram below to answer the following questions about the cycle below consisting of four open system processes in sequence 1 → 2 → 3 → → 4 → 1



i) The net work for the cycle is:
   a) Zero
   b) Positive
   c) Negative
   d) Cannot tell from the diagram

ii) The processes from states 1 → 2 and 3 → 4 are:
   a) Isothermal
   b) Isobaric
   c) Isochoric
   d) Isometric

iii) The net enthalpy change for the cycle is
  a) Zero
  b) Positive
  c) Negative
  d) Cannot tell from the diagram

iv) Work is done on the system in processes (circle ALL that apply)
  a) 1 → 2
  b) 2 → 3
  c) 3 → 4
  d) 4 → 1

9. Conceptual problems:

Review by doing text problems:

4-2C, 4-4C, 4-8C, 4-12C, 4-48C, 4-59C,

5-1C, 5-25C, 5-60, 5-93C, 5-95C, 5-101C, 5-102C,