University of California, Berkeley
Physics 7B, Lecture 002, Spring 2011 (*Xiaosheng Huang*)

Midterm 1
Tuesday, 2/22/2011
6:30 – 8:30 PM

Total Points: 100

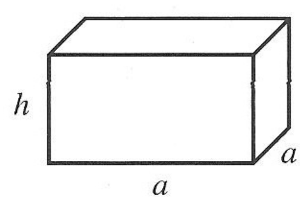
Note: *You are allowed one handwritten formula cards (3½" by 5", double sided). No calculators or any other electronic devices are permitted. Show all work, and take particular care to explain what you are doing. Please use the symbols described in the problems, define any new symbols that you introduce, and label any drawings that you make.*

1. (20 pts.) Consider a house with a square base a on each side and height h. The fraction of air that is N_2 (molecular mass = M_0) is f.

In this problem you may find the following useful:

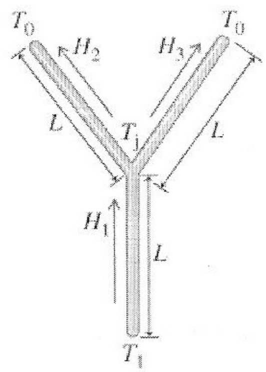
- $1/(1+x) \approx 1 - x$ for small x (Be sure to justify using it).
- STP: P = 1 atm (1.01325×10^5 Pa), T = 0°C (273.15 K).

a) Estimate how many air molecules fill the interior space of the house when the inside temperature is T and the pressure is 1 atm. What assumptions have you made for the estimate?
b) The walls of the house have a linear expansion coefficient α. If the temperature of the walls changes by $\Delta T > 0$, what is the fractional change in the interior volume?
c) Assuming that the house is *NOT* air tight, what is the fractional change in the number density of molecules (i.e. number per unit volume) corresponding to this temperature rise?



2. (20 pts.) Three identical rods are welded together to form a Y-shaped figure. The cross-sectional area of each rod is A, and they have length L and thermal conductivity k.

The free end of rod 1 is maintained at T_1 and the free ends of rods 2 and 3 are maintained at a lower temperature T_0. You may assume that there is no heat loss from the surfaces of the rods. Heat current is defined as $\Delta Q/\Delta t$.



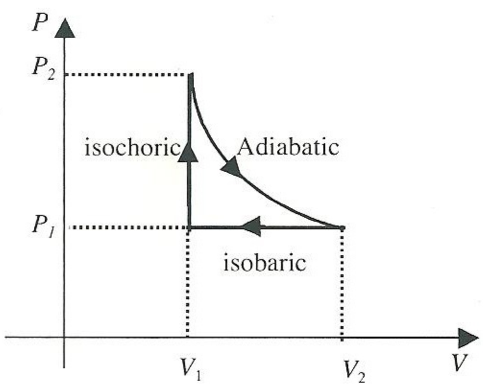
a) What is T_j, the temperature of the junction point?
b) What is the heat current H_1 in rod 1?
c) Find the heat currents H_2 and H_3.

3) (30 pts.) One mole of water is cooled from T_1 to T_2 ($<T_1$) and frozen in a refrigerator. You can treat the heat being taken out of the water as the low-temperature heat input for the refrigerator. The refrigerator then exhausts heat into a second mole of water at (again) T_1 heating it to T_3, the boiling point of water and converting a fraction (n' mole) into vapor. At this point, the refrigerator completes a cycle and its working substance returns to its initial state. Assume all processes that the refrigerator goes through are reversible.

Note*:* For parts a) through d), express your answer for each part in terms of any or all of the quantities given in the problem, T_1, T_2, T_3 and n', and relevant physical constants. You can use m as the mass of one mole of water. Also remember that there are two thermodynamic processes for each of these parts: the cooling and the freezing, or, the warming and the vaporization.

a) Find the total amount of heat, $|Q_1|$, that flows out of the first mole of water.
b) Find the total amount of entropy change, $|\Delta S_1|$, for the first mole of water.
c) Find the total amount of heat, $|Q_2|$, that flows into the second mole of water.
d) Find the total amount of entropy change, $|\Delta S_2|$, for the second mole of water.
e) What is $\Delta S_1 + \Delta S_2$? And why? Note that there are no absolute value signs around the entropy changes here. (*Hint*: What can you say about the reversibility of this whole cycle?)
f) Find n'.
g) How much work, $|W|$, must be done by the refrigerator?

4. (30 pts.) Consider the following cycle for n moles of a monatomic ideal gas as the working substance. Express your answers for all parts in terms of n, P_1, P_2, and V_1 **ONLY**.



For parts a) – c), calculate the heat, Q, that flows into (or out of) the gas and the work done by (or on) the gas, W. Remember to pay attention to the signs of Q and W.

a) The adiabatic process.

b) The isobaric process.

c) The isochoric process.

d) Find the net heat absorbed by the gas, Q_{net}, and the net work done by the gas, W_{net}, for the entire cycle.

e) Find the efficiency of this cycle.

f) Find the entropy change for the ideal gas for each of the processes. Please show your work for each process.

g) Find the total entropy changes for the ideal gas for the entire cycle, ΔS, based on your calculations in part f). Is ΔS zero or greater than zero? Can you justify your answer?

The End