University of California, Berkeley
Physics 7B, Lecture 001, Spring 2012 (*Xiaosheng Huang*)

Midterm 1
Tuesday, 2/21/2012
8:00 – 10:00 PM

Total Points: 100

Note: *You are allowed one handwritten formula card (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. **Thermal Expansion**

[20 pts] Consider a house in Berkeley made out of ordinary construction materials 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. (Please be sure to justify using it – that is, provide reasoning that x is indeed small.)

a) Estimate how many air molecules fill the interior space of the house at night when the air inside is at temperature T and pressure P. What assumptions have you made for the estimate?
b) The walls of the house have a linear expansion coefficient α. If during the course of a typical day the temperature of the walls changes by $\Delta T > 0$, what is the fractional change in the interior volume?
c) Assume that the pressure outside is the same during the day. If 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?

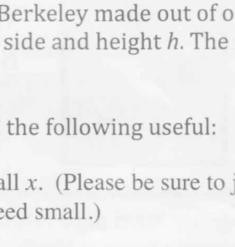

Fig. 1

2. **Ideal Engine**

[20 pts] A certain amount of ideal gas is contained in a cylindrical container with a movable, perfectly insulating, and frictionless piston. The sidewall and the bottom of the cylinder are made up of a material that has a high thermal conductivity. The canister is suspended in a water bath that can be considered a heat reservoir. The position of the piston may only be changed through the adding or removing of weights. The temperature of the water bath may be changed slowly by adding a small amount of ice water (at 0°C) or boiling water (at 100 °C) at a time.

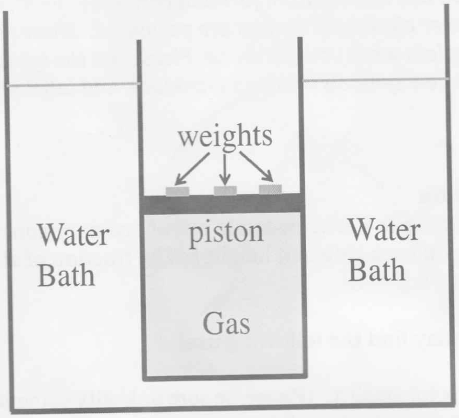

Fig. 2

The temperature of the gas is monitored through a thermometer, and the container is graded so that the volume of the gas can be measured.

We start the experiment with the gas at point a on the P–V diagram below.

In each step the experiment is conducted in such a way that the gas is only slightly out of equilibrium and hence will reach a new equilibrium quickly. That is, the experiment has to be performed quasi-statically. Practically speaking, let us stipulate that the temperature may not be changed by more than 0.1° at a time. And the pressure may not be changed by more than 0.01 atm at a time. Assume that you have many small weights to make this possible.

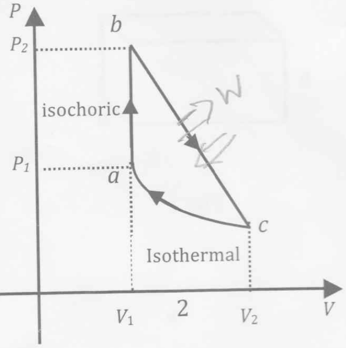

Fig. 3

Referring the *P-V* diagram (Fig. 3) above, describe how you will make the gas go along the following paths.

a) *ab*;
b) *bc*;
c) *ca*.

Your description for each of the processes should be:

(i) Specific. For example, instead of saying "raise the temperature of the gas by 0.1°C", say "add small scoops of hot water to the water bath until the temperature of the gas rises by 0.1°C."

(ii) Succinct.

(iii) In numbered steps, as in "step 1 ..."; "step 2..."; etc.

3. **Entropy Change**
[20 pts]Consider one mole of a monatomic ideal gas that goes through the above process in Fig. 3. Find the entropy change for the gas for the process *bc* in terms of P_1, P_2, V_1 and V_2, starting from $dS = dQ/T$.

4. **Entropy Production**
[20 pts] An insulated aluminum cup that has mass m_1, specific heat C_1 and is at temperature T_1 is filled with water with mass m_2, specific heat C_2, and at temperature T_2 ($>T_1$). Assume there is no phase transition in this problem.

a) Determine the final temperature of the mixture.
b) Determine the total change in entropy as a result of the mixing process.

5. **Heat Conduction**
[20 pts] Two square bars with cross-sectional area of *A* are joined end-to-end. One bar has length L_1 and is made of copper which has thermal conductivity k_1. The other bar has length L_2 and is made of aluminum which has thermal conductivity k_2. The copper end is placed in boiling water (at temperature T_H) and the aluminum end is placed in an ice-water mixture (at temperature T_L) and the system is allowed to come to a steady state. If the sides of the bars are well insulated so that no heat is lost from the sides of the bars.

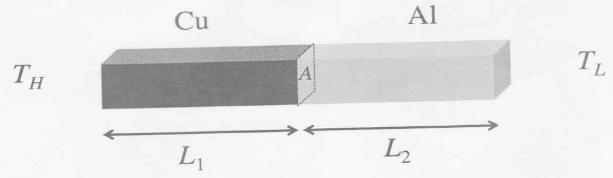

Fig. 4

a) What is the temperature at their interface where they are joined?
b) What would the length of the aluminum bar have to be in order for the temperature of the interface to be exactly 50°C?
c) What is the rate of heat flow through the copper bar, $r_1 = (dQ/dt)_{Cu}$? What is the rate of heat flow through the aluminum bar, $r_2 = (dQ/dt)_{Al}$?
d) If all the linear dimensions of the bars were increased by a factor of two, how would each of the heat flow rates change?

The End