University of California, Berkeley
Physics 7B, Fall 2007 (*Xiaosheng Huang*)

Midterm 1
Tuesday, 10/2/2007
6:00-8:00 PM

Fundamental Constants:
Avogadro's number, N_A: 6.02×10^{23}
Gas Constant, R: 8.315 J/mol·K
Boltmann's Constant, k_B: 1.38×10^{-23} J/K
Stefan-Boltzmann Constant, σ: 5.67×10^{-8} W/m^2·K^4

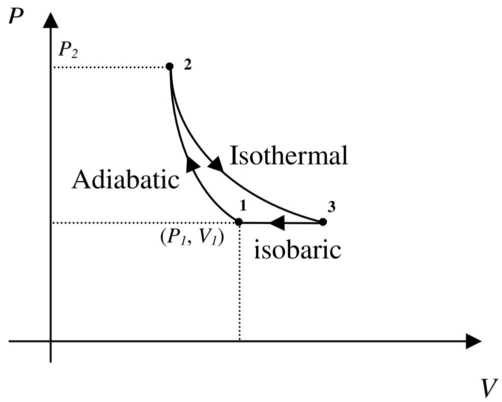
1) (20 pts.) The density of atoms, mostly hydrogen, in interstellar space is about one per cubic centimeter. The temperature of this gas is ~3000 K. The diameter of a hydrogen atom is approximately 10^{-10}m. Assume that the ideal gas law holds.

a) Estimate the pressure of this gas and express the pressure in torr. (1 atm=760 torr=$1.01\text{x}10^5$ Pa)
b) Estimate the mean free path. (You do not have to derive the expression for the mean free path.)

2) (30 pts.) A real heat engine working between heat reservoirs at T_L=350K and T_H=900K produces 700J of work per cycle for a heat input of 1800J.

a) Calculate the efficiency of this engine.
b) Calculate the efficiency of a Carnot engine operating between the same two temperatures, with the same heat input per cycle.
c) Calculate the change of entropy of the universe for each cycle of the real engine.
d) Calculate the change of entropy of the universe for each cycle of the Carnot engine operating between the same two temperatures, with the same heat input per cycle.
e) Show that, with the same heat input per cycle, the difference in work done by these two engines per cycle is $T_L\Delta S$, where ΔS is the entropy change of the real engine.

3) (40 pts.) Consider the following cycle for n moles of a monatomic ideal gas.



Calculate, in terms of n, P_1, V_1 and P_2, the heat that flows into the gas and the work done by the gas for

a) the adiabatic process;
b) the isothermal process;
c) the isobaric process.
d) The volume coefficient β is defined as $\beta=(1/V)\,(dV/dT)$. Calculate β as a function of temperature for the isobaric process.

4. (10 pts.) For a pair of dice, each having equal probability of showing 1, 2, 3, 4, 5, or 6 dots,

a) construct a table that has the number of dots for the first die, m, as its rows and that of the second die, n, as its columns. Fill the cells of the table with the average number of dots of the two dice.

	1	2	3	4	5	6
1						
2						
3						
4						
5						
6						

b) Let us define the microrstate to be the pair (m, n) and the macrostate to be the average number of dots of the two dice. Count the number of microstates that corresponds to the macrostates of 1, 2.5, and 5. Calculate the entropy for these macrostates.
c) Of all possible macrostates, which has the largest number of microstates? Calculate the entropy of this macrostate.
d) Suppose we start with two dice both showing one dot. What will the final macrostate most likely be if I throw them again?