**Physics 7b**
**Midterm Exam #1**
**Fall 2004**

Name:___________________________Disc. Section________________ SID___________

#1______

#2______

#3______

#4______

#5______

Total________

$M_w$ of $O_2$ = 32 g/mol, $k_b$=1.38x$10^{-23}$J/K, $N_A$=6x$10^{23}$

The weight of a 1kg mass on the Earth's surface is 2.2pounds.

The relative weight of each problem is indicated next to the problem number.
Most credit will be given for algebraic work. **Please do not insert numerical values until you have a final algebraic answer inside a box**. If you don't know a particular constant, use a symbol to get partial credit. It is almost impossible to award partial credit when a student has inserted numbers too early. If you get stuck on one problem, go on to the next and come back to the difficulties later in the exam period. Do not leave early until you have completed everything. Do not quit! Never, never, never quit!!

1. (20 pts) PG&E charges for natural gas in a unit called a therm.
1 therm = $10^5$BTU.
1BTU= heat to raise the temp of one pound of water by $1^oF$.
The gas price is $0.67/therm.
The price of electricity is $0.14/kW hr

When buying energy from PG&E, what is the ratio of cost per Joule for gas compared to electricity?

2. (70 points) A scuba air tank has volume $V_o$(=12liters) at ambient temperature $T_a$(=20$^o$C). The internal air pressure is $P_o$(=150atm).. The air is an ideal gas with five degrees of freedom per molecule. The coefficient of LINEAR expansion of the tank metal is $\alpha$(=2.5x10$^{-5}$(C$^o$)$^{-1}$). In the following questions, give an algebraic answer first, followed by a numerical answer. The main credit is for the algebraic answer.

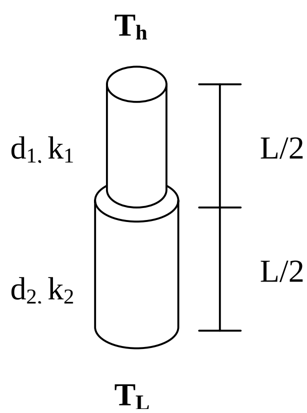
a. How many molecules of air are in the tank?
b. If a diver takes the tank into cold water which is 20C$^o$ colder than ambient, what is the <u>fractional</u> volume change of the tank?
c. The diver breaths f(=11) times per minute on land and draws in a volume v (=1.5liters) with each breath. How many minutes will the scuba tank last when the diver swims in that cold water at depth h (=20m) while breathing at the same frequency? (Assume the volume of each breath is the same as on land but the gas that fills the lungs must be at the pressure surrounding the diver)
d. In that cold water at that depth the diver blows a bubble of diameter D (=3cm). How much internal energy is stored in that bubble?
e. As the bubble rises to the surface it warms to ambient temperature. What is the bubble's diameter just below the surface?
f. What is the rms speed of an oxygen molecule in the bubble at the surface?
g. The diver's wet suit has an emissivity e=1. If another diver nearby takes a flash picture of the diver, what color will the wet suit appear?

3. (30points) A hot block of metal with initial temperature $T_m$, mass M and specific heat $C_m$, is dropped from height *h* into a container of water, specific heat $C_w=2C_m$, which also contains mass M of water but is at initial temperature $T_w$. Find the entropy change of the system (metal plus water) after the block has come to rest in the water and the combined system has reached thermal equilibrium. You may assume that no water is vaporized. Neglect the container wall heat capacity and air resistance.(hint: first find the final equilibrium temperature of the metal and water.)

4. (30points) In a low temperature experiment it is important to minimize all heat leaks. The experimental apparatus at the lowest temperature is usually surrounded by an evacuated space.

a. One way heat enters the experiment is through the wires that are required to make electrical measurements. Compute the heat leak, $\dot{Q}$ from a round wire of length L. The top half length has diameter $d_1$ and thermal conductivity $k_1$ and the bottom half has diameter $d_2$ and thermal conductivity $k_2$. The top end of the wire is connected to a temperature $T_h$ and the bottom end goes to the experiment at low temperature $T_L$.

b. Assume a Carnot refrigerator removes the heat from the cold experiment at the rate $\dot{Q}$ calculated in part *a* and delivers it to ambient temperature $T_a$. What is the power required for the electric motor operating the refrigerator. (write the answer in terms of $\dot{Q}$, not the formula for $\dot{Q}$ that you found in part a)



5. A spherical solid mass M, density $\rho$, with specific heat C, and emissivity e, is released from a space ship to float in the vacuum of space. The sphere is initially at temperature $T_o$. How **long** does it take to cool to a lower temperature $T_1$?