171.312 Statistical Physics and Thermodynamics
Homework due Wednesday, Sept 28 to Damien Benveniste in section.

1. An industrial electric mixer is submerged in a tank filled with fluid. The power input to the mixer is 4.48 kW. Heat is transferred out of the tank at the rate of 1.072 kW. Determine the change of the internal energy of this tank/fluid system per hour.

2. It's a hot summer day so your friend decides to open his refrigerator door to cool his kitchen. What happens to the temperature of his kitchen? Why?

3. An ideal gas, at a temperature of 27 C, is in a cylinder with a piston. The piston is pushed in very slowly such that the temperature of the gas remains constant. A total of 730 J of work is done to compress the gas. What was the change of entropy of the gas?

4. A system of consisting of N_1 weakly interacting atoms confined to move in a box of volume V_1 has energy $U_1 = U_0 / 3$.

(a) Find the temperature of the system.
(b) The system is brought into thermal contact with a second system consisting of $N_2 = N_1 / 3$ similar atoms in a volume $V_2 = V_1$. The initial energy of the second system is $E_2 = 2E_0 / 3$. After equilibrium has been obtained, what are the most probable values of the energy of each system?
(c) What is the equilibrium temperature?
(d) Find the total change of entropy of the two systems in going from the initial to the final state.
(e) Was the process reversible or irreversible?

5. Suppose that a gas obeys the following relation:

$$\left(P + \alpha \frac{N^2}{V^2} \right) \left(V - Nb \right) = N k_B T$$

Where P is pressure, V is volume, N is the number of gas particles, T is temperature, and α and β are constants. Further, assume that the heat capacity is

$$C_{V,N} = \frac{3}{2} N k_B .$$

Compute the Hemholtz free energy of this gas.

6. The molecules of a gas have two states of internal energy with statistical weights of g_1 and g_2 and energies 0 and ε, respectively.
(a) What is the partition function for this gas at temperature T ?
(b) What is the ratio of number of molecules in state 1 to the number of molecules in state 2, i.e., n_1 / n_2 ?
(c) Assume that $n_1 + n_2 = N$. Write separate expressions for n_1 and n_2, each in terms of g_1, g_2, ε, T, and N.
(d) What is the total internal energy, U, in terms of g_1, g_2, ε, T, and N ?
(e) What is the specific heat at constant volume, in terms of g_1, g_2, ε, T, and N ?