Qualifying Examination
Thermal Physics
January 14, 2006

PROBLEM TA.
Find the increase in the entropy of the solvent upon the solution in it of a small concentration, $\rho = n/N \ll 1$ of the solute where n is the number of solute molecules, N is the number of the solvent molecules. Use thermodynamic identity and the result for the entropy to derive the osmotic pressure of the solute.

PROBLEM TB.
What is the most efficient way to heat the house to temperature T when the outside temperature is T_0 given the source of electrical energy. Assume that electrical energy can be converted to mechanical energy without loss and ignore friction in thermal engines.

PROBLEM TC1.
The air in atmosphere has average molecular weight $\mu = 29$; it is well described by the ideal gas law and constant specific heat $c_p \approx 3.5$. Find how pressure changes with height imposing the condition of the local stability of small volumes of air. Impose now the global (i.e. mechnical) stability considering the cyclic process in which a large volume of air moves up, acquires the ambient temperature, moves down, etc. Find the maximal value dT/dz for which atmosphere becomes mechnically unstable and compare it with the empirical value $dT/dz \approx 7K/km$.

PROBLEM TC2.
In Joule-Kelvin process the gas kept at constant pressure P_i is throttled through the porous plug into another chamber kept at pressure P_f. Both chambers are well insulated. Find the change in the temperature of a slightly non-ideal gas that obeys Van-der-Waals equation.

PROBLEM TD1.
A long molecule can be often approximated as a long chain consisting of $N \gg 1$ links of length l. Consider the experiment in which one end of this molecule is fixed while a force, f, is applied to another end. Find the free energy of the molecule assuming that each link is completely free to rotate with the respect to the previous one. Find the average distance bewteen the ends of the molecule.

PROBLEM TD2.
Container contains a fixed amount of helium. At low temperatures helium liquefies, below this temperature the container contains a gas of He and liquid He. When the system is cooled further, the liquid He undergoes a superfluid transition. Apply Landau theory of phase transitions to find the effect of this transition on $P(T)$ dependence, express your result through the phenomenological paramters of Landau theory, the density, ρ, of liquid He and the pressure, P_0, at the transition temperature, T_c