PHYSICS 235
Final Examination

January 27, 2008

Duration 3 hours

1. Sketch qualitatively and comment very briefly:

a) Probability density for a velocity component along Y-direction (classical particle)
b) Probability density for the speed (velocity modulus) - classical particle in 3-dimentional space
c) Probability density for the speed (velocity modulus) - classical particle in 2-dimentional space
d) Chemical potential as function of temperature for a Fermi gas
e) Chemical potential as function of temperature for a Bose gas
f) Spectral density of the blackbody radiation vs. frequency for two temperatures T_1, T_2
$T_1 = 1.5T_2$

2. Atoms with internal degree of freedom

Consider an ideal monatomic gas. Each atom has two internal electronic energy states: the ground state and one excited state higher by energy Δ. These states are independent of the translational motion of atoms which can be treated semi-classically.

Find the following and compare to the standard monatomic gas:
a) The single-particle partition function Z_1(N,V,T)
b) the Helmholtz free energy as a function of (N, V, T)
c) the pressure
d) the total average energy
e) the chemical potential
f) the Gibbs free energy change compared to standard monatomic gas

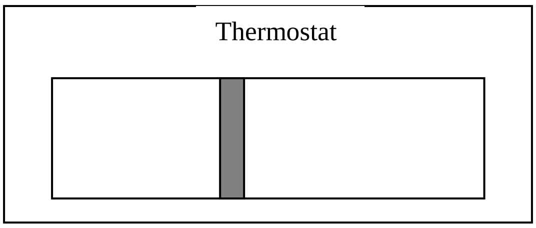
What happens in the limits $\frac{\Delta}{kT} \to \infty$ and $\frac{\Delta}{kT} \to 0$?

Real atoms actually have excited electronic states with $\Delta \sim 1$ eV. At room temperature, which limit is relevant?

Hint: On top of the standard description of the single particle Hamiltonian, there will be an additional quantum number with only two values (0,1) corresponding to the two internal eigenstates.

3. Two gases pushing each other.

An isothermal cylinder is divided into two compartments by a sliding frictionless piston. The first compartment contains the gas of particles of mass m and spin 3/2, the second contains the gas of particles of the same mass m but spin 1/2. The position of the piston adjusts itself until equilibrium is reached.



1. Formulate the equilibrium condition governing the piston position (you can use either the extremal property for the total free energy, or thebasic mechanical arguements).

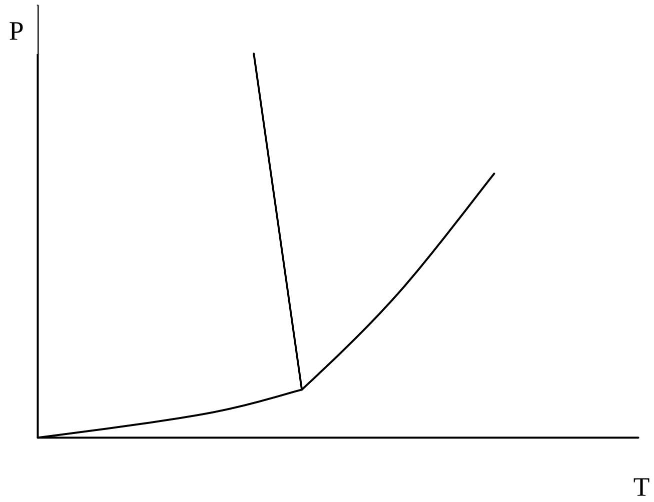
2. Find the equilibrium density ratio in the two compartments $\frac{n_1}{n_2}$

   (a) at zero temperature, and
   (b) in the limit of high T

3. What is the criterion for the temperature to be high in this case?

4. Compressing water/ice mixture

A mixture of water and ice initially at P=1 atm and T=273 K, is subjected to adiabatic compression.
In the final state (at elevated pressure) the system is still in a phase segregated water/ice state.



1. What happens to the temperature of the system in this process (increases, decreases, or stays the same) ?

Hint: use the phase diagram to show the process.

2. The answer to the previous question may seem strange. Use the I law of thermodynamics to explain what happens to
(a) volume fraction of water in the sample
(b) total energy

and how these two changes are consistent.