PHYSICS 210A : STATISTICAL PHYSICS
HW ASSIGNMENT #4

(1) Consider a three-dimensional ultrarelativistic gas, with dispersion $\varepsilon = \hbar c|\boldsymbol{k}|$. Find the viral expansion of the equation of state $p = p(n,T)$ to order n^3 for both bosons and fermions.

(2) Suppose photons had a dispersion $\varepsilon = J\boldsymbol{k}^2$. All other things being equal (surface temperature of the sun, earth-sun distance, earth and solar radii, *etc.*), what would be the surface temperature of the earth? *Hint: Derive the corresponding version of Stefan's law.*

(3) Almost all elements freeze into solids well before they can undergo Bose condensation. Setting the Lindemann temperature equal to the Bose condensation temperature, show that this implies a specific ratio of $k_{\mathrm{B}}\Theta_{\mathrm{D}}$ to $\hbar^2/Ma^2$, where M is the atomic mass and a is the lattice spacing. Evaluate this ratio for the noble gases He, Ne, Ar, Kr, and Xe. (You will have to look up some numbers.)

(4) A nonrelativistic Bose gas consists of particles of spin $S = 1$. Each boson has mass m and magnetic moment μ_0. A gas of these particles is placed in an external field H.

(a) What is the relationship of the Bose condensation temperature $T_{\mathrm{c}}(H)$ to $T_{\mathrm{c}}(H = 0)$ when $\mu_0 H \gg k_{\mathrm{B}}T$?

(b) Find the magnetization M for $T < T_{\mathrm{c}}$ when $\mu_0 H \gg k_{\mathrm{B}}T$. Calculate through order $\exp(-\mu_0 H/k_{\mathrm{B}}T)$.