Physics 831 - 2002

Statistical Physics

Problem Set 10

1. Evaluate the lowest-order exchange corrections to the equations of state of weakly-quantum Bose and Einstein gases, i.e. for $\exp(\beta\mu) \ll 1$ (6 pt)

2. A simple model of an intrinsic (no charged defects) semiconductor is as follows: there is a valence band and a conduction band, separated by an energy gap E_g. For $T = 0$, the valence band is occupied by electrons, and the conduction band is empty. As you raise temperature, some electrons go from the valence band to the conduction band. In such a process, a hole is created in the valence band, with energy $p^2/2m_h$ counted off from the top of the valence band (p is the quasi-momentum of the hole), and an electron emerges in the conduction band, with energy $p^2/2m_e$ counted off from the bottom of the conduction band (m_e and m_h are called the electron and hole effective masses, respectively). Find the electron and hole densities n and p for nonzero temperatures, assuming that $\beta E_g \gg 1$. Find the position of the chemical potential. (8 pt)

3. For a quantum harmonic oscillator, with mass m and angular frequency ω, find the probability distribution over the oscillator momentum p, for given temperature T [you can think of an oscillator weakly coupled to a thermal reservoir, as before]. Do the same problem for the classical oscillator. Compare the classical and quantum expressions in the limit of large $kT/\hbar\omega$. (5 pt)

4. Consider a degenerate electron system for $T = 0$ in a magnetic field and ignore effects of orbital quantization. The electron energy in the field is then $\pm\mu_B B$ depending on whether the spin is parallel or antiparallel to the field. Assume that this energy is much less than the Fermi energy ε_F. Find the magnetic moment related to spins, assuming that the electrons occupy the volume V and that the electron mass is m, and calculate the corresponding paramagnetic susceptibility. (6 pt).

Problems with numbers are from Kerson Huang, *Statistical Mechanics*, 2nd edition, (Wiley, NY 1987).