Physics 410 - 2003

Thermal Physics

Problem Set 12

1. 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. (5 pt)

2. Consider a two-dimensional (2D) gas of noninteracting fermions with spin $s = 1/2$ and mass m. The density of the gas is $n = N/A$, where A is the area. Find the Fermi energy ε_F and calculate pressure for $T = 0$ (5 pt)

3. For low temeperatures, find the heat capacity of an ultra-relativistic Fermi gas of N particles with spin 1/2 and energy $\varepsilon = pc$ (5 pt)

The problems are from Kittel & Kroemer, *Thermal Physics*, 2nd edition, (Freeman, NY 1980).