

## Solutions to Problems in Solid State Physics II

### Problem 2005-I

$\varepsilon_A$  is the maximum energy of band 1 (follows from the specification of the Fermi surface). The number of electronic states in one band, within the 1. Brillouin zone, is twice the number of  $k$  states, i.e. twice the number of unit cells in the system. If  $\varepsilon_h < \varepsilon_e$  all states in band 1, and no states in band 2, would be occupied by electrons at zero temperature, implying that

1) the system would be an insulator (or semiconductor).

The reciprocal lattice of an fcc is a bcc lattice. In the bcc reciprocal lattice there are 8 equivalent (111) reciprocal lattice points lying at the corners of the 1. Brillouin zone, each counting one-eighth. This implies that there is, effectively, one hole and one electron Fermi surface in one Brillouin zone. With the use of the notation introduced on the figure, we have:

$$\varepsilon_F = \varepsilon_e + \frac{(\hbar k_e)^2}{2m_e} = \varepsilon_h - \Delta + \frac{(\hbar k_h)^2}{2m_h}, \quad \varepsilon_F = \varepsilon_h - \frac{(\hbar k_h)^2}{2m_h}. \quad (1)$$

The number of holes (i.e. the number of missing electrons) in band 1 is equal to the number of electrons occupying band 2, i.e.

$$n = p. \quad (2)$$

and since both bands are parabolic, we may use Marder eq. (6.29) to obtain the lengths of the two Fermi wave vectors:

$$k_e = (3\pi^2 n)^{1/3}, \quad \text{and equivalently} \quad k_h = (3\pi^2 p)^{1/3}. \quad (3)$$

These equations are straightforwardly solved, and we get

$$2) \quad \varepsilon_F = \varepsilon_A - \frac{m_e}{m_e + m_h} \Delta.$$

$$3) \quad n = p = \frac{1}{3\pi^2} \left( \frac{2\Delta}{\hbar^2} \frac{m_e m_h}{m_e + m_h} \right)^{3/2}.$$

According to Marder eqs. (6.77) and (6.23), the specific heat is

$$c_V = \frac{\pi^2}{3} k_B^2 T D(\varepsilon_F), \quad D(\varepsilon_F) = \frac{m}{\hbar^3 \pi^2} \sqrt{2m\varepsilon_F} = \frac{mk_F}{\hbar^2 \pi^2}, \quad (4)$$

in the case of a parabolic band, when  $T \ll \varepsilon_F/k_B$ . In the present case, we need to require  $T \ll \Delta/k_B$ , and adding the electron- and hole-like contributions,

$$D(\varepsilon_F) = \frac{m_e k_e}{\hbar^2 \pi^2} + \frac{m_h k_h}{\hbar^2 \pi^2} = \frac{m_e + m_h}{\hbar^2 \pi^2} \left( \frac{2\Delta}{\hbar^2} \frac{m_e m_h}{m_e + m_h} \right)^{1/2} \quad (5)$$

the result is

$$4) \quad \gamma = c_V/T = \frac{k_B^2}{3\hbar^2} \sqrt{2m_e m_h (m_e + m_h) \Delta}.$$

# Solid State Physics Problems And Solutions

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*Problems In Solid State Physics With Solutions* Fuxiang Han, 2011-10-31 This book provides a practical approach to consolidate one's acquired knowledge or to learn new concepts in solid state physics through solving problems. It contains 300 problems on various subjects of solid state physics. The problems in this book can be used as homework assignments in an introductory or advanced course on solid state physics for undergraduate or graduate students. It can also serve as a desirable reference book to solve typical problems and grasp mathematical techniques in solid state physics. In practice it is more fascinating and rewarding to learn a new idea or technique through solving challenging problems rather than through reading only. In this aspect this book is not a plain collection of problems but it presents a large number of problem solving ideas and procedures some of which are valuable to practitioners in condensed matter physics.

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