National University of Singapore

PC3235 Solid State Physics I

(Semester I: AY2008-09, 27 November)

Time Allowed: Two Hours

INSTRUCTIONS TO CANDIDATES

1. This examination paper contains **FOUR** questions and comprises **FOUR** printed pages.
2. Answer any **THREE** questions.
3. Answers to the questions are to be written in the answer books.
4. This is a CLOSED BOOK examination.
5. A Table of Constants is provided.

1. (a) (i) Draw and label the direct and reciprocal lattices of an one dimensional linear chain. The distance between two real lattice points is a.

[4 marks]

(ii) Give the expression of reciprocal lattice primitive vector $(\vec{b})$; reciprocal lattice translation vector $(\vec{G})$ of the linear chain and specify the boundaries of the first Brillouin zone.

[5 marks]

(b) (i) Draw a primitive unit cell of a simple cube of side a and specify its primitive vectors $(\vec{a}'s)$ in the real space.

[4 marks]

(ii) Find its primitive vectors $(\vec{b}'s)$ in the reciprocal space.

[4 marks]

(iii) Find the boundaries of its first Brillouin zone.

[4 marks]

(iv) Find the distance between two adjacent (001) planes.

[4 marks]

2. (a) Show that the Hall coefficient for semiconductors is

$$R_H = \frac{p\mu_h^2 - n\mu_e^2}{e(n\mu_e + p\mu_h)^2}$$

where μ_e, μ_h are mobilities and n, p are concentrations. The subscripts e and h refer to the electrons and holes respectively.

[12 marks]

(b) Starting from the above expression for R_H, deduce the expression for the cases of n-type and p-type samples.

[6 marks]

(c) In an InP sample, the measured $R_H \approx 0$. Given that $\mu_e = 4500\,cm^2/V \cdot s$ and $\mu_h = 100\,cm^2/V \cdot s$, calculate the ratio of the electron to the total current.

[7 marks]

3. (a) Consider a planar square lattice of identical atoms of mass m with nearest neighbor interaction of force constant β. The area of the planar square lattice is S. The dispersion relation is given as

$$\omega = \sqrt{\frac{4\beta}{m}}\left(\sin\frac{ka}{2}\right)$$

Show that the expression of the density of states $D(\omega)$ for the phonon in the long wavelength limit is

$$D(\omega) = \frac{Sm\omega}{2\pi a^2 \beta}$$

[11 marks]

(b) (i) Under the free electron model, show that the Fermi momentum K_F of the electrons of concentration n can be expressed as

$$K_F^3 = 3\pi^3 n$$

[7 marks]

(ii) Calculate the Fermi velocity of copper.

Given that:

mass density $\rho_m = 8.93\times10^3\ kg/m^3$

atomic mass = $63.54\times10^{-3}\ kg/mole$

mass of electron = $9.1\times10^{-31}\ kg$

$\hbar = 1.054\times10^{-34}\ Js$

[7 marks]

4. (a) Write down the energy expression and sketch the $E-k$ curve for 1-D free electrons.

[5 marks]

(b) Starting from the expression

$$p\left(\frac{\sin \alpha a}{\alpha a}\right)+\cos \alpha a=\cos ka$$

where $p=cv_o$, v_o is the height of the potential barrier, c is a coefficient and $\alpha=\left(2mE/\hbar^2\right)^{\frac{1}{2}}$.

Derive an expression for energy of electrons in solid by free electron approximation.

[8 marks]

Sketch the $E-k_x$ curve in the periodic zone scheme.

[5 marks]

(c) Discuss the origin of the energy band gap based on electron wave reflection.

[7 marks]

C K Ong

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