UNIVERSITI SAINS MALAYSIA

First Semester Examination
Academic Session 2008/2009

November 2008

ZCC 541/4 - Solid State Physics I
[Fizik Keadaan pepejal I]

Duration : 3 hours
[Masa : 3 jam]

Please ensure that this examination paper contains **FIVE** printed pages before you begin the examination.

*[Sila pastikan bahawa kertas peperiksaan ini mengandungi **LIMA** muka surat yang bercetak sebelum anda memulakan peperiksaan ini.]*

Instruction: Answer **FOUR** questions only. Students are allowed to answer all questions in Bahasa Malaysia or in English.

*[**Arahan**: Jawab **EMPAT** soalan sahaja. Pelajar dibenarkan menjawab semua soalan sama ada dalam Bahasa Malaysia atau Bahasa Inggeris.]*

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1. (a) Describe briefly how the Bloch Theory of electrons in a solid improves on the Sommerfeld Theory.
[Huraikan secara ringkas bagaimana Teori Bloch memperbaiki Teori Sommerfeld.]

(20/100)

(b) State the Bloch Theorem for the wavefunction of an electron in a periodic potential. Show that the Bloch wavefunction is not an eigenfunction of the linear momentum operator of the electron. Is the wavefunction of a free electron an eigenfunction of its linear momentum operator ?
[Nyatakan Teorem Bloch bagi fungsi gelombang suatu elektron di dalam suatu keupayaan berkala. Tunjukkan bahawa fungsi gelombang Bloch adalah bukan suatu fungsi eigen bagi operator momentum linear bagi elektron. Adakah fungsi gelombang bagi suatu elektron bebas suatu fungsi eigen bagi operator momentum linear-nya ?]

(40/100)

(c) Show that for a free electron gas in 3-D, the density of levels $g(\varepsilon)$ is given by

$$g(\varepsilon) = \frac{V}{2\pi^2}\left(\frac{2m}{\hbar^2}\right)^{3/2} \varepsilon^{1/2} \quad , \qquad \varepsilon > 0$$

$$g(\varepsilon) = 0 \quad , \qquad \varepsilon < 0$$

(40/100)

2. (a) Consider a 2-D gas of N free electrons at 0 K. Show that the total kinetic energy U_o is given by
[Timbangkan suatu gas 2-D *yang mempunyai N elektron bebas dalam pada* 0 K. *Tunjukkan bahawa jumlah tenaga kinetik U_o adalah diberi oleh]*

$$U_o = \frac{1}{2} N \varepsilon_F$$

where ε_F is the Fermi energy.
[dimana ε_F adalah tenaga Fermi]

(40/100)

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(b) Describe briefly the uses of *Bloch Functions* and *Wannier Functions* in the theory of solid state physics.
[Huraikan secara ringkas penggunaan Fungsi Bloch dan Fungsi Wannier dalam teori fizik keadaan pepejal.]

(20/100)

(c) Show that electrons which fill up an energy band completely do not contribute to the electrical conductivity of a solid. Use the semi-classical model of the dynamics of electrons in a solid.
[Tunjukkan bahawa elektron elektron dalam suatu jalur tenaga yang diisi penuh tidak menyumbang kepada konduktiviti elektrik bagi suatu pepejal. Gunakan model semi-klasik bagi dinamik elektron dalam suatu pepejal.]

(40/100)

3. (a) State the various types of Perturbation Theory in Quantum Mechanics. Give examples of the physical systems where perturbation theory must be applied.
[Nyatakan jenis-jenis Teori Usikan dalam Mekanik Kuantum. Berikan beberapa contoh sistem fizik dimana teori usikan mesti digunakan.]

(20/100)

(b) State the basic problem of time dependent perturbation theory. Describe the mathematical steps to obtain a formula for the transition probability for a system to make a transition from state l to state k .
[Nyatakan problem asas bagi teori usikan bersandar pada masa. Huraikan langkah matematik untuk mendapatkan suatu formula bagi kebarangkalian peralihan untuk suatu sistem mengalir daripada keadaan l *ke keadaan* k *.]*

(50/100)

(c) Describe how selection rules for allowed transitions and forbidden transitions can be calculated when an atom interacts with electromagnetic radiation.
[Huraikan bagaimana peraturan pilihan bagi peralihan dibenar dan peralihan terhalang boleh dihitungkan apabila atom bersaling tindak dengan sinaran elektromagnetik.]

(30/100)

4. (a) Explain briefly the meaning of
[Jelaskan secara ringkas makna bagi]

(i) phonon
[fonon]

(ii) phonon density of levels
[ketumpatan paras fonon]

(iii) phonon dispersion relation
[hubungan sebaran fonon]

of a crystal.
[bagi suatu hablur.]

(20/100)

(b) Consider a one dimensional (1-D) crystal containing alternating ions with massess m_1 and m_2 . Assume that the ions only interact with their nearest neighbours with a spring constant s. Show that the phonon dispersion relation ω_k is given by
[Timbangkan suatu hablur satu dimensi (1-D) dengan ion berselang yang mempunyai jisim m_1 dan m_2 . Anggapkan tindakan bersaling di antara jiran terdekat sahaja dengan parameter ketengangan s. Tunjukkan bahawa hubungan sebaran fonon ω_k adalah diberi oleh]

$$\omega_k^2 = \frac{s}{m_1 m_2}[m_1 + m_2 \pm \sqrt{m_1^2 + m_2^2 + 2m_1 m_2 \cos(ka)}]$$

where a is the distance between atoms.
[dimana a adalah jarak antara atom.]

What is the main difference when compared with the dispersion relation of a monoatomic crystal where $m_1 = m_2$?
[Apakah perbezaan utama apabila dibandingkan dengan hubungan sebaran bagi suatu hablur mono-atom dimana $m_1 = m_2$?]

(50/100)

(c) The dispersion relation of a harmonic 1-D solid is given by
[Hubungan sebaran fonon bagi suatu pepejal 1-D yang harmonik adalah diberi oleh]

$$\omega_k = \omega_o \left| \sin(\frac{ak}{2}) \right|$$

where a is the interatomic distance. Show that the phonon density of levels is given by
[dimana a adalah jarak antara atom. Tunjukkan bahawa ketumpatan paras fonon adalah diberi dengan]

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