
UNIVERSITI SAINS MALAYSIA

First Semester Examination
Academic Session 2004/2005

October 2004

ZCT 307E/3 - Solid State Physics I
[Fizik Keadaan Pepejal I]

Duration : 3 hours
[Masa : 3 jam]

Please check that this examination paper consists of **THREE** pages of printed material before you begin the examination.

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

Instructions: Answer all **FOUR** (4) questions. Students are allowed to answer all questions in Bahasa Malaysia or in English.

Arahan: *Jawab kesemua **EMPAT** (4) soalan. Pelajar dibenarkan menjawab semua soalan sama ada dalam Bahasa Malaysia atau Bahasa Inggeris.]*

1. (a) Discuss the reasons for the failure of Dulong and Petit's law to predict the specific heat at low temperatures. Why should the law be valid at high temperatures?
 [(a) *Bincang mengapa hukum Dulong dan Petit tidak mampu meramal haba tentu pada suhu rendah. Kenapa hukum itu berlaku pada suhu tinggi?]*
- (b) Discuss how Debye's theory managed to overcome the shortcomings of the classical theory.
 [(b) *Bincangkan bagaimana teori Debye mengatasi masalah di atas.]*
- (c) Debye temperature of carbon is 1850 K. Compute the Debye frequency involved in the Debye theory.
 [(c) *Suhu Debye bagi karbon adalah 1850 K. Tentukan frekuensi Debye bagi kes teori Debye.]*
- (20/100)
2. (a) Discuss the failure of the classical free electron model with special reference to the specific heat of metals.
 [(a) *Bincangkan kegagalan model klasik elektron bebas berasaskan haba tentu logam.]*
- (b) Explain how Sommerfeld modified the free electron theory to remove this shortcomings.
 [(b)] *Jelaskan bagaimana model Sommerfeld mengubahsui teori elektron bebas bagi menjelaskan perkara di atas.]*
- (c) Estimate the fractions of electrons excited about the Fermi level at room temperature ($T = 300$ K). $E_F = 3.1$ eV for Na.
 [(c) *Tentukan pecahan elektron yang teruja sekitar paras Fermi pada suhu bilik ($T = 300$ K). $E_F = 3.1$ eV bagi Na.]*
- (25/100)
3. (a) The Equation below is derived from the Kronig-Penney Model for an electron in a periodic field,
 [(a) *Persamaan berikut telah diterbitkan daripada model Kronig-Penney.]*

$$P \frac{\sin \alpha a}{\alpha a} + \cos \alpha a = \cos ka$$

where [di mana] $P = \frac{mV_0ba}{\hbar^2}$ and [dan] $\alpha^2 = \frac{2mE}{\hbar^2}$

(i) Explain the physical meaning of all the terms in the equation above.
 [(i) *Jelaskan maksud fizikal bagi semua sebutan persamaan di atas.*]

[ii] Plot a graph of $P \frac{\sin \alpha a}{\alpha a} + \cos \alpha a$ versus αa . Discuss what you can deduce from the graph.

[(ii) *Plot graf $P \frac{\sin \alpha a}{\alpha a} + \cos \alpha a$ lawan αa . Bincang apa yang anda perolehi dari graf tersebut.*]

(b) Show from the E-k graph that materials can be classified into conductors, insulators and semiconductors.

[(b) *Dari graf E-k bagaimanakah anda boleh mengelaskan bahan konduktor, penebat dan semikonduktor*]

[c] Prove that for the Kronig Penney model the energy of the lowest energy

band at $k = 0$ is $E = \frac{\hbar^2 P}{ma^2}$

[(c) *Buktikan dari model Kronig-Penney bahawa tenaga bagi jalur terendah*

$k = 0$ adalah $E = \frac{\hbar^2 P}{ma^2}$]

(30/100)

4. (a) Show that for the case of intrinsic semiconductors, the carrier concentration is given by

[(a) *Tunjukkan bagi kes semikonduktor intrinsik, kepekatan pembawa diberi oleh*

$$n = p = n_i = 2 \left(\frac{k_B T}{2\pi \hbar^2} \right)^{3/2} (m_e m_h)^{3/4} e^{-E_g / 2k_B T}$$

[b] Mobilities of electrons and holes in a sample of intrinsic germanium at 300 K are $0.36 \text{ m}^2 \text{V}^{-1} \text{s}^{-1}$ and $0.17 \text{ m}^2 \text{V}^{-1} \text{s}^{-1}$ respectively. If the conductivity of the specimen is $2.12 \Omega^{-1} \text{m}^{-1}$, compute the forbidden energy gap.

[(b) *Kelincahan elektron dan lohong bagi sampel germanium intrinsik pada suhu 300 K adalah $0.36 \text{ m}^2 \text{V}^{-1} \text{s}^{-1}$ dan $0.17 \text{ m}^2 \text{V}^{-1} \text{s}^{-1}$ secara berturutan. Jika kekonduksian germanium adalah $2.12 \Omega^{-1} \text{m}^{-1}$ hitung jurang tenaga germanium.*]

(25/100)