UNIVERSITI SAINS MALAYSIA

KSCP Semester Examination
Academic Session 2007/2008

June 2008

ZCC 542/4 – Theory of Solid State Physics II
[Teori Fizik Keadaan Pepejal II]

Duration: 3 hours
[Masa : 3 jam]

Please ensure that this examination paper contains **SEVEN** printed pages before you begin the examination.
*[Sila pastikan bahawa kertas peperiksaan ini mengandungi **TUJUH** muka surat yang bercetak sebelum anda memulakan peperiksaan ini.]*

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

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

1. (a) Electric field of an optic wave polarized by a polarizer is:
*[Medan elektrik **E** bagi suatu gelombang optik yang terkutub oleh suatu bahan pengkutub ialah:]*

$$\boldsymbol{E} = (\tfrac{1}{2} E_0 e^{i\alpha},\ E_0 e^{i(\alpha-\pi/2)},\ 0)e^{i(kz-\omega t)}$$

where E_0 is the constant magnitude.
[dengan E_0 ialah magnitud yang malar.]

Explain clearly the type of polarization of light in this case.
[Huraikan dengan jelas keadaan pengkutuban cahaya yang berlaku.]

(30/100)

(b) The dielectric constant of an anisotropic medium is:
[Pemalar dielektrik bagi suatu medium tak isotropic ialah:]

$$\varepsilon = \begin{pmatrix} \varepsilon_1 & 0 & 0 \\ 0 & \varepsilon_1 & 0 \\ 0 & 0 & \varepsilon_3 \end{pmatrix}.$$

By solving the Fresnel equation, show that
[Dengan menyelesaikan persamaan Fresnel, tunjukkan bahawa]

$$\frac{1}{n^2} = \frac{\sin^2\theta}{n_e^2} + \frac{\cos^2\theta}{n_0^2}$$

where $n_e^2 = \varepsilon_3$, $n_0^2 = \varepsilon_1$, n is the refractive index of a medium. θ is the angle between the incident ray and the optical axis of the medium. The Fresnel equation is given as:
[dengan $n_e^2 = \varepsilon_3$, $n_0^2 = \varepsilon_1$, dan n ialah indeks biasan bagi suatu medium. θ ialah sudut antara sinaran tuju dengan paksi optik medium. Diberi bahawa Persamaan Fresnel ialah:]

$$n^2\left(\varepsilon_1 n_1^2 + \varepsilon_2 n_2^2 + \varepsilon_3 n_3^2\right) - \left[n_1^2\varepsilon_1(\varepsilon_2+\varepsilon_3) + n_2^2\varepsilon_2(\varepsilon_3+\varepsilon_1) + n_3^2\varepsilon_3(\varepsilon_1+\varepsilon_2)\right] + \varepsilon_1\varepsilon_2\varepsilon_3 = 0$$

(40/100)

(c) Explain the meaning of a quarter-wave plate and hence with suitable mathematical expressions explain how circular polarized light is obtained when linearly polarized light passes through a quarter-wave plate.
[Terangkan maksud suatu plat gelombang-suku dan seterusnya terangkan dengan ungkapan matematik yang sesuai bagaimana suatu cahaya terkutub bulat dihasilkan apabila cahaya terkutub linear melalui suatu plat gelombang-suku.]

(30/100)

2. (a) Landau free energy for first order ferroelectric phase transition is
[Tenaga bebas Landau perubahan fasa feroelektrik tertib pertama ialah]

$$F = \tfrac{1}{2}\alpha P^2 - \tfrac{1}{4}\beta P^4 + \tfrac{1}{6}\gamma P^6$$

where *[di mana]* $\alpha = \alpha_0(T - T_0)$, and α_0, β and γ are positive; T_0 is the Curie temperature. *[dan]* α_0, β dan γ *[adalah positif]; T_0 [ialah suhu Curie.]*

i) Derive expressions for the spontaneous polarization from the free energy expansion for supercooling temperature and critical temperature T_C.
[Terbitkan ungkapan bagi pengutuban spontan daripada kembangan Landau untuk suhu lampau sejuk dan suhu genting T_C.]

ii) Sketch a labeled diagram to show changes of spontaneous polarization with temperature and based on this diagram, explain the meaning of 'thermal hysteresis'.
[Lakarkan gambar rajah berlabel untuk menunjukkan perubahan pengutuban spontan dengan suhu dan berdasarkan rajah tersebut, terangkan maksud 'histeresis terma'.]

(60/100)

(b) Show (using Landau free energy expression) that the dielectric constants for a second order ferroelectric material for temperatures above and below T_C are:

[Tunjukkan (dengan menggunakan ungkapan tenaga bebas Landau) bahawa pemalar dielekrik bahan feroelektrik tertib kedua bagi suhu atas dan bawah T_C adalah:]

$$\varepsilon \sim \frac{1}{2\varepsilon_0\alpha_0(T - T_c)} \quad \text{for [\textit{untuk}] } T > T_C$$

and [*dan*]

$$\varepsilon \sim \frac{1}{4\varepsilon_0\alpha_0(T_c - T)} \quad \text{for [\textit{untuk}] } T < T_C$$

(40/100)

3. (a) Discuss the structural differences between smectic liquid crystal phase *A,* phase *C* and phase *C**. Explain why phase *C** shows optical activity and antiferroelectric properties.

[Bincangkan perbezaan dari segi struktur bagi hablur cecair smektik dalam fasa A, fasa C dan fasa C. Terangkan mengapa fasa C* menunjukkan keaktifan optik dan sifat antiferoelektrik.]*

(40/100)

(b) Fig. 1 shows a liquid crystal nematic cell formed between two rubbed glass plates. Assume that the molecules of director $\underset{\sim}{n}$ are strongly pinned to the glass plates at $y = 0$ and $y = d$. An electric field **E** is applied normal to the rubbing direction. The free energy function in general is:

*[Rajah 1 menunjukkan suatu sel hablur cecair nematik di antara 2 plat kaca yang tergosok. Dianggapkan vektor penunjuk $\underset{\sim}{n}$ melekat dengan kuat pada plat $y = 0$ dan $y = d$. Suatu medan elektrik **E** dikenakan secara berserenjang kepada arah gosokan. Fungsi tenaga bebas secara am adalah]*

$$F = \frac{1}{2}K_1\left(div\,\underset{\sim}{n}\right)^2 + \frac{1}{2}K_2\left(\underset{\sim}{n}.curl\,\underset{\sim}{n}\right)^2 + \frac{1}{2}K_3\left(\underset{\sim}{n}\times curl\,\underset{\sim}{n}\right)^2 - \frac{1}{2}\varepsilon_0\varepsilon_a(\underset{\sim}{n}.E)^2$$

i) By suitable approximation, show that the free energy can be reduced to
[Dengan penghampiran yang sesuai, tunjukkan tenaga bebas adalah]

$$\Im = \int [\frac{1}{2} K \left(\frac{d\theta}{dy} \right)^2 - \frac{1}{2} \varepsilon_0 \varepsilon_a E^2 \sin^2 \theta] dy$$

where θ is the angle between the *z*-axis and director $\underset{\sim}{n}$.

[di mana θ adalah sudut di antara vektor penunjuk $\underset{\sim}{n}$ dengan paksi-z.]

ii) Write the Euler Langrange equation for the profile of the director $\theta(y)$ at a general position in the cell. From the symmetry of the nematic cell, $\frac{d\theta}{dy} = 0$ at $y = \frac{d}{2}$, show that the first integral results in the differential equation for $\theta(y)$:
[Tuliskan persamaan Euler-Langrange bagi profail vektor penunjuk θ (y) pada suatu kedudukan dalam sel itu. Dari simetri sel nematik itu, $\frac{d\theta}{dy} = 0$ pada $y = \frac{d}{2}$, tunjukkan bahawa kamiran pertama menghasilkan persamaan pembezaan berikut untuk θ (y):]

$$K \left(\frac{d\theta}{dy} \right)^2 = \chi E^2 \left(\sin^2 \theta_m - \sin^2 \theta \right)$$

where θ_m is the value of θ at $y = \frac{d}{2}$.

[di mana θ_m adalah nilai θ pada $y = \frac{d}{2}$.]

(60/100)

4. The total domain wall energy in a one-dimensional magnetic material is given as (refer to Fig. 2):
[Diberi bahawa jumlah tenaga dinding domain dalam bahan magnet satu dimensi ialah (rujuk kepada Rajah 2):]

$$W = W_{ex} + W_{an}$$
$$= \tfrac{1}{2} JS^2 a \int_{-\infty}^{\infty} (\tfrac{d\theta}{dx})^2 dx + \tfrac{DS^2}{a} \int_{-\infty}^{\infty} (1 - \cos^2 \theta) dx$$

where W_{ex} and W_{an} are the exchange interaction and anisotropic energy respectively.
[di mana W_{ex} dan W_{an} ialah tenaga interaksi penukaran (exchange interaction) dan tenaga anisotopi masing-masing.]

(a) Explain the meanings of exchange interaction and anisotropic energy respectively in the domain wall energy.

(40/100)

(b) Given that θ (x) is the angle of inclination of spin to the z-axis at position x (refer to figure 2), determine the function θ (x) such that the total domain energy, W is minimum.
[Diketahui θ (x) ialah sudut condong spin pada kedudukan x kepada paksi-z (rujuk rajah 2), tentukan fungsi θ (x) supaya jumlah tenaga dinding domain, W ialah minimum.]

(60/100)

5. (a) Superconductivity is described as a macroscopic quantum phenomenon. Give accounts of the flux quantization experiments in both conventional and high-T_C materials that support this statement.
[Kesuperkonduksian dihuraikan sebagai suatu fenomenon kuantum makroskopik. Berikan penjelasan tentang eksperimen-eksperiment pengkuantuman fluks bagi bahan superkonduksi lazim dan bahan T_C tinggi untuk menyokong kenyataan ini.]

(40/100)

(b) Use the idea of macroscopic quantization to describe the mixed sate of type II superconductors and explain the distinction between reversible and irreversible materials.
[*Gunakan idea pengkuantuman makroskopik untuk menghuraikan keadaan bercampur dalam superkonduktor jenis II dan terangkan perbezaan antara bahan berbalik dengan bahan tak berbalik.*]

(30/100)

(c) Describe briefly an application of type II superconductors.
[Huraikan secara ringkas satu aplikasi *superkonduktor jenis II.*]

(30/100)

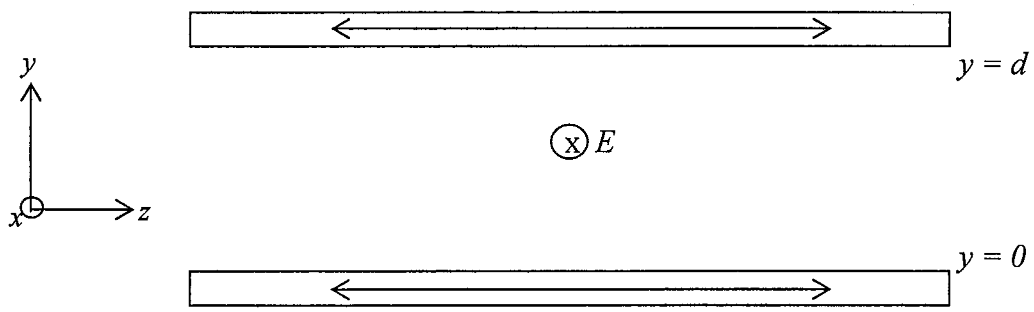

Fig.1 [*Rajah* 1]

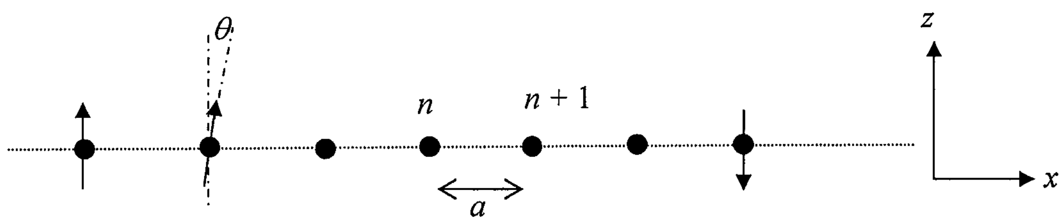

Fig. 2 [*Rajah* 2]

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