TERJEMAHAN

UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Kedua
Sidang Akademik 1996/97

April 1997

ZCC 542/4 - Teori Keadaan Pepejal II

Masa: [3 jam]

Sila pastikan bahawa kertas peperiksaan ini mengandungi EMPAT muka surat yang bercetak sebelum anda memulakan peperiksaan ini.

Jawab mana-mana EMPAT soalan. Calon-calon boleh memilih menjawab kesemua soalan dalam Bahasa Malaysia. Jika calon-calon memilih untuk menjawab dalam Bahasa Inggeris, sekurangnya satu soalan wajib dijawab dalam Bahasa Malaysia.

1. Write down Maxwell's equations for (a) vacuum electrodynamics and (b) the electrodynamics of a solid. Discuss the status of each set of equations and explain how the set (b) is related to the set (a). *(20/100)*

   It is common to discuss electrodynamics for a *linear isotropic* medium. Explain what properties are required in the medium or what approximation is made to justify the terms *linear* and *isotropic*. *(20/100)*

   Describe qualitatively the phenomenon of screening in a metal. *(20/100)*

   The Thomas-Fermi analysis gives for the potential due to a point charge q in a metal

$$\phi(r) = \frac{q}{4\pi\varepsilon_0 r}\exp(-r/r_s)$$

   where r_s is proportional to $n_0^{-1/6}$ and n_0 is the carrier density. Draw sketches of $\phi(r)$ versus r for various r_s and hence explain why r_s is called the screening length. *(20/100)*

   Explain the significance of screening for free-electron band theory. *(20/100)*

2. Explain with suitable sketches the distinction between soft and hard ferromagnetic materials and review briefly the main applications of these two classes. *(30/100)*

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Explain what is meant by easy and hard directions in a single crystal of magnetic material. *(10/100)*

Write an account of domains in ferromagnets. Include in your account a description of techniques for imaging domain patterns, the nature of domain walls and the relation between domain walls and hysteresis loops. *(60/100)*

3. Explain the operation of an inductive read head in magnetic recording. *(25/100)*

Draw a sketch to show the magnetic field dependence of the resistivity of a soft magnetic material like permalloy. Use this sketch to explain the principle of a magnetoresistive read head. Why is magnetic-field biassing of the head material necessary? *(25/100)*

The exchange coupling between two thin films of Fe separated by a thin film of Cr may be of either sign depending on the Cr thickness. Describe an experiment that illustrates this effect. *(25/100)*

Describe and explain the phenomenon of giant magnetoresistance in a Fe/Cr/Fe sandwich. *(25/100)*

4. Describe the nature of the phase transition to ferroelectricity for a simple one-dimensional two-sublattice model. *(10/100)*

Assuming that the transition is second-order, draw sketches to show the temperature dependence of (a) the specific heat, (b) the dielectric constant and (c) the spontaneous polarization P_S. *(20/100)*

The Landau free energy describing such a phase transition is

$$F = \alpha P^2 + \frac{1}{2}\beta P^4 \qquad \text{with} \quad \alpha = \alpha_0(T - T_C)$$

and α_0, β both positive. Explain with the aid of suitable sketches how the form of F corresponds to your description of the transition. Derive from F the expression for the temperature dependence of P_S. *(30/100)*

Write a brief account of the applications of ferroelectric materials. *(40/100)*

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5. Describe the Meissner effect in a Type I superconductor like Sn. Sketch magnetization curves to distinguish between Type I and Type II superconductors. *(25/100)*

Superconductivity is described as a macroscopic quantum phenomenon. Give an account of the flux quantization experiments in both conventional and high-T_C materials that support this statement. *(25/100)*

Use the idea of macroscopic quantization to describe the mixed state of Type II superconductors and explain the distinction between reversible and irreversible materials. *(25/100)*

Why are irreversible materials used in solenoid windings? Explain why solenoid wires are protected against flux-jump instabilities by a copper sheath and explain how the protection works. *(25/100)*

6. As shown in Fig. 1, a nematic liquid crystal is held in a cell between plates at $y = 0$ and $y = d$ with strong pinning on the director at the plates. An electric field is applied perpendicular to the pinning direction. The free energy is

$$F = \int_0^d [\frac{1}{2}K(\frac{d\theta}{dy})^2 - \frac{1}{2}\chi E^2 \sin^2\theta]dy$$

where θ is the angle of the director from the plane of the paper.

Explain the physical origins of the two terms in the integrand. *(10/100)*

Describe the Fredericks transition that occurs as E is increased. *(15/100)*

Write down the Euler-Lagrange equation for the director profile $\theta(y)$. Multiply the equation by $d\theta/dy$ and hence find a first integral. Noting that the symmetry of the cell means that $d\theta/dy = 0$ for $y = d/2$, show that the first integral gives the following equation for $\theta(y)$:

$$K\left(\frac{d\theta}{dy}\right)^2 = \chi E^2(\sin^2\theta_0 - \sin^2\theta)$$

where θ_0 is the value of θ at $y = d/2$. *(25/100)*

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Just above the Fredericks transition both θ_0 and $\theta(y)$ are small so that the sin functions can be replaced by their arguments. Make this substitution and evaluate the necessary integrals to prove that the critical field E_C for the Fredericks transition is

$$E_C = \frac{\pi}{d}\left(\frac{K}{\chi}\right)^{1/2}$$ *(25/100)*

Sketch a twisted-nematic display cell and explain the rôle of the Fredericks transition in the operation of the cell. *(25/100)*

You may use the result

$$\int_0^1 \frac{dx}{(1-x^2)^{1/2}} = \frac{\pi}{2}$$

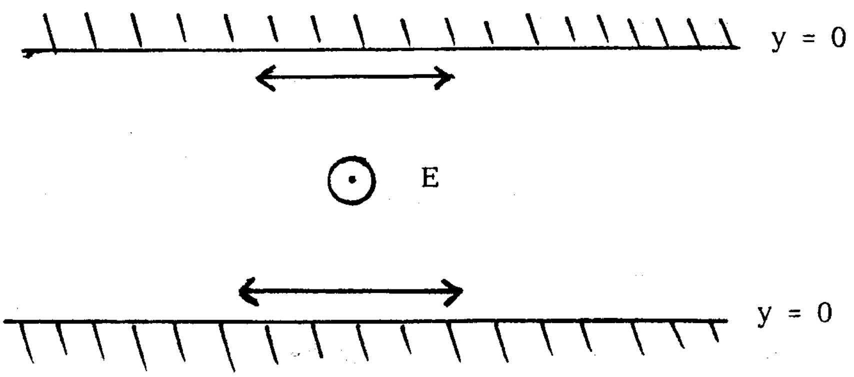

Figure 1.

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