NATIONAL UNIVERSITY OF SINGAPORE

PC4240 Solid State Physics (II)

(Semester II: AY 2013-14)

Time Allowed: 2 Hours

INSTRUCTIONS TO STUDENTS

1. This assessment paper contains **3** questions and comprises **4** printed pages.
2. Students are required to answer **all 3** questions.
3. Students should write the answers for each question on a new page.
4. This is a CLOSED BOOK examination.
5. One Help Sheet (A4 size, one side) is allowed for this examination.
6. A book of constants is provided.
7. Programmable calculators are not allowed.
8. Please write your student number only. Do not write your name.

1 (a) The dielectric function $\varepsilon(\omega)$ is a complex number: $\varepsilon=\varepsilon_1+i\varepsilon_2$. Sketch both the real and imaginary curves to describe their general behaviour as a function of ω for a damped oscillator with resonance frequency ω_0, static dielectric function $\varepsilon(0)$,asymptotic dielectric function $\varepsilon(\infty)$ and damping constant Υ . In your graph, the positions of ω_0, $\varepsilon(0)$, $\varepsilon(\infty)$,bulk plasma frequency ω_p, surface plasma frequency ω_s and their corresponding values of ε and Υ have to be indicated clearly. [6marks]

(b)Discuss two difficulties that may be encountered in coupling of light and plasmons and suggest two ways to overcome them. [8 marks]

(c) (i) Sketch and explain the $\varepsilon(\omega)$ curve for a plasma versus frequency in units of the plasma frequency. (ii)Sketch and explain the $\varepsilon(\omega)$ for a polariton versus frequency in units of the transverse optical phonon frequency ω_T for $\varepsilon(\infty)=3$, $\varepsilon(0)=4$. (iii) Comment on their similarity. [8marks]

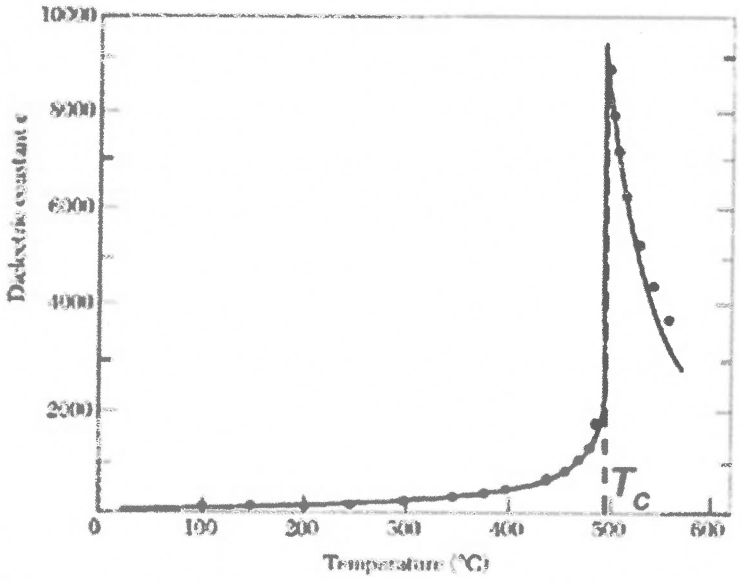
(d) An organic conductor has $\omega_p=2\times10^{15}$ s^{-1}. The relaxation time of the conductor is 3×10^{-15}s. Calculate the conductivity from these two data. [6marks]

(e) Using Mott metal-insulator transition theory, explain why a heavily doped semiconductor transits into a metallic phase. [6marks]

2 (a) Discuss the expression of eigenfunction used in (i) the central equation model; (ii) the tight binding model and state in what condition to use them. (iii) Show that they are Bloch functions. [12marks]

(b) Discuss, with the aid of equations, the helpfulness of using rotating frame in resonant experiments. How can the spin echo be used to overcome the problem of magnetic field inhomogeneity in the sample? [10 marks]

(c) The Figure below show the behaviour of temperature dependence of the dielectric constant ε(T) for a dielectric with first order phase transition, where T_c=492^{0}C and T_0=449^{0}C. Starting from the Landau free energy density expansion for the first order phase transition up to the 6th order term, derive the expression for the dielectric constant for the case of (i) T>Tc and (ii) at T=Tc by assuming $g_6(T_c)=\frac{3|g_4|}{4P_s^2}$. (iii) Comment on the consistency of your expressions with the data in the figure around the transition. [11 marks]



3 (a) Sketch and label energy diagrams to explain the energy level splitting in a magnetic field for each of the following cases: (i) electron spin; (ii) electrons in atoms; (iii)free electron gas. [6 marks]

(b) (i) Explain with the aid of equations on how a London equation $\nabla \times j = -\frac{c}{4\pi\lambda_L^2} B$ explains the Meissner effect. (ii) Given that $\frac{\partial j}{\partial t} = \frac{c^2 E}{4\pi\lambda_L^2}$ and $m\frac{dv}{dt} = qE$ for free carriers of charge q and mass m, show that $\lambda_L^2 = \frac{mc^2}{4\pi nq^2}$. [10marks]

(c) Discuss two different experimental methods for determining the critical temperature of a superconductor. [6marks]

(d) Starting from the expression of magnetization from Brillouin theory of paramagnetism, derive the expression of Neel temperature for the two-sublattice model of an antiferromagnetic in the mean field approximation. State clearly all approximation you make . [11 marks]

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