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SARDAR PATEL UNIVERSITY

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M. Sc. (Physics) 4th Semester Examination

Wednesday, 6th April, 2016

Time: 02:30 pm to 05:30 pm

Subject: PS04CPHY02 [Theoretical Solid State Physics]

Total Marks: 70

Note: (1) Figures to the right indicate marks.
(2) Symbols have their traditional meaning.

Q:1 **Attempt all of the following Multiple choice type questions. [01 mark each]** [08]

(1) When one includes relaxation time for scattering, frequency dependent dielectric function is given by

(a) $\left(1-\frac{\omega_p^2}{\omega}\right)\frac{1}{\left(\omega+i/\tau\right)}$

(b) $\left(\frac{\omega_p^2}{\omega}\right)\frac{1}{\left(\omega+i/\tau\right)}$

(c) $\left(1-\frac{\omega_p^2}{\omega^2}\right)\frac{1}{\left(\omega+i/\tau\right)}$

(d) $\left(1-\frac{\omega_p}{\omega}\right)\frac{1}{\left(\omega+i/\tau\right)}$

(2) Radius of the Fermi sphere in k-space is given by

(a) $\left(3\pi^2 n/a^3\right)^{1/2}$

(b) $\left(3\pi^2 n/a^2\right)^{1/3}$

(c) $\left(3\pi^2 n/a^2\right)^{1/2}$

(d) $\left(3\pi^2 n/a^3\right)^{1/3}$

(3) In OPW method the electron wave function outside a ion core is assumed to be a

(a) tightly bound
(b) plane wave
(c) orthogonalized plane wave
(d) highly oscillating wave

(4) Under the free electron approximation the E versus k curve is

(a) constant
(b) parbolic
(c) plane wave
(d) highly oscillating

(5) For a spherical Fermi surface for a free electron case, the velocity of an electron is

(a) $v=\hbar^2k^2/m_0$

(b) $v=\left(\hbar k/m_0\right)^2$

(c) $v=\left(\hbar k/m_0\right)^{1/2}$

(d) $v=\hbar k/m_0$

(6) The classical Debye-Huckel screening length is proportional to…

(a) $\left(\frac{N_0e^2}{T}\right)^2$

(b) $\left(\frac{N_0e^2}{T}\right)^{1/2}$

(c) $\left(\frac{N_0e^2}{T}\right)^{1}$

(d) $\left(\frac{N_0e^2}{T}\right)^{-1/2}$

(7) The transition temperature varies with average isotopic mass as

(a) $T_c \propto M^{-1/2}$ (c) $T_c \propto M^{-1/3}$

(b) $T_c \propto M^{-2}$ (d) $T_c \propto M^{1/2}$

(8) The London penetration depth _____ with temperature.

(a) decreases (c) increases

(b) remains constant (d) levels off

Q:2 **Answer any 7 of the following 9 questions briefly. [02 marks each]** [14]

1 What is Umklapp process?
2 Draw graphs of effective mass, energy, first order and second order derivative of energy as a function of wave vector k.
3 Explain how Brillouin zones are drawn with the help of suitable diagrams.
4 With the help of a suitable diagram show how solids are classified into conductors, semi-conductors and insulators.
5 What is dHvA effect?
6 List the methods used to experimentally find the Fermi surface.
7 Differentiate between type I and type II superconductors.
8 Explain energy gap at the Fermi level in the superconducting state.
9 What are Cooper pairs?

Q:3 (a) State and prove Bloch's theorem. [6]

(b) Write a detailed note on screened Coulomb potential. [6]

OR

(b) Formulate the Kronig-Penney model and establish the relation $P\frac{\sin(\alpha a)}{\alpha a} + \cos(\alpha a) = \cos(ka)$. [6]

Q:4 (a) Explain the empty lattice method of band structure calculation. What are the drawbacks of this method? [6]

(b) Explain the plane wave method of band structure calculation. [6]

OR

(b) Explain the tight binding method of energy band calculation. [6]

Q:5 (a) Write a note on effect of magnetic field on Fermi surface. [6]

(b) Write a note on quantization of electron orbits and show that the radius of the nth orbit is $r_n = \left[\frac{2\hbar}{m_o\omega_c}\left(n + \frac{1}{2}\right)\right]^{1/2}$ [6]

OR

(b) Derive Hamiltonian for interacting electron gas in terms of density [6]

Q:6 (a) Explain the Meissner effect and prove that superconductivity is diamagnetism of a different kind. [6]

(b) Discuss various thermodynamic properties of a superconductor. Prove that normal to superconducting phase transition is a second order phase transition. [6]

OR

(b) Write notes on (i) BCS ground state and (ii) Fullerenes. [6]

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