NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHYSICS DEPARTMENT

SPH 2208 - SOLID STATE PHYSICS I

BSC HONOURS PART II: MAY 2002 DURATION: 3 HOURS

ANSWER ALL PARTS OF QUESTION 1-IN SECTION A AND ANY THREE QUESTIONS FROM SECTION B. SECTION A CARRIES 40 MARKS AND SECTION B CARRIES 60 MARKS.

SECTION A

1. Answer the following questions clearly and concisely.

(a) Define the following terms

(i) Dispersion curve [2]
(ii) Symmetry operation [2]
(iii) Brillouin zone [2]
(iv) Madelung Energy [2]
(v) Fermi Energy [2]

(b) Draw the following planes and directions in a simple cubic cell:
(112) (200) [101] and [201] [4]

(c) Classify metals, semiconductors and insulators on the basis of their band structure. [6]

(d) The total energy for a Van der Waals bonded solid is given by the expression:

$$E = -A/r^6 + B\exp(-r/\rho)$$

(i) Define all terms in the above equation [3]
(ii) Sketch a graph to show both the attractive and repulsive terms, which result in a stable bond. [4]

(e) An x-ray powder photograph of a cubic substance taken with x-rays of $\lambda = 1.542\,\mathring{A}$ has spots at Bragg angles of 12.3°, 14.1°, 20.2°, 24.0°, 25.1°, 29.3°, 32.2°, and 33.1° with the cube edge $a = 6.30\,\mathring{A}$ assign miller indices to any two of these spots. [6]

(f) Discuss the contribution of the conduction electrons to the specific heat capacity of metals at room temperature, and at very low temperature. [5]

(g) State the failures of the classical free electron theory of solids. [2]

SECTION B

2. (a) Write brief notes on the following bond types
   (i) Van der Waals or Molecular bond [5]
   (ii) Ionic bond [5]
   (iii) Covalent bond [5]
   (iv) Metallic bond [5]

3. (a) Describe the Debye-Scherrrer method and briefly describe its uses. [10]

   (b) The $\sin^2\theta$ values as obtained from a powdered diffraction pattern of an element are as follows:

0.1063	0.1418	0.2836	0.3899
0.4254	0.5672	0.6735	0.7090

   The wavelength of the radiation used is $1.54\,\mathring{A}$

   (i) Determine the lattice parameter [3]
   (ii) Index the lines of the patterns [3]
   (ii) What is the Bravaais lattice of the structure? [1]

   (c) Explain briefly the factors that affect the intensity of the scattered radiation in crystal structure determination by diffraction. [5]

4. (a) Define the following terms
   (i) Lattice, [2]
   (ii) Basis, and [2]
   (iii) Crystal structure [2]

   (b) Show that for a cubic system with lattice parameter a, the distance between parallel planes d_{hkl} with miller indices (hkl) is given by

$$\frac{1}{d_{hkl}{}^2} = \frac{h^2 + k^2 + l^2}{a^2}$$

[6]

   (c) What is the difference between a primitive cell and conventional unit cell [2]

(d) Suppose identical solid spheres (representing atomic species) are distributed in space such that their centers coincide with the points of hexagonal close packed (HCP) lattice.

(i) Draw the HCP structure and determine the number of atoms per unit cell. [3]

(ii) Hence, calculate the packing fraction for the structure. [3]
[Take c/a = 1.63]

5. (a) Define any four elementary excitations in solids [8]

(b) State the law of Dulong and Petit and compare it with experimental results for the heat capacity for metallic solids. [5]

(c) Using the ideal electron gas model derive the expression for the electrical conductivity of metals. [7]

(w)

6. (a) With the aid of the sketches of *dispersion curves* highlight the fundamental differences between the quantum free electron theory and the band theory for solids. [5]

(b) How does band theory allow us to appreciate the principal forms of condensed matter, i.e. insulators, semiconductors and metals? [5]

(c) Explain how the Quantum free electron theory expalins the classical heat capacity paradox. [5]

(d) Write down the expression for the Fermi – Dirac distribution function for electrons in a solid. Sketch the Fermi – Dirac distribution as a function of the energy of electrons for $T = 0\,K$ and $T > 0\,K$ [5]

- END OF PAPER -

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