PHE-13

BACHELOR OF SCIENCE (B.Sc.)

Term-End Examination

December, 2005

PHYSICS

PHE-13 : PHYSICS OF SOLIDS

Time : 2 hours *Maximum Marks : 50*

Note : ***All*** *questions are compulsory. You may use log tables or calculators. Symbols have their usual meanings. The values of physical constants are given at the end.*

1. Attempt any ***five*** parts : $5 \times 3 = 15$

(a) Write the unit cell characteristics of monoclinic, orthorhombic and hexagonal crystal systems.

(b) The Miller indices of a plane are (201). Determine the direction and magnitude of the reciprocal lattice vector representing this plane.

(c) Differentiate between ionic and metallic bondings. Which of the two is stronger, and why ?

(d) Write the differential equation of motion of a chain of N identical atoms of mass m held together by elastic springs. What is implied by the harmonic approximation made to solve this equation ?

(e) State the difference between random thermal velocity and drift velocity of electrons in a metal. Which of the two is responsible for electrical conduction, and how ?

(f) Specifying various energy levels, draw the energy band diagram of an n-type semiconductor.

(g) Draw the alignment of spin vectors associated with atoms of ferromagnetic materials, antiferromagnetic materials and ferrites.

(h) What do you understand by crystal defects ? Explain substitutional and Schottky defects.

2. Attempt any ***three*** parts : $3 \times 5 = 15$

(a) In a body-centred cubic crystal, the lattice points are occupied by spherical atoms each of radius r. If the lattice parameter of the crystal is 3 Å, calculate the free volume in its unit cell.

(b) The primitive translation vectors of a lattice are given by

$$\mathbf{a}_1 = 2\hat{\mathbf{i}} + \hat{\mathbf{j}}$$

$$\mathbf{a}_2 = 3\hat{\mathbf{i}} + 2\hat{\mathbf{k}}$$

$$\mathbf{a}_3 = -4\hat{\mathbf{k}}$$

Determine the primitive translation vectors of its reciprocal lattice.

(c) The Debye frequency for copper is $6{\cdot}55 \times 10^{12}$ s^{-1}. Calculate the molar heat capacity of copper at 10 K according to Debye theory.

(d) The relaxation time of conduction electrons in copper is $3{\cdot}5 \times 10^{-14}$ s. If an electric field of 3×10^{2} V m^{-1} is applied along the negative x-axis, calculate the increase in the x-component of the velocity of a conduction electron between two successive collisions.

(e) The gap width, E_g of an intrinsic semiconductor is 0·5 eV. If $m_h^* = 6\ m_e^*$, calculate the position of the Fermi level and density of electrons at 300 K. Take the effective density of states in the conduction band to be $1{\cdot}25 \times 10^{25}$ m^{-3}.

3. Attempt any ***two*** parts : *2×5=10*

(a) Explain the assumptions made in the Bragg formulation and Laue formulation of X-ray diffraction from crystals. Determine the geometric structure factor for a bcc crystal.

(b) Starting with the concept of elastic energy density, determine the number of independent elastic constants required to study the elastic properties of the most anisotropic crystal.

(c) Write the equation of motion for longitudinal vibrations in a one-dimensional chain of equidistant atoms in which alternate atoms have different masses. Show that for a given value of the wave number, we get two positive values of the angular frequency of vibrations.

4. Attempt any ***two*** parts : *2×5=10*

(a) Show that, for the Kronig – Penney model, an electron moving in 1-D periodic potential must satisfy the following condition :

$$P \frac{\sin \alpha a}{\alpha a} + \cos \alpha a = \cos ka$$

(b) Explain the classification of polymers on the basis of mechanism of polymerization, giving suitable examples.

(c) How does a thin film differ from the bulk material ? Discuss the optical and mechanical properties of thin films and state one application of each of these properties.

Physical Constants :

$k_B = 1{\cdot}38 \times 10^{-23}$ J K^{-1}

$N_A = 6{\cdot}02 \times 10^{23}$ mol^{-1}

$h = 6{\cdot}62 \times 10^{-34}$ Js

$e = 1{\cdot}6 \times 10^{-19}$ C

$R = 8{\cdot}31 \times 10^{3}$ J K^{-1} kmol^{-1}

$m_e = 9{\cdot}1 \times 10^{-31}$ kg