UNIVERSITY OF FORT HARE

University of Fort Hare
Together in Excellence

SOLID STATE PHYSICS

(PHY 522)

HONOURS EXAMINATIONS

DATE: October/November 2017

DURATION: 3 HOURS

MARKS: 100

INTERNAL EXAMINER

Dr N.L. Nwokolo

EXTERNAL EXAMINER

Prof S. Chiwembani

INSTRUCTION FOR CANDIDATES

Answer all questions

QUESTION 1 (20MARKS)

1.1 Describe three common crystal structures you Know and provide two elements each that possess the described crystal structures. (6marks)

1.2 Determine the interplanar spacing corresponding to the three low index planes ratio $d_{100} : d_{110} : d_{111}$ for body centered cubic (Bcc) lattice. (7marks)

1.3 Calculate the atomic density in (100), (110) and (111) planes of copper (fcc) with the lattice parameter of 3.61 $\mathring{A}$. (7marks)

QUESTION 2 (20MARKS)

2.1 If the velocity of sound in a solid is of the order 10^3m/s, compare the frequency of the sound wave $\lambda = 10\,\mathring{A}$ for (i) a monatomic system, and (ii) acoustic waves and optical waves in a diatomic system containing two identical atoms (M=m) per unit cell of interatomic spacing 2.5 $\mathring{A}$. (7marks)

2.2 The unit cell of NaCl is a cube of side 5.6 $\mathring{A}$ and the Young's modulus in a [100] direction is 5 X 10^{10}Nm^{-2}. Estimate the wavelength at which the electromagnetic radiation is strongly reflected by crystal (At. wts. Na =23, Cl = 37). (7marks)

2.3 If the potential difference across an X-ray tube is 6000 volt and the current through it is 2.5 mA, calculate the number of electrons striking the target per second and the speed at which they strike. Also calculate the shortest wavelength of X-rays produced (e = 1.6 X 10^{-19}C and m_e = 9.11 X 10^{-31}). (6marks)

QUESTION 3 (20MARKS)

3.1 The intensity of the transmitted beam in X-rays is less than that of the incident beam, Derive an expression for the intensity (I) of transmitted beam through a material of unit cross sectional area due to scattering in terms of linear attenuation coefficient (μ) and thickness of absorbing material (x). (8marks)

3.2 A beam of X-rays consist of equal intensities of wavelengths 0.064 Å and 0.098 Å. When they pass through a piece of lead, their attenuated beam intensity are in the ratio3:1. The mass absorption coefficients are 0.164m^2/kg for the harder component and 0.35m^2/kg for the softer component. If the density of the lead is 11340kg/m^3, calculate the thickness of the lead piece. (6marks)

3.3 Determine the angle through which an X-ray of wavelength 0.440 Å be reflected from the cube face of a rock salt crystal for n_1 to n_4 order of reflection (d=2.814 Å). (6marks)

QUESTION 4 (20MARKS)

4.1 In a Laue photograph of an fcc crystal whose lattice parameter is 4.5 Å. Determine the minimum distance from the centre of the pattern at which reflections can occur from the planes of maximum spacing, if the potential difference across the X-ray tube is 50kV and the crystal to film distance is 5.0cm. (7marks)

4.2 A beam of thermal neutrons emitted from the opening of a reactor is diffracted by the (111) planes of nickel crystal at an angle of 28° 30'. Calculate the effective temperature of the neutrons. Nickel has fcc structure and its lattice parameter is 3.52 Å (d_{111} for fcc = $a/\sqrt{3}$, mass of neutron = 1.67 X 10^{-27} kg, Planck's constant h = 6.626 X 10^{-34} m^2kg/s, Boltzmann's constant k = 1.38 X 10^{-24} m^2kg/s^2K). (6marks)

4.3 In a rotation photograph, six layer lines are observed both above and below the zero layer line. If the heights of these layer lines above (or below) the zero layer are 0.29, 0.59, 0.91, 1.25, obtain the cell height of the crystal along the axis of rotation. The radius of the camera is 3cm and the wavelength of the X-rays is 1.54 Å. (7marks)

QUESTION 5 (20MARKS)

5.1 The Debye temperature for diamond is 2230K. Calculate the highest possible vibrational frequency and molar heat capacity of diamond at 10K (Planck's constant h = 6.626 X 10^{-34} m^2kg/s, Boltzmann's constant k = 1.38 X 10^{-24} m^2kg/s^2K). (5marks)

5.2 While silver metal obeys the Dulong-Petit law at room temperature, the diamond does not, explain. (7marks)

5.3 At low temperatures, the specific heat of rock salt varies with the temperature according to Debye T^3 law:

$$[C_v]_l = A\left(\frac{T}{\theta_D}\right)^3$$

Where A = 464 $calgmol^{-1}K^{-1}$ and ϑ_D = 281K. How much heat is required to raise the temperature of 2 gmol of rock salt from 10 to 50K? (8marks)