UNIVERSITY OF FORT HARE

University of Fort Hare
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SOLID STATE PHYSICS

(PHY 522)

<u>HONOURS EXAMINATIONS</u>

DATE:	**November 2018**
DURATION:	**3 HOURS**
MARKS:	**100**

INTERNAL EXAMINER

Dr N.L. Nwokolo

EXTERNAL EXAMINER

Prof S. Chikwembani

INSTRUCTION FOR CANDIDATES

Answer all questions

Constants

Planck's constant – 6.626×10^{-34} kg m^2/s, Boltzmann Constant – 1.38×10^{-23} kg m^2 /Ks, Avogadro's constant – 6.022×10^{23} mol^{-1}

QUESTION ONE (25 MARKS)

1.1 With the aid of a diagram describe how X-rays are generated in an x-ray tube and provide three properties of such x-rays. (10marks)

1.2 How much aluminum is required to reduce the intensity of a 200keV x-ray beam to 10% of its incident intensity? Assume that the half value layer for 200keV x-rays in aluminum is 0.0214m. (6marks)

1.3 What element has a K_α x-ray line of wavelength 0.7185 $\mathring{A}$ ($m_e = 9.11 \times 10^{-31}$ kg, e = 1.602×10^{-19}C, h = 6.626×10^{-34} m^2kg/s, $\varepsilon_0 = 8.85 \times 10^{-12}$ m^{-3} kg^{-1} s^4A^2, C = 3 X10^8 m/s). (9marks)

QUESTION TWO (25MARKS)

2.1 Show that the intensity of an x-ray beam passing through a given material decreases exponentially and is given by the expression: (7marks)

$$I = I_o \exp(-\mu x)$$

2.2 Derive the expressions showing the equivalence of Bragg and Laue Equations assuming a simple cubic lattice and the angle between the incident beam and diffracted beam to be 2θ. (10marks)

2.3 Calculate the atomic packing fraction for a simple cubic, body centered cubic and face centered cubic lattice systems. (8marks)

QUESTION THREE (25 MARKS)

3.1 The volume of the unit cell for a reciprocal lattice is inversely proportional to the corresponding direct lattice, prove that

$$(b_1 \cdot b_2 \times b_3) = \frac{1}{(a_1 \cdot a_2 \times a_3)}$$ (9marks)

3.2 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 28.5°. Calculate the effective temperature of the neutrons. Nickel has fcc structure and its lattice parameter is 3.52Å (mass of neutron = 1.67 X 10^{-27} kg) (7marks)

3.3 Show that the reciprocal lattice vectors of a FCC lattice is equivalent to the translation vectors of a BCC lattice given the translation vector of FCC to be

$$a_1 = \frac{a}{2}\left(\hat{j}+\hat{k}\right),\ a_2 = \frac{a}{2}(\hat{k}+\hat{i}),\ a_3 = \frac{a}{2}(\hat{i}+\hat{j}) \qquad \text{(9marks)}$$

QUESTION FOUR (25MARKS)

4.1 Show that at low temperature, the Einstein Specific heat of solids is given as shown in the below equation: Where hv>> kT, x = hv/kT and e^x >> 1.

$$C_v = 3Nk\left(\frac{hv}{kT}\right)\ \exp\left(-\frac{hv}{kT}\right) \qquad \text{(10marks)}$$

4.2 The Debye temperature for diamond is 2230K. Calculate the highest possible vibrational frequency and the molar heat capacity of diamond at 10K (h = 6.626 x 10^{-34}Js, k = 1.38 x $10^{-23}$$JK^{-1}$, R = 8.314J/mol.K) (7marks)

4.3 Estimate the Debye temperature of gold if its atomic weight is 197, the density is 1.9 x 10^4 kg/m^3 and velocity of sound in it is 2100 m/s. (8marks)