UNIVERSITY OF FORT HARE

University of Fort Hare
Together in Excellence

INTRODUCTORY TO SOLID STATE PHYSICS
[PHY 512]

HONOURS EXAMINATIONS

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DURATION: 3 HOURS

MARKS: 100

THIS PAPER CONSISTS OF **THREE** PAGES INCLUDING THE COVER PAGE

INTERNAL EXAMINER

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INSTRUCTION FOR CANDIDATES

ANSWER ALL QUESTIONS

QUESTION 1 [25]

1.1. Calculate the lattice constant for a rock salt crystal (density of NaCl = 2 180 kg/m^3 and at molar weight = 58.5), assuming it has a **fcc** lattice. The Avogadro's number, $N = 6.023 \times 10^{26}$. [8]

1.2. Calculate the **miller indices** for the plane with intercepts 2a, - 3b and 4c along the crystallographic axes. [7]

1.3. Sketch a cubic unit cell and in it show the following planes: (111) and (210). [10]

QUESTION 2 [25]

2.1. Show that the interplanar (d_{hkl}) of a tetragonal system is given by:

$$d_{hkl} = \left[\frac{h^2 + k^2}{a^2} + \frac{l^2}{a^2}\right]^{-\frac{1}{2}}$$ [8]

where symbols have their usual meanings.

2.2. What is the family of planes {hkl} with an interplanar spacing of d = 1.246 Å in Nickel (Ni) with **a** = 3.524 Å? [6]

2.3. Show that the angle between planes in a cubic system is given by:

$$Cos\phi = \frac{h_1h_2 + k_1k_2 + l_1l_2}{\sqrt{h_1^2 + k_1^2 + l_1^2}\sqrt{h_2^2 + k_2^2 + l_2^2}}$$ [7]

where symbols have their usual meanings

2.4. Calculate the angle between [101] and [100] directions in a cubic crystal. [4]

QUESTION 3 [25]

3.1. Calculate the atomic density (number of atoms per unit area) in (100), (110) and (111) for a body centred system. [8]

3.2. Show that the potential energy (cohesive energy) at equilibrium separation of an ionic solid such as **NaCl** is given by:

$$U_e = -\frac{Ae^2N}{4\pi\varepsilon_0 R_e} + \left(1 - \frac{\rho}{R_e}\right)$$ [7]

where symbols have their usual meanings.

Hence, deduce that: $\beta = \frac{Ae^2}{18R_e^4}\left(\frac{R_e}{\rho} - 2\right)$ [10]

Hint: $\beta = -V\left(\frac{dP}{dV}\right)$ and $\frac{1}{K} = \beta = -\left(\frac{dP}{dV}\right)$

QUESTION 4 [25]

4.1. The potential energy function for the force between two particular ions, carrying charges +e and –e respectively, is given by:

$$V = -\frac{Ae^2}{r^2} + \frac{B}{r^9}$$

4.1.1. Find the equilibrium separation distance for these ions. [6]

4.1.2. Find the potential energy at equilibrium separation. [6]

4.2. The potential energy of a diatomic molecule in terms of interatomic separation. R is given by:

$U(R) = -\frac{A}{R^2} + \frac{B}{R^{10}}$, where **A** and **B** are constants.

Calculate the values of the constants A and B when the equilibrium spacing R_e = 3Å and the dissociation energy is 4 eV. [7]

4.3. Show that the packing efficiency of a face centred cubic system is 74%. [6]
