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**GARISSA UNIVERSITY**

**UNIVERSITY EXAMINATION 2018/2019 ACADEMIC YEAR FOUR**

**SECOND SEMESTER EXAMINATION**

**SCHOOL OF BIOLOGICAL AND PHYSICAL SCIENCES**

**FOR THE DEGREE OF BACHELOR OF EDUCATION**

**COURSE CODE: PHY 419E**

**COURSE TITLE: SOLID STATE PHYSICS**

**EXAMINATION DURATION: 2 HOURS**

**DATE: 03/02/2020 TIME: 2.00-4.00 PM**

**INSTRUCTION TO CANDIDATES**

* **The examination has FIVE (5) questions**
* **Question ONE (1) is COMPULSORY**
* **Choose any other TWO (2) questions from the remaining FOUR (4) questions**
* **Use sketch diagrams to illustrate your answer whenever necessary**
* **Do not carry mobile phones or any other written materials in examination room**
* **Do not write on this paper**

**This paper consists of FIVE (5) printed pages *please turn over***

**QUESTION ONE (COMPULSORY)**

1. Briefly the following terms as used in solid state physics **(2mrks each)**
2. Bravais Lattice
3. Basis
4. Primitive Lattice Vectors
5. Wigner-Seitz Cell
6. Face Centered Cubic (FCC) Lattice
7. Body Centered Cubic (BCC) Lattice
8. Briefly Discuss the reasons that a periodic lattice with a five-fold symmetry axis cannot exist **(4mrks)**
9. Briefly Define the Miller indices of a lattice plane. **(4mrks)**
10. Crystalline solids are often considered in terms of the 4 idealized bonding categories listed below Yet, for each of these 4 kinds of bonding, it is the electrostatic Coulomb interaction that provides the attractive force. For each of the types of idealized bonding listed below and by considering only outer valence electrons of the atoms, discuss how the Coulomb force is operating in each case. That is, discuss the Physical Mechanisms which are primarily responsible for the bonding energy each of these kinds of solids. **(3mrks each)**
11. Ionic Bonding
12. Covalent Bonding
13. Metallic Bonding
14. Van der Waals Bonding

**QUESTION TWO**

1. What do you understand the following terms as used in solid state physics **(2mrks each)**
2. Reciprocal Lattice
3. Brillouin Zone
4. Structure Factor
5. Atomic Form Factor
6. Bragg’s Law of Diffraction
7. Laue Condition (Laue Equations)
8. Briefly Discuss the Physics underlying Bragg’s Law of Diffraction **(5mrks)**
9. Briefly Explain the reasons that the Bragg Law is equivalent to the Laue Condition (Laue Equations) **(3mrks)**

**QUESTION THREE**

1. Consider a crystal with the simple cubic (SC) lattice structure. The primitive lattice vectors are a1 = a i, a2 = a j, a3 = a k, where a is the lattice constant and i, j, k are the usual unit vectors for a Cartesian coordinate system. Prove that the reciprocal lattice is simple cubic also **(5mrks)**
2. Find separation between closest parallel planes of the lattice which have Miller indexes (1,1,0). Compare this separation with the length of the vector K = [1,1,0] in the reciprocal lattice **(5mrks)**
3. What is orientation of the vector K = [1,1,0] of the reciprocal lattice with respect to the plane (1,1,0) in the direct lattice? **(5mrks)**
4. Write two relations between the orientation and length of a general vector [k,l,m] of the reciprocal lattice and the orientation and the separation of the planes with the Miller indexes (k,l,m) in the direct lattice **(5mrks)**

**QUESTION FOUR**

The vectors of the primitive fcc unit cell connect a lattice point at the origin with lattice points at the center of the adjacent of cube faces.

1. Write these vectors in standard Miller notation and calculate the angle between any two of them **(10mrks)**
2. Prove that the volume of the fcc primitive cell is one quarter of the volume of the conventional cell **(10mrks)**

**QUESTION FIVE**

A quantitative model of bonding in ionic crystals was developed in the 1930’s by Born and Meyer. In this model, the total potential energy of the system is assumed to have the form (in SI units):

$$U\_{tot}\left(R\right)=N\frac{A}{R^{n}}-N\frac{αe^{2}}{4πε\_{0}R}$$

Here, N is the number of positive-negative ion pairs, R is the nearest neighbor distance in the material, α is the Madelung constant for the material, A & n are adjustable empirical parameters to be fit to experimental data and ε0 is the permittivity of free space.

* 1. The first term in Utot is a repulsive interaction. Briefly discuss it’s physical origin. The second term in Utot is an attractive interaction. Briefly discuss it’s physical origin **(4mrks)**
	2. Sketch Utot potential as a function of R. Note: If you don’t do this, you will lose points **(4mrks)**
	3. Calculate the equilibrium nearest-neighbor distance R0 in terms of N, A, α and ε0. The equilibrium bonding energy per ion pair in this model is simply Utot(R0). By using the R0 you just obtained in the above equation for Utot find a simple expression for the equilibrium bonding energy per ion pair. (Hint: This should be independent of the parameter A.) **(7mrks)**
	4. For the ionic salt NaCl, the constant α = 1.75, R0 = 5.63 Å and the measured bonding

energy per ion pair is 7.95 eV. Use these numbers to estimate the value of the parameter n

for NaCl. [Note: (1/4πε0) = 9.0 × 109 Nm2/C2, 1.0 eV = 1.6 × 10-19 J, 1.0 A = 1.0 × 10-10 m] **(5mrks)**