MERU UNIVERSITY OF SCIENCE AND TECHNOLOGY

P.O. Box 972-60200 – Meru-Kenya.
Tel: +254(0) 799 529 958, +254(0) 799 529 959, +254 (0)712 524 293
Website: www.must.ac.ke Email: info@mucst.ac.ke

UNIVERSITY EXAMINATIONS 2022/2023

FOURTH YEAR, SECOND SEMESTER SPECIAL/SUPPLEMENTARY EXAMINATION FOR DEGREE OF BACHELOR OF SCIENCE IN MATHEMATICS AND PHYSICS AND BACHELOR OF EDUCATION SCIENCE

SPH 3407: SOLID STATE PHYSICS

DATE: AUGUST 2023 **TIME: 2 HOURS**

INSTRUCTIONS: Answer Question ONE and any other TWO questions.

QUESTION ONE (30 MARKS)

a) Crystalline solids are often considered in terms of the four idealized bonding categories. Yet for each of these kind of bonding, it is the electrostatic interaction that provides the attraction force. For each of the type of idealized bonding and considering only outer valence electrons of the atom, discuss how the coulomb force is operating in each case. (2 Marks)

   i. Ionic bonding
   ii. Covalent bonding
   iii. Metallic bonding
   iv. Van der waals bonding

b) Briefly define or explain the following in terms of crystal structure. (4 Marks)

   i. Bravais lattice
   ii. Primitive lattice vector
   iii. Face-centered cubic (FCC) lattice
   iv. Body-centered (BCC) lattice

c) Aluminum forms an FCC structure and has an atomic radius of 0.143 nm.

i. Calculate the lattice constant (4 Marks)

ii. Calculate the atomic packaging factor, APF (4 Marks)

d) State and explain

i. Reasons for energy gap formation (2 Marks)

ii. Concepts leading to Kroning-Penney Model (2 Marks)

e) i. What is "superconductivity" in condensed matter physics? (1 Mark)

f) Define or explain the following terms giving example of a material in each case.

i. Diamagnetism (2 Marks)

ii. Paramagnetism (2 Marks)

iii. Ferromagnetism (2 Marks)

g) i. What is Nuclear Magnetic Resonance (NMR) (1 Mark)

h) ii. How many possible orientation do spin ½ nucleus have when they are located in an applied magnetic field. (2 Marks)

i) iii. What happens when radiation energy is absorbed by spin ½ nucleus in a magnetic field. (1 Mark)

j) iv) What is the name given to relaxation process due to an interaction between an excited nucleus and magnetic fields caused in molecules moving around in the sample? (1 Mark)

QUESTION TWO (20 MARKS)

Consider the model one-dimensional monatomic chain **N** atoms, equally spaced with separation **a** and each with the same mass m. the force constant coupling each atom to its nearest-neighbors is **K** and that the normal mode vibrational frequency $\boldsymbol{\omega(k)}$of a mode with wavevector **k** for this model is:$\boldsymbol{m\omega^2 = 4Ksin^2\left(\frac{ka}{2}\right)}$ $[-(\boldsymbol{\pi/a}) \leq \boldsymbol{k} \leq (\boldsymbol{\pi/a})]$

a) Derive expressions for the group velocity $\mathbf{v_g}$ as function of **K**. (10 Marks)

b) Using the result of part (a), evaluate $\mathbf{v_g}$ at very small values of K(K→ 0). Briefly, discuss the physical significance of these low k group velocities. (5 Marks)

c) i. Using the results of part(a), evaluate $\mathbf{v_g}$ for **k** at the Brillouin zone boundary $[K = (\pi/a)]$. Briefly, discuss the physical significance of these Brillouin zone boundary group velocities. (4 Marks)

ii. Specifically, what do you say about propagation of longitudinal waves in this lattice at frequencies $\boldsymbol{w(k = \pi/a)}$ (1 Mark)

QUESTION THREE (20 MARKS)

a) Derive the reciprocal lattice vectors for the primitive and conventional unit cells of the FCC lattice. (10 Marks)

b) Calculate the length of the **[211]** vector, where the Miller indices are referred to the FCC primitive reciprocal lattice. Use this result to obtain the separation of the **(211)** planes in the primitive lattice. (10 Marks)

QUESTION FOUR (20 MARKS)

The vectors of a primitive BCC cell connect atoms at the vertices of the BCC with an atom in the cube center.

a) Write these vectors in standard Miller notation and calculate the angle between any two of them. (10 Marks)

b) Prove that the volume of the BCC primitive cell is half of the volume of the conventional cell. (10 Marks)