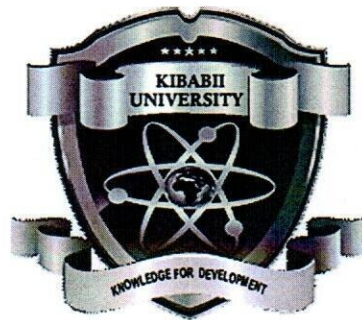


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KIBABII UNIVERSITY

**UNIVERSITY EXAMINATIONS
2022/2023 ACADEMIC YEAR**

**FIRST SEMESTER
MAIN EXAMINATIONS**

FOR THE DEGREE OF BACHELOR OF EDUCATION SCIENCE

COURSE CODE: SPH 417

COURSE TITLE: SOLID STATE PHYSICS

DURATION: 2 HOURS

DATE: 14/04/2023

TIME: 2:00-4:00PM

INSTRUCTIONS TO CANDIDATES

- Answer Question **one** and **any three** (3) Questions.
 - Indicate **answered questions** on the front cover.
- Start every question on a new page and make sure question's number is written on each page

This paper consists of **3** printed pages. Please Turn Over

KIBU observes ZERO tolerance to examination cheating

QUESTION ONE [30 Marks]

- a) Briefly explain how are X-rays produced [3Marks]
- b) Explain the terms Coordination number and Atomic packing factor as used in crystal structures [2Marks]
- c) A cubic lattice has a cube edge $a=2.665\text{\AA}$. Find the spacing of adjacent planes with the miller indices. i) (101) ii) $(\bar{2}01)$. [2Marks]
- d) Determine the relationship between the lattice parameter a and the atomic radius r for monoatomic, SC, BCC and FCC structures [1, 2, 2 Marks]
- e) State three differences between ionic compounds and covalent compounds. [3Marks]
- f) Write down two differences and similarities between classical and quantum free electron theories. [4Marks]
- g) The free electron density of Aluminium is $18.10 \times 10^{28} \text{ m}^{-3}$. Calculate its Fermi energy at 0 K. Planck's constant and mass of free electron are $6.626 \times 10^{-34} \text{ Js}$ and $9.1 \times 10^{-31} \text{ kg}$ respectively [4Marks]
- h) What is lattice vibration? What is its importance [3Marks]
- i) Explain the difference between acoustic modes and optical modes [4Marks]

QUESTION TWO [20 Marks]

- a) Show that 68% and 74 % of the available volume is occupied by hard spheres in contact in a Body-centered cubic and Face-centered cubic arrangement [6 Marks]
- b) Show that the inter planner spacing between to adjacent parallel planes of Miller indices (h k l) is given by, $d = d_2 - d_1 = \frac{a}{\sqrt{h^2+k^2+l^2}}$ [6 Marks]
- c) The density of Fe is $7.87 \times 10^3 \text{ kg/m}^3$. Atomic weight of Fe is 55.8. If Fe crystallizes in BCC space lattice, find lattice constant. Given Avogadro's number (N) = $6.02 \times 10^{26} / \text{kg/mole}$. [4 Marks]
- d) Aluminium has FCC structure. Its density is 2700 kg/m^3 . Find the unit cell dimensions and atomic diameter. Given that the weight of Al = 26.98 [4 Marks]

QUESTION THREE [20 Marks]

- a) Sketch a well labeled graph to show the variation of potential energy with atomic spacing [2 Marks]
- b) The potential energy of a system of two atoms is given by the relation;

$$U = -A/r^2 + B/r^{10}$$

A stable molecule is formed with the release of 8 eV of energy when the interatomic distance is 2.8\AA . Find A and B and the force needed to dissociate this molecule into atoms and the interatomic distance at which the dissociation occurs [8 Marks]

- c) Show that the energy required to dissociate two atoms of the molecule into an infinite separation is given by

$$U_{Min} = -\frac{a}{r_0^m} \left[1 - \frac{m}{n} \right] \quad [4 \text{ Marks}]$$

- d) Discuss the following secondary bonds on the basis of electric dipole-dipole interaction
- i) Van Der Waals Bond [3 Marks]
 - ii) Hydrogen Bond [3 Marks]

QUESTION FOUR [20 Marks]

- a) Describe an experimental procedure for finding the XRD pattern [8Marks]
- b) The following diffractometer data (expressed as 2θ) were generated from a specimen irradiated with silver (Ag) K_α radiation: 14.10° ; 19.98° ; 24.57° ; 28.41° ; 31.85° ; 34.98° ; 37.89° ; 40.61° .
 - i) Determine the crystal structure. [1Mark]
 - ii) Calculate the lattice constant, a. [2Marks]
 - iii) Assume that the crystal is a pure metal and on the basis of the hard-sphere approximation calculate the atomic radius. [3Marks]
 - iv) At what angle θ would we find the first reflection if, instead of K radiation, we used silver L radiation to illuminate the specimen? [6Marks]

QUESTION FVE [20 Marks]

- a) Discuss the merits of quantum free electron theory [6Marks]
- b) Show that the sum of the probability of occupancy of an energy state at ΔE above the Fermi level and that at ΔE below the Fermi level is unity. [8Marks]
- c) The Fermi level in potassium is 2.1 eV. What are the energies for which the probability of occupancy at 300 K are 0.99, 0.01 and 0.5? [6Marks]

Data for Question Three

Data Reduction of Diffractometer Experiment: incident x-ray $Ag_{K_\alpha} \rightarrow \lambda = 0.574 \text{ \AA}$

2θ	$\sin^2\theta$	normalize d	clear fractions	try again	hkl	$10^3 \frac{\sin^2 \theta}{h^2 + k^2 + l^2}$
14.10	0.0151	1.00	1	2	110	7.550
19.98	0.0301	1.99	2	4	200	7.525
24.54	0.0452	2.99	3	6	211	7.533
28.41	0.0602	3.99	4	8	220	7.525
31.85	0.0753	4.99	5	10	310	7.530
34.98	0.0903	5.98	6	12	222	7.525
37.89	0.1054	6.98	7	14	321	7.529
40.61	0.1204	7.97	8	16	400	7.525