KIBABII UNIVERSITY

UNIVERSITY EXAMINATIONS
2020/2021 ACADEMIC YEAR

THIRD YEAR FIRST SEMESTER
MAIN EXAMINATIONS

FOR THE DEGREE OF BSC (PURE PHYSICS)

COURSE CODE: SPC 311

COURSE TITLE: SOLID STATE PHYSICS

DURATION: 2 HOURS

DATE: 16/05/2022 **TIME: 2:00PM-4:00PM**

INSTRUCTIONS TO CANDIDATES

- Answer **QUESTION ONE** (Compulsory) and any other two (2) Questions.
- The following constants might be used: mass of electron= 9.1×10^{-31} kg; electronic charge=1.6×10^{-19} C; Planck's constant= 6.62×10^{-34} JS; atomic mass of Lithium= 1.152×10^{-26} kg; Boltzmann's constant =8.63×10^{-5} eV/k

QUESTION ONE [30 Marks]

a) Define crystal lattice. [2]
b) Give Bragg condition for direct lattice. [4]
c) Determine the number of atoms per unit cell for the face centered cubic cell [4]
d) Obtain an expression for interplanar spacing for simple cubic system. [4]
e) A beam of electrons with kinetic energy 1KeV is diffracted as it passes through a polycrystalline metal foil. The metal has a cubic crystal structure with a spacing of 1□.
i) Calculate the wavelength of the electrons [4]
ii) Calculate the Bragg angle for the first order diffraction maximum. [4]
f) Define a lattice plane (Crystal plane). [2]
g) Calculate the Miller indices of crystal planes which cut through the crystal axes at
i) (6a, 3b, 3c)
ii) (2a, -3b, -3c) [4]
h) Describe briefly the formation of an ionic bond. [2]

QUESTION TWO [20 Marks]

a) i) Define ionization energy and electron affinity. [2]
ii) Sketch (111) and (110) planes in simple cubic cell. [2]
iii) Determine the structure factor in a body centered cubic CsCl unit cell. [3]
b) Show that Laue and Bragg condition are equivalent. [5]
c) Calculate the distance between two lattice planes, which give first order diffraction at an angle of 26.4^0 with a wavelength 0.75□. [3]

d) Distinguish between Einstein's theory of specific heat of solids and Debye's theory and hence define Einstein temperature [5]

QUESTION THREE [20 Marks]

a) A beam of x-ray is incident on NaCl crystal whose lattice spacing is 2.82×10^{-10} m. The first order Bragg reflection is observed at gracing angle 8.5^0; What is the wavelength of x-rays? At what angle would second and third order Bragg reflection occur? [5]

b) The Bragg angle corresponding to the first order reflection from (111) planes in a crystal is 30^0 when x-rays of wavelength 1.75 □ are used. Calculate the interatomic spacing. [3]

c) Bragg found that KCl crystal strong reflection from set of planes (100), (110) and (111) are obtained for angles 5.38^0,7.62^0 and 9.41^0. Show that KCl crystal has a simple cubic structure. [4]

d) KCl is an example of an ionically bonded crystal for which the cohesive energy per ion pair may be written as

$U(r) = A\exp(\frac{-r}{\rho}) - \frac{\alpha Z^2}{4\pi\varepsilon_0 r^2}$, where r is the nearest neighbor distance, Z is the ionic charge.

I) Explain the origins of the two terms and the meaning of the symbols A, ρ and α. [4]

II) For a crystal of KCl, calculate the cohesive energy per ion pair relative to the separated neutral gas atoms, expressing your answer in units of eV. (For KCl, $A=2.05\times10^{-15}$. P=0.326□, r=3.147□, α=1.748, K has first ionization energy of 4.34 eV, Cl an electron affinity of 3.16 eV). [4]

QUESTION FOUR [20 Marks]

a) Which type of bonding is likely to be present in the following solids. Briefly explain the origins of the bonds.

I) Xenon (Xe) [2]

II) Cesium bromide (CsBr) [2]

III) Copper (Cu) [3]

IV) Silcon (Si) [2]

b) Calculate the mass density of Lithium (Li), which has a lattice parameter of 0.350nm. (Lithium has a bcc crystalline structure) [4]

c) Show that the atomic radius r a simple cubic crystal (sc) is given by r=a/2 and for a body centered cubic (bcc) crystal is given by $r = \frac{a\sqrt{3}}{4}$ where a is the lattice parameter. [7]

QUESTION FIVE [20 Marks]

a) Discuss the Drude's classical Free electron model of conduction in metals. [10]

b) The total energy of an ionic solid is given by an expression $E = \frac{-\alpha e^2}{4\pi\varepsilon_0 r} + \frac{B}{r^9}$ where α is the Madelung constant, r is the distance between the nearest neighbor in crystal and B is a constant. If r_0 is the equilibrium separation between the nearest neighbor, determine the value of B. [5]

c) Calculate the packing fraction of the body-centered cubic structure. [5]