CHUKA  **UNIVERSITY**

UNIVERSITY EXAMINATIONS

FOURTH YEAR EXAMINATION FOR THE AWARD OF DEGREE OF BACHELOR OF SCIENCE AND BACHELOR OF EDUCATION (SCIENCE)

PHYS 413/410: SOLID STATE PHYSICS

STREAMS: BSC& B ED. SC **TIME: 2 HOURS**

DAY/DATE: 03/12/2018 **11.30AM -1.30PM**

INSTRUCTIONS:

- Answer question ONE and any other TWO questions.
- Clearly show your working.

The following constants may be useful.
Speed of light in air $c = 3x10^8 m/s$
Avogadro's number $= 6.023x10^{23}$
Boltzman constant $k_B = 1.38x10^{-23} J/K$=8.63 x 10-5 eV/K)
Planks constant $h = 6.63x10^{-34}$J.S
Mass of an electron = 9.1 x 10^{-31} kg
Reduced Plancks constant $\hbar = 1.05x10^{-34} J.S.$

QUESTION ONE

(a) Explain why most solids are in crystalline in nature. (2 marks)

(b) Complete the following table.

Crystal System	a,b,c	α,β,γ
Tetragonal	(2 marks)	(2 marks)
(2 marks)	a≠b≠c	α=β=γ=90

(c) A plane makes intercepts 1, 2 and 0.5 $\dot{A}$ on the crystallographic axes of acrystal with $a: b: c = 1: 1: 1$.

(i) Draw a diagram representing this plane in the crystal system. (3 marks)

(ii) Determine its Miller indices. (3 Marks)

(d) The primitive translation vectors of a two dimensional lattice are:

$$a = 2i + j$$
$$b = 2j$$

Assuming that the third translation vector c of the given lattice lies along the z axis and is of unit magnitude, i.e, c=k, determine the primitive translation vectors of the reciprocal lattice. (4 marks)

(e) Distinguish between a metal, a semiconductor and an insulator on the basis of the energy band structure. (6 marks)

(f) Using a well labeled diagram, explain the effect on the band gap of an intrinsic semiconductor after doping with Aluminium. (4 marks)

(g) State the assumption of the Band theory. (2 marks)

QUESTION TWO

(a) Explain what phonons are. (2 mark)

(b) Explain phase velocity and group velocity. (4 marks)

(c) Radiation of wavelength 500 nm undergoes scattering from a crystal of refractive index 1.5.Given the velocity of sound in the crystal as 5000 ms^{-1},

(i) Calculate the maximum frequency of the phonon generated. (5 marks)

(ii) Determine the change in frequency of the incident radiation. (5 Marks)

(iii)Determine the fractional change in frequency of the incident photon. (4 Marks)

QUESTION THREE

(a) Explain why X-rays are suitable for probing crystal structure. (3 Marks)

(b) Using two examples, explain what crystalline imperfections are. (3 marks)

(c) The lattice parameter of the unit cell of an fcccrystalof density $1.99x10^3 kgm^{-3}$ is found to be 6.29 x 10^{-10} mby X-ray diffraction. Determine:

(i) The interplanar spacing for (200) planes. (4 Marks)

(ii) The wavelength of the X-ray beam diffracted by the cubic crystal, if the glancing angle for the second order reflection from (200) planes is 13°. (5 Marks)

(iii)The glancing angle for the second order reflection from (100) planes.(5 Marks)

QUESTION FOUR

(a) Describe the motion of the valence electrons as described by the free electron gas model. (4 marks)

(b) State and explain the Bloch theorem. (4 marks)

(c) For Copper at 1000K, find the energy at which the probability F(E) that a conduction electron state will be occupied is 0.9 if E_F = 7 eV. (6 marks)

(d) The atomic radius of bcc sodium is 1.86$\dot{A}$. Calculate the volume of its unit cell and the Fermi energy of sodium at absolute zero. (6 Marks)

QUESTION FIVE

(a) Explain what a superconductor is. (4 marks)

(b) The Curie temperature is very important in the description of a ferromagnetic material. Explain its significance. (4 Marks)

(c) The critical temperature of metal in the superconducting state is 6.2K at zero magnetic field and a critical field of 0.064 MAm^{-1} at 0K. Determine the critical field at 4K. (6 Marks)

(d) Distinguish between the characteristic features of diamagnetism, paramagnetism and ferromagnetism. (6 marks)

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