JARAMOGI OGINGA ODINGA UNIVERSITY OF SCIENCE AND TECHNOLOGY

SCHOOL OF BIOLOGICAL AND PHYSICAL SCIENCES

UNIVERSITY EXAMINATION FOR THEDEGREE OF BACHELOR OF EDUCATION (SCIENCE)

4TH YEAR **1ST SEMESTER**

MAIN

REGULAR

COURSE CODE: SPH 401

COURSE TITLE: SOLID STATE PHYSICS

EXAM VENUE: **STREAM: (BED SCI)**

DATE: **EXAM SESSION:**

TIME: 2:00HRS

Instructions:

1. **Answer question 1 (Compulsory) and ANY other 2 questions.**
2. **Candidates are advised not to write on the question paper.**
3. **Candidates must hand in their answer booklets to the invigilator while in the examination room**

QUESTION ONE

a. The free electron model for a metal assumes that the conduction electrons can be approximated by a gas of free electrons where the only important parameters for the gas are *n*, the number density of electrons and τ , the time between collisions.

i.) Show that in this model the electrical conductivity of a metal can be expressed as

$$\sigma = \frac{ne^2\tau}{m}$$ (5 marks)

ii.) Estmate the collision time t for an electron in copper. The resistivity of copper metal is 1.7×10^{22} atoms/cm^3. (3 marks)

(b)Metallic sodium crystalizes in body-centred cubic form, the length of the cube being 4.25×10^{-8} cm. Find the concentration of conduction electrons. Assume one conduction electron per atom. Adopting the free electron fermi gas model for the conduction electrons.

i.) Derive an expression for the fermi energy at 0 K 4marks

ii Show that it depends only on the concentration of consuction electrons, but not on the mass of the crystal (4mks)

(c)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 Angstrom.

Given m, q, h, c

i). Calcilate the wavelength of the electrons 3marks

ii). Calculate the Bragg angle for the first order diffraction maximum. 3 marks

(d) What is the Debye frequency for copper,if it has the Debye temperature of 315 K and find the Debye specific heat at 10K and 300K (6mks)

(e) State any two assumptions made in the study of free electron theory (2 mks)

QUESTION TWO

(a) (i) The density of states functions for electrons in a metal is given by $Z(E)dE = 13.6\times10^{27}E^{1/2}dE$ Calculate the Fermi level at a temperature few degrees above absolute zero for copper which has 8.5×10^{28} electrons per cubic metre (2mks)

(ii) Using the results of problem (i),Calculate the velocity of electrons at the Fermi level in copper (2mks)

(b) For silver (A = 108),the resistivity is $1.5\times10^{3}kg/m^{3}$ and Fermi energy $E_F = 5.5eV$. Assuming that each atom contributes one electron for conduction ,find the ratio of the mean free path λ to the interatomic spacing d. (10 mks)

(c) Find the probability of occupancy of a state of energy

(i) 0.05 eV above the Fermi energy (2mks)

(ii) 0.05 eVbelow the Fermi energy (2mks)

(iii) Equal to the Fermi energy. Assume a temperature of 300K (2mks)

QUESTION THREE (20 marks)

The figure 1.1 below shows a hypothetical two-dimensional crystal consisting of atoms arranged on a square grid

a. On the diagram anexample of a primitive unit cell. (\4 marks)
b. Define the reciprocal lattice and explain its relation to Bragg reflection (8 marks)
c. On the diagram, show the reciprocal lattice and the first Brillion zone. How is this zone related to Bragg reflation? (8 marks)

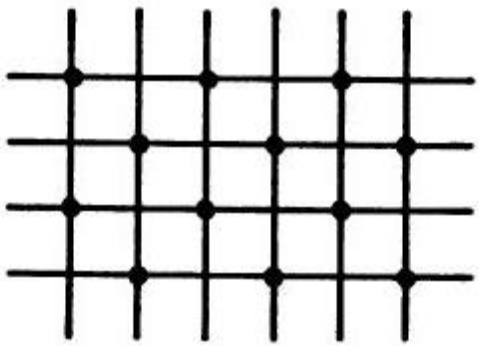

Fig. 1.1

(20 mks)

QUESTION FOUR

(a) Briefly describe what you mean by the following terms as used in solid state physics
   (i) Paramagnetism (2mks)
   (ii) Diamagnetism (2mks)
   (iii) Ferromagnetism (2mks)

(b) Show that $\pi/6$ of the available volume is occupied by hard spheres in contact in a simple cubic arrangement (4 mks)

(c) While sitting in front of a colour TV with a 25kv picture tube potential, you have an excellent chance of being irradiated with x-rays.
   (i) What process produces most of the x-ray flux (2mks)
   (ii) For the resulting continous distribution . Calculate the shortest wavelength (maximum energy) x-ray. (3mks)
   (iii) For a rock salt (NaCl) crystal placed infront of the tube,calculate the Bragg angle for a first order reflection maximum at $\lambda = 0.5A$ (density of sodium chloride is 2.16 g/cm^3 (5 mks)

QUESTION FIVE

a)Distinguish between type **I** and type **II** superconductors. (4 marks)

ii) Determine the value of the Hall constant for a sample of p-type

germanium of conductivity $100\Omega^{-1}m^{-1}$ (Take $\mu_e = 0.39m^2V^{-1}s^{-1}$ and

$\mu_h = 0.19m^2V^{-1}s^{-1}$ for germanium) (3 marks)

iii) What causes Magnetic properties in a material? (4 marks)

b) Discuss the following magnetic properties

i) Diamagnetism

ii) Paramagnetism

iii) Ferromagnetism (9 marks)