UNIVERSITY OF EMBU

2016/2017 ACADEMIC YEAR

SECOND SEMESTER EXAMINATION

THIRD YEAR MAIN EXAMINATION FOR THE DEGREE OF BACHELOR OF SCIENCE

SPH 303: SOLID STATE PHYSICS I

DATE: APRIL 13, 2017 **TIME: 2:00-4:00PM**

INSTRUCTIONS:

Answer Question ONE and ANY Other TWO Questions.

Constants: Unless otherwise specified, take;

- $g = 9.8\ m.s^{-2}$
- $c = 3.0 \times 10^{8}\ m.s^{-1}$
- $e = 1.6 \times 10^{-19} C$,
- $\varepsilon_o = 8.854 \times 10^{-12}\ F/m$.
- $m_e = 9.1 \times 10^{-31}\ kg$,
- $h = 6.625 \times 10^{-34}\ J\text{-}s$
- Avagadro's No. $= 6.023 \times 10^{23}$

Some semiconductor constants, © Bart J. Van Zeghbroeck 1997.

Name	Symbol	Ge	Si	GaAs
E_g at 300K	E_g (eV)	0.66	1.12	1.424
For density of states				
Electrons	m_c/m_o	0.56	1.08	0.067
Holes	m_h/m_o	0.29	0.57/0.81[1]	0.47
For conductivity				
Electrons	m_c/m_o	0.12	0.26	0.067
Holes	m_h/m_o	0.21	0.36/0.386[1]	0.34

QUESTION ONE (30 MARKS)

a) Define the following.

i) Lattice

ii) Point Defects

iii) Interplanar spacing

iv) Frenkel Defect

v) Schottky defect (5 marks)

b) Calculate the distance of the atomic parking factor (APF) for an FCC crystal (4 marks)

c) Explain how a crystal structure is obtained and mention two features of crystal structure. (5 marks)

d) i) What is Fermi energy level? (1 mark)

ii) What is the basic requirement for electrical conduction with respect to Fermi energy level in a solid? (2 marks)

e) (i) An atomic plane in a crystal lattice makes intercept of 3a, 4b and 6c with the crystallographic axes where a, b and c are the dimensions of the unit cell. Calculate the Miller indices of the atomic plane. (3 marks)

(ii) In a single cubic crystal find the ratio of the intercepts on the three axes by (123) plane. (3 marks)

f) Find the interplanar distance of (200) plane and (111) plane of Nickel crystal. The radius of Nickel atom is 1.245 Å. (3 marks)

g) Calculate the Bragg angle if (111) planes of a cube (a = 3.57 Å) crystal are exposed to X-rays (wavelength = 1.54 Å) (4 marks)

QUESTION TWO (20 MARKS)

a) Showing all calculations, draw the planes (020), (120) and (220) in a FCC structure. (6 marks)

b) In a cubic unit cell, find the angle between normals to the planes (111) and (121). (4 marks)

c) Determine the packing efficiency and density of sodium chloride from the following data:

(i) radius of the sodium ion = 0.98 Å, (ii) radius of chlorine ion = 1.81 Å (iii) atomic mass of sodium = 22.99 amu and atomic mass of chlorine = 35.45 amu. (5 marks)

d) The lattice constant of a unit cell of KCl crystal is 3.03 Å. Find the number of atoms/ mm^2 of planes (100), (110) and (111). KCl has simple cubic structure. (5 marks)

QUESTION THREE (20 MARKS)

a) 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 8eV energy when the interatomic distance

is 2.8Å. Find A and B and the force needed to dissociate this molecule to atoms and the interatomic distance at which the dissociation occurs. (10 marks)

b) The lattice energy of KCl crystal containing N-molecules of KCl is given by $U = -N(Mq^2/4\pi\varepsilon_0 R - B/R^n)$. Find the repulsive exponent n. Given: nearest neighbour equilibrium distance, $R_0 = 3.14$ Å, compressibility of KCl, $K = 5.747 \times 10^{-11}$ m^2/N and Madelung constant $M = 1.748$.

(5 marks)

c) The ionic radii of Mg^{++} and S^{--} respectively are 0.65 Å and 1.84 Å. Calculate the force of attraction between these ions. (5 marks)

QUESTION FOUR (20 MARKS)

a) Evaluate the temperature at which there is one per cent probability that a state with energy 0.5 eV above the Fermi energy will be occupied by an electron.

(5 marks)

b) There are 10^{19} electrons/m^3, which serves as carriers in a material. The conductivity of material is 0.01 Ohm^{-1}/m. Find the drift velocity of these carriers, when 0.17 Volt is applied across 0.27 mm distance with the material. (5 marks)

c) Find the conductivity of copper at 300 K. The collision time for electron scattering in copper at 300 K is 2×10^{-14} sec. Given that density of copper = 8960 kg/m^3, atomic weight of copper = 63.54 amu. (5 marks)

d) (i) The mean free time between the collisions is 10^{-14} sec. Find the mobility of electrons?

(2 marks)

ii) The conductivity of silver is 6.5×10^7 per Ohm per m and number of conduction electrons per m^3 is 6×10^{28}. Find the mobility of conduction electrons and the drift velocity in an electric field of 1 V/m. (3 marks)

QUESTION FIVE (20 MARKS)

a) i) On what factors does the ability of a semiconductor depend to conduct electricity?

(2 marks)

ii) On what factors does the conductivity of a semiconductor depend?

(3 marks)

b) Find the conductivity and resistivity of a pure silicon crystal at temperature 300°K. The density of electron-hole pair per cm^3 at 300°K for a pure silicon crystal is 1.072×10^{10} and the mobility of electron $\mu_e = 1350$ cm^2/volt-sec and hole mobility $\mu_h = 480$ cm^2/volt-sec.

(5 marks)

c) A silicon wafer is doped with phosphorus of concentration 10^{13} atoms/cm^3. If all the donor atoms are active, what is its resistivity at room temperature? The electron mobility is 1200 cm^2/Volt-sec charge on the electron is 1.6×10^{-19}Coulomb. (2 marks)

d) Find the resistance of an intrinsic germanium rod 1 cm long, 1 mm wide and 1 mm thick at temperature of 300°K. For germanium $n_i = 2.5 \times 10^{13}$, $\mu_n = 3900$ cm^2/Volt-sec, $\mu_h =$ 1900 cm^2/Volt-sec at 300°K.

(3 marks)

e) The Figure 1 shows the plot of log of resistivity versus reciprocal of temperature for two different semiconductors A and B. Assume that mobility is proportional to $T^{-3/2}$.

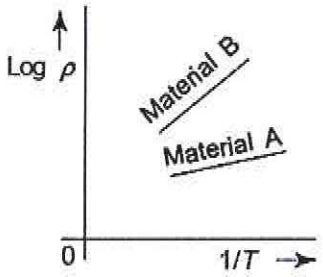

Fig. 1

Find (i) which material has wider band gap? (ii) Which material will require light of shorter wavelength for generation of an electron-hole pair? (5 marks)

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