UNIVERSITY OF EMBU

2017/2018 ACADEMIC YEAR

SECOND SEMESTER EXAMINATIONS

THIRD YEAR MAIN EXAMINATION FOR THE DEGREE OF BACHELOR OF SCIENCE AND BACHELOR OF EDUCATION SCIENCE

SPH 303: SOLID STATE PHYSICS I

DATE: APRIL 5, 2018 **TIME: 2:00-4:00PM**

INSTRUCTIONS:

Answer Question ONE and ANY Other TWO Questions.

Constants: Unless otherwise specified, take;

- $g = 9.8\ m.s^{-2}$
- $c = 3.0 \times 10^{8}\ m.s^{-1}$
- $e = 1.6 \times 10^{-19} C$,
- $\varepsilon_o = 8.854 \times 10^{-12}\ F/m$.
- $m_e = 9.1 \times 10^{-31}\ kg$,
- $h = 6.625 \times 10^{-34}\ J\text{-}s$

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_e/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) State four basic factors used to classify atomic bonding. (2 marks)

b) There are basically two groups of bonding which classify common bonds. Explain these groups giving examples in each case. (3 marks)

c) Explain the meaning of the following terms (i) Bond energy (ii) Bond length (2 marks)

d) Distinguish between crystalline and non crystalline solids; (2 marks)

e) Briefly explain the following with respect to solids.

i) Coordination number (ii) Space Lattice (ii) Single crystals (iii) Point defects

(2 marks)

f) If there is only one atom located at each lattice point, calculate the number of atoms per unit cell in the FCC crystal system. (3 marks)

g) i) Briefly explain what is Fermi energy level? (2 marks)

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

h) Identify the defects shown in the figure 1.1 below. (3 Marks)

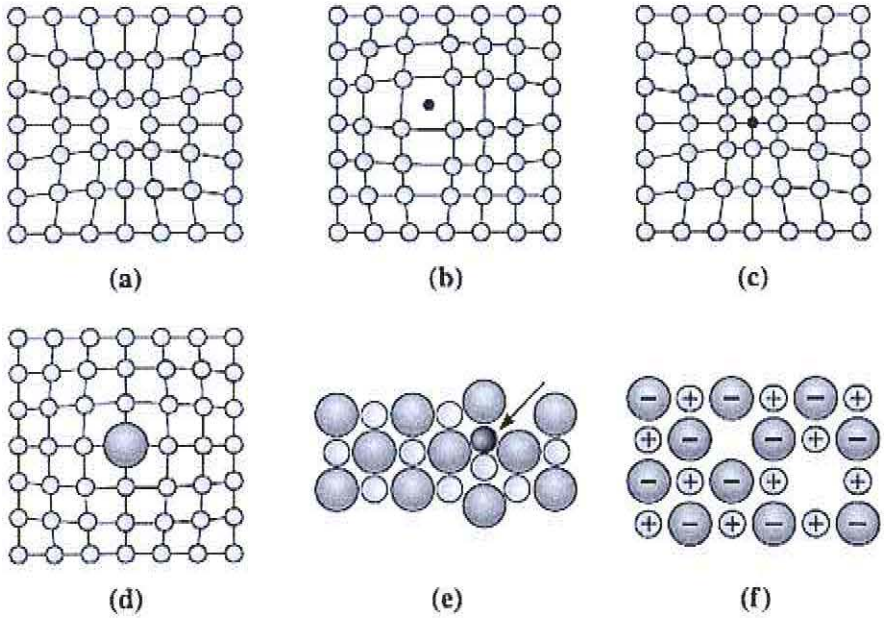

Fig 1.1

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)

j) Calculate the concentration of vacancies in copper at room temperature (25°C). (3 marks)

k) Calculate the electron densities at room temperature (300 K) in the conduction bands of the insulator carbon (Eg = 5.33 eV) and the semiconductor like germanium (Eg = 0.7 eV). (3 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 energy between two atoms a distance r apart can be expressed as:

$$E_r = -\frac{a}{r} + \frac{b}{r^7}$$ where a and b are constants.

(i) Calculate the distance r at equilibrium (4 marks)

(ii) In stable equilibrium, how many times is the energy of attraction that of the repulsion? How does the forces of attraction and repulsion compare? (6 marks)

(iii) If the two atoms are pulled apart, calculate the distance at which they will separate most easily. (4 marks)

b) Let the interaction energy between two atoms be given by:

$$E(r) = -\frac{A}{r^2} + \frac{B}{r^8}$$

If the atoms form a stable molecule with an inter-nuclear distance of 0.4 nm and a dissociation energy of 3 eV, calculate A and B. (6 marks)

QUESTION FOUR (20 MARKS)

a) Calculate the temperature at which there is 1% probability that a state with energy 0.5 eV above the Fermi energy will be occupied by an electron. (5 marks)

b) In a certain material, there are 10^{19} electrons/m^3, which serve as charge carriers. If the conductivity of this material is 0.01 Ohm^{-1}/m. Find the drift velocity of these carriers, when a pd of 0.17 V is applied across 0.27 mm distance of the material. (5 marks)

c) In copper, the collision time for electron scattering at 300 K is 2 $x10^{-14}$ sec. Given that density of copper = 8960 kg/m^3 and atomic weight of copper = 63.54 amu. Find the conductivity of copper at 300 K. (5 marks)

d) i) Find the mobility of electrons given that the mean free time between the collisions is 10^{-14} sec. (2 marks)

ii) The conductivity of silver is 6.5 $x10^7$ per Ohm per m and number of conduction electrons per m^3 is 6 $x10^{28}$. 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) With the aid of diagrams explain the mechanism of current flow in a forward biased P-N junction (10 marks)

b) For a P-N junction, solve the Poisson's equation: $\frac{d^2\phi}{dx^2} = \frac{\rho(x)}{\varepsilon}$. Hence determine,

i) The width w of the depletion region and (ii) The electric feld E_o at the center of the junction. (10 marks)

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