UNIVERSITY OF EMBU

2018/2019 ACADEMIC YEAR

SECOND SEMESTER EXAMINATIONS

THIRD YEAR EXAMINATION FOR THE DEGREE OF BACHELOR OF SCIENCE

SPH 303: SOLID STATE PHYSICS I

DATE: APRIL 11, 2019 **TIME: 2:00 PM – 4:00 PM**

INSTRUCTIONS:

Answer Question ONE and ANY Other TWO Questions.

Constants: Unless otherwise specified, take;

- g = 9.8 m.s^{-2}
- c = 3.0 x 10^{8} m.s^{-1}
- e = 1.6x10^{-19}C,
- ε_o = 8.854 x10^{-12} F/m.
- m$_e$ = 9.1 x10^{-31} kg,
- h = 6.625 x10^{-34} J-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

Coefficients of linear expansion

SUBSTANCE	α (per deg C)
aluminum	23 × 10^{-6}
brass	19 × 10^{-6}
glass	9 × 10^{-6}
rubber	80 × 10^{-6}
Ice	51 × 10^{-6}
lead	29 × 10^{-6}
steel	11 × 10^{-6}
concrete	10 × 10^{-6}

- one electron volt = 1.60 × 10^{-19} J
- Boltzmann's constant k_B = 1.38 × 10^{-23} JK^{-1}
- Avogadro's number = 6.02 × 10^{23}
- Gravitational constant, G = 6.67 X 10^{-11} m^3/s^2. kg.
- Earth's mass, M=5.98 X 10^{24} kg.
- Earth's radius, R$_E$ = 6.37 X 10^{6} m.

QUESTION ONE (30 MARKS)

a) Crystals possess *symmetry.* State and briefly explain the elements of symmetry in crystals. (3 marks)

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

c) Distinguish between *crystalline* and *amorphous* solids. (2 marks)

d) Briefly explain the following terms with respect to solids.

(i) Short-Range Order (SRO) (ii) Long-Range Order (LRO) (ii) Single crystals (iii) Point defects. (2 marks)

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

f) Explain the term Fermi energy level. (2 marks)

g) 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. (4 marks)

h) Calculate the density of BCC iron, which has a lattice parameter of 0.2866 nm. (3 marks)

i) Calculate the interplanar distance of (200) and (111) planes of a Nickel crystal given that the radius of Nickel atom is 1.245×10^{-10} m. (3 marks)

j) How much heat must be supplied to 250 g of tungsten to raise its temperature from 25°C to 650°C? Take the specific heat of tungsten to be 0.032 cal/g K. (3 marks)

QUESTION TWO (20 MARKS)

a) Describe the differences in the properties of Solids that are *crystalline* and *non-crystalline* (10 marks)

b) Find the atomic packing factor (APF) for a FCC crystal. (5 marks)

c) i) Explain briefly how a crystal structure is obtained. (3 marks)

ii) Mention two main features of a crystal structure (2 marks)

QUESTION THREE (20 MARKS)

a) The probability that a particular quantum state of energy E is occupied at a temperature T is given by the so called *Fermi- Dirac distribution function.* Use it to sketch, on the same graph, the Fermi-Dirac (FD) distribution given that $T_1 < T_2 < T_3$ where one of the temperatures represents absolute zero. Explain all steps and pay particular attention to the labels in your graph. (10 marks)

b) Calculate the probability that an electron occupies an energy level $3kT$ below the Fermi energy. Repeat for an energy level $3kT$ above the Fermi energy. (5 marks)

c) Assuming that the thermal energy is 5μ where the energy of the system is E and the fermi level is μ, complete table 3.1shown below where $f(E)$ is the probability density. (5 marks)

E/μ	0.0	0.4	0.8	1.2	1.6	2.0
$f(E)$						

QUESTION FOUR (20 MARKS)

a) Explain with the aid of diagrams the mechanism of current flow in a forward biased P-N junction (10 marks)

b) Consider a P-N junction. Solve the Poisson's equation:

$$\frac{d^2\phi}{dx^2} = \frac{\rho(x)}{\varepsilon}$$

Determine,

i) The width w of the depletion region and

ii) The electric feld E_o at the center of the junction.

(10 marks)

QUESTION FIVE (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^{2+} and S^{2-} respectively are 0.65 Å and 1.84 Å. Calculate the force of attraction between these ions. (5 marks)

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