JARAMOGI OGINGA ODINGA UNIVERSITY OF SCIENCE & TECHNOLOGY UNIVERSITY EXAMINATIONS 2012/2013

4TH YEAR 1ST SEMESTER EXAMINATION OF BACHELOR OF EDUCATION (SCHOOL BASED)

COURSE CODE: SPH 401

COURSE TITLE: SOLID STATE PHYSICS

DATE: 26 /8/13 **TIME: 2.00 - 4 .00PM**

DURATION: 2 HOURS

INSTRUCTIONS

1. **This paper contains five (5) questions.**
2. **Answer question 1 (compulsory) and ANY other TWO questions.**
3. **Write all answer in the booklet provided.**
4. **Marks will be awarded for clearly worked out solutions.**

Useful Constants

Permeability of Vacuum	$\mu_0 = 4\pi \times 10^{-7}\ Hm^{-1}$
Electron charge	$e = 1.6 \times 10^{-19}\ C$
Electron Mass	$M_e = 9.11 \times 10^{-31}\ kg$
Permittivity of Vacuum	$\varepsilon_0 = 8.85 \times 10^{-12}\ Fm^{-1}$
Boltzman constant	$K = 1.38 \times 10^{-23}\ JK^{-1}$

Q1. a) i) What is crystallization? (2 marks)

ii) Why is the Debye model for specific heat capacity of solids preferred over Einstein's model? (4 marks)

b) i) What are the limitations of the free electron model? (3 marks)

ii) State Curie's law. (2 marks)

c) i) Explain what is meant by zero point energy and give the mathematical expression used to calculate it. (3 marks)

ii) State **two** main causes of electrical resistivity in a conducting solid. (2 marks)

d) i) Explain how thermal conduction takes place in solids. (4 marks)

ii) What is superconductivity? (2 marks)

e) Briefly describe the following statistics:

i) Fermi-Dirac (2 marks)

ii) Bose- Einstein (2 marks)

iii) Maxwell's-Boltzmann (2 marks)

f) State **two** conditions for magnetic resonance to occur. (2 marks)

Q2. a) i) Derive the density of states in the form

$$\rho(E) = \frac{V}{2\pi^2}\left(\frac{2m_e}{\hbar^2}\right)^{3/2} E^{1/2} \quad \text{(6 marks)}$$

ii) Using the density of states equation above show that the kinetic energy of a three dimensional gas containing N free electrons at 0 K is given by

$$U_o = \frac{3}{5} N E_F \quad \text{(6 marks)}$$

b) Briefly describe the following crystal growth techniques:

i) liquid phase epitaxy

ii) vapor phase epitaxy

iii) molecular beam epitaxy

iv) chemical beam epitaxy (8 marks)

Q3. a) i) Assuming a free electron model, write down the Schrodinger equation for this problem and obtain the general solution to the problem by setting the correct boundary conditions, given that the distance between the walls is L. (6 marks)

ii) Obtain the expression for the energy eigen values. (6 marks)

b) The energy of N oscillators in the Einstein's model of specific heat capacity of a solid is given by $E = N\langle n\rangle\hbar\mu$ where $\langle n\rangle$ is the Bose-einstein distribution function, show that the heat capacity at constant volume is given by

$$C_v = 3Nk_B(\ \hbar\mu)^2 \frac{e^{\ \hbar\mu}}{(e^{\ \hbar\mu} - 1)^2}$$ (8 marks)

(Assume each of the atoms N has 3N degrees of freedom)

Q4. a) i) 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 $«_e = 0.39m^2V^{-1}s^{-1}$ and $«_h = 0.19m^2V^{-1}s^{-1}$ 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)

Q5. a) Show that the field inside a solenoid with a soft iron core is given by

$$B = «_o«_r H$$

where $«_r = 1 + ¡_m$ where the symbols have their usual meanings.

(6 marks)

b) Calculation of Fermi-energy of some monovalent elements gave the following results.

Metal	Cu	Li	Rb	Cs	Ag	K
E_F (eV)	7.04	4.74	1.82	1.53	5.51	2.12

If the Fermi velocity of the electrons in one of the metals above series is $0.73\times10^{6} m/s$,

i) Identify the metal. (5 marks)

ii) Compute its Fermi temperature. (3 marks)

iii) Would the Fermi temperature of a metal like Ag be higher or lower if the electrons had the same velocity? (2 marks)

c) Name the factors that determine the value of Debye temperature of a particular element? (4 marks)