TECHNICAL UNIVERSITY OF MOMBASA

Faculty of Engineering & Technology

DEPARTMENT OF ELECTRICAL & ELECTRONIC ENGINEERING

SUPPLEMENTARY UNIVERSITY EXAMINATION 2017/2018

SECOND YEAR FIRST SEMESTER UNIVERSITY EXAMINATIONS FOR THE DEGREE OF BACHELOR OF TECHNOLOGY IN ELECTRICAL AND ELECTRONIC ENGINEERING

TEE 4203: PHYSICAL ELECTRONICS

SUPPLEMENTARY EXAMINATION

TIME: 2 HOURS

DATE: SEPTEMBER, 2018 SERIES

INSTRUCTIONS

1. This paper consists of **FIVE** Questions.
2. Answer Question **ONE** and any other **TWO**

3. Physical constants and properties of semiconductors are listed at the end of the paper.

Question ONE

(a) (i) From the Bohr principles, show that for the electron allowed energy levels:

$$E_n = E_{vac} - \frac{mq^4}{2(4\pi\varepsilon_o)^2 n^2 \hbar^2}$$

(ii) Calculate the first **FOUR** Bohr energies for the hydrogen atom.

(iii) Explain why we say that the energies in (i) are quantized.

(15 marks)

(b) (i) Draw and explain a graph of Fermi probability function versus energy for different temperatures.

(ii) Calculate the probability of occupancy of a state at the bottom of the conduction band in intrinsic Si at room temperature.

(9½ marks)

(c) Consider a varactor diode:

(i) Draw the circuit symbol

(ii) With the aid of a well labelled characteristic curves, briefly explain the operating principles of the diode.

(5½ marks)

Question TWO

(a) (i) State the Pauli exclusion principle.

(ii) Derive an expression for the total number of electrons in the conductor band at equilibrium for a non-degenerate semiconductor.

(iii) Hence show that:

$$E_i = \frac{E_c + E_v}{2} + \frac{kT}{2}\ln\frac{Nv}{Nc}$$

(iv) Find the intrinsic concentration n_i for the use of $Si(n_o = p_o = n_i)$ at room temperature (300K).

(10 marks)

(b) (i) Differentiate between intrinsic and compensated semiconductors.

(ii) Explain how compensated semiconductor can be formed.

(iii) Draw energy band diagram for uncompensated p-type and compensated n-type material. **(10 marks)**

Question THREE

(a) For a Zener diode.

(i) Draw the circuit symbol

(ii) With the aid of well labelled characteristics curve briefly explain the operating principle of the diode.

(iii) Highlight **ONE** area of application for the diode.

(5 marks)

(b) State and briefly describe the **TWO** junction break-down mechanisms in a p-n junction. **(6½ marks)**

(c) Find the maximum resistance of a rectangular block of germanium of dimension 10mm x 1mm x 2mm if it can be connected between any pair of parallel forces. Assume there are $10^{21}m^{-3}$ mobile electrons with a charge of $-1.6 \times 10^{-19}C$ each and the electron mobility is $0.39m^2V^{-1}s^{-1}$.

(3 marks)

(d) During a photo-electronic experiment, 420nm violet light was used:

(i) Determine the energy in joules and electron volts of a photon of 420nm violet light.

(ii) Determine the maximum kinetic energy of the electrons ejected from calcium by 420nm violet light, given that the work function of electrons for calcium is 2.7eV.

(iii) Determine the maximum velocity of the electrons emitted.

(5½ marks)

Question FOUR

(a) (i) With the aid of energy band diagrams explain qualitatively the difference between a metal, insulator and semiconductor.

(ii) Explain why a semiconductor acts as an insulator at 0K and why conductivity increases with increasing temperature.

(iii) If the Fermi level is 2.3kT below the conduction band edge the probability of occupancy of the lowest energy state in the conduction band is 10%. Verify this statement.

(9 marks)

(b) The probability that an energy state in the conduction band edge, E_c of S_i is 10^{-4}.

(i) Determine the type of semiconductor

(ii) Find $N_D - N_A$

(5 marks)

(c) Using an appropriate diagram show and define the following terms:

(i) Energy gap

(ii) Ionization energy

(iii) Electron affinity

(6 marks)

Question FIVE

(a) (i) Define barrier potential.

(ii) Derive an expression of built-in potential for a p-n junction.

(4 marks)

(b) (i) Calculate the value of the built-in voltage for a *Si pn* junction in which the *n* region is uniformly doped with 10^{16} net donors per cm^3 and the p-region has a uniform net acceptor concentration of 10^{15}per cm^3.

(ii) In an abrupt silicon junction diode $N_A = 10^{22}$ atoms/cm^3 and $N_D = 10^{21}$atoms/cm^3.

Calculate:

(I) Width of the junction (w)
(II) Maximum electric field (max)
(III) Junction capacitance (Cj)

(8½ marks)

(c) (i) Describe conduction in semiconductors.

(ii) Differentiate between drift current and diffusion current.

(iii) A *Si* sample is doped with 10^{17} arsenic atoms/cm^3.

Find minority carrier concentration at room temperature.

(7½ marks)