05

(University of Choice)

MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY (MMUST)

UNIVERSITY EXAMINATIONS

2021/2022 ACADEMIC YEAR

FIRST YEAR FIRST SEMESTER

SPECIAL/SUPPLEMENTARY EXAMINATIONS

FOR THE DEGREE

OF

MASTER OF SCIENCE IN PHYSICS

COURSE CODE: SPH 850E

COURSE TITLE: THEORY OF SEMICONDUCTORS

DATE: WEDNESDAY 3RD AUGUST, 2022 **TIME:** 8 AM - 11 AM

INSTRUCTIONS TO CANDIDATES

TIME: 3 Hours

Answer any five questions. All questions carry equal marks (14mks)
Symbols used bear the usual meaning.

MMUST observes ZERO tolerance to examination cheating

Useful Constants

Electronic charge, $q = 1.6 \times 10^{-19}\ C$

Permittivity of free space, $\varepsilon_0 = 8.854 \times 10^{-14}\ F/cm$

Boltzmann constant, $k = 8.62 \times 10^{-5}\ eV/K$

Planck constant, $h = 4.14 \times 10^{-15}\ eV \cdot s$

Free electron mass, $m_o = 9.1 \times 10^{-31}\ kg$

Thermal voltage $kT/q = 26\ mV$ at room temperature

$kT = 0.026\ eV = 26\ meV$ at room temperature

$kTln(10) = 60\ meV$ at room temperature

Question One (14mks)

(a) Distinguish briefly between the following (i) classical free electron theory (ii) Quantum free electron theory and (iii) Band theory of Solids. (6mks)

(b) Indicate an energy level diagrams the conduction and valence bands, donor and acceptor levels for intrinsic semiconductor. (4mks)

(c) Explain the concept of drift and diffusion currents and hence derive the relation between diffusion and mobility. (4mks)

Question Two (14mks)

(a) Define Fermi-Dirac distribution function, $f_F(E)$, electron distribution, $n(E)$ and hole distribution, $p(E)$. Write down the expression of each. (4mks)

(b) Explain with aid of a diagram the effect of temperature on Fermi-Dirac distribution. (5mks)

(c) Calculate the probability that a quantum state in conduction band at $E = E_C + \frac{kT}{2}$ is occupied by an electron and calculate the thermal equilibrium electron concentration in Silicon at

$T = 300K$.(Assume Fermi Energy is $0.25eV$ below conduction band and $N_c = 2.8 \times 10^{19} cm^{-3}$ $E_C - E_F = 0.25eV$) (5mks)

Question Three (14mks)

(a) Give two reasons why silicon is the most common semiconducting material. (2mks)

(b) Draw a diagram of a Czochralski process (CZ) crystal grower and identify all the major parts. (4mks)

(c) Give four types of contamination found on wafer surfaces and state techniques used to keep contamination out of a cleanroom. (2mks)

(d) Describe the difference between molecular beam epitaxy (MBE), vapor phase epitaxy (VPE), and Metalorganic chemical vapor deposition (MOCVD) systems. (6mks)

Question Four (14mks)

(a) Sketch the Density of States function, Fermi-Dirac distribution, and areas representing electron and hole concentrations if Fermi Energy, E_F is near the midgap energy. (4mks)

(b) Explain the differences among conductors, insulators and semiconductors using the Energy Band Diagrams. (6mks)

(c) Silicon at $T = 300K$ contains an acceptor impurity concentration of $N_a = 10^{16} cm^{-3}$. Determine the concentration of donor impurity atoms that must be added so that the silicon is n-type and Fermi energy is 0.20eV below the conduction band edge. (4mks)

Question Five (14mks)

(a) Explain the phenomenon of Hall Effect in semiconductors and derive the expression for Hall coefficient. Mention its applications (7mks)

(b) A p-type silicon sample shown in Figure 5(b) below, has the following parameters:

$$L = 0.2\,cm\,,\ W = 10^{-2}\,cm,\ d = 8 \times 10^{-4}\,cm$$
$$p = 10^{16}\ \text{cm}^{-3}\,,\ \mu_p = 320 cm^2/V^{-s}.$$
$$V_x = 10\,V\,,\ B_z = 500\ gauss = 5 \times 10^{-2}\ tesla$$

Determine the value of $I_x$and V_H (7mks)

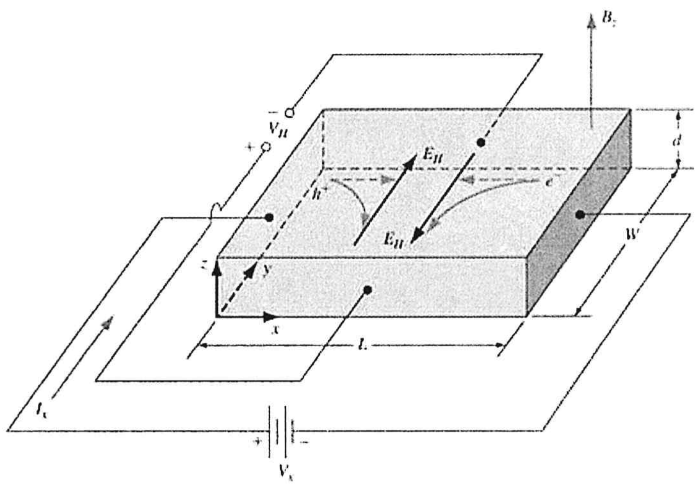

Figure 5(b)

Question Six (14mks)

(a) Explain the effect of doping semiconductors on Fermi level. (2mks)

(ii) Consider a p-type silicon semiconductor at $T = 300\ K$ in which $N_a = 10^{16} cm^{-3}$ and $N_d = 3.0 \times 10^{15} cm^{-3}$. The intrinsic carrier concentration is assumed to be $n_i = 1.5 \times 10^{10} \mathrm{cm}^3$. Determine the thermal equilibrium hole and electron concentrations. (6mks)

(b) Differentiate with well-illustrated diagrams between degenerate and non-degenerate semi-conductor (6mks)