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(University of Choice)

MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY (MMUST)

UNIVERSITY EXAMINATIONS
2021/2022 ACADEMIC YEAR

FIRST YEAR SECOND SEMESTER MAIN EXAMINATIONS

FOR THE DEGREE OF MASTER OF SCIENCE IN PHYSICS

COURSE CODE: SPH 850E

COURSE TITLE: THEORY OF SEMICONDUCTOR

DATE: TUESDAY 19TH APRIL, 2022 **TIME:** 9:00 AM - 12:00 PM

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

This Paper Consists of 3 Printed Pages. Please Turn Over.

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 (14 marks)

(a) What are the advantages and disadvantages of quantum free electron theory? (3 marks)

(b) Calculate the thermal equilibrium electron and hole concentration in silicon at $T = 300K$, where the Fermi energy level is 0.22 eV below the conduction band energy E_c. ($E_F = E_c - 0.22\ eV$). Assume $N_c = 2.8 \times 10^{19}\ cm^{-3}$ and $N_v = 1.04 \times 10^{19}\ cm^{-3}$ (6 marks)

(c) Find the resistivity of intrinsic silicon at room temperature and classify it as an insulator, semiconductor, or conductor. ($\mu_n \approx 1350$ (cm^2/V·s), $\mu_p \approx 500$ (cm^2/V·s also assume "room temperature" with $n_i = 10^{10} cm^{-3}$) (5 marks)

Question Two (14 marks)

(a) Distinguish between intrinsic, extrinsic and compensated semiconductor (2 marks)

(ii) Derive the expression for intrinsic carrier concentration in intrinsic semiconductors.(4 marks)

(b) Explain with aid of a diagram the difference between degenerate and non-degenerate semiconductor. (8 marks)

Question Three (14 marks)

(a) Derive the expression for current generated due to drifting of charge carriers in semiconductors in the presence of electric field. (7 marks)

(b) Consider a gallium arsenide sample at $T = 300K$ with doping concentration of $N_a = 0$ and $N_d = 10^{16} cm^{-3}$. Assume complete ionization and assume electron and hole mobilities given is $\mu_n = 8500\ cm^2/v.s$ and $\mu_p = 400\ cm^2/v.s$. Calculate the drift current density if the applied electric field is E = 10 V/cm. (7 marks)

Question Four (14 marks)

(a) Differentiate between Complete ionization and Freeze-out as applied to semiconductors. (2 marks)

(b) Assuming there is complete ionization, consider Germanium at $300K$: $n_i = 2.4 \times 10^{13} cm^{-3}$, $N_a = 5 \times 10^{13} cm^{-3}$, and $N_a = 0$. Calculate the electron n_o and hole p_o concentration. (4 marks)

(c) Prove that the Fermi level is lies exactly in between conduction band and valence band of intrinsic semiconductor. (8 marks)

Question Five (14 marks)

(a) Explain quantum confinement distinguishing clearly between Quantum Wells, Quantum Wire and Quantum Dots. (6 marks)

(b) Describe with the aid of diagrams the three primary processes used in lithography. (8 marks)

Question Six (14 marks)

(a) Describe with aid of a diagram the Hall Effect in a semiconductors. (7 marks)

(b) Give the expressions of the electron density n (hole density p) in the conduction band (valence band, respectively. (2 marks)

(c) Discuss qualitatively the evolution of the Fermi level from $0K$ until high temperatures above $600K$. Sketch also qualitatively the Fermi level position and the fraction of ionized impurities in such a wide temperature range. (5 marks)