MACHAKOS UNIVERSITY

University Examinations for 2018/2019

SCHOOL OF ENGINEERING AND TECHNOLOGY
DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

SECOND YEAR SPECIAL/SUPPLEMENTARY EXAMINATION FOR

BACHELOR OF SCIENCE (ELECTRICAL AND ELECTRONICS ENGINEERING)

EEE 205: PHYSICAL ELECTRONICS (supp)

DATE: **TIME:**

INSTRUCTIONS

Answer question **ONE** and **ANY OTHER TWO** questions

Constants:

$q = 1.6 \times 10^{-19}$ C $\quad$ $k = 1.38 \times 10^{-23}$ J/K

$h = 6.626 \times 10^{-34}\ m^2kg/s$ $\quad$ $m_o = 9.11 \times 10^{-31}$ kg

QUESTION ONE (COMPULSORY) (30 MARKS)

a) Determine the probability of finding an electron at an energy level of 3kT above the Fermi energy E_F of at 300K.

(3 marks)

b) Assuming that the Fermi energy level is 0.3eV below the conduction band energy E_C and the temperature is 300K, determine the

i. probability of a state being occupied by an electron at $E = E_C + kT/4$;

ii. probability of a state being occupied by an electron at $E = E_C + kT$.

(7 marks)

c) With the aid of a sketch describe how a n-type extrinsic semiconductor is created by doping.

(9 marks)

d) Consider an n-type Silicon semiconductor at T = 300K in which $N_d = 10^{16}$ cm^{-1} and $N_a = 0$. The intrinsic carrier concentration is assumed to be $n_i = 1.5 \times 10^{10}$ cm^{-3}. Determine the thermal equilibrium electron and hole concentrations.

(4 marks)

e) A semiconductor in thermal equilibrium, has a hole concentration of $p_o = 10^{16}$ and an intrinsic concentration of $n_i = 10^{10}$ cm^{-3}. The minority carrier lifetime is 2×10^7 s.

i. Determine the thermal-equilibrium recombination rate of electrons;
ii. Determine the change in the recombination rate of electrons if an excess electron concentration of $\delta_n = 10^{12}$ cm^{-3} exists.

(7 marks)

QUESTION TWO (20 MARKS)

a)
i. Describe the Hall effect;
ii. State any **TWO** applications of Hall effect.

(4 marks)

b) The Hall coefficient of a specimen of a doped semiconductor is 3.66×10^{-4} m^3c^{-1} and the resistivity of the specimen is 8.93×10^{-3} Ω-m. Determine the carrier mobility in $m^2v^{-1}s^{-1.}$

(3 marks)

c) An abrupt silicon p-n junction consists of a *p*-type region containing 2×10^{16} cm^{-3} acceptors and an *n*-type region containing also 10^{16} cm^{-3} acceptors in addition to 10^{17} cm^{-3} donors.

i. Calculate the thermal equilibrium density of electrons and holes in the *p*-type region as well as both densities in the *n*-type region.

ii. Calculate the built-in potential of the p-n junction

iii. Calculate the built-in potential of the p-n junction at 400 K.

(8 marks)

d) Assume an n-type Silicon semiconductor with a donor impurity concentration of $N_d = 10^{16}$ cm^{-3} and mobility $\mu_n = 1200$ cm^2/Vsec. Calculate the dielectric relaxation time constant.

(5 marks)

Question Three.

a) Differentiate between mobility, conductivity, resistivity and diffusion;

(8 marks)

b) 4H-SiC is doped with 2×10^{17} cm^{-3} nitrogen donor atoms ($E_c - E_d = 90$ meV). Use $N_c = 4 \times 10^{20}$ cm^{-3}.

i. Calculate the electron density at 300 K.

ii. Calculate the hole density at 300 K after adding 2×10^{18} cm^{-3} aluminum acceptor atoms ($E_a - E_c = 220$ meV).

Use $N_v = 1.6 \times 10^{20}$ cm^{-3}.

(12 marks)

QUESTION FOUR (20 MARKS)

a) The average distance travelled by a carrier between collisions is called the mean free path. The electron mobility in GaAs at 77 K (the temperature at which nitrogen becomes a liquid) is 30 m /V-s. If the effective mass of electron is $0.067m_o$, determine the mean free path.

(4 marks)

b) A long strip of material of width w = 1 cm and thickness d = 1 mm is subjected to a magnetic field along a direction parallel to the edge d. A current of 1 A flows in the strip parallel to its length. The mobility of the carriers (of density 2.5×10^{22} per m^3) is 5 m^2 /V-s.

i. Determine the magnitude and direction of the net electric field.

ii. If B = 0.1 T, calculate the potential difference V_H between the opposite points of the strip parallel to the width.

(8 marks)

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

(8 marks)

QUESTION FIVE (20 MARKS)

a) i. Calculate the built-in potential for a silicon p-n junction with $N_A = 10^{18}$ cm^{-3} and $N_D = 10^{15}$ cm^{-3} at 300 K.

ii. For a silicon one-sided abrupt junction with $N_A = 10^{19}$ cm^{-3} and ND = 10^{16} cm^{-3}, calculate the depletion layer width and the maximum field at zero bias (T = 300 K). (12 marks)

b) For a silicon one-sided abrupt junction with $N_A = 2 \times 10^{19}$ cm^{-3} and $N_D = 8 \times 10^{15}$ cm^{-3}, calculate the junction capacitance at zero bias and reversed bias of 4 V (T = 300 K). (8 marks)