



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:

$$q = 1.6 \times 10^{-19} \text{ C}$$

$$h = 6.626 \times 10^{-34} \text{ m}^2\text{kg/s}$$

$$k = 1.38 \times 10^{-23} \text{ J/K}$$

$$m_0 = 9.11 \times 10^{-31} \text{ kg}$$

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
- probability of a state being occupied by an electron at $E = E_C + kT/4$;
 - 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 $T = 300\text{K}$ in which $N_d = 10^{16} \text{ cm}^{-3}$ and $N_a = 0$. The intrinsic carrier concentration is assumed to be $n_i = 1.5 \times 10^{10} \text{ cm}^{-3}$. 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 $n_i = 10^{10} \text{ cm}^{-3}$. The minority carrier lifetime is $2 \times 10^7 \text{ s}$.
- Determine the thermal-equilibrium recombination rate of electrons;
 - Determine the change in the recombination rate of electrons if an excess electron concentration of $\delta_n = 10^{12} \text{ cm}^{-3}$ exists.
- (7 marks)

QUESTION TWO (20 MARKS)

- a)
- Describe the Hall effect;
 - State any **TWO** applications of Hall effect.
- (4 marks)
- b) The Hall coefficient of a specimen of a doped semiconductor is $3.66 \times 10^{-4} \text{ m}^3\text{C}^{-1}$ and the resistivity of the specimen is $8.93 \times 10^{-3} \Omega\text{-m}$. Determine the carrier mobility in $\text{m}^2\text{V}^{-1}\text{s}^{-1}$. (3 marks)
- c) An abrupt silicon p-n junction consists of a p-type region containing $2 \times 10^{16} \text{ cm}^{-3}$ acceptors and an n-type region containing also 10^{16} cm^{-3} acceptors in addition to 10^{17} cm^{-3} donors.
- Calculate the thermal equilibrium density of electrons and holes in the p-type region as well as both densities in the n-type region.
 - Calculate the built-in potential of the p-n junction
 - 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 $N_d = 10^{16} \text{ cm}^{-3}$ and mobility $\mu_n = 1200 \text{ cm}^2/\text{Vsec}$. 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 $2 \times 10^{17} \text{ cm}^{-3}$ nitrogen donor atoms ($E_c - E_d = 90 \text{ meV}$).
Use $N_c = 4 \times 10^{20} \text{ cm}^{-3}$.
i. Calculate the electron density at 300 K.
ii. Calculate the hole density at 300 K after adding $2 \times 10^{18} \text{ cm}^{-3}$ aluminum acceptor atoms ($E_a - E_c = 220 \text{ meV}$).
Use $N_v = 1.6 \times 10^{20} \text{ cm}^{-3}$.
(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 $30 \text{ m}^2/\text{V}\cdot\text{s}$. If the effective mass of electron is $0.067m_0$, determine the mean free path.
(4 marks)
- b) A long strip of material of width $w = 1 \text{ cm}$ and thickness $d = 1 \text{ mm}$ 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 $2.5 \times 10^{22} \text{ per m}^3$) is $5 \text{ m}^2/\text{V}\cdot\text{s}$.
i. Determine the magnitude and direction of the net electric field.
ii. If $B = 0.1 \text{ T}$, 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 $N_A = 10^{18} \text{ cm}^{-3}$ and $N_D = 10^{15} \text{ cm}^{-3}$ at 300 K.
ii. For a silicon one-sided abrupt junction with $N_A = 10^{19} \text{ cm}^{-3}$ and $N_D = 10^{16} \text{ cm}^{-3}$, calculate the depletion layer width and the maximum field at zero bias ($T = 300 \text{ K}$).
(12 marks)
- b) For a silicon one-sided abrupt junction with $N_A = 2 \times 10^{19} \text{ cm}^{-3}$ and $N_D = 8 \times 10^{15} \text{ cm}^{-3}$, calculate the junction capacitance at zero bias and reversed bias of 4 V ($T = 300 \text{ K}$).
(8 marks)