MACHAKOS UNIVERSITY

University Examinations for 2020/2021

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

SECOND YEAR FIRST SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (ELECTRICAL AND ELECTRONICS ENGINEERING)

EEE 205: PHYSICAL ELECTRONICS

DATE: 10/8/2021 **TIME: 2:00 – 4:00 PM**

INSTRUCTIONS

Question ONE is compulsory

Answer any other TWO questions

Planks constant=$6.626X10^{-34}$J-sec.
Electronic charge =$1.6X10^{-19}$C
1eV=$1.6X10^{-19}$ Joules
Mass of electron, m_e=$9.1X10^{-31}$kg
Permittivity of free space, ϵ_o=$8.854X10^{-12}$ F-m
K=1.38X10-23

QUESTION ONE (COMPULSORY) (30 MARKS)

a) Explain what is meant by mean free path. (2 marks)

b) In germanium sample, donor type impurity is added to the extent of 1 atom per 10^8 germanium atoms. Determine its conductivity and resistivity. Assume μ_n is 3800cm^2/v-s, μ_p is 1800cm^2/v-s, ni is $2.5X10^{13}$/cm^3, number of germanium toms Nge is $4.41X10^{22}$/cm^3. (5 marks)

c) The atom of a certain element has 12 electrons in total. For this atom, determine:

i. Total energy possessed by electrons in 2nd and 3rd orbits

ii. Frequency of electromagnetic radiation emitted when electron falls from 3rd to 2nd orbit.

iii. Wavelength of the emitted electromagnetic wave.

iv. Radius of 1st orbit

v. Velocity of electrons in the 1st orbit (10 marks)

d) In an application of solar cells, an earth satellite has on board 13V battery which supplies a continuous current of 1A. Solar cells are used to keep the battery charged. The solar cells are illuminated by sun for 10 hours in every 24 hours. If the during exposure, each cell gives 0.5V at 100mA, determine the number of cells required. To charge the battery 14.0 volts are needed. (6 marks)

e) Consider a silicon crystal at room temperature (300 ^{o}K) doped with arsenic atoms so that N_D =6X10^{16} per cm^3. Find the equilibrium electron concentration n_o, hole concentration p_o and Fermi level E_F with respect to intrinsic Fermi level E_i and conduction band edge E_C. Take n_i=1.45X10^{16} per cm^3, the Boltzmann constant k=8.61X10^{-5}eV/K and silicon band energy gap E_g=1.12 eV. Sketch the band energy diagram, placing E_F in the correct place. (7 marks)

QUESTION TWO (20 MARKS)

a) With aid of a VI- characteristic, briefly describe the behavior of a tunnel diode when forward and reverse biased. (5 marks)

b) With aid of a labelled diagram of voltage against current characteristic, describe the three electric discharge regimes namely dark discharge, glow discharge and arc discharge. (5 marks)

c) A germanium a semiconductor is doped with 6x10^{16} cm^3 gallium atoms per and 3x10^{16} atoms of arsenic per cm^3. Determine:

i. Type of the impure semiconductor.

ii. Majority and minority charge carriers. (5 marks)

d) The expression of Schrodinger time independent wave equation is given by $E\Psi = \frac{\hbar^2}{2m}\frac{d^2\Psi(x)}{dx^2} + V\Psi(x)$. Use the expression to derive Schrodinger time dependent wave equation. (5 marks)

QUESTION THREE (20 MARKS)

a) Explain the mass action law and give its expression. (3 marks)

b) Explain any three applications of light emitting diode. (3 marks)

c) Derive the expression to proof that the Fermi level is mid-way between conduction band and the valence band in a pure semiconductor. (5 marks)

d) Derive the expression of mobility of electrons in a good conductor. (4 marks)

e) Determine the applied voltage to achieve a forward current of 0.5 μA in a PN junction silicon diode at 27°C, if the reverse saturation current is 0.8 nA. If the reverse saturation current in a germanium diode is 8μA, what current would result if the voltage determined is applied in the forward direction assuming $\eta = 1$ for germanium and 2 for silicon diodes. (5 marks)

QUESTION FOUR (20 MARKS)

a) Explain any THREE Bohr atom postulates. (3 marks)

b) Briefly describe the two parameters of intrinsic semiconductors that determines its conductivity, and describe how they vary with changes in temperature. (4 marks)

c) A semiconductor at 300K has intrinsic concentration, $Ni=1.5x10^{16}/m^3$ and resistivity of $\rho=2x10^{13}$ohm-meter. Donor impurity atoms $N_D=1x10^{20}$ per m^3 were added as dopants. Determine the shift in Fermi energy level due to doping in electron-volts. (6 marks)

d) Find the velocity of charge leading to a current of 2 A which flows in an aluminium conductor of cross section 2 cm^2 and length 15 kilometers. Free electron density of aluminium is $12 \times 10^{28}/m^3$. How long will it take for the electric charge to travel from one end of the conductor to the other in terms of years?
(7 marks)

QUESTION FIVE (20 MARKS)

a) Sketch a well labeled diode characteristic. (4 marks)

b) Calculate the voltage which has to be applied across a PN semiconductor junction to cause a forward current of 5 A/cm^2, assuming that the saturation current density at 300K is 25 micro ampere per cm^2. (4 marks)

c) Briefly describe the four quantum numbers. (6 marks)

d) A light emitting diode with minimum and maximum voltage drops of 1.8 volts and 3 volts respectively is connected alternately with 24 volt supply (with 820 ohm resistor) and 5 volts supply (with 120 ohm resistor). Indicate which supply voltage will keep the brightness of the diode constant. (6 marks)