MACHAKOS UNIVERSITY

University Examinations 2019/2020Academic year

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF PHYSICAL SCIENCES

SECOND YEAR FIRST SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (APPLIED PHYSICS AND TECHNOLOGY)

SPH 206: SEMICONDUCTOR PHYSICS

DATE: 9/12/2019 **TIME: 2.00-4.00 PM**

INSTRUCTIONS TO CANDIDATES

(i) This paper consists of ***FIVE*** *questions in* ***FIVE*** *printed pages. Answer* ***Question One*** *(compulsory) and any* ***TWO questions*** *from the rest of the questions.*

(ii) Cheating will lead to automatic disqualification.

IMPORTANT CONSTANTS

Charge on an electron, $e = 1.6 \times 10^{-19}\ C$

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

QUESTION ONE (30 MARKS)

a) Define the following terms with reference to the energy band theory

i. Conduction band (2 marks)

ii. Valence band (2 marks)

iii. Fermi level (2 marks)

b) State the values of forbidden energy gap for silicon (Si) and germanium (Ge) at a room temperature of $27\ ^0C$. (2 marks)

c) Write the electronic configuration of the following elements

i. Antimony $(Z = 51)$ (2 marks)

ii. Gallium $(Z = 31)$ (2 marks)

d) In the circuit shown in Figure 1, calculate I_B, I_C, V_{CE}, V_B, V_C and V_{BC}. Assume $V_{BE} = 0.7$ V and $\beta = 50$. (6 marks)

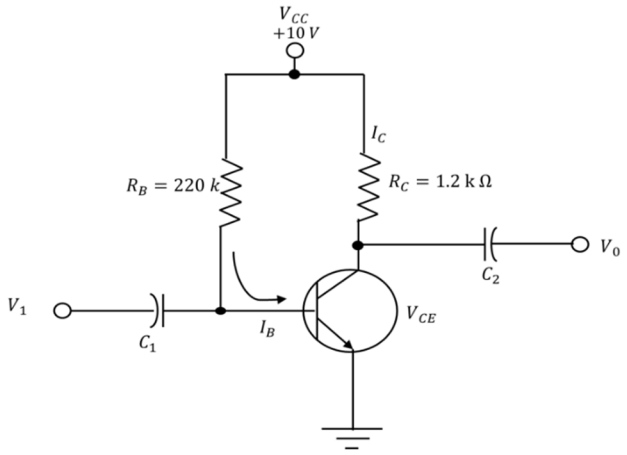


Figure 1

e) Find the resistivity of an intrinsic semiconductor (silicon) at 300 K if the intrinsic concentration of silicon at this temperature is 1.5×10^{10} / cm^3, $\mu_n = 1300\ \text{cm}^2/\text{V.s}$ and $\mu_p = 500\ \text{cm}^2/\text{V.s}$. (4 marks)

f) Write the Fermi-Dirac distribution function and state its significance. (3 marks)

g) Explain with the aid of a diagram how a phototransistor can be used in controlling a light activated relay through a power-switching transistor. (5 marks)

QUESTION TWO (20 MARKS)

a) Explain with aid of diagrams the meaning of the following terms

i. Pinch off voltage (3 marks)

ii. Cut off voltage (3 marks)

b) Describe with the aid of a diagram how a combination of an LED and a photodiode can be used as *raindrop sensor* for automobile windscreen. (6 marks)

c) The collector current of a transistor is found to be 9.9 mA for an emitter current of 10 mA in the common base mode. Calculate the transistor parameters and the base current. (4 marks)

d) The pinch off voltage of a depletion layer type MOSFET is -4 V and the drain current at zero gate voltage is 10mA. Find the mutual conductance when the gate voltage is $+6$ V. (4 marks)

QUESTION THREE (20 MARKS)

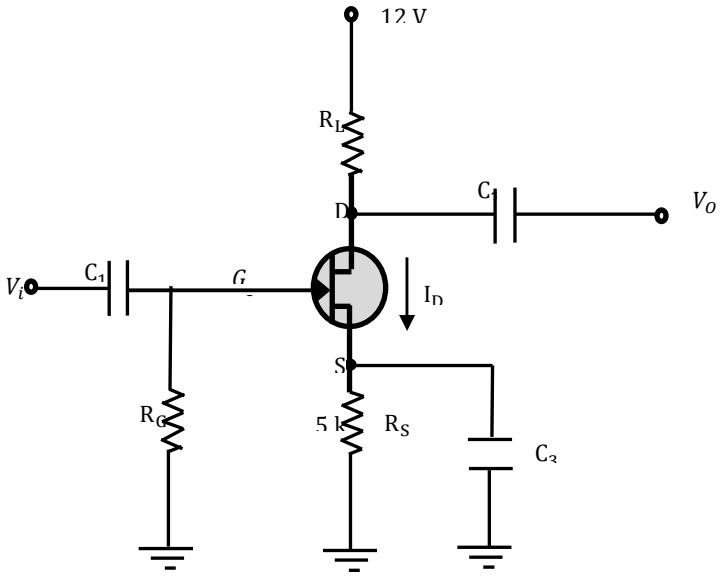
a) What is a Field effect transistor? (2 marks)

b) Draw and explain the V-I characteristic of a PN junction. (4 marks)

c) Describe using energy bands how a PN junction behaves under forward bias and reverse bias conditions. (4 marks)

d) The saturations current density of a PN Junction Gemanium diode is $250\ \text{mA/m}^2$ at 300 K. Find the voltage that must be applied across the junction to cause a forward current density of $10\ \text{A/m}^2$ to flow. (5 marks)

e) Determine the quiescent value of V_{GS}, I_D and V_{DS} for the JFET circuit of Fig 2 given that $I_{DSS} = 10$ mA, $R_S = 5$ k and $V_P = -5$ V. (5 marks)



QUESTION FOUR (20 MARKS)

a) Define the following types of materials using energy band models, clearly showing the forbidden energy gaps

i. A semiconductor (2 marks)

ii. A metal (2 marks)

iii. An insulator (2 marks)

b) Explain the mechanism of conduction in an intrinsic semiconductor, by free electrons and holes. (3 marks)

c) A bar of intrinsic silicon semiconductor has a cross-sectional area of $2.5 \times 10^{-4}\ \text{m}^2$. The electron density is $1.5 \times 10^{16}\ /\text{m}^3$. Current through the bar is 1.2 mA when 9 V is applied across it, how long is the bar? Given that $\mu_n = 0.14\ \text{m}^2/\text{V.s}$ and $\mu_p = 0.05\ \text{m}^2/\text{V.s}$.

(6 marks)

d) Calculate the Q - point values (I_C and V_{CE}) for the circuit in Figure 3. (5 marks)

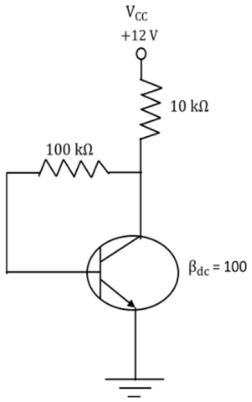


Figure 3

QUESTION FIVE (20 MARKS)

a) What do you understand by the following terms as used in semiconductor devices,

i. Depletion region (2 marks)

ii. Load line (3 marks)

iii. Quiescent point (3 marks)

b) Explain the formation of the following semiconductors and explain how conduction takes place in each.

i. An N-type semiconductor. (3 marks)

ii. A P-type semiconductor. (3 marks)

c) Find the DC load line for common emitter circuit shown in Figure 4, assuming $V_{BE} = 0.7$ V. (6 marks)

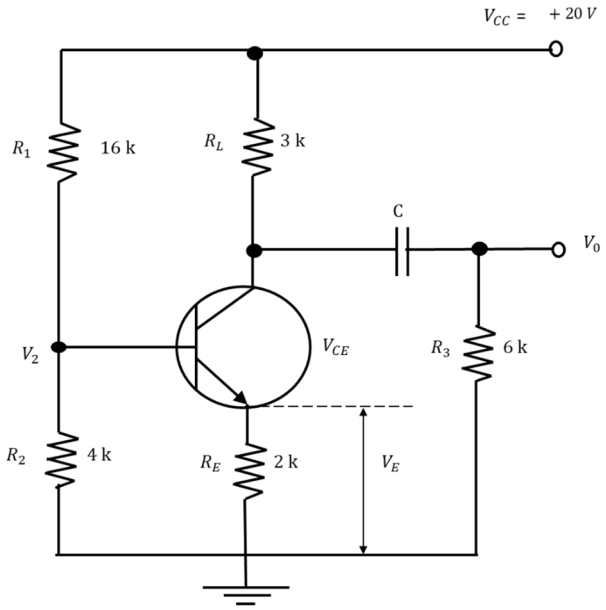


Figure 4