MACHAKOS UNIVERSITY

UNIVERSITY EXAMINATIONS 2018/2019

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF PHYSICAL SCIENCES

SECOND YEAR SECOND SEMESTER EXAMINATION FOR DEGREE IN BACHELOR OF SCIENCE (ENGINEERING)
SPH 206: SEMICONDUCTOR PHYSICS

DATE: 24/9/2019 **TIME: 8:30 – 10:30 AM**

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

INSTRUCTIONS TO CANDIDATES

I. Answer **QUESTION ONE** *and* **ANY OTHER TWO** questions in this paper.
II. Cheating will lead to automatic disqualification.

QUESTION ONE

a) With the help of energy band theory, define the following terms
   (i) Conduction band (3 marks)
   (ii) Valence band (3 marks)
   (iii) Forbidden energy gap (3 marks)
b) State the values of forbidden energy gap for silicon Si and germanium Ge at a room temperature of $27\,^0$C. (2 marks)
c) 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)

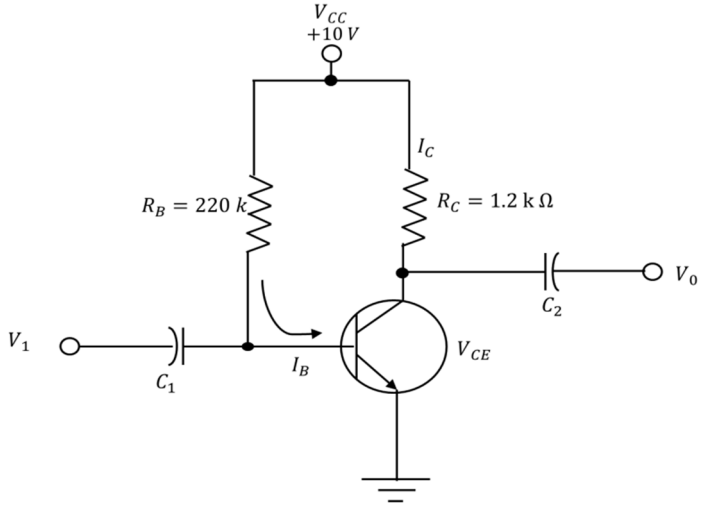

Figure 1

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

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

f) Design a fixed biased circuit using a silicon transistor having β value of 100. V_{CC} is 10 V and dc bias conditions are to be $V_{CE} = 5$ V and $I_C = 5$ mA. Label your circuit with all correct values. (6 marks)

QUESTION TWO (20 MARKS)

a) Explain with aid of diagrams the meaning of the following terms
   ii. *Pinch off* voltage (3 marks)
   iii. *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 +6V. (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) Why is an N-type or P-type semiconductor considered electrically neutral? (2 marks)

e) The saturations current density of a PN Junction Ge 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)

f) What is Fermi-Dirac probability function? State is significance. (3 marks)

QUESTION FOUR (20 MARKS)

a) Distinguish between the following materials using energy band diagrams clearly showing the forbidden gap
   (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 2. (5 marks)

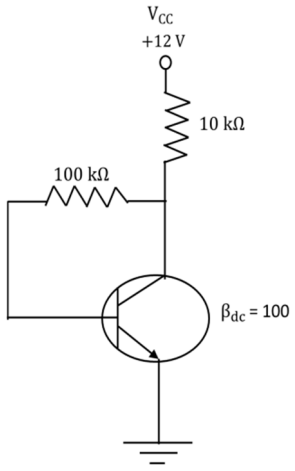

Figure 2

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 and AC load lines for common emitter circuit shown in Figure 3, assuming $V_{BE} = 0.7$ V. (6 marks)

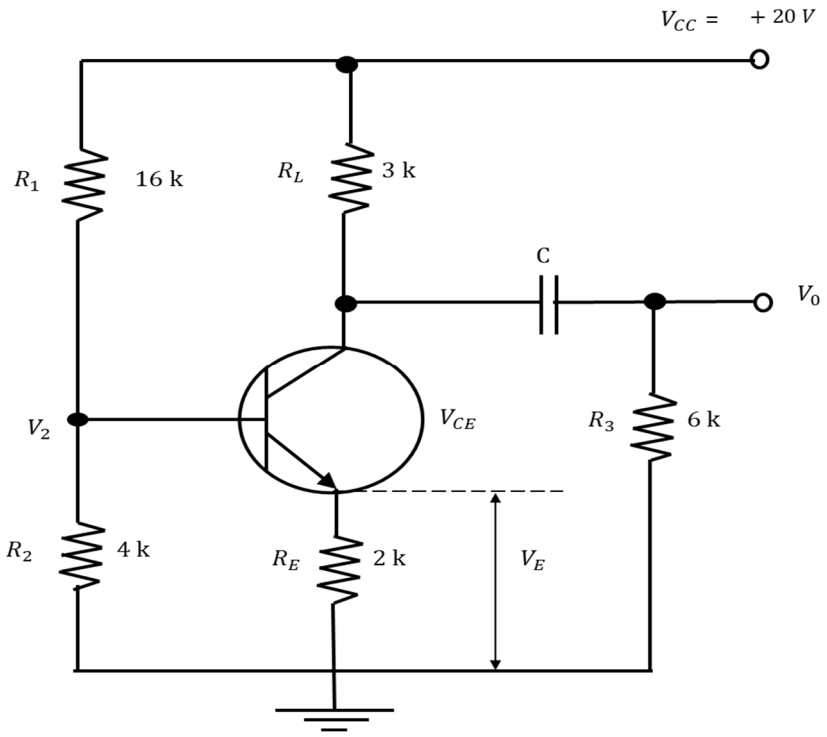

Figure 3