MACHAKOS UNIVERSITY

University Examinations 2018/2019

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF PHYSICAL SCIENCES

THIRD YEAR SECOND SEMESTER EXAMINATION FOR

BACHELOR OF EDUCATION (SCIENCE)

SPH 340: SEMICONDUCTOR PHYSICS AND DEVICES

DATE: 24/4/2019 **TIME: 2.00-4.00 PM**

INSTRUCTIONS TO CANDIDATES

Answer question one and any other two questions

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 the help of energy band theory,

i. Conduction band (2 marks)

ii. Valence band (2 marks)

iii. Forbidden energy gap (2 marks)

b) Explain the main differences in operation between a photodiode and a light emitting diode (LED). (4 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)

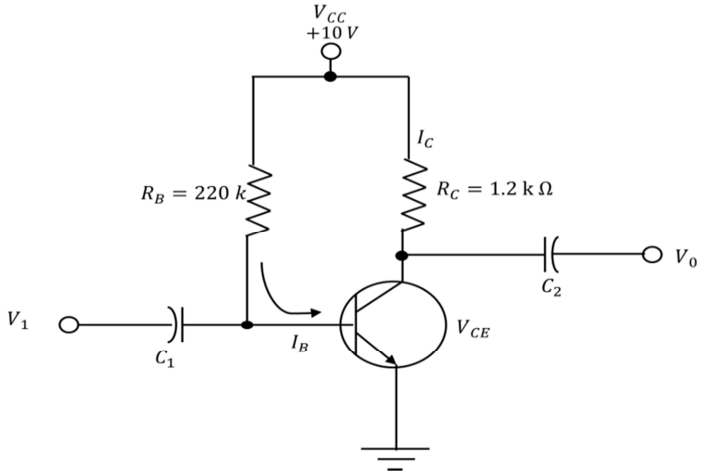

Figure 1

d) Find the resistivity of an intrinsic semiconductor (silicon) at 300 K if the intrinsic concentration of silicon at this temperature is 1.5×10^{10} / cm^3, $\mu_n = 1300$ cm^2/V-s and $\mu_p = 500$ cm^2/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. (5 marks)

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

QUESTION TWO (20 MARKS)

a) Explain with aid of diagrams the meaning of the following terms as used in field transistors

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 10 mA. Find the mutual conductance when the gate voltage is +6 V. (4 marks)

QUESTION THREE (20 MARKS)

a) What is a field effect transistor (FET)? (2 marks)

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

c) In a common-base connection the emitter current is 1 mA. The collector current is 50 μA when the emitter circuit is open. If $\alpha = 0.92$, find the total collector current. (4 marks)

d) Why is an N-type or P-type semiconductor considered electrically neutral? (2 marks)

e) Explain the following.

i. The action of an NPN transistor accounting for all currents in its terminals. (5 marks)

ii. How a zener diode works as a voltage regulator. (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 2.5×10^{-4} m^2. The electron density is 1.5×10^{16} /m^3. Current through the bar is 1.2 mA when 9 V is applied across it, how long is the bar? Given that $\mu_n = 0.14$ m^2/V-s and $\mu_p = 0.05$ m^2/V-s. (6 marks)

d) Calculate the Q - point values (I_C and V_{CE}) for the circuit in Figure 2. (5 marks)

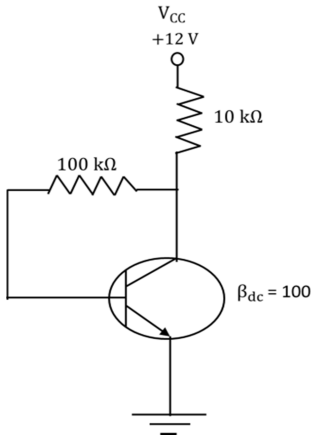

Figure 2

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

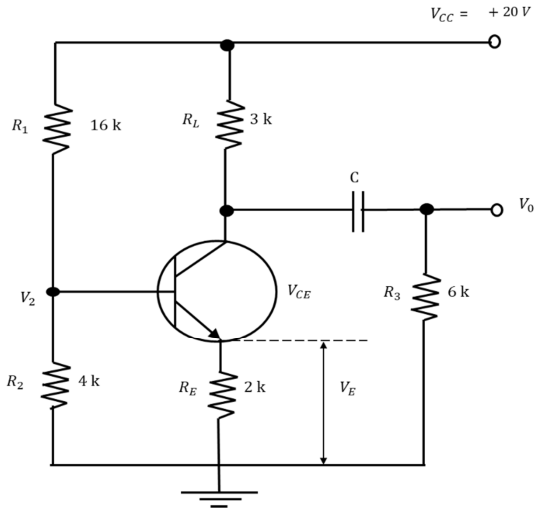

Figure 3