



THE CATHOLIC UNIVERSITY OF EASTERN AFRICA

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MAIN EXAMINATION

JANUARY – APRIL 2018 TRIMESTER

FACULTY OF SCIENCE

DEPARTMENT OF PHYSICS

REGULAR PROGRAMME

PHY 307: PHYSICAL ELECTRONICS

Date: APRIL 2018

Duration: 2 Hours

INSTRUCTIONS: Answer Question ONE and any other Two Questions

You may use the following list of constants

- Planks constant (h) 6.63×10^{-34} J.s
- Electronic charge 1.602×10^{-19} C
- Germanium electron mobility (μ_n) $3600 \text{ cm}^2\text{V}^{-1}\text{s}^{-1}$
- Intrinsic carrier concentration of germanium(n_i) $2.5 \times 10^{13} \text{ cm}^{-3}$
- Ratio (μ_n/μ_p) for germanium at 300K 2.0
- Speed of light in a vacuum 2.99792×10^8 m/s
- μ_n for silicon $0.135\text{m}^3/\text{v-s}$
- μ_p for silicon $0.048\text{m}^3/\text{v-s}$

- Q1. a) Distinguish between intrinsic and extrinsic semiconductors **(2 marks)**
- b) Using sketches of energy band diagrams distinguish between direct and indirect transition in semiconductors citing examples in each case. **(4 marks)**
- c) Describe the “cut-in” voltage of a semiconductor p-n junction diode **(2 marks)**
- d) Determine the miller indices of a plane intercepting the x-axis, y-axis and z-axis at $1, \frac{1}{2}$ and 1 respectively **(3 marks)**

- e) Distinguish between the valence band and conduction band in semiconductors clearly explaining the concept of band gap in semiconductors **(4 marks)**
- f) Using energy band diagrams clearly differentiate between metals semiconductors and insulators in terms of their electrical behavior. **(4 marks)**
- g) Define the following terms
- i) Doping
 - ii) Drift current
 - iii) Diffusion current
 - iv) Mobility **(4 marks)**
- h) Differentiate between elemental and compound semiconductors giving examples in each case **(4 marks)**
- i) Determine the germanium P-N junction diode current for the forward bias voltage of 0.25 V at room temperature of 26°C with reverse saturation current equal to 2 mA. Take $\eta=2$. **(4 marks)**

- Q2. a) A germanium semiconductor at 300k is doped with donor impurity at a rate of 10^6 germanium atoms for every donor atom. Calculate the resistivity of the resulting semiconductor device. Assume there are 4.2×10^{22} germanium atoms per cubic centimeter. **(6 marks)**
- b) Movement of charge carriers across a P-N junction determines the total current passing through the junction. State and explain any two processes through which charge carriers move across the P-N junction. What are the factors that affect their movement? **(5 marks)**
- c) Draw the current – voltage (I-V) characteristics of a p-n junction diode, state the equation relating the total current through the junction and the applied voltage. **(3 marks)**

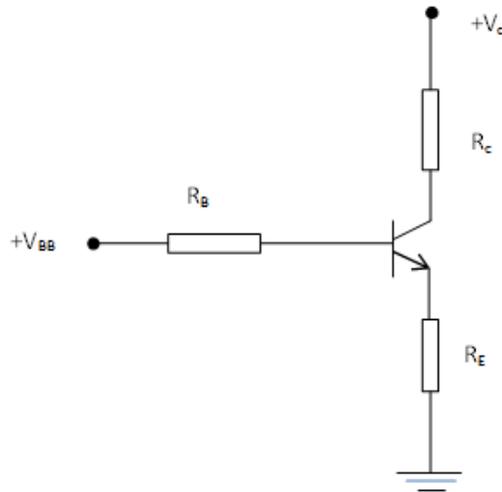
- d) Given that the drift current density is

$$J_{drift} = e(\mu_p p + \mu_n n)E$$

Show that the resistivity of an n-type material is given as $\rho = \frac{1}{e\mu_n n}$ **(6 marks)**

- Q3. a) Briefly explain the following terms
- i) Active region in C-B configuration **(2 marks)**
 - ii) Saturation region in C-E configuration **(2 marks)**
- b) Draw a circuit for n-p-n transistor in the common emitter(C-E) configuration for an active mode operation and derive an expression for the collector current. **(5 marks)**

- c) Using a circuit diagram explain any bipolar junction transistor (BJT) model. **(4 marks)**
- d) The collector current in common base configuration is 6 mA, given that the base current is $150 \mu A$. Determine the emitter current. **(3 marks)**
- e) The figure below shows a transistor in common emitter configuration.



Given that the transistor has the following parameters; $h_{FE} = 50$, $V_{CC} = 25V$, $V_{BB} = 10$, $R_B = 40K\Omega$, $R_C = 15 K\Omega$ and $R_E = 5 K\Omega$. Assuming that the transistor is in saturation, find; I_B and I_C . **(4 marks)**

- Q4. a) Using a well labelled diagram, briefly describe the operation of a junction field effect transistor (JFET) **(4 marks)**
- b) Outline the two categories of JFET **(2 marks)**
- c) Define the following terms as used in JFET **(4 marks)**
- Pinch voltage
 - Transconductance
 - Channel
 - I_{DSS}
- d) Differentiate between a JFET and a MOSFET **(2 marks)**
- e) Explain why N-channel MOSFETs are more popular than P-channel **(2 marks)**
- f) With the aid of a diagram the depletion mode of JFETs **(3 marks)**
- g) The data sheet of a certain JFET indicate that $I_{DSS} = 4 \text{ mA}$ and $V_p = -6 \text{ V}$. determine the drain current for $V_{GS} = -2V$. **(3 marks)**

- Q5. a) What is a p-n junction diode (1 mark)
- b) Explain the possible biasing of a junction diode in a circuit (2 marks)
- c) Silicon diode has a saturation current of $0.01 \mu A$ at room temperature of 300K. Find the saturation current at 400K. (5 marks)
- d) A transistor has $\beta=180$. Calculate the approximate collector and base currents, if the emitter current is 12 mA. (3 marks)
- e) Determine the germanium P-N junction diode current for the forward bias voltage of 0.25V at a temperature of 500K with reverse saturation current of 1 mA. (3 marks)
- f) With the aid of a diagram explain forward and reverse biasing of a p-n junction (4 marks)
- g) Describe how a space charge region is formed in a p-n junction. (2 marks)

END