UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
(TAKE HOME)
SEMESTER II
SESSION 2019/2020

COURSE NAME	:	SEMICONDUCTOR ELECTRONIC AND DEVICES
COURSE CODE	:	BED 20103
PROGRAMME CODE	:	BEJ
EXAMINATION DATE	:	JULY 2020
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS **OPEN BOOK EXAMINATION**

THIS QUESTION PAPER CONSISTS OF **SIX (6)** PAGES

TERBUKA

Q1 (a) Defects in a semiconductor material introduce allowed energy states within the forbidden bandgap. Assume that a particular defect in silicon introduces two discrete levels: a donor defect level 0.25 eV above the top of the valence band, and an acceptor defect level 0.65 eV above the top of the valence band.

(i) Analyze which defect level dominates in the semiconductor.

(7 marks)

(ii) Analyze the carrier concentration and Fermi level position with respect to the intrinsic Fermi level if the semiconductor is doped with 4.25×10^{16} antimony/cm^3 and 8.74×10^{14} indium/cm^3 at 300 K.

(6 marks)

(b) Analyze how carrier concentration contributes toward current (I).

(6 marks)

(c) Sketch **ONE** energy band diagram **each** for intrinsic, N-type and P-type semiconductor showing clearly the followings:

(i) Density of state function and Fermi-Dirac function
(ii) Fermi level
(iii) Carrier distribution (electron and hole)

(6 marks)

Q2 (a) Analyze the transport phenomena in diode and photo diode.

(5 marks)

(b) A GaAs semiconductor at T = 300 K is doped with multiple implants, which are 5.23×10^{15} antimony atoms/cm^3, 8.67×10^{16} gallium atoms/cm^3, 3.34×10^{15} phosphorus atoms/cm^3 and 4.56×10^{16} indium atoms/cm^3. Analyze the following:

(i) carrier mobilities

(4 marks)

(ii) conductivity and resistivity of the semiconductor.

(6 marks)

(c) (i) Design an ideal transistor based on the properties in **TABLE Q2(c)**.

(4 marks)

(ii) Analyze the bottleneck of an ideal transistor in order to be the next generation of transistor.

(6 marks)

TABLE Q2(c)

	Si	Ge	GaAs	InAs
μ_n (cm^2/V·s)	1400	3900	8500	30000
μ_p (cm^2/V·s)	470	1900	400	500

Q3 (a) Consider a GaAs pn junction at $T = 300$ K with zero applied bias was doped with boron = 10^{18} cm^{-3} and phosphorus which results in $V_{bi} = 0.8$ V.

(i) Find the doping concentration of phosphorus dopant.

(2 marks)

(ii) Determine the x_n, x_p, W and $|E_{max}|$.

(7 marks)

(iii) Based on the values from **Q3(a)(ii)**, identify the type of PN junction.

(2 marks)

(iv) Analyze the effect of applying a reverse biased voltage, $V_R = 6V$ to the width of the space charge region and the maximum electric field.

(6 marks)

(v) Calculate the junction capacitance when $V_R = 6V$ is applied.

(2 marks)

(b) A sufficiently large reverse-biased voltage, V_R is applied to a uniformly doped PN junction.

(i) Sketch the space charge density at the junction with V_R effect of zero bias and reverse biased.

(2 marks)

(ii) Briefly explain **ONE (1)** predominant breakdown mechanism that give rise to the reverse bias breakdown in a PN junction.

(4 marks)

Q4 (a) For $V_{GS} > V_T$ in a MOSFET, analyze the channel I_D versus V_{DS} curve as V_{DS} is increased in the following condition:

(i) $V_{DS} > 0$ V.

(3 marks)

(ii) V_{DS} equals $V_{DS\,(SAT)}$.

(3 marks)

(iii) V_{DS} greater than $V_{DS\,(SAT)}$.

(3 marks)

(b) At room temperature, consider a long-channel Silicon MOSFET that has the following parameters,

$L = 2.65$ µm $Z = 6.88$ µm $N_A = 5 \times 10^{15}$ cm^{-3} $\mu_n = 1500$ cm^2/V-s

$C_o = 3.54 \times 10^{-7}$ F/cm^2 $V_T = 0.6$ V $\varepsilon_0 = 8.85418 \times 10^{-14}$ F/cm

Calculate drain saturation voltage, V_{Dsat}, and drain saturation current, I_{Dsat}, for $V_G = 6.5$ V

(5 marks)

(c) Predict the future of Moore's Law as number of transistors in a chip no longer doubles in every 18 months.

(11 marks)

-END OF QUESTIONS-

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Physical constant

Boltzmann constant, $k = 8.6173324 \times 10^{-5}$ eV/K or 1.38066×10^{-23} J/K

Thermal voltage at 300 K, $kT/q = 0.025852$ V

Permittivity in vacuum, $\varepsilon_0 = 8.85418 \times 10^{-14}$ F/cm

Elementary charge, $q = 1.60218 \times 10^{-19}$ C

Properties of Si and GaAs at 300 K

Properties	**Si**	**GaAs**
Effective density of states in conduction band, N_C (cm^{-3})	2.86×10^{19}	4.7×10^{17}
Effective density of states in valence band, N_V (cm^{-3})	2.66×10^{19}	7.0×10^{18}
Dielectric constant	11.9	12.4
n_i (cm^{-3})	9.65×10^{9}	2.25×10^{6}
Energy gap (eV)	1.12	1.42
Mobility (cm^2/V-s)		
μ_n (electrons)	1450	9200
μ_p (holes)	505	320

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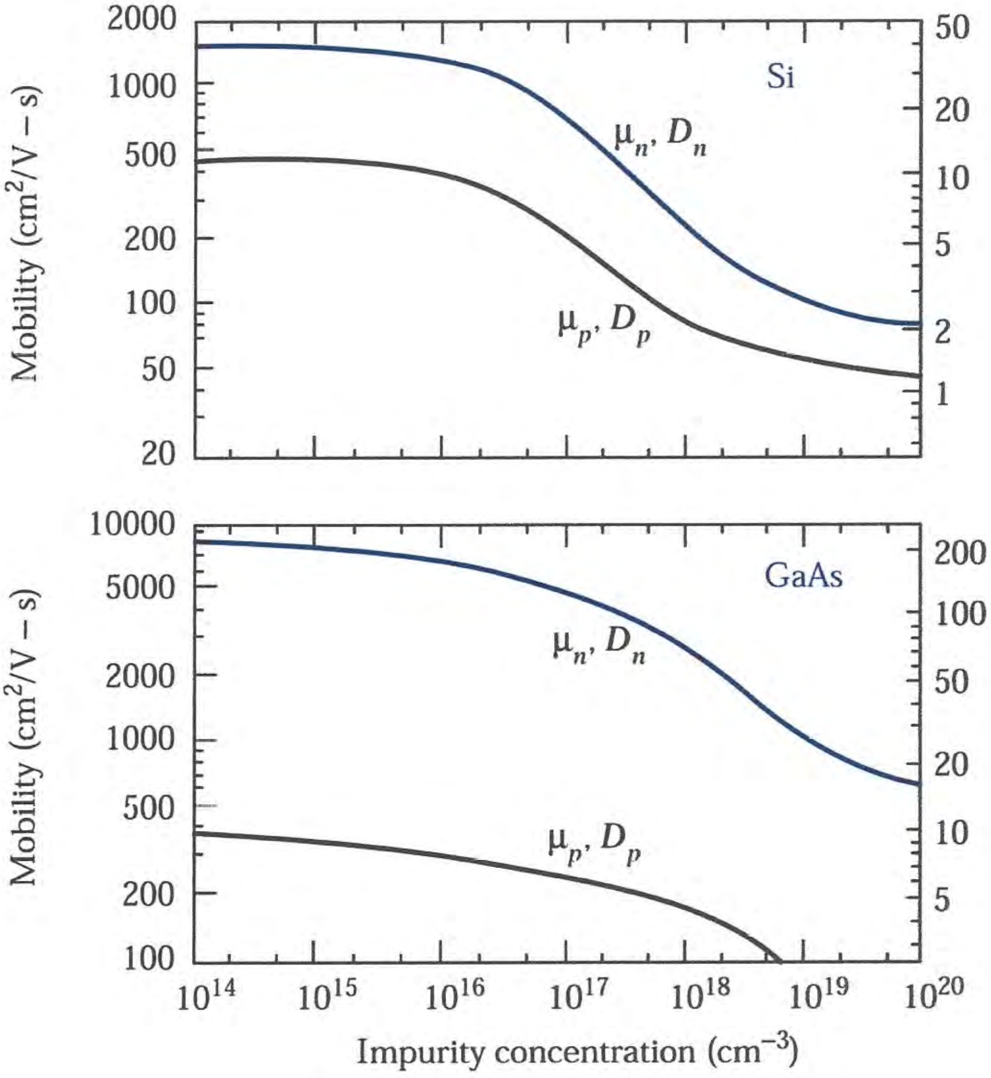

Mobilities and diffusivities in Si and GaAs at 300 K as a function of total impurity concentration.