CONFIDENTIAL

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION (ONLINE) SEMESTER II SESSION 2020/2021

COURSE NAME	:	FUNDAMENTAL OF SEMICONDUCTOR
COURSE CODE	:	BEJ 33103
PROGRAMME CODE	:	BEJ
EXAMINATION DATE	:	JULY 2021
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS **OPEN BOOK EXAMINATION** PLEASE UPLOAD YOUR ANSWER IN PDF FORM TO AUTHOR (UTHM LMS) WITHIN THE SPECIFIED TIME GIVEN.

TERBUKA

THIS QUESTION PAPER CONSISTS OF **FIVE (5)** PAGES

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. With the aid of energy band diagram, justify your answer.

(6 marks)

(ii) Calculate 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.

(7 marks)

(b) The properties of semiconductors are determined to a large extent by the crystal structure.

(i) Identify the number of atoms of Si unit cell on (111) plane.

(2 marks)

(ii) Determine the miller indices for **plane A** in **Figure Q1(b)(ii)**.

(4 marks)

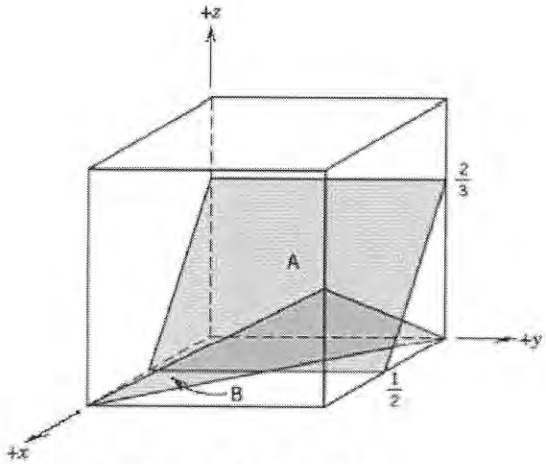

Figure Q1(b)(ii)

(c) Explain the electrical conductivities correspond to the following material:

(i) Conductor

(2 marks)

(ii) Insulator

(2 marks)

(iii) Semiconductor

(2 marks)

Q2 (a) Sketch the plot of average drift velocity as a function of applied electric field for electron and hole in silicon.

(1 mark)

(b) Based on the plot in **Q2(a),** determine the step to obtain mobility.

(2 marks)

(c) Another technique for determining the conductivity type of a semiconductor is called the hot probe method. It consists of two probes and an ammeter that indicates the direction of the current. One probe is heated and the other is at room temperature. No voltage is applied, but a current will exist when the probes touch the semiconductor. With the aid of a diagram, explain the operation of the hot probe technique and relate it with carrier transport phenomena.

(6 marks)

(d) With the aid of a diagram, discuss the effect of lattice scattering and impurity scattering towards mobility as a function of temperature

(6 marks)

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

(4 marks)

(ii) Discuss **THREE (3)** bottlenecks of an ideal transistor to be the next generation of transistor.

(6 marks)

TABLE Q2(e)(i)

	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) Sketch a fully labelled diagram of each of the following distributions for an N$^+$-P junction:

(i) electrostatic potential

(2 marks)

(ii) charge density

(2 marks)

(iii) electric field

(2 marks)

(b) Describe **ONE (1)** physical mechanism that give rise to the reverse bias breakdown in P-N junction. Explain briefly with the aid of appropriate diagram.

(4 marks)

(c) For a silicon one-sided abrupt P^+-N junction with $N_A = 4 \times 10^{17}\ cm^{-3}$ and $N_D = 3 \times 10^{14}\ cm^{-3}$ at 170 K and zero bias, calculate:

(i) built-in potential

(3 marks)

(ii) depletion layer width

(3 marks)

(iii) maximum electric field

(3 marks)

(d) Sketch the energy band diagram and circuit of a N-P junction for the following condition:

(i) Thermal equilibrium condition

(2 marks)

(ii) Forward bias condition

(2 marks)

(iii) Reverse bias condition

(2 marks)

Q4 (a) With the aid of energy band diagram, explain the MOS diode operation with n-type substrate in accumulation, depletion and inversion modes.

(6 marks)

(b) Explain **TWO (2)** approaches to overcome the problems arising from the scaling of MOSFET.

(8 marks)

(c) Predict the future of Moore's Law as number of transistors in a chip no longer doubles in every 18 months since 2008. Give **FIVE (5)** reasons to justify your answer.

(11 marks)

-END OF QUESTIONS-

FINAL EXAMINATION

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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, $\varepsilon_o = 8.85418 \times 10^{-14}$ 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