UNIVERSITY OF TORONTO

FACULTY OF APPLIED SCIENCE AND ENGINEERING

FINAL EXAMINATION, APRIL 19, 2001

Third Year - Program 07

ECE335S - ELECTRONIC DEVICES

Examiner: W.T. Ng

EXAMINATION TYPE: C

Aids allowed: One aid sheet consisting of a page no larger than 8.5x11 inches. No other aids are allowed.

Calculators: Only non-programmable types are permitted.

INSTRUCTIONS

All questions have equal weight but not necessary the same level of difficulties. Answers ALL questions.

Physical Constants:

Boltzmann's constant	$k = 1.38\times10^{-23}$ J/K
Electronic charge	$q = 1.6\times10^{-19}$ coulomb
Permittivity of free space	$\varepsilon_0 = 8.85\times10^{-14}$ F/cm
Planck's constant	$h = 6.625\times10^{-34}$ J·s
Thermal voltage at 300K	$kT/q = 0.0259$ volt

Semiconductor Properties at 300K

Property	Si	GaAs	Ge	SiO_2	Unit
Dielectric constant	11.7	13.1	16.0	3.9	
Bandgap energy	1.12	1.42	0.66	≈9	eV
Electron affinity, χ	4.03	4.07	4.13	- -	V
Intrinsic carrier conc., n_i	1.5×10^{10}	1.8×10^{6}	2.4×10^{13}	- -	cm^{-3}
Breakdown field, E_{crit}	4×10^{5}	4×10^{5}	1×10^{5}	10^{7}	V/cm

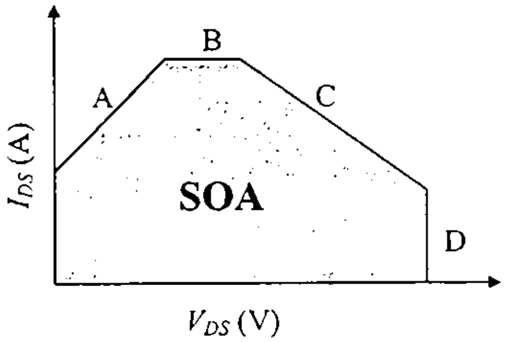
QUESTION (1)

a) What are the two most popular types of DRAM cells? (2 points)

b) Name any two types of fault that can occur in memory chips (2 points)

c) What will happen to a CCD pixel if the incident light has a wavelength that is longer than the critical wavelength ($\lambda \geq \lambda_c$). (2 points)

d) What are the phenomena that determine the boundaries A, B, C, and D in the following safe operating area for a power MOSFET. (4 points)



QUESTION (2)

Two identical MOS capacitors were fabricated on the same silicon substrate, but with different gate oxide thicknesses (30Å and 150Å). Assuming that the same positive oxide charge density is located close to the oxide-semiconductor interface for both capacitors ($Q_i = q \times 5 \times 10^{10}$ coul·cm^{-2}).

a) Find the flat band voltage shifts due to this positive oxide charge for both capacitors. (6 points)

b) What are the threshold voltage shifts for both capacitors? (4 points)

QUESTION (3)

In a 1-D *npn* silicon bipolar transistor structure has the following device parameters: actual base width, $w_b = 0.937$ μm; base doping concentration, $n_b = 10^{16}$ cm^{-3}; collector doping concentration, $n_c = 5\times10^{14}$ cm^{-3}; abrupt junctions.

a) An increase in the reverse base-collector voltage will reduce the neutral base width, w_{nb} (base width modulation). At what value of v_{CB} will the neutral base width reduce to zero (punch-through breakdown)? (4 points)

b) The punch-through breakdown voltage of this 1-D *npn* transistor can be improved by increasing the actual base width, w_b. What is the minimum base width, w_b required to change the breakdown voltage to avalanche breakdown. What will be the BV_{CBO} of this new device? (6 points)

QUESTION (4)

a) An electric field of E = 1V/μm produces a current density of $J = 0.8\times10^9$ A/m^2 through an n-type doped semiconductor with doping concentration of $N_D = 10^{17}$ cm^{-3}. What will be the current density if the electric field is increased 5 times such that the electrons reach the velocity saturation v_{max} = 0.1μ/ps? (4 points)

b) A bar of silicon has the following dimensions, L = 1 cm, W = 0.5 cm, and H = 0.05 cm. The resistance measured from end of to end is 190Ω. The silicon bar has an uniform doping concentration of $N_D = 1\times10^{15}$ cm^{-3}. What is the electron mobility? What will be the drift velocity of the electrons if 10V is applied across the length of this bar of silicon? (6 points)

QUESTION (5)

A silicon pn junction diode in steady state and at room temperature has the following carrier concentration.

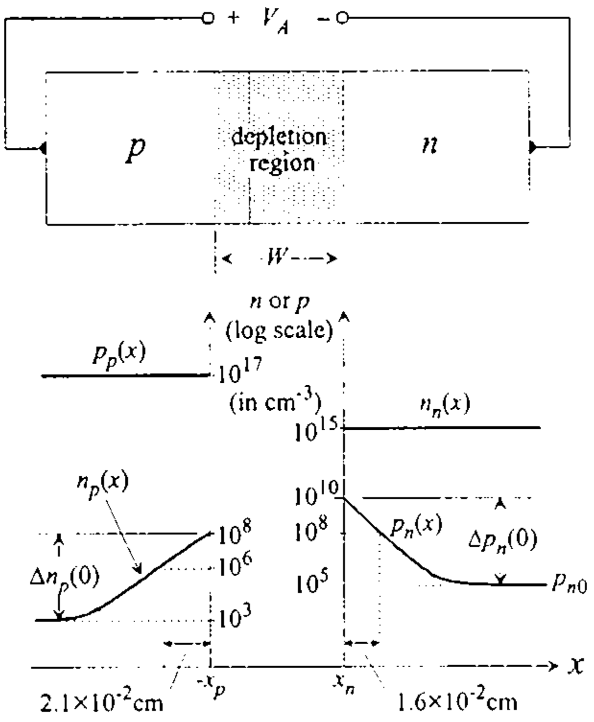
a) Is the diode forward or reverse biased? **Explain** how you arrived at your answer. (1 points)

b) Is the diode operating in low-level or high-level injection? **Explain**. (1 points)

c) What is the applied voltage V_A? **Remember** to specific the correct sign! (2 points)

d) What are the electron and hole diffusion lengths, L_p and L_n in this diode? (2 points)

e) What are the electron and hole current densities, J_n and J_p at the edge of the depletion region? (4 points)



Given: $N_A = 1\times10^{17}$ cm^{-3}

$N_D = 1\times10^{15}$ cm^{-3}

$D_n = 25$ cm^2/sec $\quad D_p = 10$ cm^2/sec

Useful formulae:

$$W = \left\{\frac{2\varepsilon_o\varepsilon_s(V_{bi}-V_A)}{q}\left[\frac{N_A+N_D}{N_AN_D}\right]\right\}^{1/2}$$

$$J_p = q\mu_p pE - qD_p\frac{\partial p}{\partial x}$$

$$J_n = q\mu_n nE + qD_n\frac{\partial n}{\partial x}$$