EECS-130

Integrated Circuit Devices

Midterm Exam # 1

FEBRUARY 13, 1996

Name_____

One 8½ x 11 sheet allowed for formula reference

Table 1-1 Physical constants

Constant	Symbol	Magnitude
Avogadros number	N_A	6.023 x 10^{23} molecules/mol
Boltzmanns constant	k	1.38 x 10^{-23} J/K = 8.62 x 10^{-5} eV/K
Electronic charge	q	1.6 x 10^{-19} J
Electronvolt	eV	1.6 x 10-19 J
Free-electron mass	m	9.1 x 10^{-31} kg
Permittivity of free space	0	8.854 x 10^{-14} F/cm
Permeability of free space	μ_0	1.257 x 10^{-8} H/cm
Plancks constant	h	6.625 x 10^{-34} Js
Thermal voltage at 300K	VT	25.8 mV
Velocity of light	c	3 x 10^{10} cm/s

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1. A silicon abrupt junction, approximated by a step junction, has a doping of Boron 5 x 10^{15} cm^{-3} and Phosphorous = 10^{15} cm^{-3} and a cross sectional area of 10^{-4} cm^2. Assume the depletion approximation, no applied voltage and n_i = 10^{10} cm^{-3} to: (40 points)

(a) calculate the built in voltage, ϕ (5 pts)

(b) calculate x_n, x_p and the total depletion width. (5 pts)

(c) find the total positive ionic charge in the depletion width. (5 pts)

(d) calculate the electric field at the metallurgical junction ($x = 0$). (5 pts)

(e) sketch to a relative x-axis scale the charge density and electric field. (5 pts)

(f) calculate the values of the minority carriers in the bulk regions (n_p and p_n). (5 pts)

(g) draw the electron energy band diagram for the device. (5 pts)

(h) find the percentage of total depletion width in the p-depletion region, the n-depletion region. (5 pts)

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2. The $1/C^2$ versus applied voltage relation in a silicon p^+ - n n^+ junction diode is measured to have a form shown in Figure 1. The junction area is 10^{-3} cm^2. (25 points)

(a) Find the built-in voltage, ϕ (5 pts)

(b) Calculate the N_a and N_d concentrations in the p^+ and n regions. (10 pts)

(c) Calculate the width of the n-region. (5 pts)

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3. A silicon sample has a uniform dopant density of $N_d = 10^{16}$ cm^{-3} and $N_a = 10^{14}$ cm^{-3}. Assume that all the dopant atoms are fully ionized. The donor energy level is 0.049 eV below the conduction band and the acceptor energy level is 0.045 eV above the valence band. (35 points)

(a) Find the conductivity of the sample at room temperature. (7 pts)

(b) Find the Fermi energy level relative to the valence band edge E_v or the conduction band edge, E_c at 300° K. (7 pts)

(c) Find the equilibrium minority carrier concentration. (7 pts)

(d) Using the donor and acceptor energy levels given, find the fraction of the dopant atoms that are not ionized. (7 pts)

(e) Assuming the sample is 2 cm long and has a cross sectional area of 2 mm^2, calculate the samples resistance. (7 pts)