EE 207: MidSem Exam

Date: 15/09/2018, Duration - 2 hrs

Note: In case of any ambiguity/apparent inconsistency/ missing parameters, make appropriate assumptions. Provide justifications to your assumptions and solve the problem. **Do not ask!**

Relevant parameters:

Parameter	Value
n_i (for Silicon)	$10^{10} cm^{-3}$
T	300K
kT/q	0.0256V
Electron mobility	$1000 cm^2/Vs$
Hole mobility	$400 cm^2/Vs$
Dielectric permittivity of Si	$11.8 \times 8.854 \times 10^{-14} F/cm$
Band gap of Si	1.12eV

$$\frac{\frac{F}{cm} \times V \times cm^{3}}{e}$$

Question 1 (3 marks)

A. The electron density of a sample of intrinsic silicon is $10^{15} cm^{-3}$. Estimate the hole density.

B. For a silicon sample with $N_A = 10^{17} cm^{-3}$, find the electron and hole densities (1 mark)

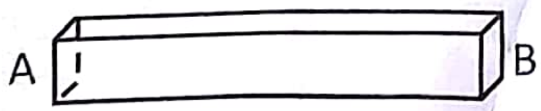
C. Under some excitation, a Silicon sample has an excess electron density of $10^{12} cm^{-3}$. Assuming charge neutrality conditions, estimate the excess hole density (1 mark)

Question 2 (4 marks):

(a) The conductivity of a p-type doped Si sample of length $L = 10\mu m$ is $32\ S/cm$. Estimate the doping density (1 mark)

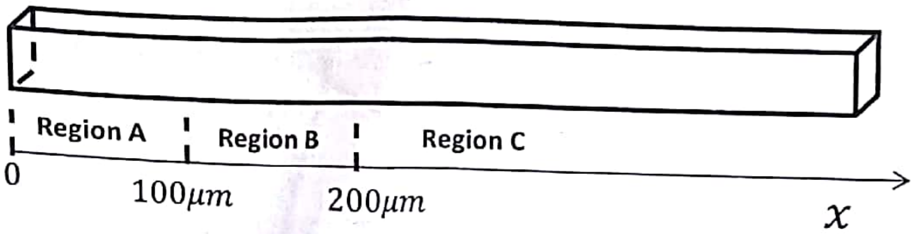
(b) Draw the E-B diagram of the sample under a bias of 1V. Assume $\Delta n = \Delta p = 0$ at both the Silicon-metal contacts and neglect diffusion. Also indicate the electric field (1 mark)

(c) Consider a p-typed doped Si sample with length L. All the faces of the sample (see below) are characterized by electron hole recombination with the rate of reaction being given as $\frac{dn}{dt} = -S\Delta n$, where S is a constant. It is given that $S = 0$ for all faces except A and B. For low level injection scenario due to uniform illumination, estimate the effective minority carrier lifetime subject to the following conditions: (i) Consider only SRH recombination and neglect radiative recombination. (ii) Neglect any spatial variation in carrier densities. (2 marks.)



Question 3 (7 marks):

A semi-infinite p-type Si sample consists of three regions whose properties are listed below.



Region	Definition (also see Figure)	Lifetime	Generation
A	$0 \leq x < 100\mu m$	$\tau_n = \tau_p = \infty$	$G = 10^{18} cm^{-3} s^{-1}$
B	$100\mu m \leq x < 200\mu m$	$\tau_n = \tau_p = \infty$	$G = 0$
C	$x \geq 200\mu m$	$\tau_n = \tau_p = 1\mu s$	$G = 0$

The boundary condition at $x = 0$ is given by $\frac{dn}{dx} = 0$. Assuming steady state and low level injection conditions, answer the following:

A. Making use of the boundary conditions at $x = 0$ and at $x = \infty$, provide appropriate expressions for electron density in the three regions (3 marks. Use the least number of unknown variables).

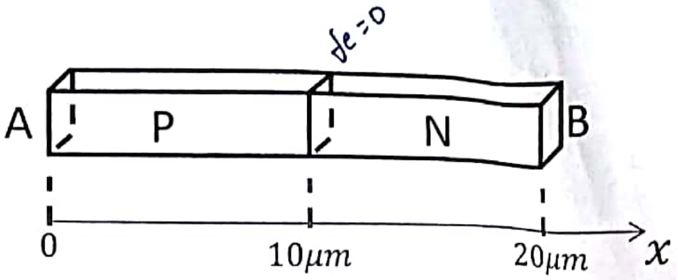
B. Estimate the electron flux density at $x = 200\mu m$ (1 mark. Hint: You may want to avoid solving for all the unknown variables of part A)

C. Using the information in part B, evaluate the carrier density profile for region C. Also indicate the carrier density at $x = 200\mu m$ (1 mark)

D. With the information in part C, estimate the minority carrier density at $x = 100\mu m$ (1 mark)

E. Using the information in part D, estimate the carrier density profile for region A. Indicate the carrier density at $x = 0$ (1 mark)

Question 4 (11 marks): A PN junction diode is shown below. The doping densities of the P and N regions are $10^{18} cm^{-3}$ and $10^{16} cm^{-3}$, respectively. The boundary condition at both the faces A and B is $\Delta n = \Delta p = 0$. The carrier lifetime in the N region is given as $\tau_n = \tau_p = \infty$ (while that of the P region is to be estimated). Neglect any carrier recombination in the depletion region.



A. Estimate the width of depletion region under equilibrium conditions and the built-in potential (2 marks).

B. At some applied forward bias, we have the following information regarding the carrier flux density at the faces A and B. For the rest of the questions, you may ignore x_n and x_p, if required.

Face	Electron flux density	Hole flux density
A	0	$1.5 \times 10^{15} cm^{-2}s^{-1}$
B	To be estimated	$10^{15} cm^{-2}s^{-1}$

(i) Using the above information and properties of the diode, estimate the applied bias (2 marks)

(ii) Estimate the minority carrier lifetime in the P type region (2 marks)

C. Assume that the diode is under **reverse bias** with V= -1V (the diode is still working properly and not in break-down conditions). Now, assume that the quasi-neutral N region is under uniform illumination with photons of energy 1.2eV which results in a carrier generation rate of $G = 10^{16} cm^{-3}s^{-1}$. Estimate

(i) electron and hole flux at face A (2 marks)

(ii) electron and hole flux at face B (2 marks)

(iii) current through the diode (1 mark)