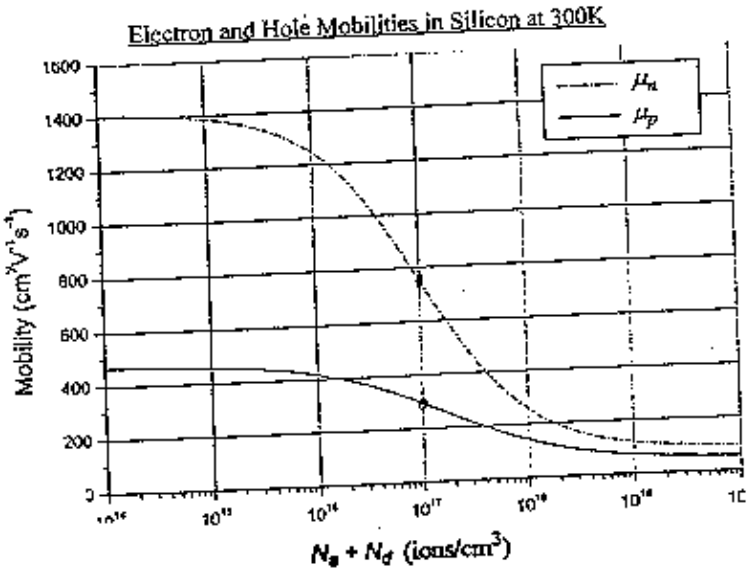
EE 130 Fall 2000
Midterm 1
Prof. King

INSTRUCTIONS:
1. Use the values of physical constants listed below.
2. SHOW YOUR WORK.
3. Write answers clearly in spaces provided
4. Specify units whenever appropriate.



Physical Constants

Description	Symbol	Value
electronic charge	q	1.6×10^{-19} C
electron rest mass	m_o	9.1×10^{-31} kg
thermal voltage at 300K kT/q		0.026 V

Properties of Silicon at 300K

Description	Symbol	Value
band gap	E_g	1.12 eV
intrinsic carrier density	n_i	10^{10} cm^{-3}
permittivity	ε_{Si}	1.0×10^{-12} F/cm
electron affinity	χ_{Si}	4.05 V

Problem #1: Semiconductor Fundamentals [20 points]

Consider a silicon sample maintained at 300K under equilibrium conditions, doped with the following impurities:

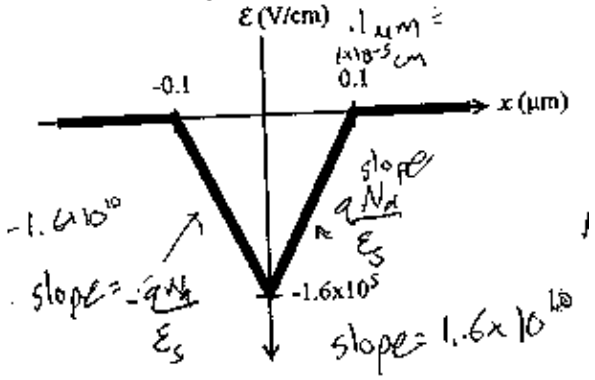
Phosphorus: 5x10^16 cm^-3
Boron: 5x10^16 cm^-3

a.) What are the carrier mobilities in the sample? [4 pts]
MUn and MUp = ?
b.) What are the electron and hole concentrations in the sample? [4 pts]
n and p = ?
c.) What is the conductivity type of the sample? [2 pts]
d.) What is the resistivity of the sample? [4 pts]
rho = ?
e.) What is the mean scattering time for electrons in the sample? [3 pts]
Assume Mn = 0.26 M0. Note: 1 kg-cm^2/V-s/C = 10^-4 s
TAUmn = ?

f.) What is the hole diffusion constant in the sample? [3 pts]
Dp = ?

Problem #2: pn Junction: Electrostatics [25 points]

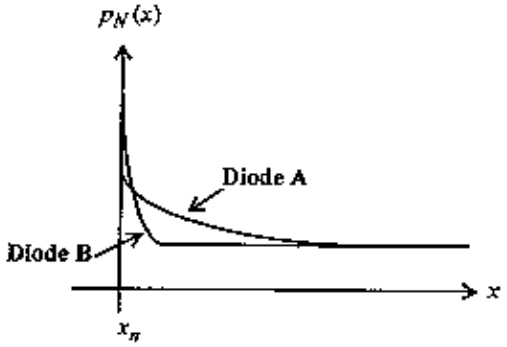
Given the following electric-field distribution inside an ideal Si pn step junction maintained at 300K:



a.) Sketch the doping profile of this pn junction. [6 pts]
{sketch}
b.) What is the built-in potential of this junction? [4 pts]
Note: (kT/q) ln 10 = 0.060 V at 300K
PHIbi = ?
c.) What is the applied bias Va for the given electric-field distribution? [3 pts]
Va = ?
d.) Sketch the energy-band diagram. Show the positions of the quasi-Fermi levels relative to Ei and to each other on both sides of the junction. [5 pts]
{sketch}
e.) What is the junction capacitance at this bias? [3 pts]
Cj = ?
f.) Calculate the reverse-bias breakdown voltage, assuming that the critical electric field EPSILONcrit is 5x10^5 V/cm. [4 pts]
Vb = ?

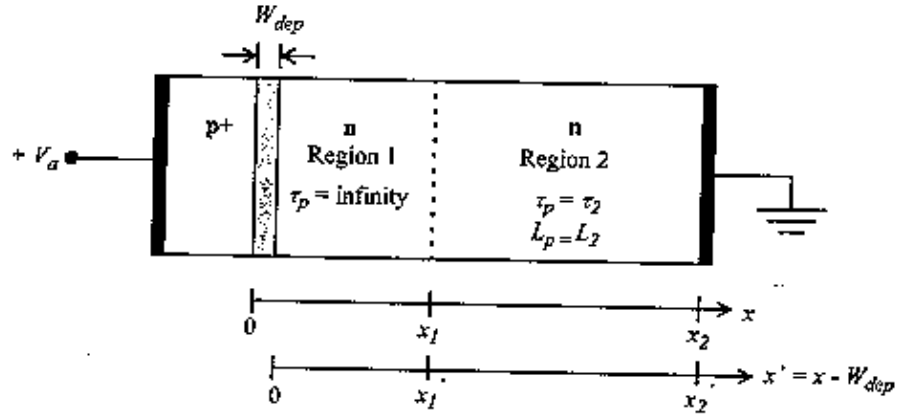
Problem #3: pn Junctions [35 points]

a.) The minority-carrier concentration profiles on the n-side of two ideal Si p+n step-junction diodes maintained at 300K are pictured below:



Check the appropriate boxes in the table below, and provide brief justifications for your answers. [20 pts]

b.) Consider the Si p+n step-junction diode below. The doping on the n-side is uniform, but the minority-carrier lifetime TAUp is infinite in region 1 and has finite value TAU2 in region 2. Assume that the depletion width Wdep is smaller than X1, and that the length of region 2 is much longer than the minority-carrier diffusion length L2 in region 2.



i.) Write expressions for the excess minority-carrier concentration in region 1 and region 2. [5 pts]
Note: You should express your answers in terms of several position-dependent parameters.
Region 1: Pn'(X') = ?
Region 2: Pn'(X') = ?

ii.) Sketch the excess minority-carrier profile in the quasi-neutral n region under forward bias. Specify the boundary conditions at X' = 0, X1' and X2'. [10 pts] *{sketch}*

Problem #4: Metal-Semiconductor Contact [20 points]

Cosider an ideal Schottky diode maintained at 300K, made by depositing tungsten (qPSIm = 4.5 eV) onto n-type Si.

a.) What is the work function of Si, if Nd = 10^17 cm^-3? [5 pts]
PSIsi = ?

b.) What is the Schottky barrier height? [3 pts]
PHIbn = ?

c.) What is the built-in potential? [3 pts]
PHIbi = ?

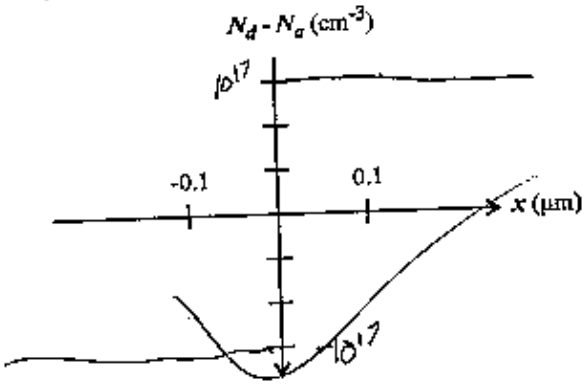
d.) Draw the equilibrium energy-band diagram of the Schottky diode. Label qPSIm, qPSIsi, qXsi, qPHIbn, and qPHIbi, as well as Ec, Ev, Ei, and Ef in the Si. [9 pts]
{drawing}

ANSWERS:

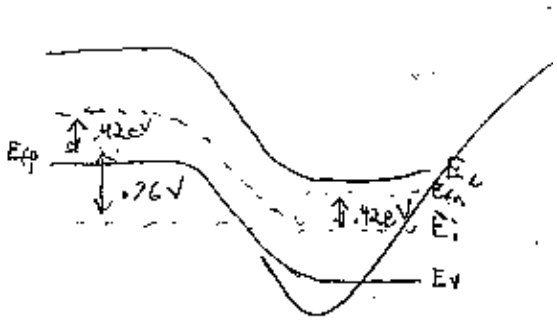
1.) a.) MUn = 750 cm^2/V*s, MUp = 300 cm^2/V*s
b.) n = 10^10 cm^-3, p = 10^10 cm^-3
c.) SIGMA = 1.68x10^-6 A/V*cm
d.) RHO = 4.17x 10^5 OHM*cm

e.) TAUmn = 1.11x10^-13 s
f.) Dp = 7.8cm^2/s

2.) a.)



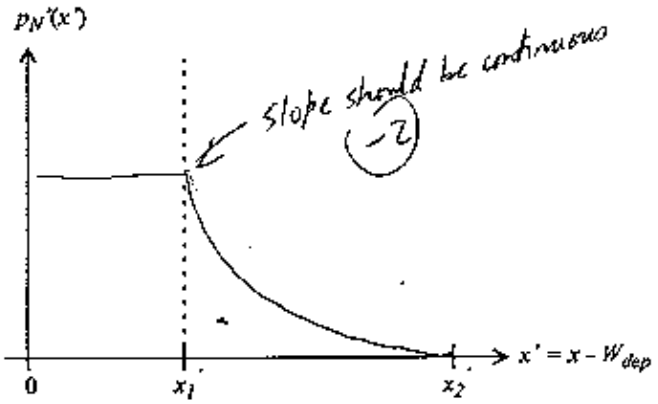
b.) PHIbi = 0.84 V
c.) Va = -0.76 V
d.)



e.) Cj = 5x10^-8 F/cm^2
f.) Vb != 15.6 V

3.) a.)

b.) i.) Region 1: Pn'(X') =
Region 2: Pn'(X') =
ii.)



4.) a.) PSIsi = 4.20 V
b.) PHIbn = 0.45 V
c.) PHIbi = 0.304 V
d.)