EECS 130 Fall 1997

Integrated Circuit Devices Professor King

Midterm Examination #1

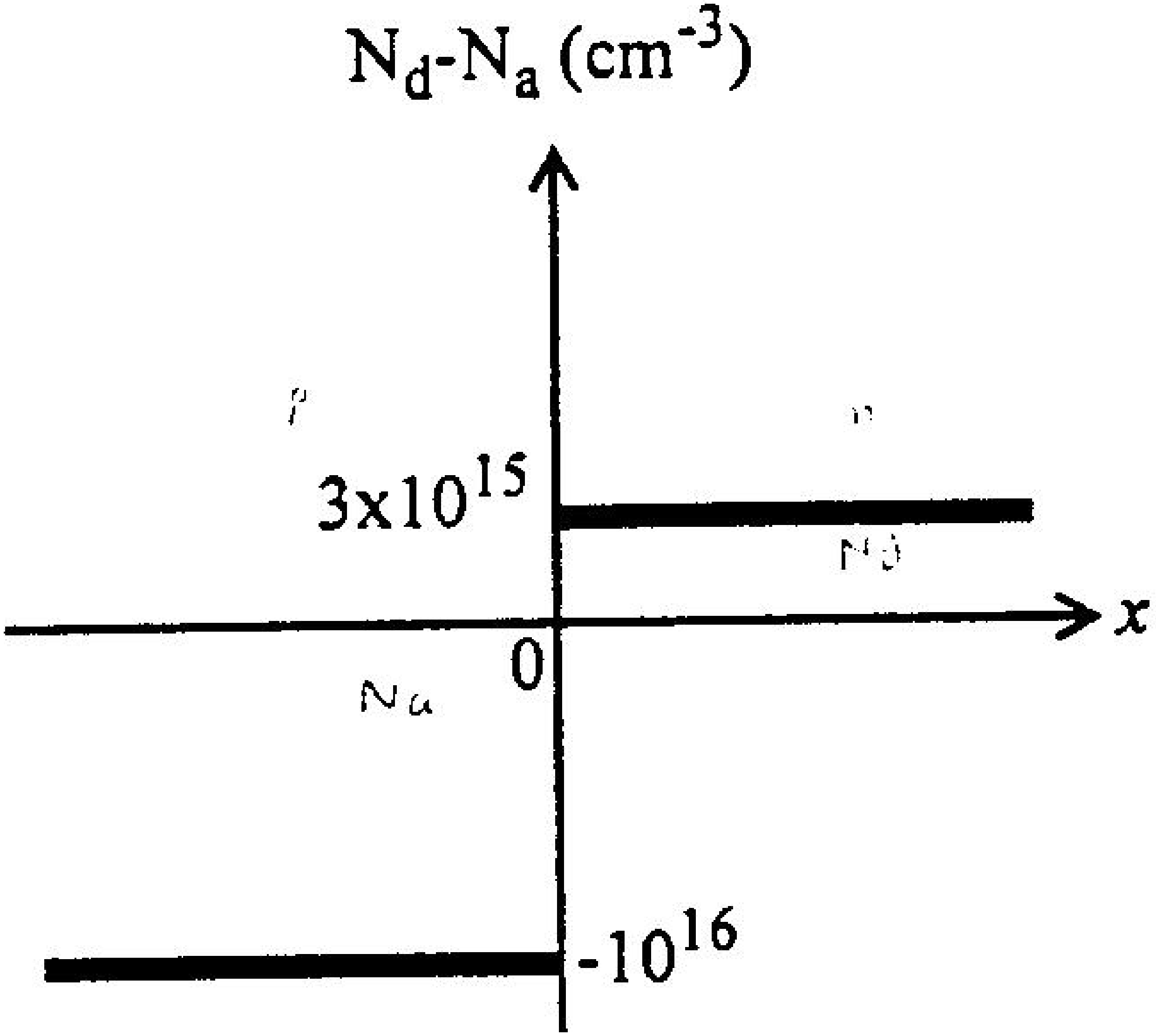
October 2, 1997

Time allotted: 80 minutes.

Problem 1. [15 points]

The doping profiles for 2 ideal silicon long-base p-n junction diodes maintained at 300k are picture below.

DIODE A



The minority carrier lifetimes in the quasi-neutral regions (τ_n, τ_p) are the same for these 2 diodes.

Answer the following questions (circle the correct choice):

a) The magnitude of the built-in potential in Diode A is

[larger than, equal to, smaller than]

the magnitude of the built-in potential in Diode B.

b) The saturation current of Diode A is

[larger than, equal to, smaller than]

the saturation current of Diode B.

c) The reverse breakdown voltage of Diode A is

[larger than, equal to, smaller than]

the reverse breakdown voltage of Diode B.

d) The minority carrier diffusion length on the n-type side is

[larger, equal, smaller]

in Diode A as compared with Diode B.

e) For a given forward bias ($V_a >0$), the excess hole density at the edge of the depletion region on the n-type side $p'_n(x_n)$, will be

[larger, equal, smaller]

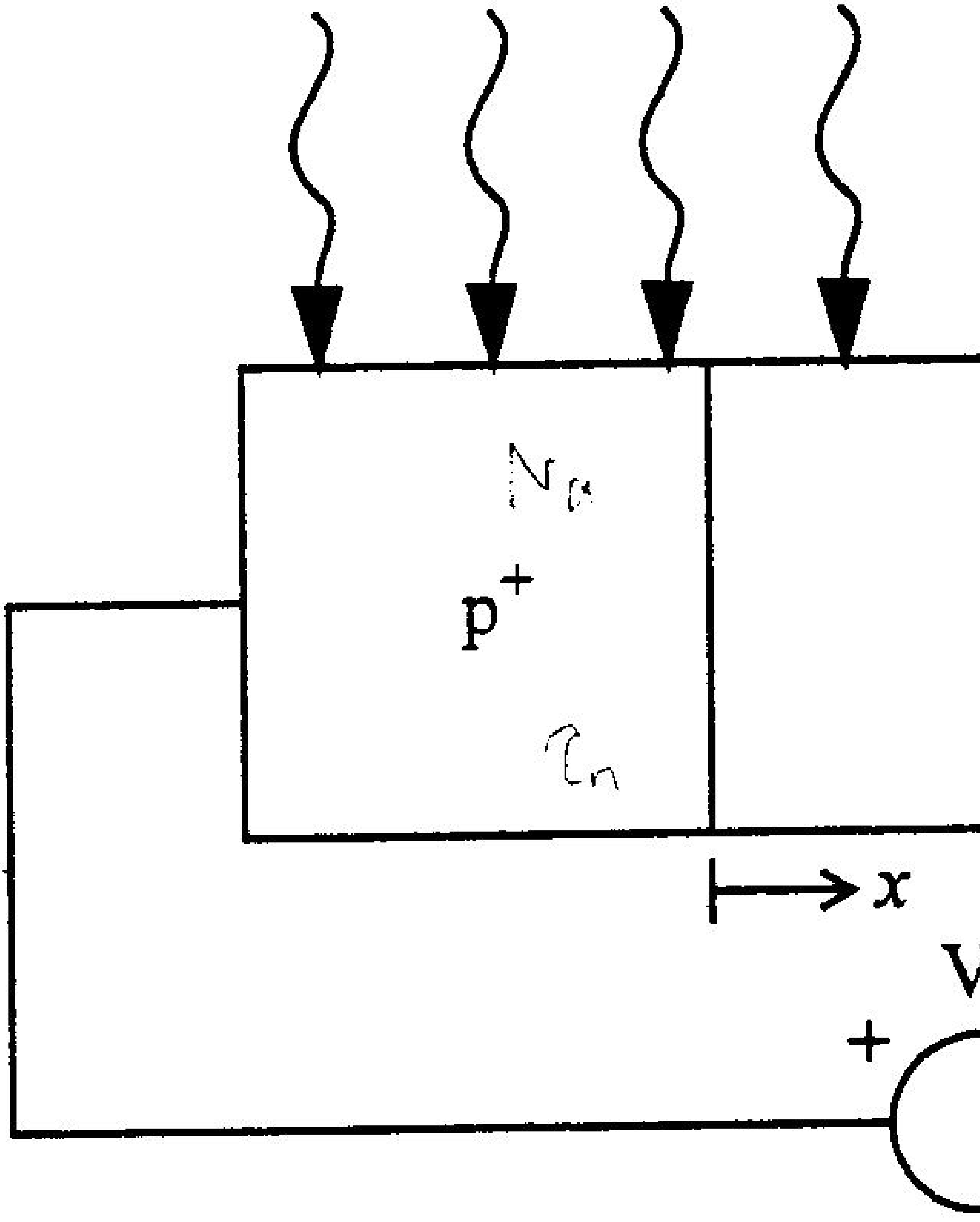
in Diode A as compared with Diode B.

Problem 2 (20 points)

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

Phosphorous: 1*10^16 cm^(-3)

Boron : 2*10^16 cm^(-3)



Parameters:

a) What are the electron and hole concentrations in this sample?

b) What is the mean free path of an electron in this sample?

(note: 1kg cm^2/V s/C=10^(-4) s)

c) What is the resistivity of this sample?

d) Draw the energy band diagram, including the Fermi level, for this sample. Indicate (E_c-E_f) and E_f-E_v to within 0.0001 eV.

Answers to Problem 2.

a)

Electron concentration: [3 pts]

Hole concentration: [3 pts]

b)

Mean free path: [5 pts]

c)

Resistivity [4 pts]

d)

Energy band diagram [5 pts]

Problem 3 [25 points]

Consider an ideal long-base P+ - n step-junction diode with cross-sectional area A which is uniformly illuminated with light, resulting in a photogeneration rare of G_l electron-hole pairs per cm^3-sec. Assume that steady-state and low-level injection conditions prevail.

a) what is the excess hole concentration on the n-type side a large distance (x->infinity) from the metallurgical junction?

b) Derive an expression for the excess hole distribution, $p'_n(x)$, on the n-type side.

(Hint: solve the minority carrier diffusion equation, and use the boundary condition established in part (a). Also, assume that the excess hole concentration at the edge of the depletion region, $p'_n(x_n)$, is not significantly affected by the photogenertation, i.e. use the standard depletion-edge boundary condition).

c) From your answer in part (b), derive an expression for I-V characterisitc of the P+-n diode under the stated conditions of illumination. Assume that no recombination-generation (including photogeneration) occurs in the depletion region.

Answers to Problems 3

a)

P'n(x->infinity): [5 pts]

b)

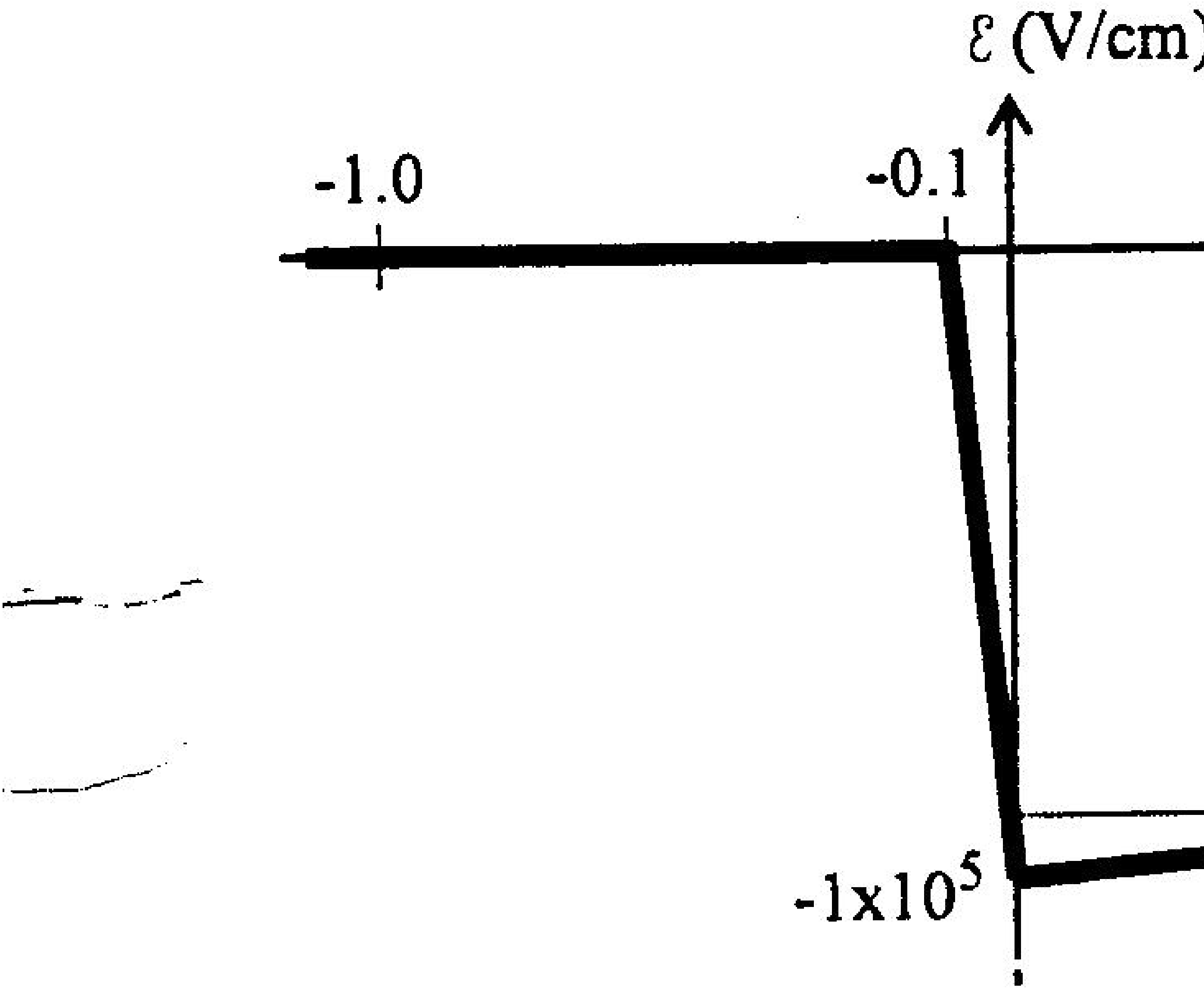
p'n(x)= [10 pts]

c)

I= [10 pts]

Problem 4 (40 points)

Given the following electric field distribution in a reverse-biased silicon p-n-n+ junction diode maintained at 300K:



Note: It is common to assume that the Fermi level (E_f) coincides with E_c in n+ (degenerately doped n-type) semiconductor and with E_v in p+ (degenerately doped p-type) semiconductor.

a) Sketch the doping profile of this p-n-n+ junction between x=-1 um and x=1 um. Indicate the numerical values of the doping concentrations in the p and n regions.

b) Sketch the energy band diagram for this device at zero bias (between x=-1 um to x=2 um). Include E_c , E_v , and $E_f$on your diagram, and indicate energy (difference between these energy levels in each region of the device. (Numerical values are required).

c) What is the built-in potential of this p-n junction?

d) What is the bias voltage applied across this p-n junction (in the Figure above)?

e) What is the junction capacitance at this bias?

f) What is the punch-through voltage of this device, i,e, what is the minimum (reverse) bias which will ensure that the depletion width on the n-type is 1.0 um?

Answers to Problem 4

a)

Doping Profile

b)

Equilibrium Energy Band Diagram

c)

d)

V_a =

e)

C_j =

f)

V punch-through=