Microelectronic Devices and Circuits- EECS 105

First Midterm Exam

Wednesday, October 11, 2000

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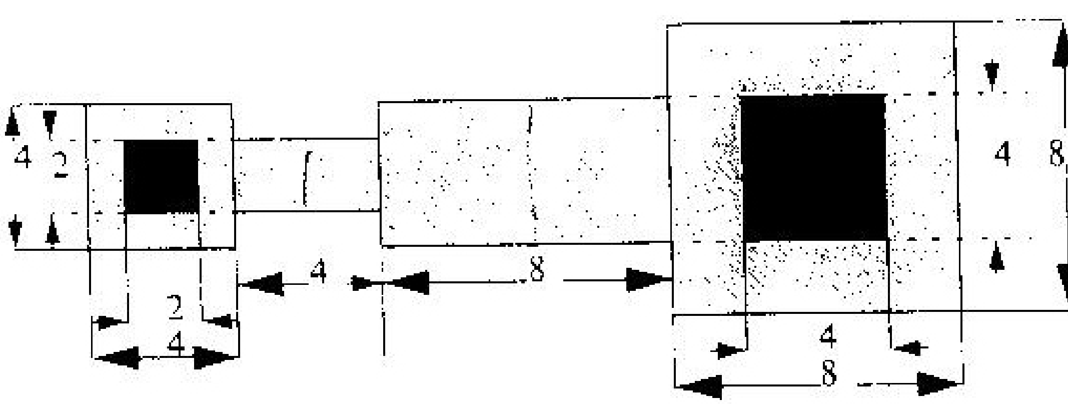
Problem 1 of 4 (35 pts)
Answer each question briefly and clearly. Assume room temperature and thermal equilibrium unless otherwise noted.

What types and concentrations of charges exist in intrinsic silicon? (6 pts)

List the type (holes, electrons, ions), sign (+/-) and concentrations of all charges in silicon doped with 10^17/cm^3 As and 10^15/cm^3 Boron.
Be sure to mention whether each charge is mobile or not. (8 pts)

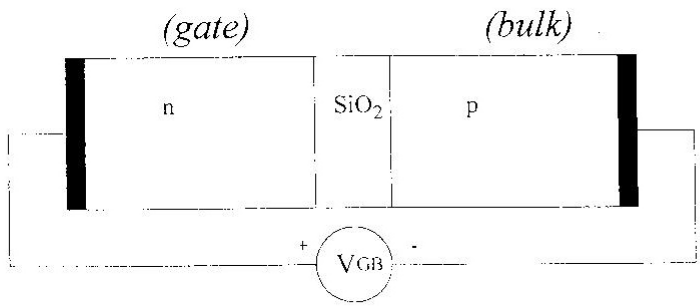
What are the four types of currents you can find across a p-n junction in thermal equilibrium? (6 pts)

Find the contact-to-contact resistance of the following structure (drawn to scale), if the Rs is 10 ohms/square. Assume that "dogbone" contact areas amount to 0.65 squares. (8pts)



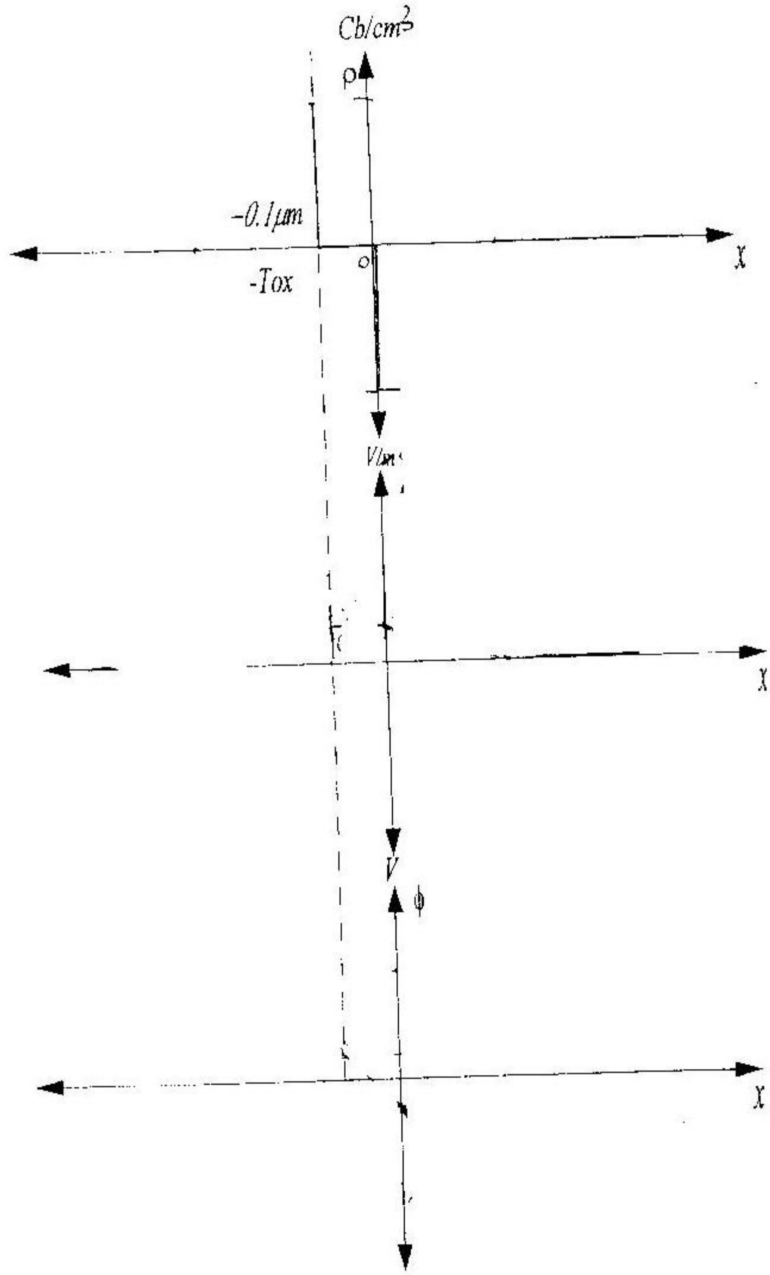
You are given doped silicon that at thermal equilibrium has an electron concentration 10^16/cm^3. What is the built-in potential
with reference to intrinsic silicon? What would be the concentration of electrons at some point within this lattice, if you raised the potential
at that point by 120mV? (7 pts)

Problem 2 of 4 (35 pts)
Consider the following structure that consists of n-type silicon (10^16/cm^3), 0.1 micrometers of SiO2 and p-type silicon (10^16/cm^3).
(Hint: This is nothing more than a MOS capacitor whose gate is made out of weakly doped silicon. This means that the gate will also deplete and/or invert under proper conditions. The symmetric concentrations in the channel and the gate should make this problem easy to solve...)



a. Calculate the depth of the depletion regions when Vgb = 0 (10 pts)

b. Draw the density, E-field and potential plots in thermal equilibrium (Vgb = 0). Mark the key values on the charge densities, Electric Fields, and potential graphs.
(If you failed to solve part a, do these plots anyway, assuming that each depletion region has a depth of 0.1 micrometers. Please check this box if you opt to use this value: PUT BOX HERE) (7 pts)



c. If you apply a positive bias on the gate (i.e. Vgb>0), both depletion regions will grow deeper, up to the point where there will be inversion. Because of the concentration symmetry, both the gate and the body will invert at the same time. Calculate the value of Vgb needed to bring this device at the onset of inversion. (10 pts)

Problem 3 of 4 (15 pts)

The process sequence described below is meant to create a p-channel transistor within a n-well.
Follow the steps and draw the two cross sections at the steps indicated: (10 pts)
Step 0: Start with the 1 micrometer deep n-well and 0.5 micrometer thick isolation oxide as shown.

What is the necessary dose of P (in atoms/cm^2) that is required to achieve a uniform concentration of 10^16/cm^3 in the n-well?

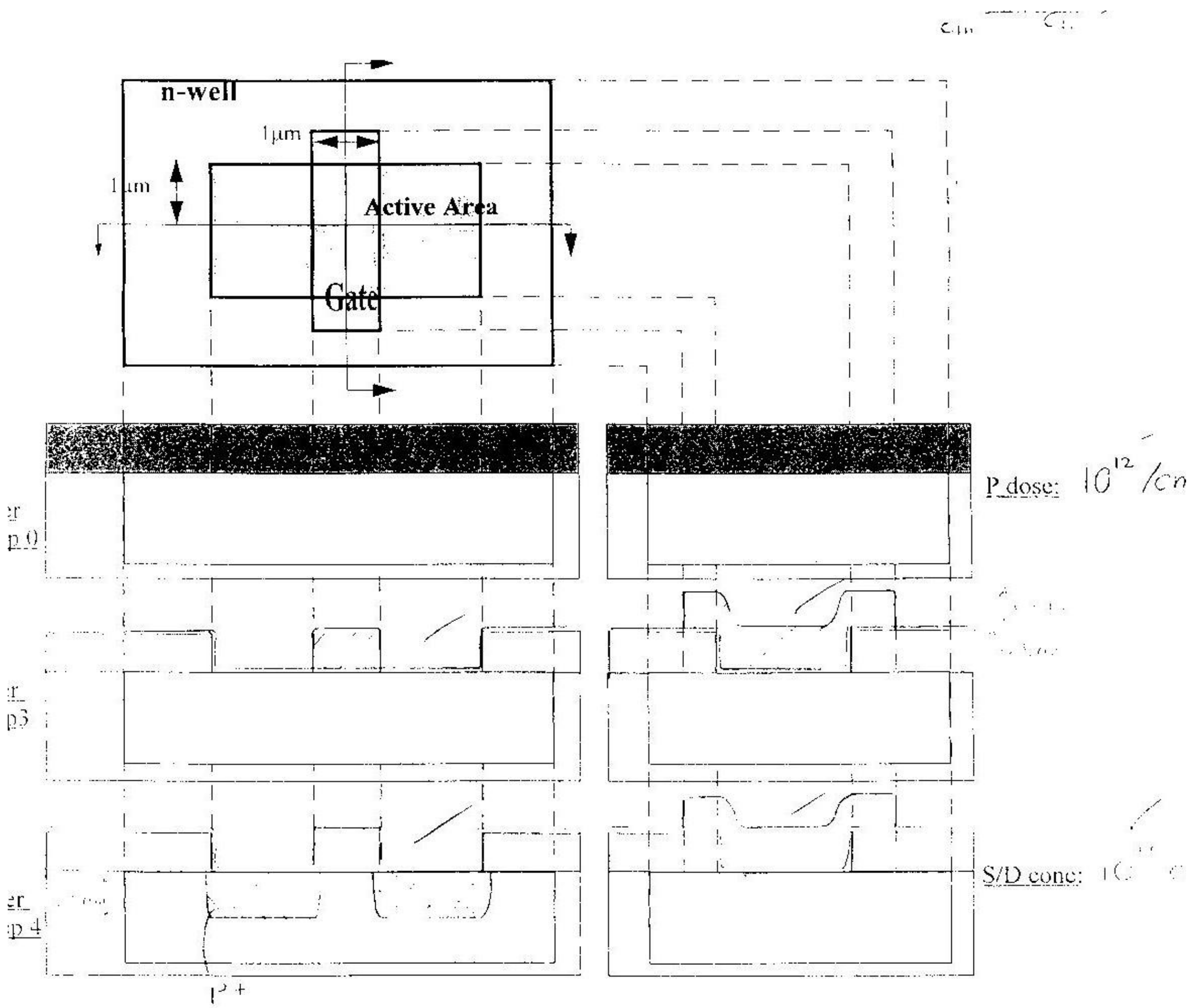
Step 1: Remove the 0.5 micrometer of isolation oxide where indicated by the active area mask.

Step 2: Grow 100 Angstroms of gate oxide.

Step 3: Deposit and pattern 0.5 micrometer thick polysilicon gate, where indicated by the gate mask.

Step 4: Implant p+ source/drain to a depth of 0.5 micrometer, using a dose of 0.5*10^15 Boron atoms/cm^2.

Calculate the Boron concentration in the source/drain regions.



Problem 4 of 4 (15 pts)

You are given a n-channel MOS transistor with micro(n)*Cox = 50microAmps/V^2, V(Ton) = 1.0 V, lambda(n) = (0.1/L)V^-1 (L in micrometers) and phi(p) = -0.42V.

a. Draw the small signal model of the MOS transistor in saturation, assuming V(BS) = 0, v(bs) = 0 and ignoring all capacitances.

b. Given that W = 10 micrometers, L = 10 micrometers, V(DS) = 2V, find the V(GS) value that will yield a g(m) of 50 microAmps/V.
Calculate r(0) under these conditions. *(Hint: confirm that your solution is such that the transistor is saturated. You can ignore the effect of lambda(n) in the calculation of g(m)).*