EE 105, Fall 1998
Midterm #1
Professor CJ Spanos

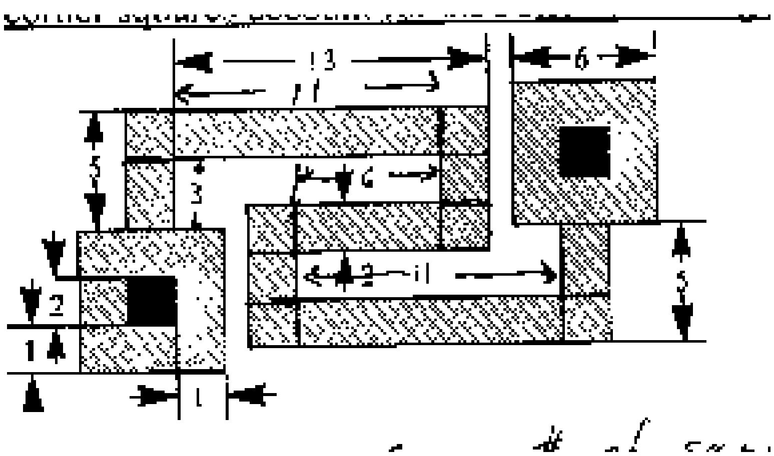
Problem #1 (35 points)

What is the mass-action law (as it applies to holes and electrons in Silicon, of course)? (5 pts)

What is the concentration of holes, electrons and ions if Si is doped with 10^16 As atoms/cm³ at room temperature? (n_i=10^10) (5 pts)

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

Find the resistance of the following structure (drawn to scale), if the Rs is 10 Ohms/square. Assume corner squares account for 0.56 Rs, while "dogbone" contact areas amount to 0.65 squares. (8 pts)



At what gate-to-bulk bias potential do you obtain the *minimum* possible capacitance of an MOS structure on top of a p-type substrate? (5 pts)

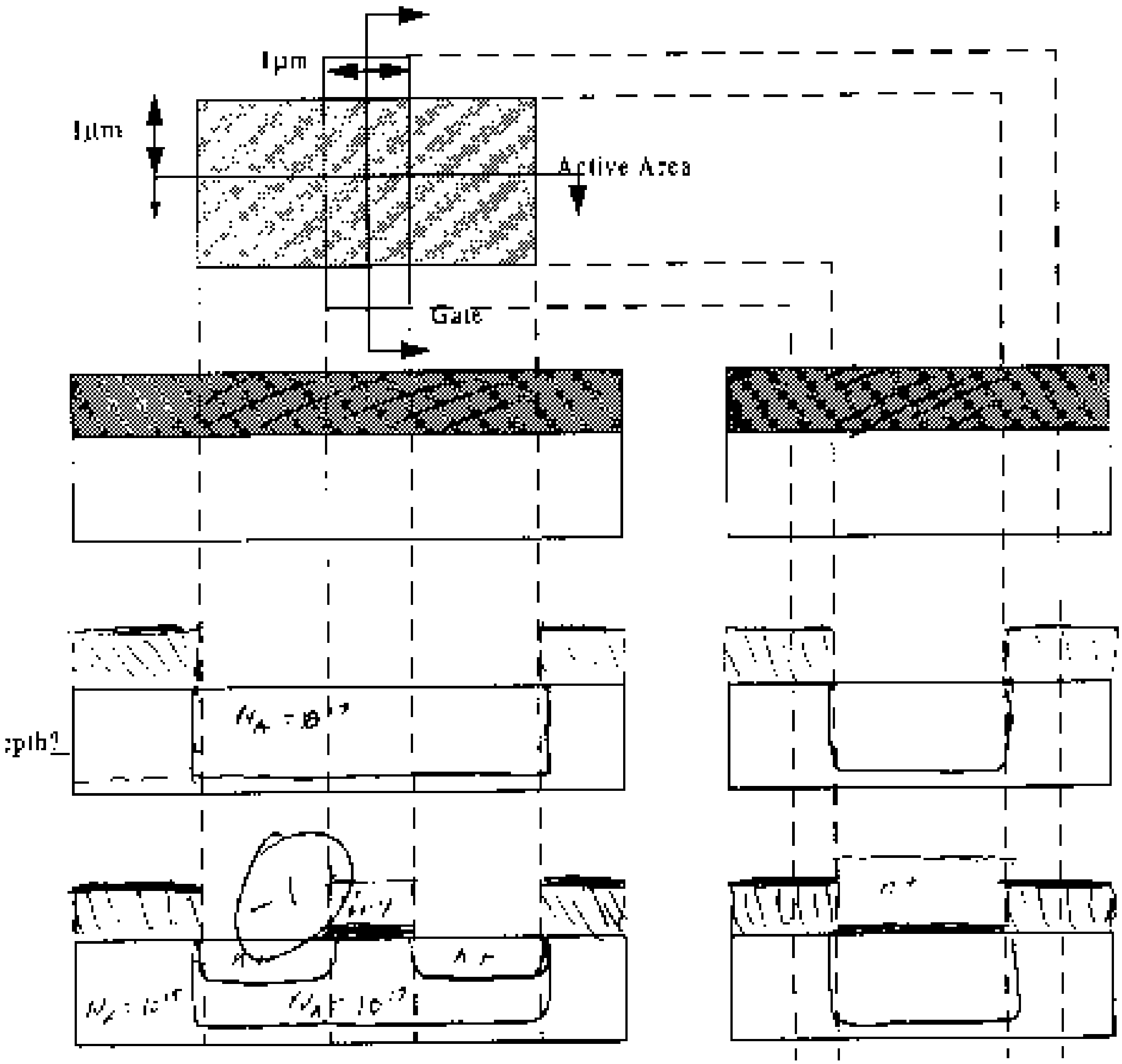
Consider an MOS sructure on top of a *n-type* substrate, while using *n*+ type gate. Mark the type of charges (ie. positive ions / negative ions / free electrons / free holes) on the gate and the substrate as a function of the biasing conditions on the following table (6 pts):

Bias	Gate Charges	Substrate Charges
Accumulation		
Depletion		

Inversion		

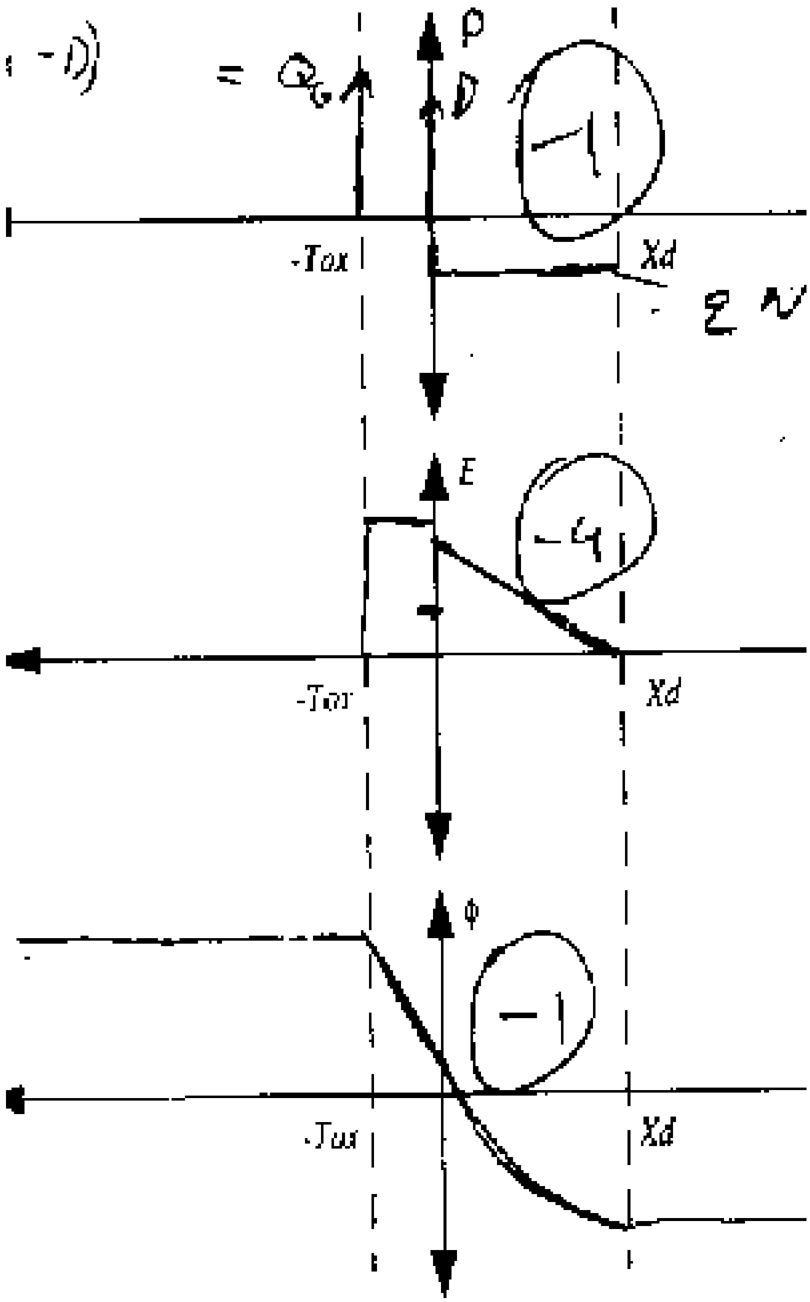
Problem #2 (40 points)

Sometimes, a special "Vt-adjust" implant is being used in order to set the threshold voltage of a device at a specific value. The process sequence described next is an example of this. Please follow the steps and draw the two cross sections at the steps indicated (10 pts)
Step 0: start with 10^15 atoms/cm^3 p-type wafer and 0.5 um of isolation oxide.
Step 1: use mask shown to create active area (ie. remove the thick gate oxide in shaded region.)
Step 2: implant a dose of 10^12 atoms of Boron per cm^2, so that the annealed profile has a uniform concentration of 10^17/cm^3 from the surface down to a finite depth. (draw the two cross sections marked on the graph and calculate and mark the depth of the annealed Boron profile.)
Step 3: grow 100 Angstroms of gate oxide
Step 4: deposit and pattern gate
Step 5: Implant n+ source/drain and gate, to a depth of 0.5um. (draw the two cross sections marked on the graph)



On a different example of using the Vt adjust implant, make the assumption that the implant is very shallow, so all its charge can be approximated by a delta function at the surface of the channel. Now consider the specific case where we have n+ poly (assume phi_m=0.55V), p-type substrate with 10^16/ cm³ concentration of Boron, and a Tox of 100 Angstroms. The unknow in this problem is the dose D and the polarity of the implanted material, in # of atoms/cm².

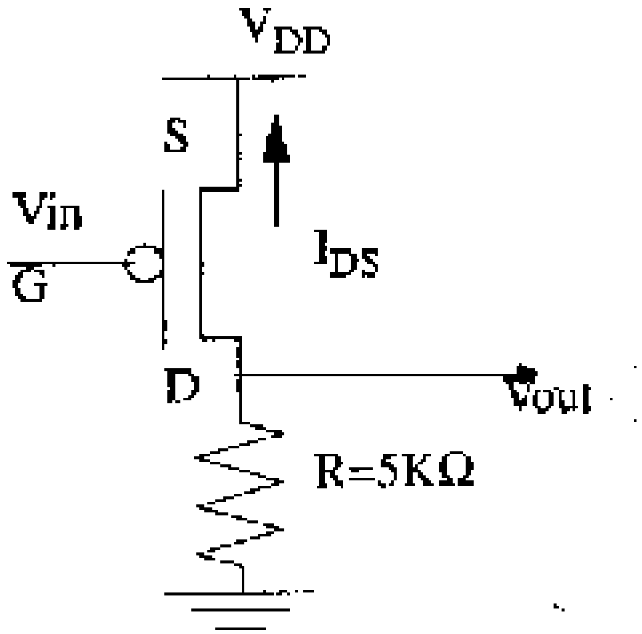
Sketch the charge density (rho), electric field (E) adn potential (phi) diagrams and label all values with the proper symbolic expressions. (15 pts)



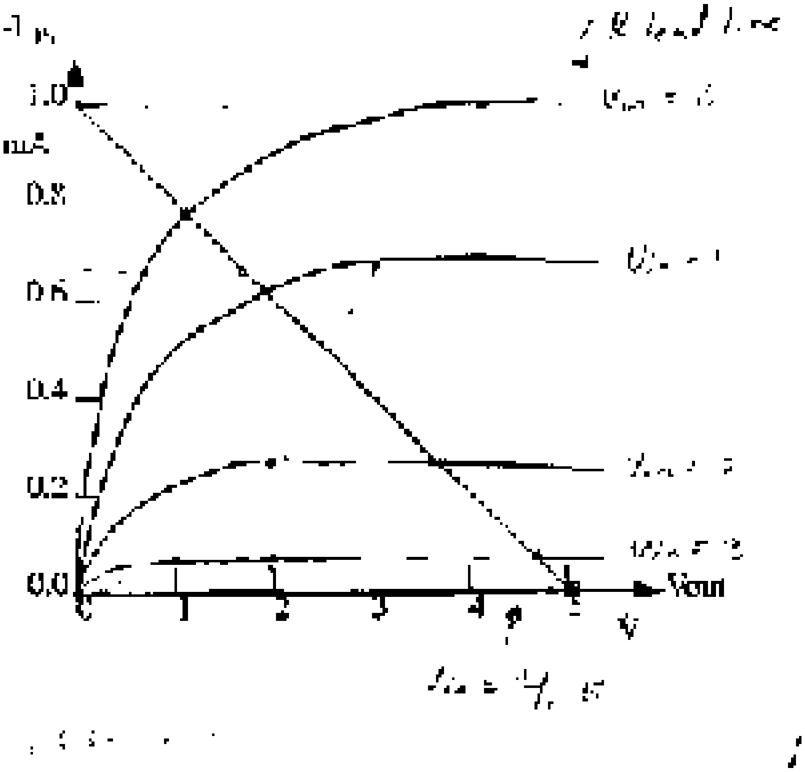
Find the dose and type (donor or acceptor) of the channel implant so that the depletion depth X_d is exactly 0.1um when V_GS=V_BS=0V (e_0=8.85*10^-14F/cm, e_ox=3.9e_o, e_Si=11.7e_0, electron charge is -1.6*10^-19Cb) (15 pts)

Problem #3 (25 points)

You just found in your basement a batch of old, n-type wafers from the 70s. You decide to make some cheap inverters on them, just by using p-channel transistors and diffusion resistors. This is the design of the inverter you come up with:



Now, assume that W/L is 10/2, V_DD=5V, Vtp=-1V, u_pCox is 25uA/V² and lambda_p=0V^-1. Sketch the load line diagrams for the resistor and the transistor, and mark the approximate values of Vout for Vin taking the values 0V, 1V, 2V, 3V, 4V and 5V. Make sure to indicate the status of the transistor at each point. (15 pts)



Last question! Draw the small signal equivalent circuit and calculate Av when Vin=2V. (10 pts)

Posted by HKN (Electrical Engineering and Computer Science Honor Society)
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