EE 105, Fall 1999
Midterm #1
Professor Costas J. Spanos

(Note: Greek letters are in caps, "micro" is represented by a 'u'.)

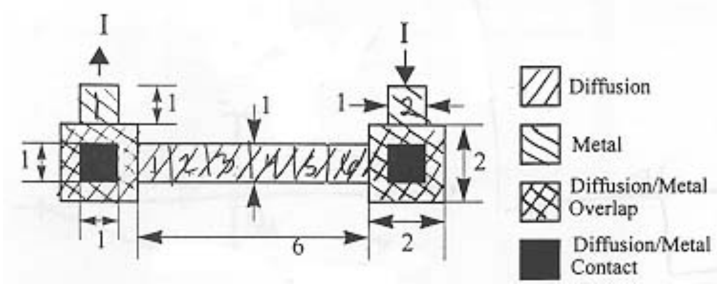
Problem 1 of 3. Answer each question briefly and clearly. (35 points)

What happens to n_i if the temperature increases? Give a brief qualitative explanation (5 pts)

What is the concentration of holes, electrons and positive / gnegative ions if S_i is doped with 10^17 Boron atoms/cm^3, and 10^19 As atoms/cm^3 at room temperature? (n_i = 10^10) (5 pts)

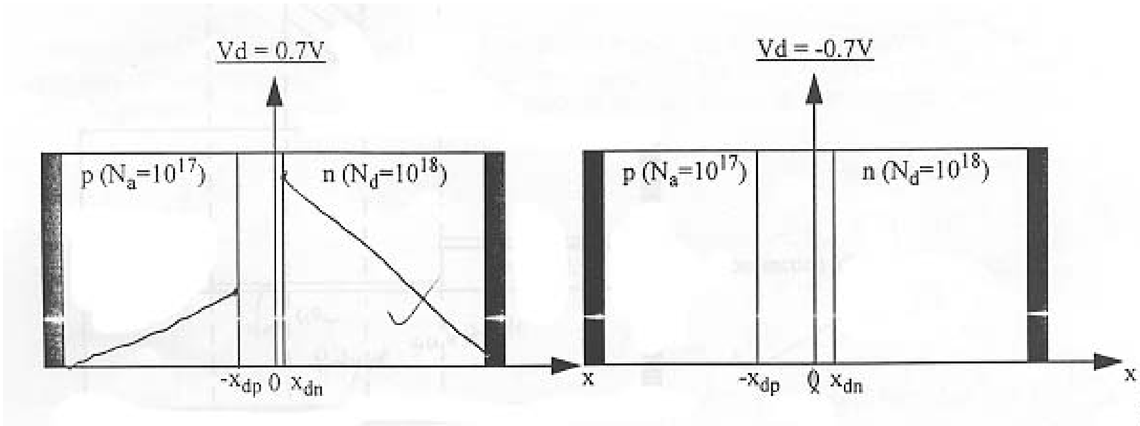
What are the three types of charges in an MOS capacitor under inversion? Mention carrier type (holes or electrons), ion polarity (positive or negative), charge nature (depletion, accumulation, or inversion) and location (gate, substrate surface or bulk). (Gate is n+, bulk is p) (6 pts)

Find the resistance of the following structure (drawn to scale), if the R_{S1} (diffusion) is 20 ohms/square, R_{S2} (metal) is 1 ohm/square and contact hole conductivity (i.e. the area where the two layers touch) is 1 Siemens/um^2. (1 Siemens = 1/Ohm). Assume that "dogbone" contact areas amount to 0.65 squares. (6 pts)



What is the "law" of the junction? (5 pts)

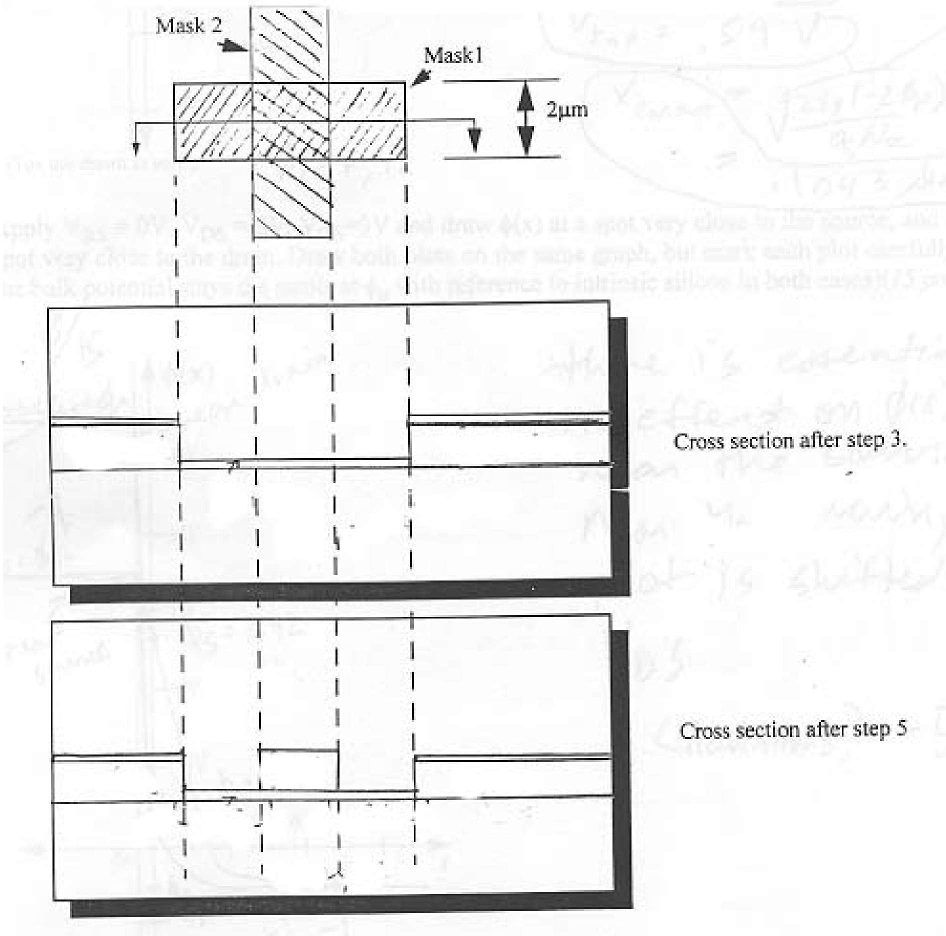
Sketch the minority charge concentration in the bulk of a pn junction under forward bias, and also under reverse bias (no need to calculate the width of the depletion regions - assume that the diode is "short"). (8 pts):



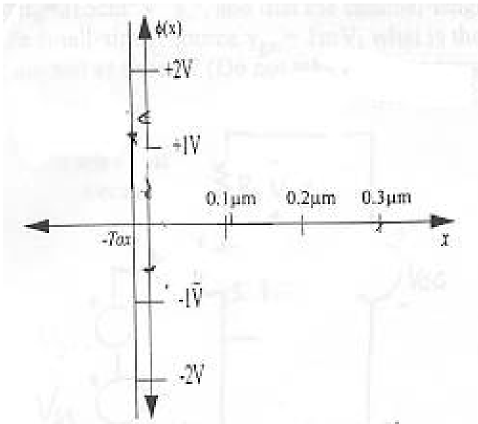
Problem 2 of 3 (40 points)

Follow these steps to create an MOS transistor:

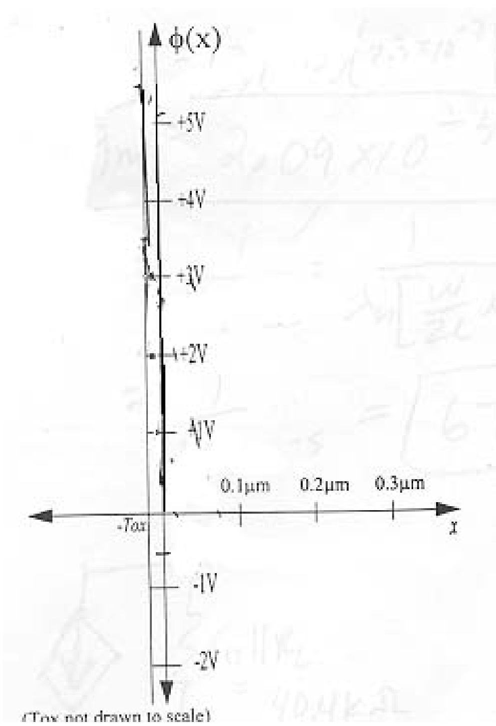
0. Start with p-type 10^17/cm^3 Boron Substrate.
1. Grow 0.5um of SiO_2 everywhere.
2. Use mask 1 to etch SiO_2 where mask 1 is dark.
3. Grow 15nm SiO_2 everywhere. (draw cross section after this step)
4. Deposit and pattern 0.5um of n+ poly using mask 2 (poly remains where mask
5. Implant n+ regions (to make source and drain) in areas *not* covered by bpol (draw cross section after this step).
6. The device is finished by cutting contact holes over source/drain, and by patterning metal (contact hole and metal masks not shown) (*10 points*).



After the transistor has been completed, apply V_{DS}=0V, V_{BS}, and V_{GS} = V_{tn0} to brin
to the *onset of inversion*. Draw phi(x) (with reference to intrinsic silicon) an
X_{dmax}. (e_0 = 8.85x10-14 F/cm, e_{0X} = 3.9e_0, e_{si} = 11.7e_0, electron charge is -1.6x1(

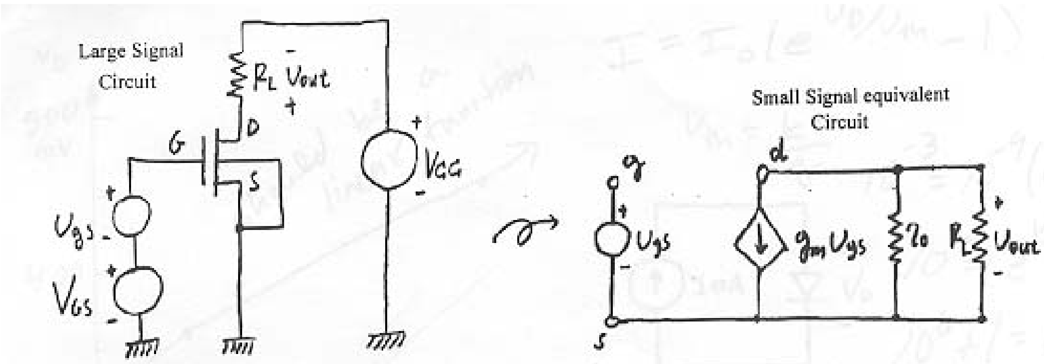


Apply V_{BS} = 0V, V_{DS} = 2V, V_{GS} = 3V and draw phi(x) at a spot very close to the so
spot very close to the drain. Draw both plots on the same graph, but mark each
the bulk potential stays the same, at phi(font size = 1>p(/font> with reference
in both cases) (*15 points*).



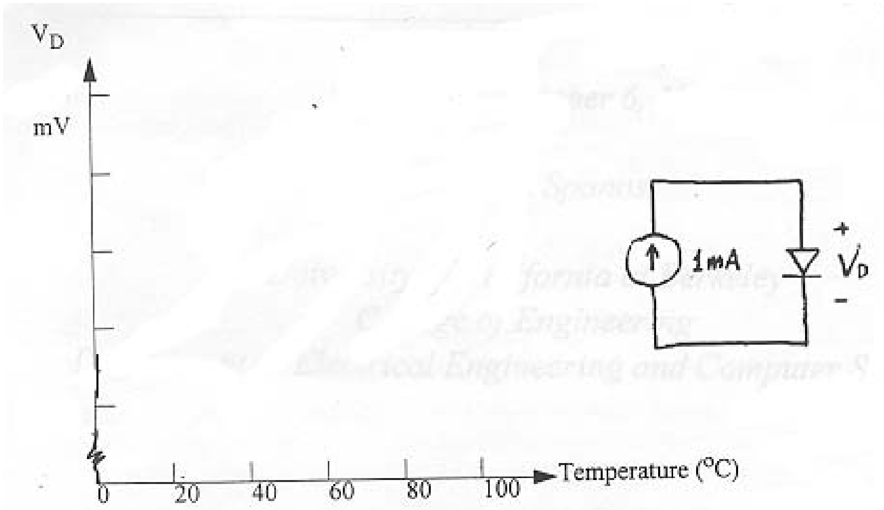
Consider the small signal model for this transistor at V_{GS}=2V, V_{BS}=0V. The larg
V_{CC} is such that the transistor is saturated. Calculate the values of g_m and r_o
u_n=215 cm^2V-1s-1, and that the channel-length modulation parameter lambda$_n$ is 0
a small-signal source v_{gs} = 1mV, what is the small signal voltage, v_{out}, across R

connected as shown? (Do not take lambda$_n$ into account when you calculate g_m). (



Problem 3 of 3 (25 points)

Consider a short pn junction with I_o = 10^-9 A. You want to make a thermometer by feeding it with a constant forward current of 10^-3 A, and by reading the bi of function of temperature will be this voltage? (linear or some other kind?) C values for 0, 25, and 100 degrees C. Graph the relationship between temperatur (Boltzman's constant is 1.38x10^-23 J/K. The absolute zero temperature is at 0 (*15 points*).



How would a npn BJT be affected by the following parameters (draw up or down ar
indicate that a parameter increases or decreases, respectively, given an increa
the respective design variable.) (*10 points*)

Design Variable	β_F	α_F
Emitter Doping		
Emitter Width		
Base Doping		
Base Width		

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