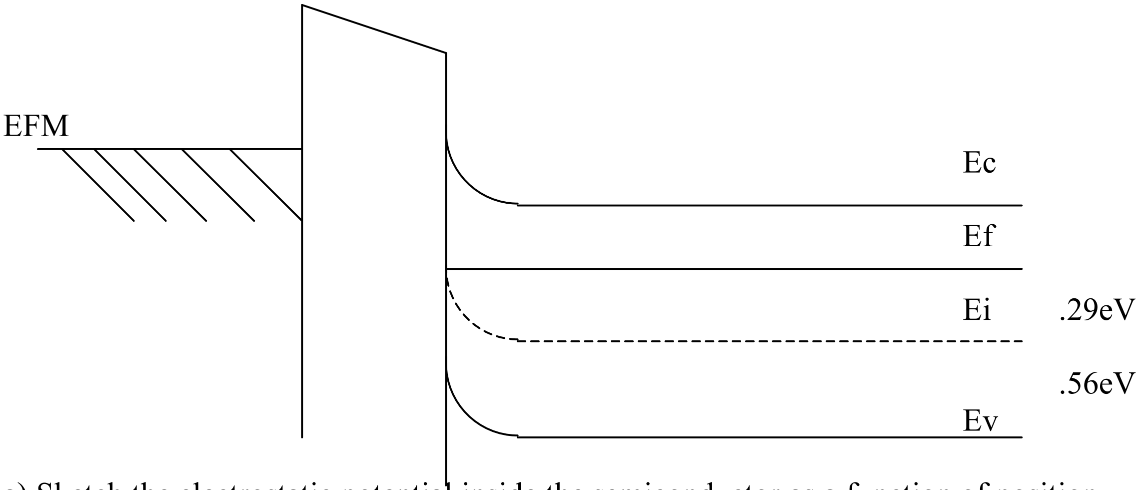
1.The energy band diagram for an ideal x_o=.2um MOS-C operated at T=300K is shown below. Note that the applied gate voltage causes band bending in the semiconductor such that E_F=E_i at the Si-SiO2 interface. Invoke the delta-depletion approximation as require in answering the questions below.



a) Sketch the electrostatic potential inside the semiconductor as a function of position.

b) Roughly sketch the electric field inside the oxide and semiconductor as a function of position.

c) Do equilibrium conditions prevail inside the semiconductor? Explain.

d) Roughly sketch the electron concentration versus position inside the semiconductor.

e) What is the electron concentration at the Si-SiO2 interface?

f) Nd=

g) Phi_s=

h) Vg=

i) What is the voltage drop across the oxide?

j) What is the normalized small-signal capacitance C/Co of the MOS-C at the picture bias point?

2. PN vs. MS diodes [25pts]

Consider two devices, one PN junction and one MS junction:
The PN junction has a p-tpe SI region with Phi_p=4.96eV and an N-tpye region with Phi_n=4.13eV, the MS junction has a p-type Si region with Phi_p=4.96eV and a metal with Phi_m=4.13. Answer the following questions:

a) [4 pts] What is Vbi for each of these devices?

Vbi(PN)=

Vbi(MS)=

b) [3pts] Which of theses devices has a higher reverse leakage current? Why?

c) [4 pts] What is the reverse bias capacitance for each of these devices at VA=1V?

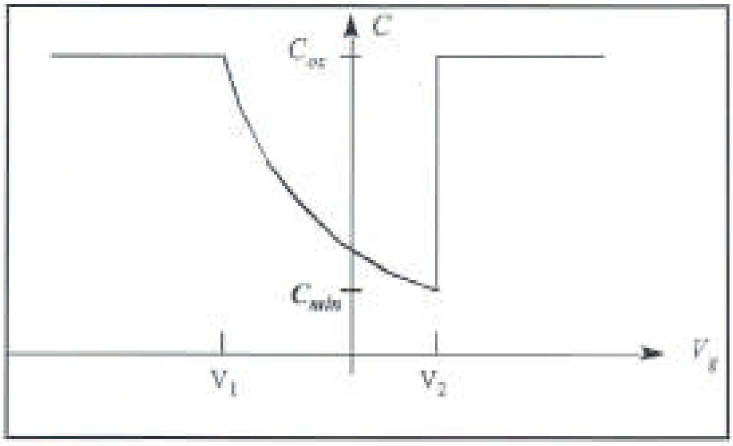
C_J (PN)=

C_J(MS)=

d) [3pts] Suppose you used each one of these devices as a photodiode by shining light on the junction. Which one of these devices is more likely to have a higher efficiency (photons in vs. current out?). Why? (Hint: The interface between the metal and semiconductor will have a higher defect density than the interface between p-type and n-type materials on the same semiconductor.)

3. MOSCAP C-V curve [25 pts]
All curves you will draw in this question will be graded qualitatively and not quantitatively.

a) [10 pts] Given below is a low frequency CV curve of MOSCAP with oxide thickness Tox=10 nm, gate work function Phi_m =4.51eV, and substrate doping density of Nsub=10^15cm-3. What type of dopant (donor or acceptor) is used in the silicon substrate? Calculate the ratio of Cmin/Cox, V1 and V2.



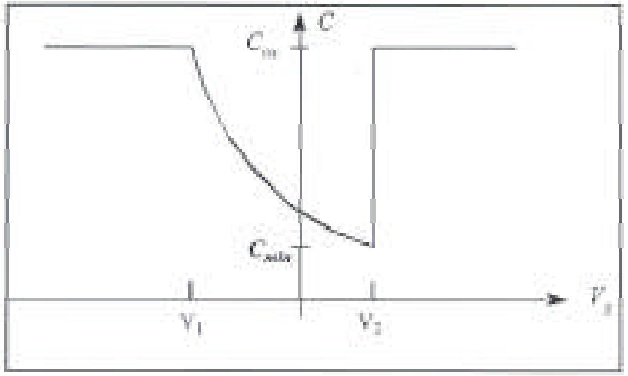
Dopant Type (Circle one): Donor or Acceptor

Cmin/Cox=

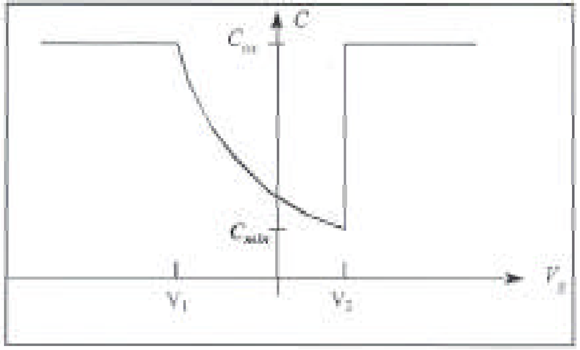
V_1=

V_2=

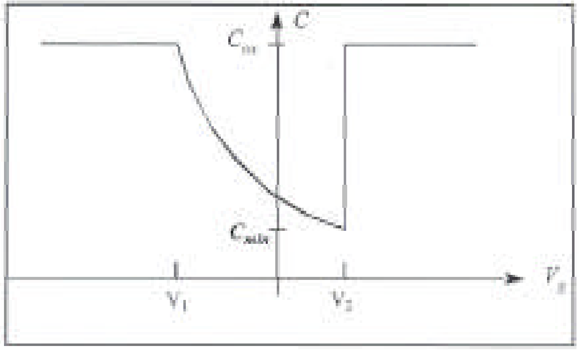
b) [5pts] Given below is the low frequency C-v curve of a MOSCAP. Draw a second low frequency curve corresponding to the same device, but with fixed positive oxide charge at the interface of the oxide and the substrate.



c) [5 pts] Given below is the low frequency C-v curve of a MOSCAP with metal gate. The work function of the metal is Phi_m=4.05eV. Redraw the low frequency C-v curve if the gate were made of P+ Poly instead of metal. (Note: include poly depletion effect).



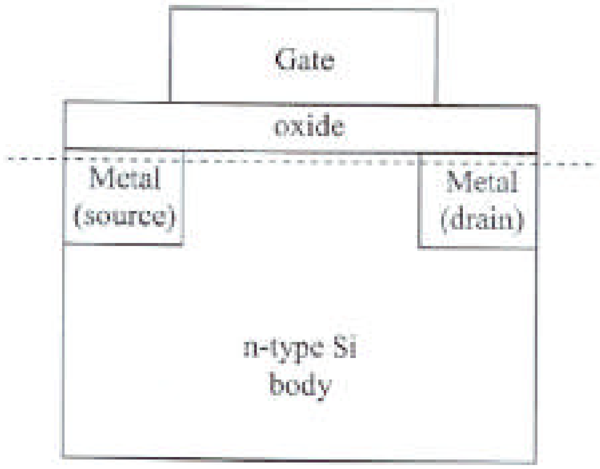
d) [5 pts] Given below is the low frequency C-v curve of a MOSCAP with metal gate. The work function of the metal is Phi_m=4.05eV. Redraw the low frequency C-V curve if the gate were made of N+ Poly instead of metal. Assume the electron affinity for Si is 4.1eVan the band gap is 1.1 eV. (Note:: include poly depletion effect)



4. Schottky Barrier MOSFET [30pts]

In recent years, MOSFET-like structures with metal S/D contacts (rather than heavily doped semiconductor contacts) have received considerable attention due to a number of potential benefits that their offer. These devices are ofern called Schottky barrier (SB) MOSFETs.

Assuem SB-MOSFET structure as shown below with SB height of 0.3 eV at the source and drain for holes. The body is an n-type Si.



a) [8 pts] Draw two separate band diagrams for this device from source to drain (along the dashed line), one for the ON-state and the other for the OFF-state for a finite V_{DS} value below the pinch-off. Label E_c, E_v, Φ_B, Fermi (or quasi Fermi) levels, source/drain, and V_{DS} on the two diagrams.

b) [6 pts] What are the three possible carrier injection mechanisms from the source to the semiconductor? Briefly explain each mechanism.

c) [3 pts] Redraw the band diagram for the ON-state from part a). On this diagram clearly show and label the three carrier injection mechanisms at the source by using arrows.

d) [6 pts] Qualitatively draw the IDS-VDS characteristic of this device for an arbitrary gate voltage value where VG<VT. When plotting the curve, make sure that your maximum VDS is higher than the pinch-off voltage. (Hint: when drawing the I-V curve for this device think how it should be different than a conventional MOSFET with doped contacts.)

e) [7 pts] Fill in the blank cells in the table, using the following symbols: up arrow for increase, down arrow for decrease, and – for no change. If the cell has already been provided with an X I means that you are not responsible for filling that cell out. When moving along a row, consider only the change brought on due to the parameter specified in the first cell of that row. (Note: Nd is the doping density of the SI body, Tox is the oxide thickness, and Wdep and Cdep are the depletion width and capacitance respectively.)

	SB height at source	Wdep at source	Cdep at drain
Nd increasing			
Tox decreasing		x	x
SB height at drain decreasing			