UNIVERSITY OF CALIFORNIA
College of Engineering
Department of Electrical Engineering and Computer Sciences

EECS 130 Professor Chenming Hu
Spring 2005

Midterm II

March 31, 2005

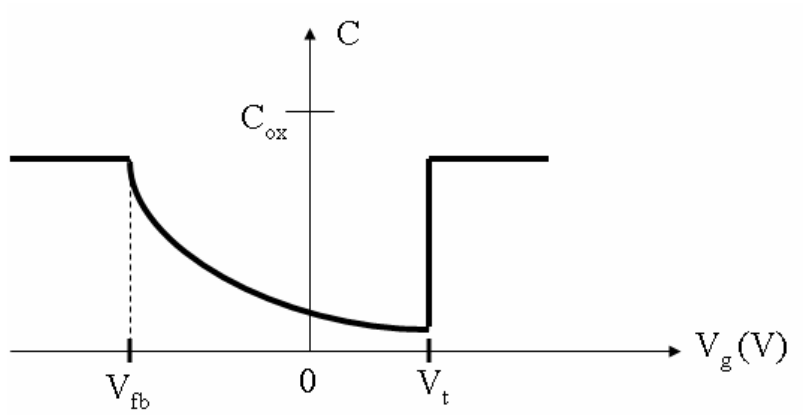
Name: _____
SID: _____

Instructions:
Print your name on the cover page CLEARLY now
Show major intermediate steps on exam pages to facilitate grading
Make sure your copy of the exam paper has 7 pages (including cover page)
Closed book. Two sheets of note are allowed.

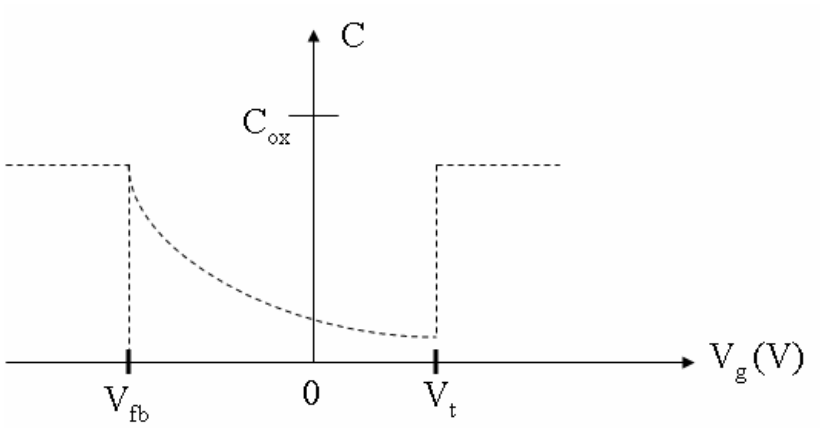
Physical Constants:

Electronic charge	q	1.6×10^{-19}
Boltzmann's constant	k	1.38×10^{-23} J K^{-1}
Thermal voltage at T=300 K	kT/q	0.0259 V
Permittivity of vacuum	ε_0	8.85×10^{-14} F cm^{-1}
Permittivity of oxide	$\varepsilon_{0x} = 3.9\ \varepsilon_0$	
Permittivity of silicon	$\varepsilon_s = 11.7\ \varepsilon_0$	

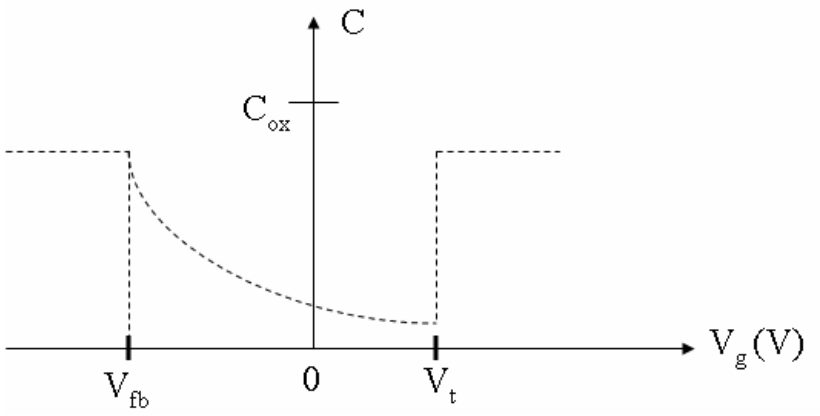
1. **The MOS CV for N^+-poly gate and substrate doping $N_a = 10^{17}cm^{-3}$ is given below (18 pts.)**



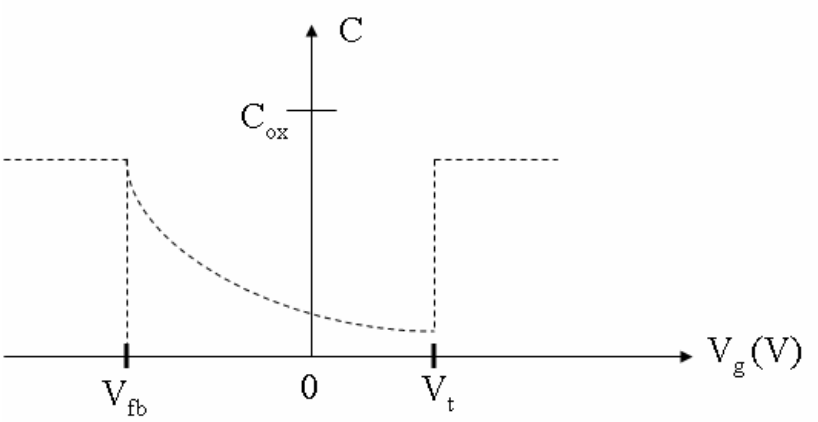
a) Plot the CV for a **lower N_a**. *(Note that the original CV is drawn in dotted line for reference)* (6pts.)



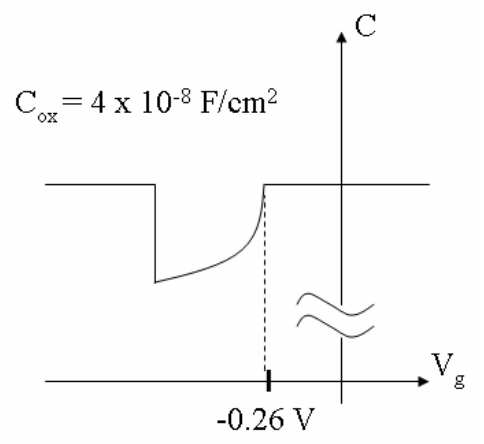
b) Plot the CV for a thinner **T_{ox}**. *(Note that the original CV is drawn in dotted line for reference)* (6pts.)

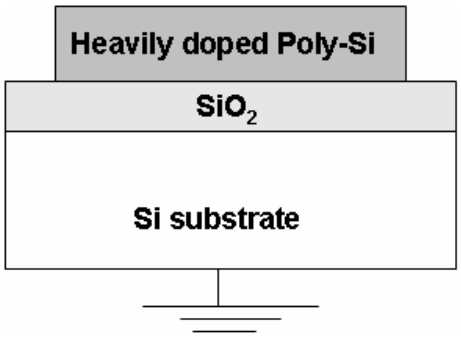


c) Plot the CV for the case of **P^+-poly gate**. *(Note that the original CV is drawn in dotted line for reference)* (6pts.)



2. Metal-Oxide-Semiconductor Capacitor (20pts.)





a) Does this MOS capacitor have a N or P-type substrate? Give one sentence explanation. (4pts.)

b) Is this a transistor CV or a HF capacitor CV? Give one sentence explanation. (4pts.)

c) Is the poly gate N^+ or P^+ type? Give one sentence explanation. (4pts.)

d) What is the substrate doping N_{sub}. (4pts.)

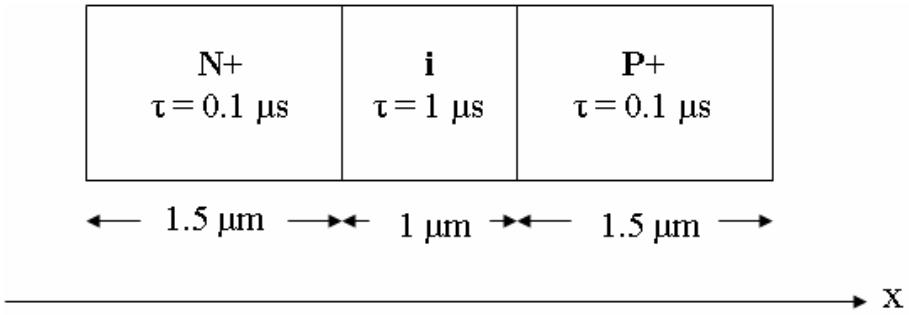
e) What is the oxide thickness T_{ox}? (4pts.)

3. **Given Na = $10^{17}cm^{-3}$, T_{ox} = 10 nm, N^+-poly gate MOS capacitor is biased at V_g = 2V.**

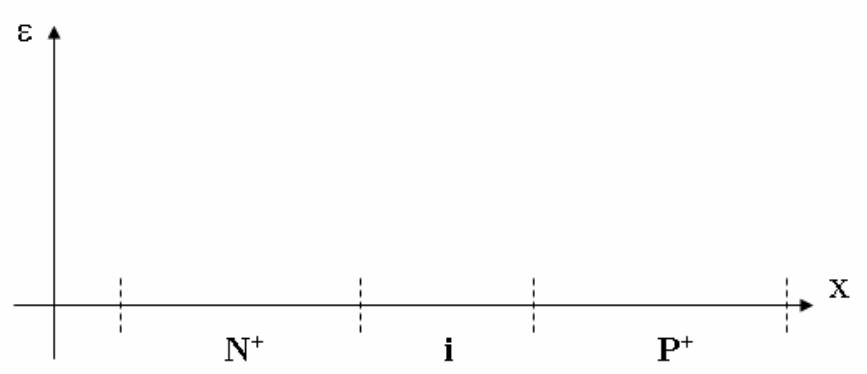
   a) Find φ_s, W_{dep}, and Capacitance @ HF (12 pts.)

   b) Sketch the energy-band diagram (5pts.)

4. **N^+-i-P^+ diode (15pts.)**



   a) Plot electric field ε vs. x at zero bias. Indicate the value of the peak electric field. (5pts.)



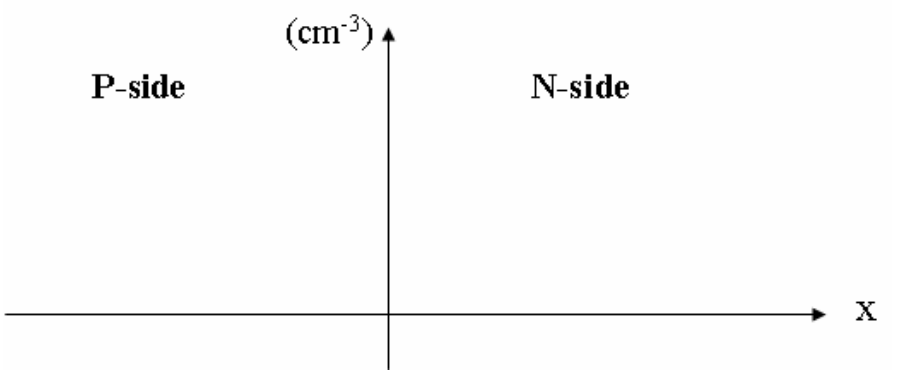
   b) Assume breakdown occurs when electric field exceeds 5 x 10^5 V/cm. What is the breakdown voltage of the diode? (5pts.)

   c) What is the capacitance at 2V reverse bias? (5pts.)

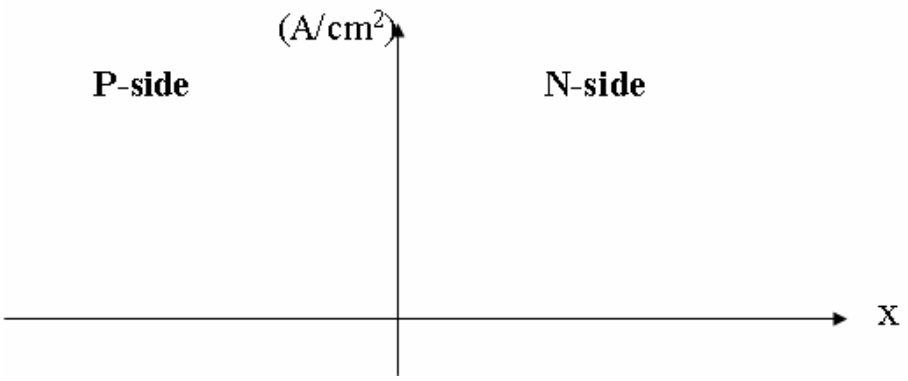
5. Consider a silicon P-N junction. Assume the diode is under forward bias and the depletion thickness is negligible. Make your plot consistent with any quantitative information that are given. (30pts.)

P N_a = 5 x 1014cm-3 τ_n =k, μ_n=h	**N** N_d=1 x $10^{15}cm^{-3}$ τ_p =2k, μ_p=h/2

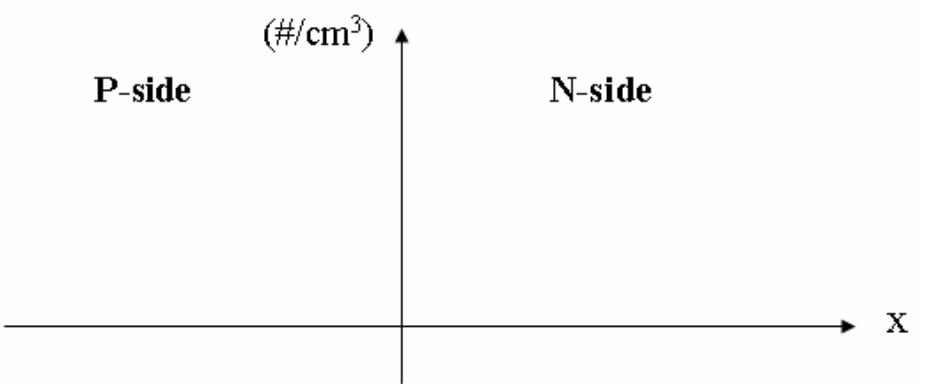
a) Plot $p_N'(x)$ and $n_{p'}(x)$ on both sides of the junction. Label the curves. Mark the diffusion length of p and n sides on the x-axis. (5pts.)



b) Plot the majority and minority current densities on both sides of the junction. Label the curves. Mark the diffusion length of p and n sides on the x-axis. (5pts.)

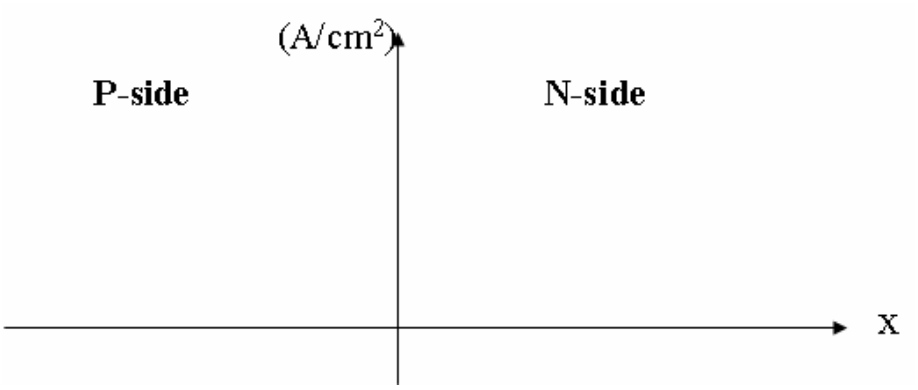


c) Plot the rate of the recombination (#/cm^3). (5pts.)



d) Write down or derive an expression of the diode current density under reverse bias? The answer may contain “h”, “k” and other commonly known quantities. (5pts.)

e) Plot $J_p(x)$ for $x>0$. Assume $\tau_p = k/2$. Mark the diffusion length on the x-axis. (5pts.)



f) Plot charge density $\rho(x)$ (Coul/cm^3) on both sides under zero bias. Write down the peak values of the p(x). Of course the depletion width cannot be neglected in this case. (5pts.)