University of California at Berkeley

University of California at Berkeley

College of Engineering

Dept. of Electrical Engineering and Computer Sciences

EE 105 Midterm II

Spring 2000 **Prof. Roger T. Howe** **April 18, 2000**

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Your Name (Last, First)

Guidelines

IMPORTANT:your LOWEST SCORE WILL BE THROWN OUT and your total Will be calculated as follows:

Total = (50/40)X(Sum of 4 highest scores).

Closed book and notes, one 8.5"X11" page (both sides) of *your own notes* is allowed.

You may use a calculator.

Do not unstaple the exam.

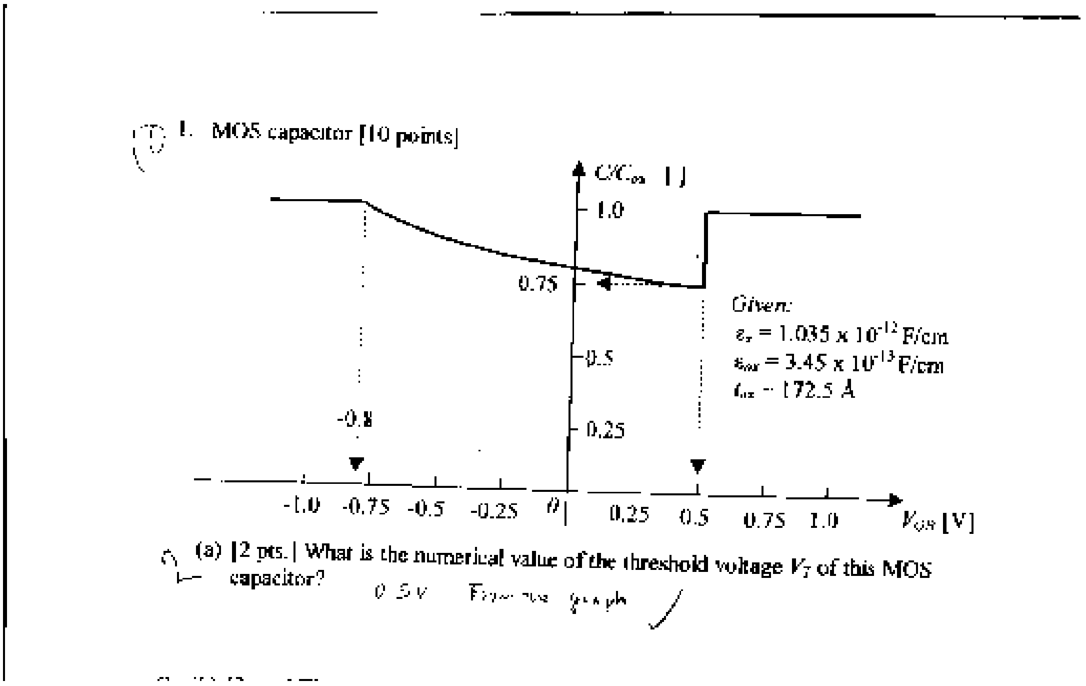
Show all your work and reasoning on the exam in order to receive full or partial credit.

Score

Problem	Points Possible	Score
1	10	
2	10	
3	10	
4	10	

5	**10**
Total	**50**

1. MOS capacitor [10 points]



1. MOS capacitor [10 points]

Given:
$\varepsilon_s = 1.035 \times 10^{-12}$ F/cm
$\varepsilon_{ox} = 3.45 \times 10^{-13}$ F/cm
$t_{ox} = 172.5$ Å

(a) [2 pts.] What is the numerical value of the threshold voltage V_T of this MOS capacitor?

0.5 V From the graph ✓

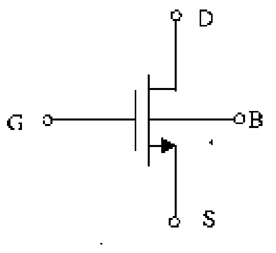
(a) [2 pts.] What is the numerical value of the threshold voltage *VT* of this MOS capacitor?

(b) [2 pts.] The area of the MOS capacitor is 15 um X 15 um: What is the capacitance (units: fF) when V_{GB} = 0.75V?

(c) [3 pts.] What is the numerical value of the depletion (bulk) capacitance C_b for this15 um X 15 um capacitor (units: fF) when V_{GB} = 0.475 V?

(d) [3 pts.] What is the numerical value of the inversion charge Q_{inv} (units: Coulombs) for this 15 um X 15 um MOS capacitor when V_{GB} = 1V?

2. MOS Transistors [10 points]



Device parameters:

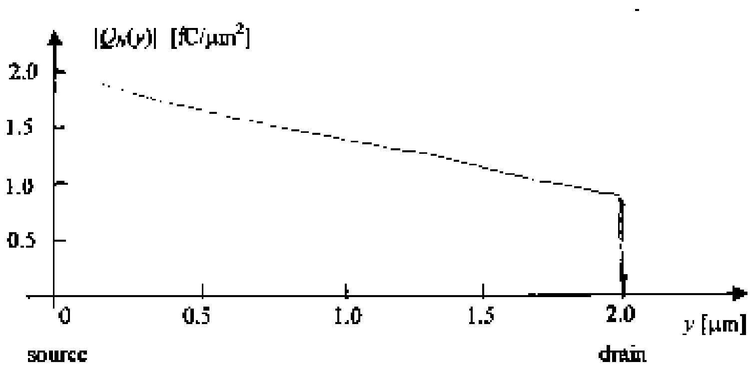
μ_n = 50 cm²/(Vs)
C_{ox} = 2 fF/μm²
W = 50 μm
L = 2 μm
V_{Tn} = 1 V
γ_n = 0.4 V$^{1/2}$
2 ϕ_p = -1 V

(a) [2 pts] At the operating point

(V_{GB} = 2V, V_{DS} = 0.5 V, and V_{BS} = 0 V)

In what region of operation is the MOSFET? Circle one: cutoff saturation triode

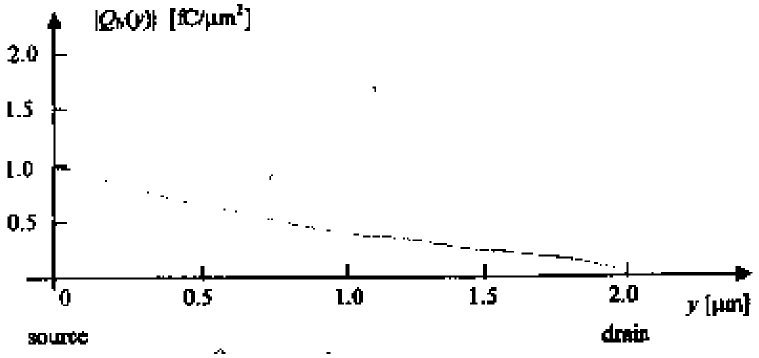
(b) [3 pts.] Sketch the magnitude of the channel charge $|Q_N(y)|$ from source (y=0) to drain (y=L) for the operating point in part (a) on the graph below. Your values at the ends of the channel should be numerically accurate



(c) [3 pts.] Sketch the magnitude of the channel charge $|Q_N(y)|$ from source (y=0) to drain (y=L) for the following operating point on the graph below.

(V_{GS} = 1.5 V, V_{DS} = 0.5 V, and V_{BS} = 0 V)

Your values at the ends of the channel should be numerically accurate.

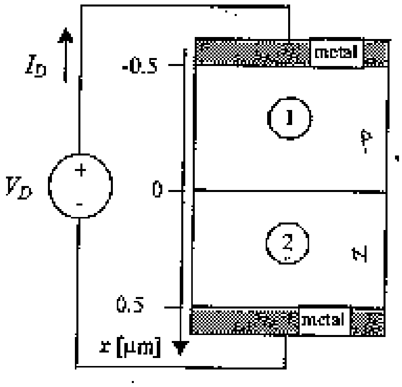


(d) [2 pts.] For the new operating point:

(V_{GS} = 1.5 V, V_{DS} = 0.1 V, and V_{BS} = 0 V)

Find the numerical value of the drift velocity of electrons in the channel in cm/s.

3. pn Heterojunction Diode Currents [10 points]



Region 1: SiGe alloy
$n_{i1}^2 = 2 \times 10^{10}\ \mathrm{cm}^{-3}$
$N_a = 10^{17}\ \mathrm{cm}^{-3}$
$D_n = 30\ \mathrm{cm}^2/\mathrm{s}$
$D_p = 30\ \mathrm{cm}^2/\mathrm{s}$

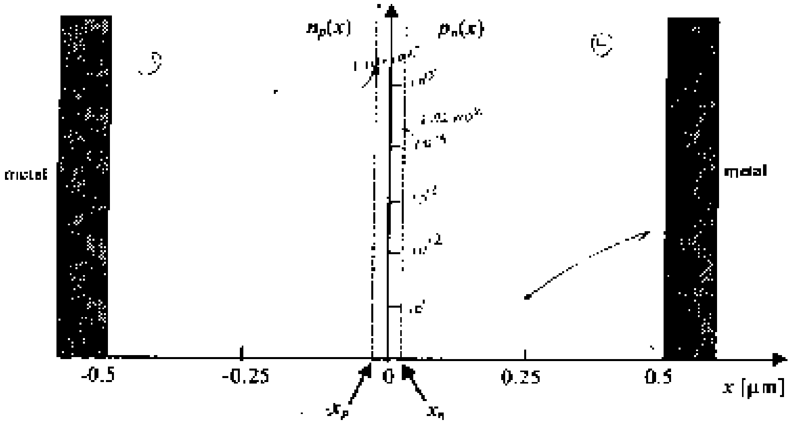
Region 2: silicon
$n_{i2}^2 = 10^{10}\ \mathrm{cm}^{-3}$
$N_d = 10^{17}\ \mathrm{cm}^{-3}$
$D_n = 25\ \mathrm{cm}^2/\mathrm{s}$
$D_p = 10\ \mathrm{cm}^2/\mathrm{s}$

$q = 1.6 \times 10^{-19}\ \mathrm{C}$

(a) [2 pts.] What are the numerical values of the hole and electron concentrations at the depletion region edge in region 1, for a forward bias of V*D* = 0. 660 V? You can assume that the law of the junction still applies to this "heterojunction diode;" however, you must use the correct value for the intrinsic concentration in this region.

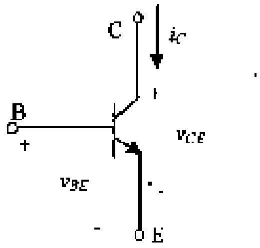
(b) [2 pts.] What are the numerical values of the hole and electron concentrations at the depletion region edge in region 2, for a forward bias of V*D* = 0.660 V? You can assume that the law of the junction still applies to this "heterojunction diode;" however, you must use the correct value for the intrinsic concentration in this region.

(c) [3 pts.] Sketch the minority carrier concentrations in region 1 and region 2 , for a forward bias of V_D = 0.660 V. You should label the numerical values for the minority electron and hole concentrations at the depletion edges x = $-x_p$ and x = x_n. If you couldn't solve parts (a) and (b), you can assume that the minority carrier concentrations are both 10^{15} cm^{-3} at the depletion region edges - not the correct answer to (a) and (b), needless to say.



(d) [3 pts.] What fraction of the diode current is from the hole diffusion current on the n-side of hte diode? You can neglect the width of the depletion region in finding the diffusion currents.

4. New Bipolar Transistor Model [10 points]



For high currents, a better model for the bipolar transistor in the forward-active region is:

$$i_C = I_{S2} e^{V_{BE}/2V_{th}} (1 + V_{CE}/V_{A2})^3$$

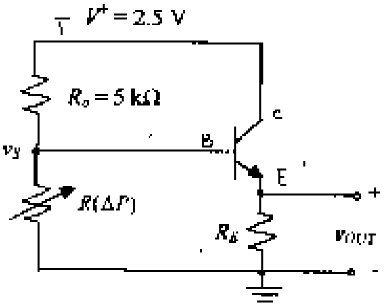
The high-current saturation current and Early voltage are $I_{S2} = 10^{-8}$ A and $V_{A2} = 30$ V; $V_{th} = 26$ mV.

(a) [2 pts.] Find the numerical value of the DC base-emitter voltage V_{BE} for $i_C = 116$ mA and $V_{CE} = 1.5$V.

(b) [4 pts.] Find the numerical value of the small-signal transconductance g*m* at the operating point in part (a) in S= 1/Ω

(c) [4 pts.] Find the numerical value of the small-signal collector-emitter resistance r*o* at the operating point in part (a) in Ω

5. **Bipolar Transistor Interface Amplifier [10 points]**



Transistor Parameters:

$V_{BE} = 0.7$ V
$\beta = \beta_o = \beta_F = 100$
$V_{An} = 40$ V

The variable resistor is a function of pressure, with

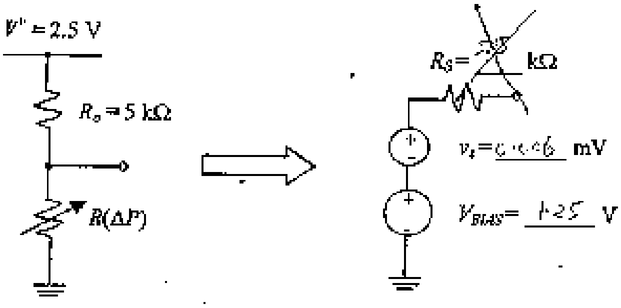
$$R(\Delta P) = R_o + K\Delta P = 5\text{k}\Omega + (25\Omega / atm) \cdot \Delta P,$$

where the pressure change is in atmospheres (atm).

(a) [2 pts.] For $\Delta P = 0$ and neglecting the DC base current I_B, find the numerical value of R_E such that the DC collector current $I_C = 75$ μA. Note that $R(\Delta P) = R_o = 5$ kΩ since $\Delta P = 0$.

(b) [2 pts.] Neglecting the base current, what is the change in the voltage V_S when the pressure change is $\Delta P = 2$ atm, compared to the case when $\Delta P = 0$.

(c) [3 pts.] Fill in the blanks for the circuit model for the input DC voltage V*BLAS*, the small signal voltage V*S*, and the source resistance Rs that models the pressure-sensing resistor divider with a pressure change of ΔP = 2 atm.



(d) [3 pts.] Using the two-port model for this bipolar amplifier stage, find the numerical value of the small-signal output voltage Vout for a pressure change of ΔP = 2 atm. If you couldn't solve part (c), you can assume for this part that Rs= 1 KΩ, Vs= 3 mV, and V*BLAS* = 1 V for this part (all of these are incorrect answer to (c), of course.)