Microelectronic Devices and Circuits – EECS 105
Spring 2003 Midterm 1
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<u>MOS Device Data (otherwise indicated on the particular problem)</u>
(you may not have to use all of these…)
$\mu_n C_{ox} = 50\mu A/V^2$, $\mu_p C_{ox} = 25\mu A/V^2$, $V_{Tn} = -V_{Tp} = 1$ V, Lmin = 1μm. $V_{BS} = 0$.
$\lambda_n = \lambda_p = 0.1\ V^{-1}$ when L = 1 μm, and it is otherwise proportional to 1/L
$C_{ox} = 2.3\ fF/\mu m^2$.

Also: $\varepsilon_o = 8.85\ 10^{-14}$ F/cm, $\varepsilon_{ox} = 3.9\ \varepsilon_o$ and $\varepsilon_{si} = 11.7\ \varepsilon_o$.

Problem 1 of 4: Answer each question briefly and clearly. (5 pts each, 40 total)

1.1 Assume a diffused resistor with a fixed thickness. What happens to the Sheet Resistance (Rs) if the doping level doubles (assuming that there is only a single dopant and that mobility does not change)?

- □ … stays the same
- □ … doubles
- □ … is reduced by 50%
- □ … none of the above

1.2 Find the "built-in potential" φ_B of a junction that has $N_A = 10^{16}/cm^3$ and $N_D = 10^{17}/cm$.

1.3 Place check marks where appropriate to indicate the correct region of operation, assuming that $V_{Tn} = -V_{Tp} = 1$ V.

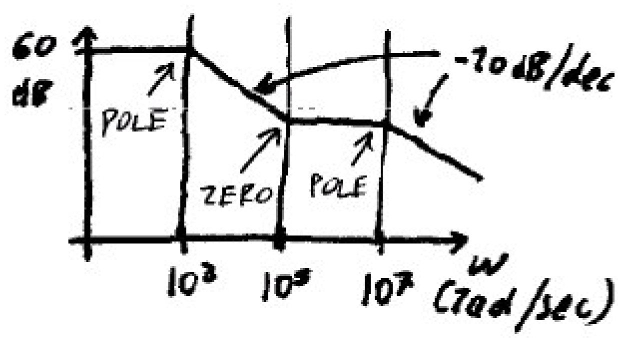
Transistor	**V_{GS}**	**V_{DS}**	**V_{BS}**	**Off**	**Triode**	**Saturation**
NMOS	**2**	**2**	**0**			
NMOS	**2**	**0.5**	**0**			
PMOS	**-2**	**-2**	**0**			
PMOS	**2**	**0.5**	**0**			

1.4 Choose the most appropriate answer.
A negatively charged "depletion" region in doped Si is characterized by …

- □ … an abundance of electrons and negative ions
- □ … too many electrons, too few holes
- □ … a severe imbalance between negative ions and holes
- □ … the complete depletion of charge density

1.5 We have a 2-terminal device that accumulates charge as a function of voltage according to the equation: $Q = 5V^2 + 3V + 2$, where Q is in pico Cb and V is in volts. Find the small signal capacitance of this device in pF at 2V.

1.6 Write the expression of a transfer function that corresponds to the Bode plot drawn.



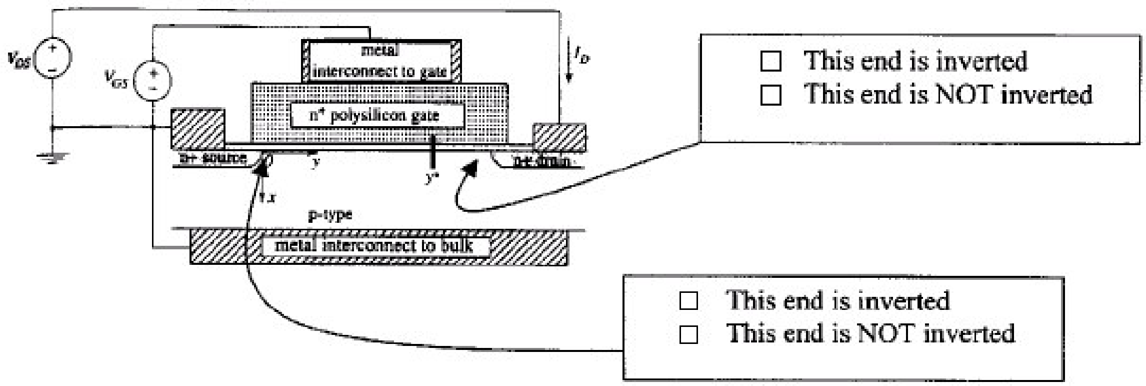
1.7 The value of a voltage source is $5 + 0.02\cos(10^6 t + 45^\circ)$ Volts. Please complete the list below:

V_s =

v_s =

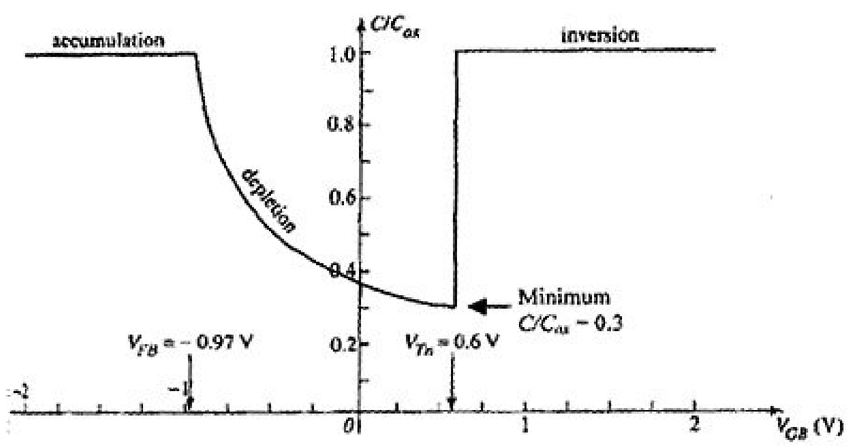
V_s =

1.8 For the n-channel MOS transistor shown below, please consider the two ends of the channel (near the source and near the drain) and indicate whether or not each must be inverted so that this device is in saturation.



Problem 2 of 4: Answer each question briefly and clearly. (20 points)

The C/V plot below was taken by "scanning" the gate-to-bulk voltage of an MOS structure. We know (from other measurements) that $\varphi_{n+} = 0.55$V and $C_{ox} = 2.3\text{fF}/\mu\text{m}^2$. Also, $\varepsilon_o = 8.85\ 10^{-14}$ F/cm, $\varepsilon_{ox} = 3.9\ \varepsilon_o$ and $\varepsilon_{si} = 11.7\ \varepsilon_o$. Use the graph to calculate:



2.1 The oxide thickness t_{ox}.

	expression	value and units
t_{ox} =		

2.2 The maximum depth of the depletion region (*What is the V_{GB} voltage that yields the maximum depth of the depletion region?*).

expression	value and units
$x_{dmax} =$	

V_{GB} when maximum depletion depth is achieved =

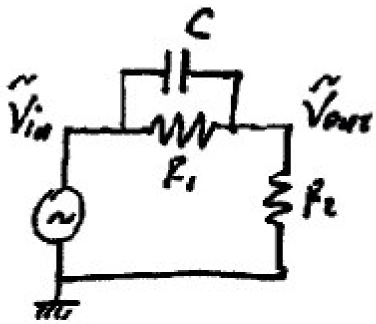
2.3 The doping concentration of acceptors (N_A) in the channel.

expression	value and units
$N_A =$	

2.4 The charge density of the inversion layer (in Cb/cm^2) when V_{GB} is 2V.

expression	value and units
$Q_i =$	

Problem 3 of 4: Answer each question briefly and clearly. (20 points)
Consider the circuit below. Assume R_1 = 1MΩ, R_2 = 100Ω, and C = 1pF.

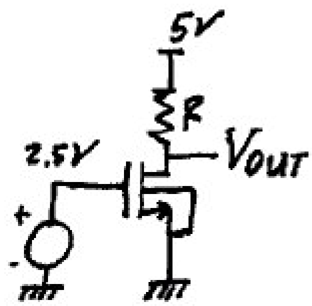


3.1 Write the transfer function v_{out} / v_{in}.

3.2 Calculate the gain at DC, the gain at extremely high frequencies (ω = infinity), and the numerical values of any poles and/or zeros that this function has.

expression	value
Gain $_{\text{at DC}}$ =	
Gain$_{\text{at } \omega = \text{infinity}}$ =	
Pole 1 = Pole 2 = …	
Zero 1 = Zero 2 = …	

Problem 4 of 4: Answer each question briefly and clearly. (20 points)
You are given an NMOS transistor, connected as shown.



4.1 Find an expression for W so that the output voltage V_{out} is 2.5V. Assume $\lambda_n = 0.1\ V^{-1}$ when L = 1µm, and it is otherwise proportional to 1/L.

expression

W =

4.2 Assume R = 10kΩ, $\mu_n C_{ox} = 50\mu A/V^2$, $V_{Tn} = 1V$, $\lambda_n = 0.1\ V^{-1}$ when L = 1µm, and it is otherwise proportional to 1/L. Find W/L when L is 2µm, and when L is 4µm.

value

$W/L_{\text{when } L = 2\mu m}$ =
$W/L_{\text{when } L = 4\mu m}$ =