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

EE 105: Microelectronic Devices and Circuits

Fall 2017 Prof. Ming Wu

MIDTERM EXAMINATION #2
Time allotted: 80 minutes

NAME: ________________________ ________________________ ________________________
(print) Last First Signature

STUDENT ID#: ____________________

INSTRUCTIONS:

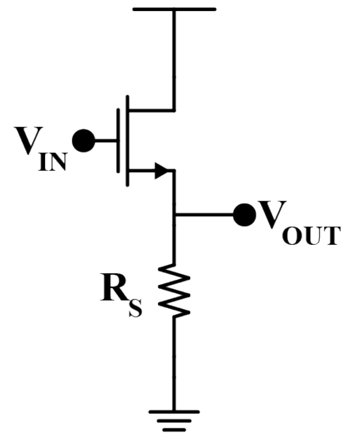
1. **SHOW YOUR WORK. (Make your methods clear to the grader!)**
2. **Clearly mark (underline or box) your answers.**
3. **Specify the units of your answer to receive full credit.**
4. **Unless stated in the problem, use the values of physical constants provided below.**
5. **You can use approximations within 20% accuracy any time.**
6. **Calculator is allowed. (Cell phone is not allowed).**

****** If you need more space for your answer, use the blank pages in the back. Clearly label which problem is your answer for ******

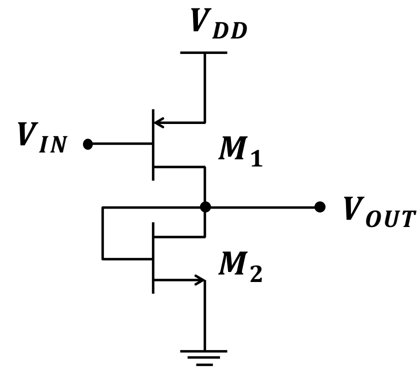
Commonly used constants and physical parameters:		
Electronic charge	q	1.6×10^{-19} C
Boltzmann's constant	k	8.62×10^{-5} eV/K
Thermal voltage at 300K	$V_T = kT/q$	0.025 V
Relative permittivity of Si	$\epsilon_{r,Si}$	12
Relative permittivity of SiO_2	$\epsilon_{r,ox}$	4
Vacuum permittivity	ϵ_0	$8.854\text{x}10^{-14}$ F/cm

Points	Problem 1	25	
	Problem 2	25	
	Problem 3	25	
	Problem 4	25	
	Total	100	

1) **Small Signal Response**. Consider the amplifier on the right, with the NMOS transistor operating in saturation.
   a) Draw the small signal equivalent circuit, indicating very clearly the dependent sources. Include r_0, the FET drain-to-source resistance. Clearly label the three terminals of the FET.
   b) Find the small signal voltage gain (v_{out} / v_{in}) of the amplifier assuming $r_0 = \infty$. Express your answer in terms of the transistor g_m and R_s ONLY.
   c) What happens to the voltage gain as $R_S \rightarrow \infty$?



2) **Large Signal Response**: Assuming V_{Tp}, V_{Tn}, k_p, k_n are given for the PMOS and NMOS devices in the circuit on the right. The power supply voltage is V_{DD}.



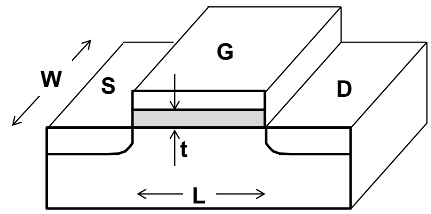
a) What are the operating regions for M_2 (Saturation or triode)? Why?
b) Find values of V_{in} such that M_1 is in the saturation region (in terms of the given parameters).
c) What is the DC value of V_{out} (again, in terms of the given parameters)?

3) A MOSFET has a channel length L, width W, oxide thickness t, threshold voltage V_t, and power supply voltage V_{DD}. Now consider a modified transistor with

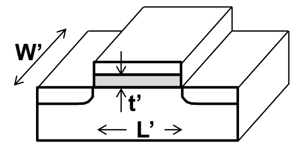
   a) Channel length scaling: L are changed by a factor of k (i.e. L'=kL). All other parameters remain the same. How do the maximum drain current I_D (at $V_{GS} = V_{DD}$) and transconductance g_m (also at $V_{GS} = V_{DD}$) change? Express your answers in scale factor, k. Show your derivation.

   b) Uniform scaling: W, L, t, V_t and V_{DD} are all changed by a factor of k. How does I_D and g_m change? Show your derivation.

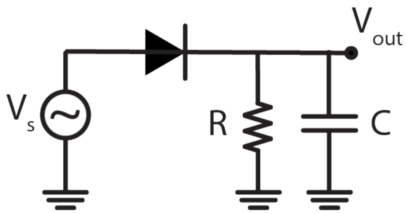
Reference MOSFET:

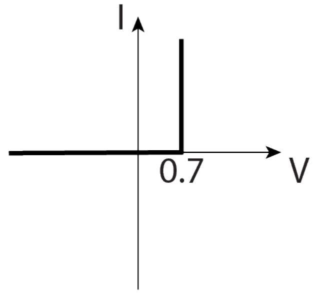


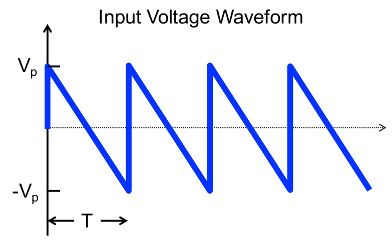
Scaled MOSFET:



4) The circuit below is made with an ideal diode with the I-V characteristic given below. The input waveform is shown below. Assume the peak voltage $V_p > 3V$.







a) Explain how the circuit works.

b) Assume R = ∞, draw the output waveform on the right.

c) Now consider a finite resistance value R such that $e^{-\frac{T}{RC}} = \frac{1}{2}$, where T is the period of the input waveform. Draw the qualitative output waveform on the right.

d) What is the maximum and minimum output voltages in c)? Express your answers in V_p .