EXAMINATION NO. 1

NAME_____SCORE_____/100

INSTRUCTIONS: This exam is closed book. You are allowed to have one page of handwritten (or typed) notes (both sides). The exam consists of 4 questions for a total of 100 points. Please show your work leading to your answers so that maximum partial credit may be given where appropriate. Be sure to turn in your exam with the problems in numerical order, firmly attached together.

TRANSISTOR INFORMATION:

The following is for an NMOS transistor only (with appropriate sign changes they can be used for PMOS transistors):

$$V_T = V_{T0} + \gamma(\sqrt{|2\phi_F| + \text{VSB}} - \sqrt{|2\phi_F|}$$

For long-channel devices, the current equations are:

If $V_{GS} \geq V_T$

and $V_{DS} \geq V_{GS} - V_T$ (the saturation region) $I_{DS} = \frac{k}{2}(V_{GS} - V_T)^2 (1+\lambda V_{DS})$

or $V_{DS} \leq V_{GS} - V_T$ (the linear region) $I_{DS} = \frac{k}{2}[2(V_{GS} - V_T)V_{DS} - V_{DS}^2]$

If $V_{GS} < V_T$ (subthreshold region) $I_{DS} \approx 0$

For velocity saturated short-channel devices, the current equations are:

If $V_{GS} \geq V_T$

and $V_{DS} \geq \frac{(V_{GS} - V_T)E_cL}{(V_{GS} - V_T) + E_cL}$ (saturation region) $I_{DS} = Wv_{sat}C_{ox}\frac{(V_{GS} - V_T)^2}{(V_{GS} - V_T) + E_cL}$

or $V_{DS} < \frac{(V_{GS} - V_T)E_cL}{(V_{GS} - V_T) + E_cL}$ (linear region) $I_{DS} = \frac{W}{L}\frac{\mu_e C_{ox}}{\left(1 + \frac{v_{DS}}{E_cL}\right)}\left(V_{GS} - V_T - \frac{V_{DS}}{2}\right)V_{DS}$

If $V_{GS} < V_T$ (subthreshold region) $I_{DS} = I_s \exp\left(\frac{q(V_{GS} - V_T - V_{offset})}{nkT}\right)\left[1 - \exp\left(\frac{-qV_{DS}}{kT}\right)\right]$

		0.18μm		0.13μm		
Name	Symbol	NMOS	PMOS	NMOS	PMOS	Units
Oxide Thickness	t_{ox}	35	35	22	22	Å
Oxide Capacitance	C_{ox}	1.0	1.0	1.6	1.6	μF/cm^2
Threshold Voltage	V_{TO}	0.5	-0.5	0.4	-0.4	V
Body-Effect Term	γ	0.3	0.3	0.2	0.2	V$^{0.5}$
Fermi Potential	$2\lvert\phi_F\rvert$	0.84	0.84	0.88	0.88	V
Junction Cap. Coeff.	C_{j0}	1.6	1.6	1.6	1.6	fF/μm^2
Built-In Junct. Potential	ϕ_B	0.9	0.9	1.0	1.0	V
Grading Coefficient	m	0.5	0.5	0.5	0.5	-
Nominal Mobility	μ_o	540	180	540	180	cm^2/V·s
Effective Mobility	μ_e	270	70	270	70	cm^2/V·s
Critical Field	E_c	6x10^4	24x10^4	6x10^4	24x10^4	V/cm
Critical Field x L	E_cL	1.2	4.8	0.6	2.4	V
Effective Resistance	R_{eff}	12.5	30	12.5	30	kΩ/sq.

CAPACITOR INFORMATION:

	Cutoff	Linear	Saturation
C_{gs}	C_{ol}	$C_{ol} + 0.5C_g$	$C_{ol} + 0.67C_g$
C_{gd}	C_{ol}	$C_{ol} + 0.5C_g$	C_{ol}
C_{gb}	$1/(1/C_g+1/C_{jc})<C_{gb}< C_g$	0	0
C_{sb}	C_{jSB}	$C_{jSB} +\alpha_1 C_{jc}$	$C_{jSB} +\beta_1 C_{jc}$ (α,β small)
C_{db}	C_{jDB}	$C_{jDB} +\alpha_2 C_{jc}$	$C_{jDB} +\beta_2 C_{jc}$ (α,β small)

where, C_{ol} = overlap capacitance C_{jc} = channel to substrate depeletion capacitance

$$C_g = C_{ox} L \qquad C_j = \frac{C_{jb}(A_b+A_{sw})}{\left(1 - \frac{V_j}{\phi_B}\right)^{mj}}$$

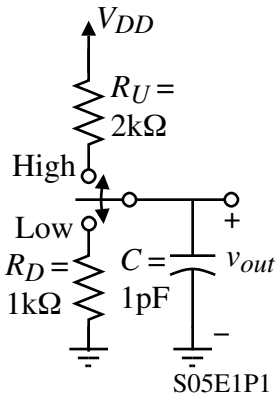
where A_b = area of source/drain and A_{sw} = area of side of source/drain facing the channel

OTHER INFORMATION:

$\varepsilon_{ox} = 4\varepsilon_o = 4 \cdot 8.85\text{x}10^{-14}$ F/cm = $3.54\text{x}10^{-13}$ F/cm

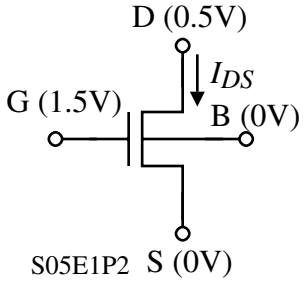
Problem 1 - (25 points)

A logic circuit is modeled as shown. Assume that at time t =0, the capacitor is uncharged and the switch is connected to the "high" state. At some time later, after the output voltage has reached its high state, the switch is connected to the "low" state. Find the propagation time delay of this logic circuit.



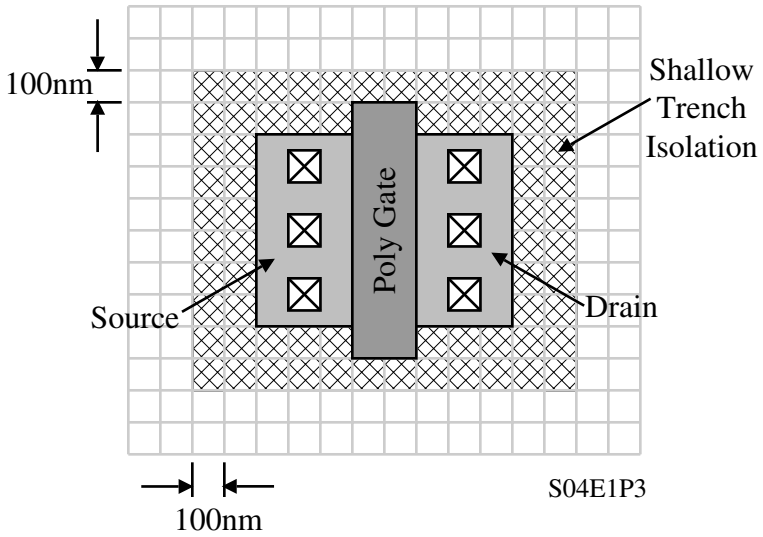
Problem 2 – (25 points)

Solve for the dc value of the drain current, I_{DS}, for the NMOS transistor shown assuming 0.18μm CMOS technology. The *W* and *L* for this transistor are given in Problem 3.



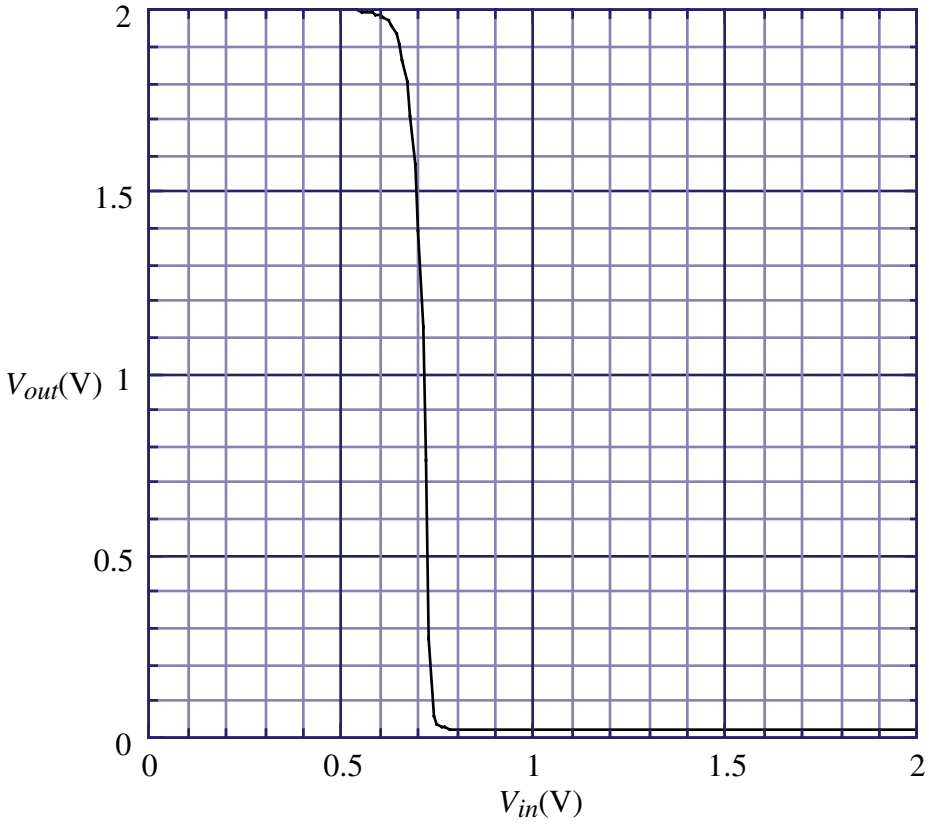
Problem 3 – (25 points)

Given the layout for the NMOS transistor of Problem 2, find the value of C_{gs}, C_{gd}, C_{gb}, C_{db}, and C_{sb} assuming that the junction depth of the source-drain diffusions is x_j = 50 nm, m = 0.5 and the lateral diffusion is 10nm.



Problem 4 – (25 points)

The transfer function curve for an inverter is shown. Find the values of V_{OH}, V_{OL}, V_{IL}, and V_{IH} from the curve below. Use this information to find the values of NM_H and NM_L.



Extra Sheet