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EEE591 ###

Problem 1

a) $C_{ox} = \frac{\varepsilon_{ox}}{t_{ox}} = \frac{3.9 \times 8.85 \times 10^{-12}}{9 \times 10^{-9}} = \boxed{3.835 \times 10^{-3}\ F/m^2}$

b) $k_n' = \mu C_{ox} \Rightarrow$

$k_n = \mu C_{ox} \frac{W}{L} = 560 \times 10^{-4} \cdot 3.835 \times 10^{-3} \cdot \frac{\#\times 10^{-6}}{0.23 \times 10^{-6}}$

$= \boxed{0.1718\ mA/V^2}$

c) $V_{GS} - V_{tn} = 2.5 - 0.6$

$= 1.9$

$V_{DS} = 1.25 < 1.9 \Rightarrow$ triode

$\Rightarrow C_{gd} = C_{gs} = \frac{WC_{ox}L}{2} = \frac{2\mu m\,(3.835 \times 10^{-3})\,0.25\mu}{2}$

$= \boxed{9.588 \times 10^{-16}\ F}$

$C_{db} = \frac{C_{j0} \cdot L_S \cdot W}{\Phi} + \frac{C_{jsw0}(2L_S + W)}{\Phi}$

$= \frac{1.7f \cdot 0.6\mu \cdot 2\mu}{\Phi} + \frac{0.4f\,(2(0.6\mu) + 2\mu)}{\Phi}$

$= \boxed{1.28 \times 10^{-21}\ F}$

Problem 2

a) $V_m = \frac{V_{tn} + r(V_{DD} - |V_{tp}|)}{1+r}$ $\quad r = \sqrt{\frac{\mu_p \cdot W_p}{\mu_n \cdot W_n}}$

$= \sqrt{\frac{220\times10^{-4} \cdot 0.8\times10^{-6}}{560\times10^{-4} \cdot 0.36\times10^{-6}}}$

$= 0.934$

$V_m = \frac{0.6 + 0.934(2.5 - |0.6|)}{1+0.934}$

$= \frac{2.375}{1.934} = \boxed{1.23\ V}$

b) $R_n = \frac{1}{k_n' \frac{W}{L}(V_{DD} - V_{tn})} = \frac{1}{0.2mA\left(\frac{0.36\mu m}{0.25\mu m}\right)(2.5 - 0.6)}$

$k_n' = \frac{1}{2}(560\times10^{-4})\left(\frac{0.36}{0.25}\right) 3.833\times10^{-3}$

$= 0.155\ mA/V^2 \approx 0.2$ $= \boxed{1.8\ k\Omega}$

$R_p = \frac{1}{k_p' \frac{W}{L}(V_{DD} - V_{tn}} = \frac{1}{0.13mA\left(\frac{0.8}{0.25}\right)(2.5 - |0.6|)}$

$\approx \boxed{1.3\ k\Omega}$

$k_p' = \frac{1}{2}\left(220\times10^{-4} \cdot \left(\frac{0.8}{0.25}\right) 3.833\times10^{-3}\right)$

$= 0.13\ mA/V^2$

c) for V_m to equal half V_{DD}, the transistors would need to be balanced, so the PMOS & NMOS would be the same size so that $r = \sqrt{\frac{\mu_p W_p}{\mu_n W_n}} = 1$

d) C_{dbn} C_{dbp} are to gnd
C_{gdn} C_{gdp} $\cdot C_2 = 74fF$

$C_{dbp} = \frac{C_j W_p L_s}{(1+1.25)^{1/2}} + \frac{C_{jsw}(2L_s + W_p)}{(1+1.25)^{1/3}}$

$= \frac{1.7(0.8)0.6}{2.25^{1/2}} + \frac{0.4(1.2+0.8)}{2.25^{1/3}}$

$= 1.16fF$

$C_{dbn} = \frac{C_j W_n L_s}{\left(1+\frac{V_{db}}{\phi}\right)^{1/2}} + \frac{C_{jsw}(2L_s + W_n)}{\left(1+\frac{V_{db}}{\phi}\right)^{1/3}}$

$V_{db} = \frac{V_{DD}}{2} = 1.25$

$= \frac{1.7f(0.36)(0.6)}{\left(1+\frac{1.25}{1}\right)^{1/2}} + \frac{0.4(2(0.6)+0.36))}{\left(1+\frac{1.25}{1}\right)^{1/3}}$

$= 0.67fF$

$C_{gd_p} + C_{gd_n} = (W_p + W_n) C_o$
$= (0.8 + 0.36)(0.4 fF/\mu m)$
$= 0.4 fF$

$C_{TOTAL} = C_{db_p} + C_{db_n} + 2(C_{gd_p} + C_{gd_n}) + C_L$
$= 1.16 fF + 0.67 fF + 2(0.4) fF = 76.7 fF$

$t_{pHL} = 0.7 R_n C_{TOT} = 0.7 (1.8k)(76.7 fF)$
$= \boxed{96.6 ps}$ ← worst case
(↑ nmos)

$t_{PLH} = 0.7 R_p C_{TOT} = 0.7 (1.6k)(76.7 f)$
$= \boxed{86 ps}$

e) delay 2x when R_{on} 2x

$\Rightarrow 3.6k = (1.8k)^2$

$3.6 k\Omega = \dfrac{1}{0.2m \cdot \frac{0.36}{0.2} (V_{DD} - 0.6)}$

$3.6 (V_{DD} - 0.6) = 3.472 k$

$V_{DD} - 0.6 = 0.96$

$\boxed{V_{DD} = 1.56 V}$

Problem 3

a) $V_{BA} = V_{DD} \Rightarrow$ pmos off $\Rightarrow I_{off} = \frac{W}{L}(I_0) e^{\frac{q(V_{gs} - V_{th})}{nkT}}$

$V_{DS} = 0$

$I_{off} = 0.36 (10^{-7}) e^{\frac{0 + 0.6}{3(26m)}}$

$= \boxed{2.19 mA}$

$V_{in} = 0 \Rightarrow$ nmos off $\Rightarrow I_{off} = \frac{W}{L} I_0 e^{\frac{q(V_{gs} - V_{th})}{nkT}}$

$= 2.5 (10^{-7}) e^{\frac{0 - -0.6}{3(26m)}}$

$= \boxed{5.5 mA}$

b) $P_s = \frac{E_{total}}{T} = C V_{DD}^2 f$

$\Rightarrow E_{tot} = C V_{DD}^2$

$= 50f (2.5)^2$

$= \boxed{0.313 pJ}$

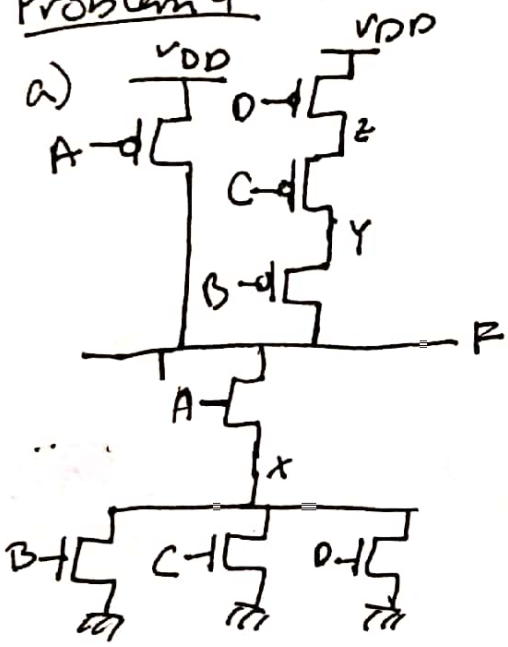
a) $E_L = P_L$ (time)

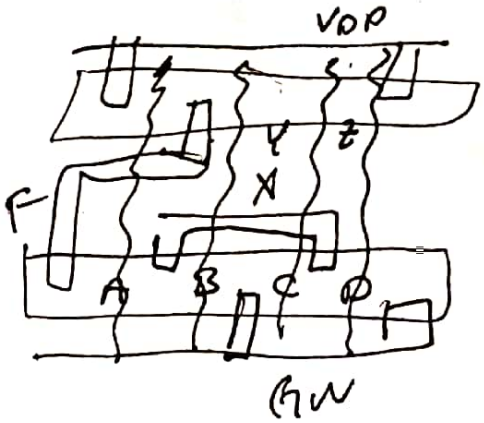
$\uparrow$ $I_{DD} V_{DD}$

$= (2.19m \cdot 2.5)(200ns)$

$= \boxed{1.095 nJ}$

Problem 4





b) $\overline{F} = A(B+C+D)$

$F = \bar{A} + \bar{B}\bar{C}\bar{D}$

A	B	C	D	$\overline{F}$	F
0	0	0	0	0	1
0	0	0	1	0	1
0	0	1	0	0	1
0	0	1	1	0	1
0	1	0	0	0	1
0	1	0	1	0	1
0	1	1	0	0	1
0	1	1	1	0	1
1	0	0	0	0	1
1	0	0	1	0	0
1	0	1	0	0	0
1	0	1	1	0	0
1	1	0	0	0	0
1	1	0	1	0	0
1	1	1	0	0	0
1	1	1	1	0	0