1. This question is based on Problem 2.13 of the text: The transit frequency, $f_T$, of a MOS transistor is defined as the frequency at which the small-signal current gain of the transistor is equal to unity (while the source and drain terminals are held at ac ground).

(a) Show that:

$$f_T = \frac{g_m}{2\pi(C_{GS} + C_{GD})}$$

(b) Using square-law characteristics show that for an NMOS of size (W/L) we have

$$f_T \approx \frac{3\mu_n V_{eff}}{\pi L^2}$$

This relation shows the dependence of speed of operation to the technology feature size and to the supply voltage.

2. (a) Using long-channel MOS equations find the expression for $g_m/I_D$ when the MOS transistor is operating in its active region.

(b) Use HSPICE to simulate the following circuit and plot $g_m/I_D$ versus $V_{eff}$ for an NMOS transistor with W=10.5\(\mu\)m and L=0.35\(\mu\)m when $V_{eff}$ varies between -300mV to 300mV.

(c) Is there any discrepancy between the simulation result of part (b) and the result expected from the expression in part (a). If yes, briefly explain why?

(d) Repeat part (b) for an NMOS with L=0.7\(\mu\)m.

(e) Repeat part (b) for a PMOS transistor. Note that you need to use a diode-connected PMOS (a PMOS with its gate and drain connected together and source connected to $V_{DD}$). Compare the results with those of part (b).
3. For the following circuit use HSPICE to sketch $V_{out}$ versus $V_{in}$ as $V_{in}$ varies from 0 to $V_{DD}$. Identify the important segments (and transition points between the segments) of the curve and the corresponding regions of operation of transistors $M_1$ and $M_2$ (e.g., cut-off, linear, or active) for each segment of the curve.

Assume $L=0.35\mu m$, $(W/L)_{NMOS} = 40$, $(W/L)_{PMOS} = 30$, $V_{DD}=3.3V$, and $R_1=R_2=10k\Omega$.

**Hint:** After plotting the curve, try to identify the important segments of the curve and transistors regions of operation qualitatively, using long-channel transistor equations.

![Circuit Diagram]

Good luck!