9.13

(a) $K = k'\left(\frac{W}{L}\right) = 50 \times 10^{-6}\ A/V^2, \quad V_T = 1V$

For $V_i \le 1V$, $I_D = 0$

For $1V \le V_i \le 3V$, $I_D = \frac{k}{2}(V_i - V_T)^2$ because the MOSFET is saturated.
$= 25\times10^{-6}(V_i - 1)^2$

For $3V \le V_i \le 4V$, $I_D = k\left[(V_i - V_T)V_{DD} - \frac{V_{DD}^2}{2}\right]$, the MOSFET is not saturated.
$= 100\times10^{-6}(V_i - 2)$

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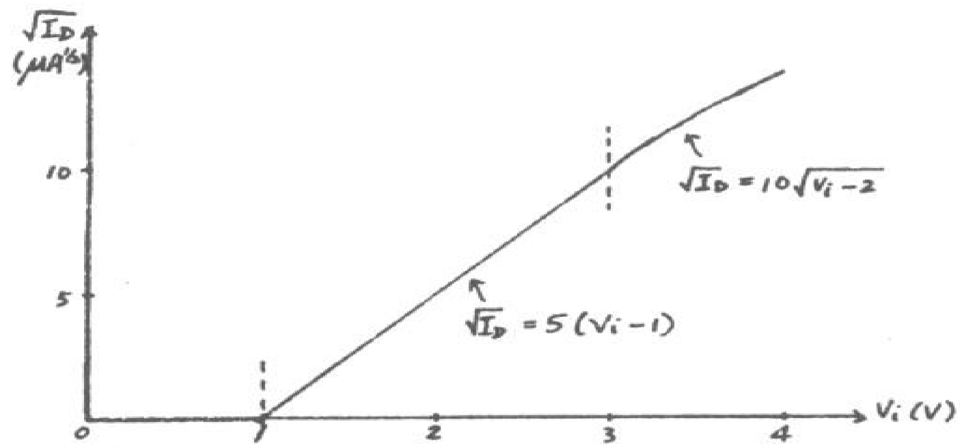



(b) & (c)

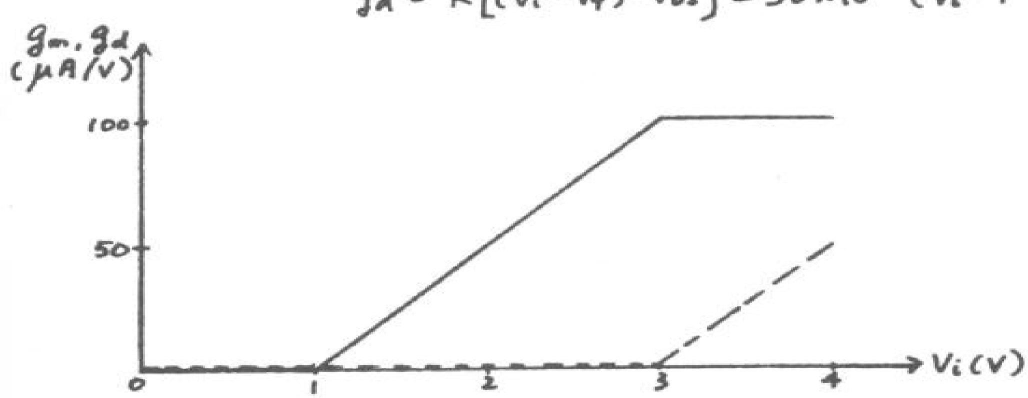
For $V_i \le 1V$, $g_m = g_d = 0$

For $1V \le V_i \le 3V$, $g_m = \frac{\partial I_D}{\partial V_i} = 50\times10^{-6}(V_i - 1)$

$g_d = \frac{\partial I_D}{\partial V_{DS}} = 0$

For $3V \le V_i \le 4V$, $g_m = k V_{DD} = 100\times10^{-6}\ A/V$

$g_d = k\left[(V_i - V_T) - V_{DS}\right] = 50\times10^{-6}(V_i - 1 - 2)$



ECE 441. HW 12.

Problem 9.17

$$V_{Dsat} = \frac{\mathcal{E}_{sat} L (V_G - V_T)}{\mathcal{E}_{sat} L + V_G - V_T} \quad \therefore \quad \mathcal{E}_{sat} = \frac{2 v_{sat}}{\mu_{eff}}$$

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$$I_{Dsat} = W C_{ox} (V_G - V_T - V_{Dsat}) v_{sat}$$

Plugging in $V_{Dsat}$ & $\mathcal{E}_{sat}$

$$I_{Dsat} = W C_{ox} \left( V_G - V_T - \frac{2 L v_{sat} (V_G - V_T)}{2 L v_{sat} + (V_G - V_T) \mu_{eff}} \right) v_{sat}$$

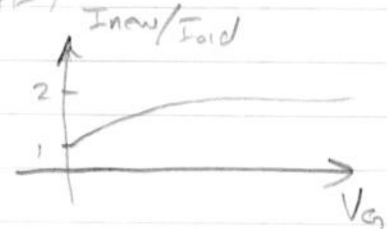
$$= W C_{ox} \left( \frac{(V_G - V_T)^2 \mu_{eff}}{2 L v_{sat} + (V_G - V_T) \mu_{eff}} \right) v_{sat}$$

(a) $v_{sat}(new) = 2 v_{sat}$.

$$\therefore \frac{I_{Dsat}(new)}{I_{Dsat}(old)} = 2 \left( \frac{2 L v_{sat} + (V_G - V_T) \mu_{eff}}{4 L v_{sat} + (V_G - V_T) \mu_{eff}} \right)$$

$\therefore$ As $V_G \to V_T = 0$, ratio is 1

$V_G \to \infty$, ratio is 2

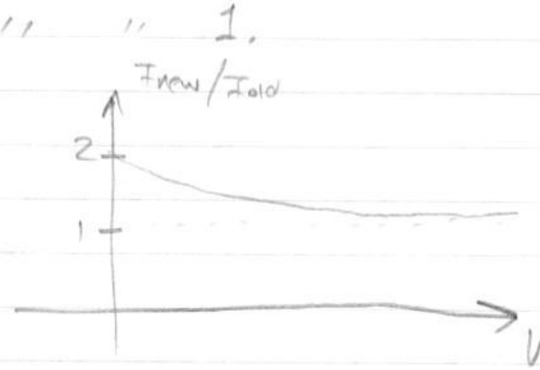



(b) $\mu_{eff}(new) = 2 \mu_{eff}$

$$\text{Ratio} = \left( \frac{2 L v_{sat} + (V_G - V_T) \mu_{eff}}{2 L v_{sat} + 2 (V_G - V_T) \mu_{eff}} \right) \cdot 2$$

As $V_G \to V_T = 0$, ratio is 2

As $V_G \to \infty$, " " 1.



# Problem 3

$$dV_c(y) \approx \frac{I_D\, dy}{\mu_n C_{ox} W \left[ V_G - V_T - V_c(y) \right]}$$

$$\int_{V_S=0}^{V_c(y)} \left( V_G - V_T - V_c(y) \right) dV_c(y) = \frac{I_D}{\mu_n C_{ox} W} \int_0^y dy$$

$$-\frac{1}{2} \left[ V_G - V_T - V_c(y) \right]^2 \Big|_0^{V_c(y)} = \frac{I_D\, y}{\mu_n C_{ox} W}$$

$$-\frac{1}{2} \left[ V_G - V_T - V_c(y) \right]^2 + \frac{1}{2} (V_G - V_T)^2 = \frac{I_D\, y}{\mu_n C_{ox} W}$$

$$\left[ V_G - V_T - V_c(y) \right]^2 = (V_G - V_T)^2 - \frac{2 I_D\, y}{\mu_n C_{ox} W}$$

$$V_G - V_T - V_c(y) = \sqrt{(V_G - V_T)^2 - \frac{2 I_D\, y}{\mu_n C_{ox} W}}$$

$$\boxed{V_c(y) = V_{GT} - \sqrt{V_{GT}^2 - \frac{2 I_D\, y}{\mu_n C_{ox} W}}} \quad \#$$

$$\mathcal{E}_y(y) = -\frac{dV_c(y)}{dy} = +\frac{1}{\cancel{2}} \left( V_{GT}^2 - \frac{2 I_D\, y}{\mu_n C_{ox} W} \right)^{-1/2} \frac{\cancel{2} I_D}{\mu_n C_{ox} W}$$

$$\boxed{\mathcal{E}_y(y) = -\frac{I_D}{\mu_n C_{ox} W} \left( V_{GT}^2 - \frac{2 I_D\, y}{\mu_n C_{ox} W} \right)^{-1/2}} \quad \#$$

b) at the edge of saturation $V_{DS} = V_{GS} - V_T$

since $V_S = 0$, $V_D = V_G - V_T$

$$\therefore \quad \mathcal{E}_c(y) = -\frac{I_D}{\mu_n C_{ox} W}\left(V_D^2 - \frac{2 I_D y}{\mu_n C_{ox} W}\right)^{-1/2}$$

at the source side, $\mathcal{E}_c(y=0)$

$$\mathcal{E}_c(y=0) = -\frac{I_D}{\mu_n C_{ox} W}\left(V_D^2\right)^{-1/2} = -\frac{1}{V_D} \cdot \frac{I_D}{\mu_n C_{ox} W}$$

$$V_c(y=L) = V_D = V_{GT} = V_{GT} - \sqrt{V_{GT}^2 - \frac{2 I_D L}{\mu_n C_{ox} W}}$$

$$\frac{I_D}{\mu_n C_{ox} W} = \frac{V_{GT}^2}{2L} = \frac{25}{2(10 \times 10^{-4})} = 12.5 \times 10^3$$

$$= 1.25 \times 10^4$$

$$\mathcal{E}_c(y=0) = -\frac{1}{5} \cdot 1.25 \times 10^4 \text{ V/cm}$$

$$= -0.25 \times 10^4 \text{ V/cm}$$

$$\boxed{\mathcal{E}_c = -2.5 \times 10^3 \text{ V/cm}} \quad /\!/$$