10.43 The channel conductance for a p-channel MOSFET is defined as

$$g_d = \left.\frac{\partial I_D}{\partial V_{SD}}\right|_{V_{SD}\to 0}$$

Plot the channel conductance for the p-channel MOSFET described in Problem 10.38 for $0 \le V_{SG} \le 2.4$.

- First, find K_p.

****

10.38 Consider an ideal p-channel MOSFET with the following parameters: $V_T = -0.35$ V, $\mu_p = 210$ cm²/V-s, $t_{ox} = 11$ nm $= 110$ Å, $W = 35$ μm, and $L = 1.2$ μm.

****

From Table B.6, $\varepsilon_r = 3.9$ for SiO_2 at 300 K.

Linear Region [$0 \le V_{SD} \le V_{SD}$(sat) **and** $V_{SG} > V_T$]

$$I_D = \frac{W\mu_p C_{ox}}{2L}\left[2(V_{SG}+V_T)V_{SD} - V_{SD}^2\right] = K_p\left[2(V_{SG}+V_T)V_{SD} - V_{SD}^2\right] \quad (10.70).$$

Saturation [$V_{SG} \ge V_T$ & $V_{SD} \ge V_{DS}$(sat)] **Does not apply as $V_{SD} \to 0$.**

From above or page 416 of text (use MKS units),

$$K_p = \frac{W\mu_p C_{ox}}{2L} = \frac{35\times10^{-6}(210\times10^{-4})\,3.9(8.8541878\times10^{-12})/11\times10^{-9}}{2(1.2\times10^{-6})}$$

$\Rightarrow$ **$K_p = 9.61384\times10^{-4}$ A/V² $= 0.961384$ mA/V².**

For an inversion layer, we need $V_{GS} \le V_T = -0.35$ V $\Rightarrow V_{SG} \ge 0.35$ V. Therefore, $I_D = 0$ when $V_{SG} < 0.35$ V (no inversion layer to carry current).

$$g_d = \left.\frac{\partial I_D}{\partial V_{SD}}\right|_{V_{SD}\to 0} = \left.\frac{\partial(0)}{\partial V_{SD}}\right|_{V_{SD}\to 0}$$

$\Rightarrow$ **$g_d = 0$ for $V_{SG} < 0.35$ V.**

For $V_{SG} \ge 0.35$ V, we are in the linear region, and the channel conductance is

$$g_d = \left.\frac{\partial I_D}{\partial V_{SD}}\right|_{V_{SD}\to 0} = \left.\frac{\partial K_p\left[2(V_{SG}+V_T)V_{SD} - V_{SD}^2\right]}{\partial V_{SD}}\right|_{V_{SD}\to 0}$$

$$= K_p\left[2(V_{SG}+V_T)1 - 2V_{SD}\right]\Big|_{V_{SD}\to 0} = (0.961)2(V_{SG} - 0.35)$$

$\Rightarrow$ **$g_d = 1.922767\,(V_{SG} - 0.35)$ mA/V for $V_{SG} \ge 0.35$ V.**

Plot g_d versus V_{GS} using Matlab

```
% p10_43.m
% EE362
% Dr. Thomas P. Montoya
%
clear; clc; close all;
VT = -0.35; mp = 210*10^-4;
tox = 11*10^-9; er = 3.9; e0 = 8.8541878*10^-12;
W =  35*10^-6; L =  1.2*10^-6; es = er*e0;
Kp = W*mp*es/tox/2/L
VSG1 = [0, 0.35]; gd1 = [0, 0]; % below inversion
VSG2 = 0.35:0.1:2.4; gd2 = 2*Kp*(VSG2+VT); % linear
VSG = [VSG1, VSG2];  gd = [gd1, gd2];
plot(VSG,gd*1000,'r-','linewidth',2)
axis([0 2.4 0 4]),
ylabel('{\itg_d} (mA/V)','fontsize',14,'fontname','times'),
xlabel('{\itV_{SG}} (V)','fontsize',14,'fontname','times'),
title('Channel conductance','fontsize',16,'fontname','times'),
set(findobj('type','axes'),'linewidth',2)
```