Assignment 9
E3225
Art of Compact Modeling

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1 Problem 1

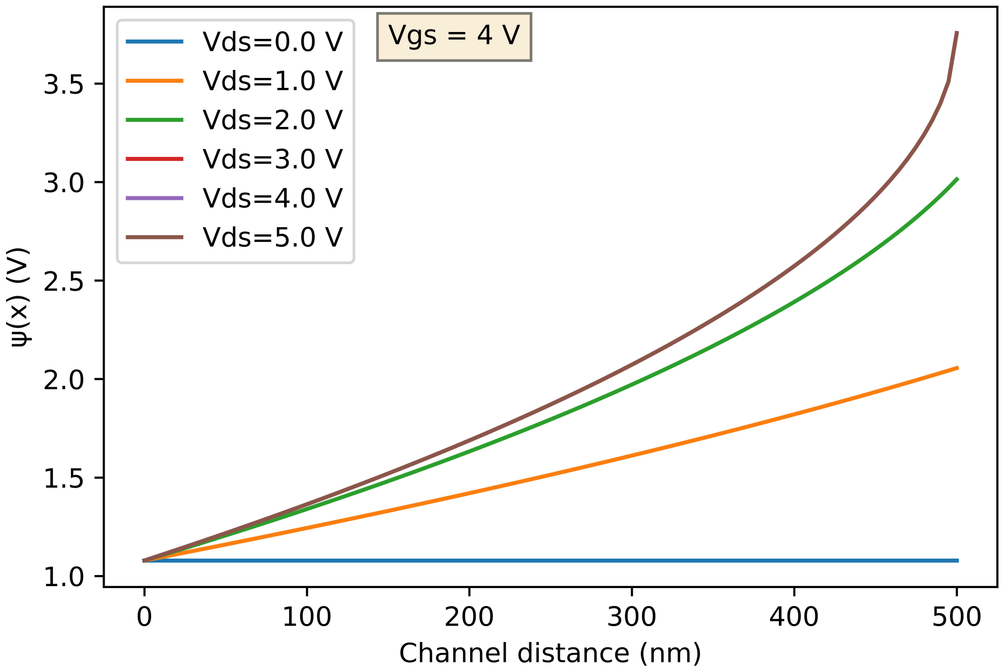
Plot Surface Potential as a function of X (along the channel, from source to drain) at a given V_G, for $V_{DS} \geq 0$.

Solution:
$\psi(x)$ **vs x:**

$$f(\psi_s) = \mu C_{ox}^{'}[(V_{GB} - V_{FB} + \phi_t)\psi_s - \frac{1}{2}\psi_s^2 - \frac{2}{3}\gamma\psi_s^{3/2} + \phi_t\gamma\psi_s^{1/2}] \tag{1}$$

$$\frac{x}{L} = \frac{f(\psi_s(x)) - f(\psi_{s0})}{f(\psi_{sL}) - f(\psi_{s0})} \tag{2}$$

equation (1) is used in equation (2) for calculating $f(\psi_s(x))$.



It deviates from linearity above strong inversion point, for that particular V_{gs}. After V_{ds} of 2 V it starts saturating.

2 Problem 2

Plot Terminal Charges (Q_G, Q_D, Q_S, Q_B) as function of V_G, at high and low V_D.

Solution:

Charge Calculation:

$Q_B^{'} = -\sqrt{2q\epsilon_s N_A}\sqrt{\psi_s(x)}$

$Q_B = W\int_0^L Q_B^{'}\,dx$

$Q_G^{'} = C_{ox}^{'}(V_{GB} - V_{FB} - \psi_s(x)) - Q_o^{'} = C_{ox}^{'}\gamma\sqrt{\psi_s(x) + \phi_t e^{\frac{\psi_s(x)\ -\ (2\phi_f + V_{cb})}{\phi_t}}} - Q_o^{'}$

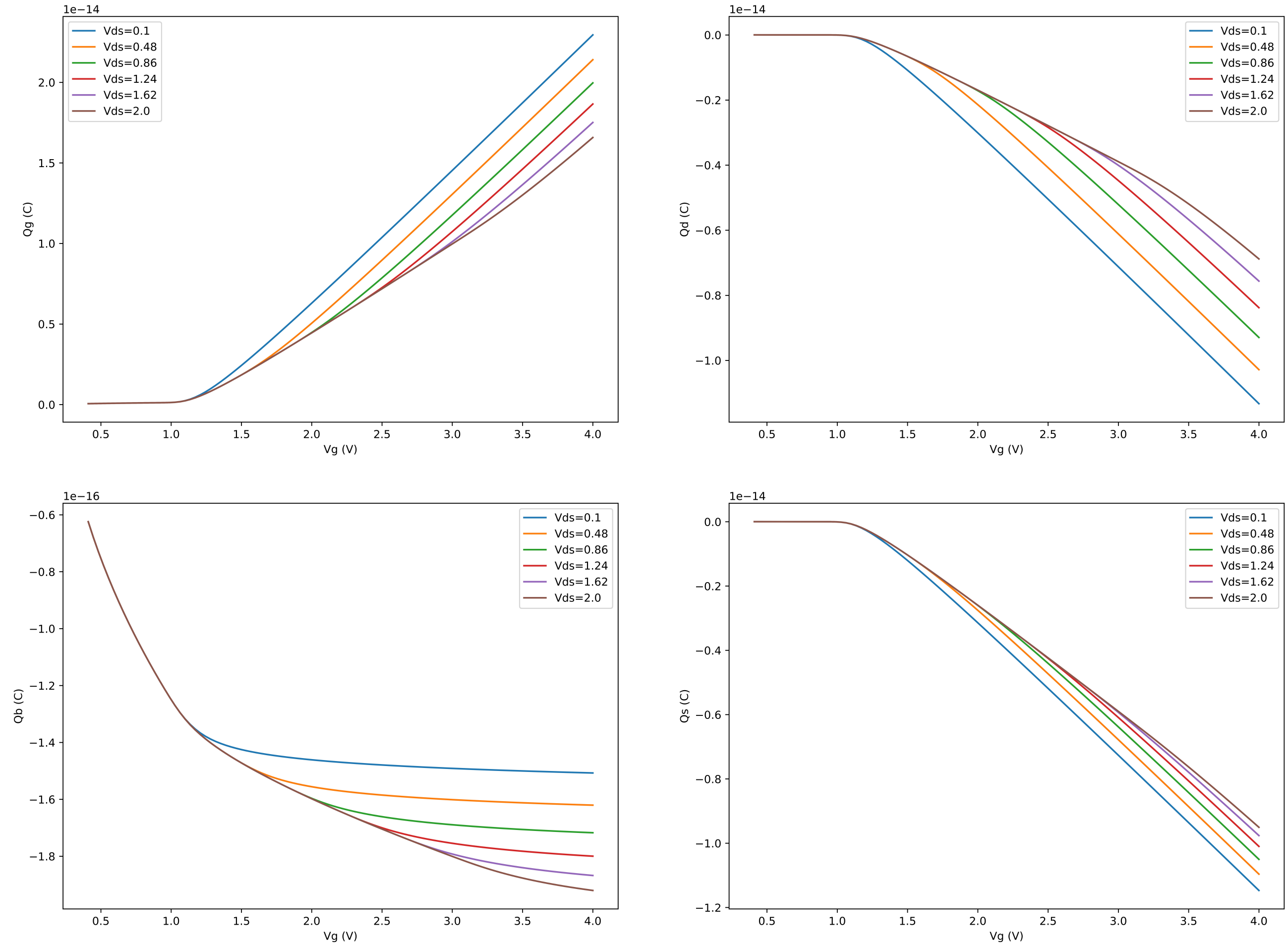
$Q_G = W\int_0^L Q_G^{'}\,dx$

$Q_I^{'} = -Q_G^{'} - Q_B^{'} = -\sqrt{2q\epsilon_s N_A}[\sqrt{\psi_s(x) + \phi_t e^{\frac{\psi_s(x)\ -\ (2\phi_f + V_{cb})}{\phi_t}}} - \sqrt{\psi_s(x)}]$

- From $Q_I^{'}$, Q_S and Q_D can be calculated as follows:

$Q_D = W\int_0^L \frac{x}{L} Q_I^{'}\,dx$

$Q_S = W\int_0^L (1 - \frac{x}{L}) Q_I^{'}\,dx$



There is change in slope at different V_{ds} as it moves in to strong inversion point.

3 Problem 3

Plot Transcapacitances (C_{gg}, C_{dg}, C_{sg}, C_{bg}) as function of V_G, at high and low V_D.

Solution:

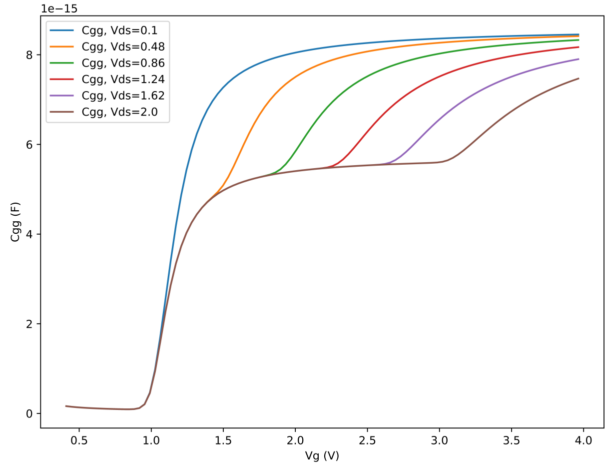
Transcapacitance Calculation:

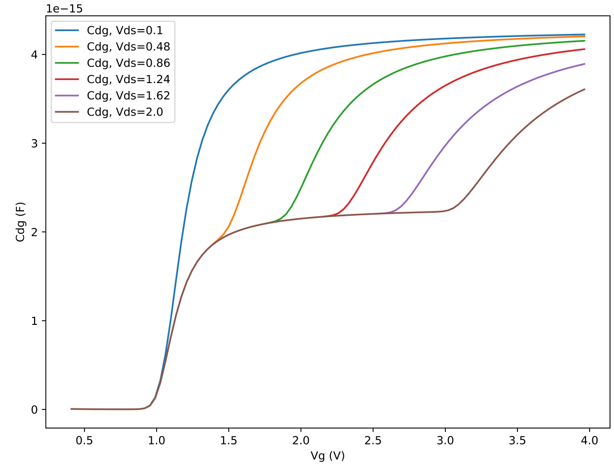
$C_{gg} = \frac{dQ_G}{dV_G}$

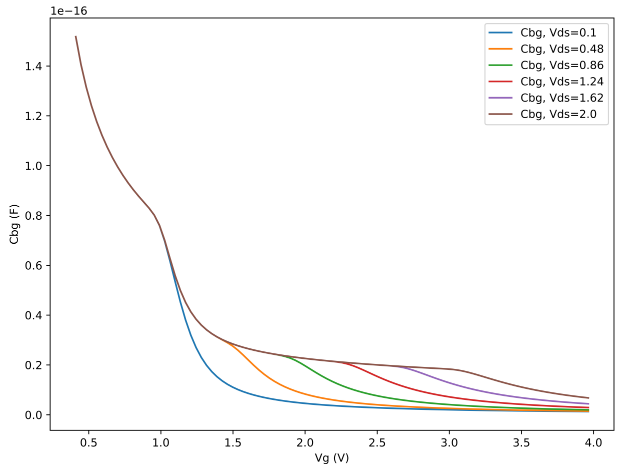
$C_{bg} = \frac{dQ_B}{dV_G}$

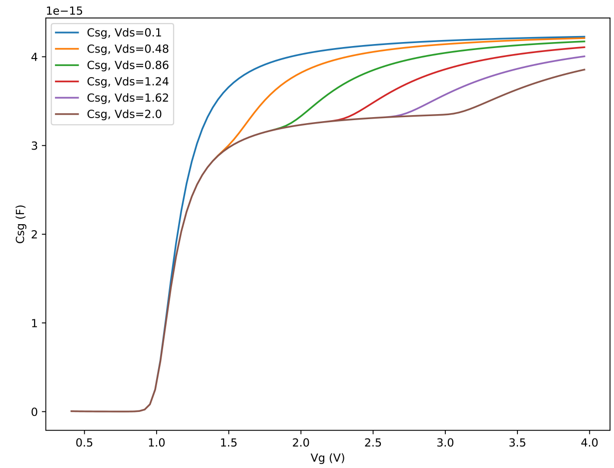
$C_{dg} = \frac{dQ_D}{dV_G}$

$C_{sg} = \frac{dQ_S}{dV_G}$









The second onset in Capacitance curve is attributed to the slope change of corresponding Charge curve (attributed to inception of strong inversion point).

4 Problem 4

Plot Inversion Charge Density as a function of V_G, using EKV and Surface Potential Based model and compare.

Solution:
EKV model input voltage equation:

* $\Psi_p \equiv \Psi_s(Q_i = 0) = V_G - V_{FB} - \Gamma^2(\sqrt{\frac{V_G - V_{FB}}{\Gamma^2} + \frac{1}{4}} - \frac{1}{2})$

* $\frac{\Psi}{\psi} = \frac{V}{v} = \frac{\Phi}{\phi} = \frac{\Gamma^2}{\gamma^2} = \phi_t$

* $v_p = \psi_p - (2\phi_f + v_{sh})$

* $v_{sh} = ln(\frac{4n}{\gamma}\sqrt{\psi_p})$

* $2q_i + lnq_i = v_p - v \implies 2q_i e^{2q_i} = 2e^{(v_p - v)} \implies \boxed{LambertW(2q_i) = 2e^{(v_p - v)}}$

Surface Potential Based model:

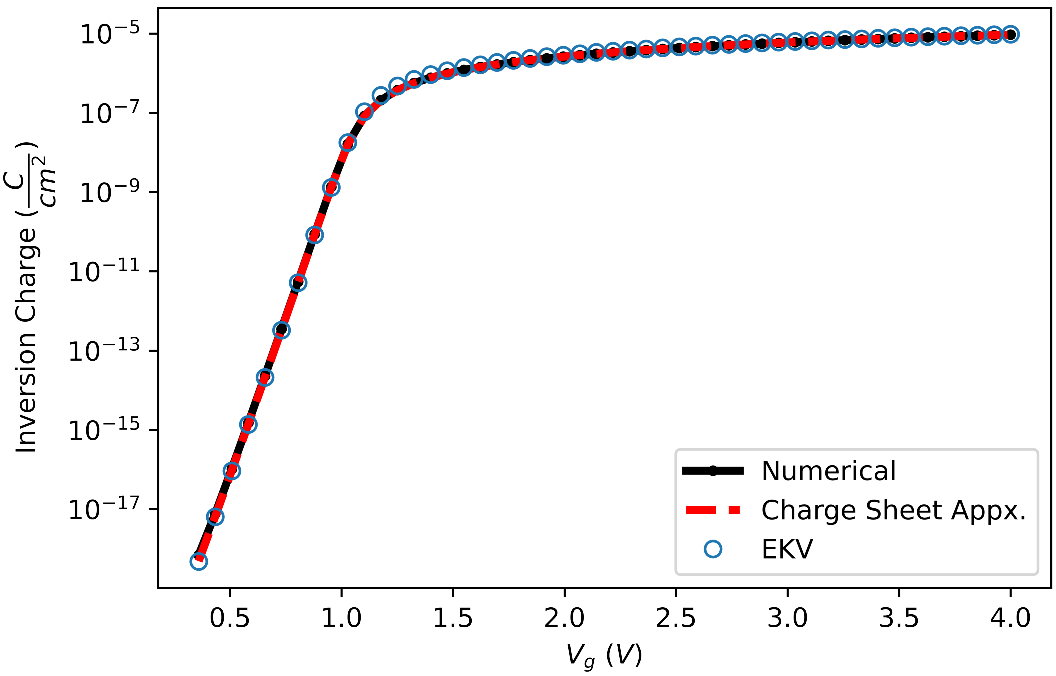
Numerically calculated:

$q_i(y) = qn_0 e^{\frac{\psi(y) - v_{cb}}{\phi_t}}$; $n_0 = \frac{n_i^2}{N_a}$

$Q_i = \int_0^{t_{Si}} q_i(y)\, dy$

Charge Sheet Approximation:

$Q_i = n_i q = -\sqrt{2qN_a\epsilon_s}[\sqrt{\psi(y) + \phi_t e^{\frac{\psi(y) - 2\phi_f - v_{cb}}{\phi_t}}} - \sqrt{\psi(y)}]$



Both the model matches well to the desired accuracy.