Nanoscale MOSFETs 2017 – Excercise 2

1. Show that the (point) inverse subthreshold slope, or subthreshold swing is given by $SS = \frac{d}{dV_G}\log_{10}(I_D)$. From the 2D 3-capacitor model, show that $SS^{-1} = 2.3\frac{kT}{q}\left[1 + \frac{C_S+C_D}{C_G}\right]$, and calculate the minimum inverse subthreshold slope at room temperature for an ideal MOSFET. Similarly, show that the DIBL is given by $\frac{\Delta V_{GS}}{\Delta V_{DS}} = \frac{C_D}{C_G}$. You can assume that $I \propto e^{\frac{q}{kT}\Psi_s}$,that is, ignore the effect of the depletion capacitance.

2. A single sub band quantum well FET has an effective mass m^* and a high-k dielectric with thickness t_{ox} and dielectric constant ε_r =25. Assuming degenerate statistics, derive an expression for $Q(V_{GS})$, neglecting any potential variations inside the well. For m^*={0.023, 0.1} m_0, calculate the maximal effective capacitance, as well as the oxide thickness which gives a capacitance within 90% of the maximum. This illustrates the DOS bottleneck for a FET. *Hint - start from Eq 2.12a.*

3. For a MOS-diode, show that $\delta\psi_S = \delta V_{GS}$if C_{ox}>>C_q and that $\delta\psi_S = 0$ if C_{ox}<<C_q. The first limit is called the bipolar, or quantum capacitance limit. The second case corresponds to the MOS-limit.

4. A 2D FET has α_D=α_S =0.1 and α_G=0.8, and is operating in the velocity saturated regime. If C_{ox}=C_G=1.0 µF/cm^2 (assumed to be << C_q) and v_{sat}=10^7 cm/s, calculate g_m, g_d and the intrinsic voltage gain, g_m/g_d if the transistor is operating above threshold. For the same transistor operating below threshold (where the channel charge can be neglected), calculate the sub threshold slope and the DIBL.

5. For a more accurate expression of the charge centroid capacitance, one can assume that the charge is distributed according to the wave function of the first subband, $\rho(y) = -\frac{2qn_s}{t_w}\sin^2\left(\frac{\pi y}{t_w}\right)$. Derive an expression for C_c assuming this charge distribution. Hint: There are nice tools for evaluation of integrals.