1. For a silicon nMOSFET device calculate body effect coefficient $\gamma$. Given that $\text{Tox} = 0.1 \mu\text{m}$ and $N_A = 5 \times 10^{15} \text{cm}^{-3}$.

2. A p-type MOS-capacitor with $N_A = 1 \times 10^{18} \text{cm}^{-3}$ and $\text{Tox} = 3 \text{nm}$ was fabricated to characterize van Dort’s analytical bandgap widening quantum mechanical (QM) model we discussed in class. Due to inversion layer quantization, the increase in the effective bandgap $\Delta E_g = E_g^{\text{QM}} - E_g^{\text{CL}} \approx 100 \text{mV}$. Here $E_g^{\text{QM}}$ and $E_g^{\text{CL}}$ represent the QM and classical (CL) values of bandgap ($E_g$) respectively. Assume $Q_f = 0$, $V_{\text{SUB}} = 0$, and $N^+\text{ poly gate}$.

(a) Show that the intrinsic carrier concentration due to QM effect is given by:

$$n_i^{QM} = n_i^{CL} e^{-\frac{\Delta E_g}{2kT}}$$

(b) Calculate the value of $n_i^{QM}$ at room temperature $T = 300^\circ\text{K}$

(c) Calculate the value of threshold voltage $V_{th}(\text{CL})$ using the classical approach

(d) Calculate the value of threshold voltage $V_{th}(\text{QM})$ due to QM effects

(e) Calculate the shift $\Delta V_{th}$ due to QM effects.

3. An MOS device structure of a typical 0.1 $\mu\text{m}$ CMOS technology is shown below.

(a) Calculate the shift $\Delta V_{th}$ for $L_g = 0.1 \mu\text{m}$ and $W >> 10 \mu\text{m}$ device compared to a longer channel ($L_g >> 10 \mu\text{m}$) device due to short channel effect only

(b) If $W$ is reduced to 1 $\mu\text{m}$, calculate the shift $\Delta V_{th}$ for the device in part (a) compared to a longer channel ($L_g >> 10 \mu\text{m}$) and wider device ($W >> 10 \mu\text{m}$) due to both short and narrow channel effects. Assume $\alpha = 0.25$

(c) Compare and explain the difference in part (a) and (b), if any.