1. a) \( V_{tn} \) for NMOS

\( V_{tn} \) implants @ step 16: \( \bar{B} 11, 30 \text{keV}, D_I = 9 \times 10^{11}/\text{cm}^2 \)

\( \overrightarrow{R_P} = 0.1 \ \mu\text{m}, \ \Delta R_P = 0.035 \ \mu\text{m} \) 

- Implantation has an equivalent "DT" as
  \[ DT = \frac{1}{2} \Delta R_P^2 = 6.13 \times 10^{-12} \ \text{cm}^2 \]

- High temp stops after step 16 (see HW#9)
  \[ \Sigma DT = 1.1 \times 10^{-10} \ \text{cm}^2 \]

\( \Rightarrow \) total DT = \( 1.16 \times 10^{-10} \ \text{cm}^2 \)

\[ N_5 = \frac{N_e}{2} = \frac{1}{2} \frac{D_T}{\sqrt{2 \pi \chi DT}} = 1.18 \times 10^{16} / \text{cm}^2 \]

\( \therefore X_5 = \frac{D_T}{N_5} = 0.76 \ \mu\text{m} \) approx.

need test \( W_{dop} \) w/ \( N_5 \):

\( X_{d, N_5} = \sqrt{\frac{2 \varepsilon_s}{q} \frac{1}{N_5} \frac{2}{\Phi_{f, N_5}}} \)

\( = \sqrt{2 \times 11.7 \times 8.85 \times 10^{-14} \times \frac{1}{1.6 \times 10^{-19}} \times \frac{1}{1.18 \times 10^6}} = 0.26 \ \mu\text{m} < X_5 \)

Ok, the \( \frac{I}{2} \) \( (V_{th}) \) covers all depletion region, assumption is correct.

\( V_{tn} = -0.86 - (-0.6) = -0.57 \ \text{V} \)

\[ \Phi_f = \frac{\varepsilon_s \varepsilon_0}{4 \pi} = 3.9 \times 8.85 \times 10^{-14} = 5.8 \times 10^{-8} / \text{V} \cdot \text{cm}^2 \]
b) PMOS $V_{tp}$

The total implants (Boron) since you wanna deplete all the p-type implants:

$$V_{tp} = V_{FB} - 2q\phi_F - \frac{Q_B}{C_{ox}}$$

Approx. 0.3

$$V_{tp} = (\Phi_S, N_S - \phi_p + n^+ ~ \text{gate}) - 2 q \phi_F - \frac{D_{z.8}}{C_{ox}}$$

NS is same as that of NMOS

$$V_{tp} = (-0.3 - 0.56) + 0.6 + \frac{9 \times 10^{11} \times 1.6 \times 10^{-19}}{5.8 \times 10^{-8}}$$

$$= [2.22 \ V]$$

C) Mobility vs. concentration chart

@ $1.18 \times 10^{16} \text{ cm}^{-3}$ ($N_S$)

$$\mu_p = 4.25 \ text{ cm}^2/\text{V.s} \quad \mu_n = 1250 \text{ cm}^2/\text{V.s}$$

$$\therefore \kappa_p = \mu_p C_{ox} = 2.47 \times 10^{-5} \text{ F/\text{V.s}}$$

$$\kappa_n = \mu_n C_{ox} = 7.25 \times 10^{-5} \text{ F/\text{V.s}}$$
d) Channel stop implants @ step 10

B11, 100 keV, \( P_I = 10^{13} \text{ cm}^{-2} \) P-Field Channel stop

\[ P \Rightarrow P_F = 0.32 \mu \text{m}, \Delta P_F = 0.07 \mu \text{m} \]

\[ D_T = 2.45 \times 10^{-11} \text{ cm}^2 \]

\[ \Sigma D_T \text{ afterwards} = 2.43 \times 10^{-10} \text{ cm}^2 \]

\[ \Rightarrow \text{ total } D_T = 2.68 \times 10^{-10} \text{ cm}^2 \]

\[ N_S = \frac{1}{2} \frac{P_F}{N_{0_p}} = \frac{1}{2} \frac{P_F}{\sqrt{\text{eV}}} = 8.62 \times 10^{16} \text{ cm}^{-3} \]

\[ X_{\text{in}, NS_{p,F}} = \sqrt{\frac{2 \epsilon_S}{\epsilon} N_{S_{p,F}}} = 0.1 \mu \text{m} < X_S\]

\[ V_{TH, PF} = V_{FB} - 2\phi_F - \frac{Q_B}{\text{Cox}} \]

\[ = -0.99 - (-0.6) = 1.3 \times 10^{-9} \text{ V/cm} \]

\[ V_{FB} = \phi_F, N_S_{p,F} = \phi_A \]

\[ = -0.3 - (-0.56 - 0.11) \]

\[ = -0.99 \text{ V} \]

\[ e) \ V_{TH, n-field} \]

Implants @ step 12

\( P, D_I = 5 \times 10^{12} \text{ cm}^{-2}, 400 \text{ keV} \)

\[ \Rightarrow P_F = 0.05 \mu \text{m}, \Delta P_F = 0.022 \mu \text{m} \]

\[ D_T = 2.42 \times 10^{-12} \text{ cm}^2 \]

\[ \text{total } D_T = 2.42 \times 10^{-12} + 2.43 \times 10^{-10} \text{ cm}^2 \]

\[ X_{\text{in}, N_{S_{n,F}}} < X_S \]

\[ V_{TH} = V_{FB} - 2\phi_F - \frac{Q_B}{\text{Cox}} = (0.3 - 0.58 - 0.11) - 0.6 - \]

\[ \sqrt{2 \times 1.17 \times 8.5 \times 10^{-9} \times 1.6 \times 10^{-17} \times 4.52 \times 10^{-16} \times 2 \times 0.3} \]

\[ = 52.86 \text{ V} \]

\[ \therefore \text{ Assume } V_{FB} \text{ has the same } \epsilon \text{ as SiO}_2 \]

\[ = \sqrt{2 \times 1.17 \times 8.5 \times 10^{-9} \times 1.6 \times 10^{-17} \times 9.48 \times 10^{-18}} \]

\[ = 9.48 \times 10^{-8} \text{ cm}^2 \]