7.2 Calculate the built-in potential barrier, V_{bi}, for Ge pn junctions if they each have the following dopant concentrations at $T = 300$ K:

(*a*) $N_d = 10^{14}\ \text{cm}^{-3}$ $\quad N_a = 10^{17}\ \text{cm}^{-3}$

(*b*) $N_d = 5 \times 10^{16}$ $\quad N_a = 5 \times 10^{16}$

(*c*) $N_d = 10^{17}$ $\quad N_a = 10^{17}$

From Table B.4, $n_i = 2.4 \times 10^{13}\ \text{cm}^{-3}$ for germanium (Ge) at 300 K.

Per (7.10), the built-in voltage is $V_{bi} = \dfrac{k_B T}{e} \ln\left(\dfrac{N_a N_d}{n_i^2}\right) = V_t \ln\left(\dfrac{N_a N_d}{n_i^2}\right)$.

At 300 K, the thermal voltage $V_t = \dfrac{k_B T}{e} = \dfrac{8.617333 \times 10^{-5}\ \text{eV/K}\,(300\,\text{K})}{e} = 0.025852$ V.

a) Here, $V_{bi} = 0.025852 \ln\left(\dfrac{10^{14}\, 10^{17}}{(2.4 \times 10^{13})^2}\right)$ $\Rightarrow$ $\boxed{V_{bi} = 0.252367\ \text{V}}$.

b) Here, $V_{bi} = 0.025852 \ln\left(\dfrac{(5 \times 10^{16})^2}{(2.4 \times 10^{13})^2}\right)$ $\Rightarrow$ $\boxed{V_{bi} = 0.395108\ \text{V}}$.

c) Here, $V_{bi} = 0.025852 \ln\left(\dfrac{(10^{17})^2}{(2.4 \times 10^{13})^2}\right)$ $\Rightarrow$ $\boxed{V_{bi} = 0.430946\ \text{V}}$.