HW5 Solution (ECE6453)

1. Prob. 6, chap. 2

w/ $\eta = 1.2$, it can be an abrupt heterojunction theoretically.

$$\frac{\epsilon_N N_d}{\epsilon_P N_A} = 0.2 \Rightarrow \underline{N_A \approx 5 \frac{\epsilon_N}{\epsilon_P} N_D}$$

(Note. In reality, this could be a graded junction if recombination is significant)

2. Prob. 2, chap. 5

For GaAs, $n_i = 1.79 \times 10^6 \text{ cm}^{-3}$, $E_g = 1.424$ (eV)

$$\phi_B = 0.9 \text{ (eV)}, \; q\Phi_n = \frac{1.424}{2} - 0.0259 \ln\left(\frac{2e17}{1.79e6}\right) = 0.05 \text{ (eV)}$$

depletion width $d = \sqrt{\frac{2\epsilon_s}{qN_D}(\phi_B - \Phi_n)} = 810 \text{ Å}$ $\quad \phi_{bi} = \phi_B - \Phi_n = 0.85$

$$\phi_{00} = \frac{qN_D}{2\epsilon_s} a^2 = 3.1 \text{ V}.$$

$$V_{D,sat} = \phi_{00} - \phi_{bi} - V_{GS} = \underline{2.25 \text{ V}}$$

a. $V_{DS} < V_{D,sat}$, linear region

$$I_D = I_{D\max}\left(d - s + \frac{2}{3}s^{3/2} - \frac{2}{3}d^{3/2}\right)$$

$$d = \frac{\phi_{bi} - V_{GS} + V_{DS}}{\phi_{00}} = 0.4354, \quad s = \frac{\phi_{bi} - V_{GS}}{\phi_{00}} = 0.274$$

$I_{D\max} = 0.89$ Amp.

$$\boxed{I_D = 0.058 \text{ Amp} = 58 \text{ mA}}$$

b. $V_{DS} > V_{DS,sat}$, Saturation region.

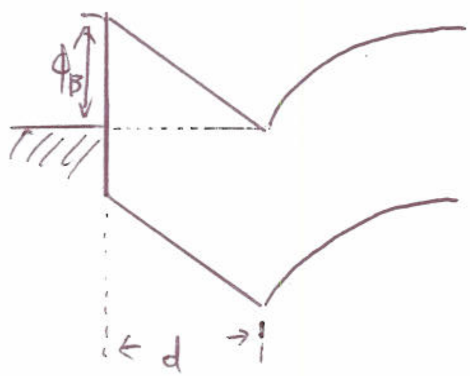
$d = 1$,

$I_{D,sat} = \underline{138\,mA}$

3. Prob. 4, chap. 5

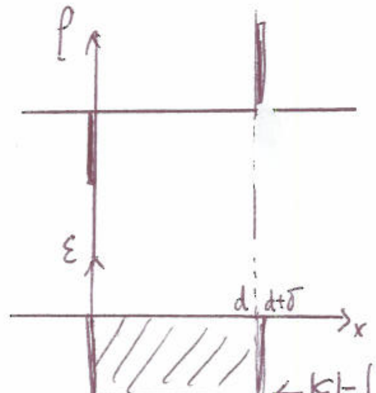
a. $g_m = \dfrac{W v_{sat} \epsilon_s}{d} = \dfrac{2\times10^{2}\times10^{-4}\times10^{7}\times8.85\times10^{-14}\times13.2}{3\times10^{-2}\times10^{-8}} = \underline{0.0778\ S}$

b.



c. $\phi_{bi} = \phi_B$

d.



$\leftarrow |\mathcal{E}| = \int_d^{d+\delta} \rho(x)\,dx = \dfrac{q\sigma}{\epsilon}$

$\phi_{00} = \dfrac{q\sigma}{\epsilon} d$

$V_T = -\phi_{00} + \phi_B = \phi_B - \dfrac{q\sigma}{\epsilon_s} d$

4. Prob. 9, chap. 5.

(a) $m_e^* = 0.067\ m_0$ make it in eV units.

$$E_1 = \frac{\hbar^2}{2m_e^*}\left(\frac{\pi}{L}\right)^2 = \frac{h^2}{8m_e^*}\cdot\frac{1}{L^2} = \frac{(6.626\times10^{-34})^2}{8\times9.1\times10^{-31}\times0.067}\times\frac{1}{(10^{-8})^2}\times\frac{1}{1.6\times10^{-19}}$$

$$= 56.2\ (\text{meV})$$

$$E_2 = 4E_1 = 0.225\ (\text{eV})$$

(b) $$n_s = D\int_{E_1}^{\infty}\frac{1}{1+\exp\left(\frac{E-E_F}{kT}\right)}dE = DkT\ln\left[1+\exp\left(\frac{E_F-E_1}{kT}\right)\right]$$

$$D = m^*/\pi\hbar^2$$

(c) $$dE_f/dn_s = 1/(dn_s/dE_F)$$

$$\frac{dn_s}{dE_f} = D\cdot\frac{1}{1+\exp\left(\frac{E_1-E_f}{kT}\right)} \approx D$$ (assume $E_f > E_1$)

$$\Rightarrow \frac{dE_f}{dn_s} \cong \frac{1}{D},\quad D = \frac{m_e^*}{\pi\hbar^2} = 1.727\times10^{36}\ m^{-2}\cdot J^{-1}$$

(d) $$\Delta x_b = \frac{\epsilon_s}{q^2}\cdot\frac{1}{D} = \frac{13.2\times8.85\times10^{-12}}{(1.6\times10^{-19})^2}\cdot\frac{1}{1.727\times10^{36}}$$

$$\boxed{\Delta x_b = 26.42\ \text{Å}}$$

5. Prob. 12, chap. 5.

$$n_s = D(E_f - E_1) + 2D(E_f - E_2),\quad E_1 = 1.11\times10^{-9}(n_s)^{2/3},\ n_s = 2\times10^{12}$$
$$E_2 = 1.95\times10^{-9}(n_s)^{2/3},\ D = 1.727\times10^{32}\ cm^{-2}J^{-1}$$

$$\Rightarrow \boxed{E_f = 0.289\ \text{eV}}$$ #.