Homework 8

1) $n_i = 2.5\times10^{13}\ cm^{-3}$ $N_D = 5\times10^{13}\ cm^{-3}$ $N_A = 2.5\times10^{13}$ $D_n = 100\ cm^2/s$ $D_p = 50\ cm^2/s$

a) $E_F - E_i = E_g = 0.67\ eV$

$V_T = 0.0259$

$$n = \frac{(N_D - N_A) + \sqrt{(N_D-N_A)^2 + 4n_i^2}}{2} = 2.795\times10^{13}\ cm^{-3}$$

$\mu_n = \frac{D_n}{V_T} = 3861$ $\mu_p = \frac{D_p}{V_T} = 1930.5$ $q = 1.602\times10^{-19}$

$\sigma = q(n\mu_n + p\mu_p) = \boxed{0.024\ C\cdot m/s}$ $p = \frac{n_i^2}{n} = 2.236\times10^{13}\ cm^{-3}$

b) $\Delta\phi = \underset{4.5eV}{\phi_M} - \underset{4.0eV}{\chi} = \boxed{0.5eV}$

Schottky barrier because $\phi_M > \chi$

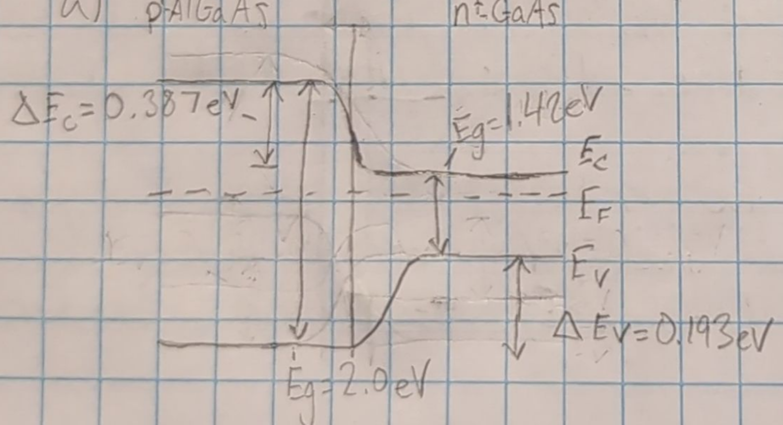
2) $V_0 = 1.6$ $N_D = 10^{16}$ $N_A = 3\times10^{19}$ $\varepsilon_1 = 12$ $\varepsilon_2 = 13$

$V_0 = V_{01} + V_{02}$ $V_{01} = \frac{V_0}{\left(1 + \frac{\varepsilon_1 N_A}{\varepsilon_2 N_D}\right)} = \boxed{0.578\ mV}$

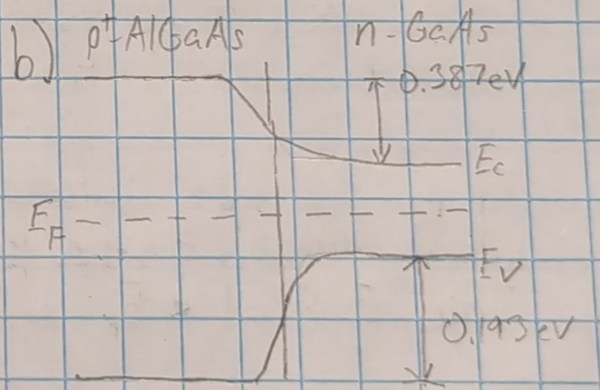
$V_{02} = V_0 - V_{01} = \boxed{1.59942\ V}$

3) AlGaAs $E_g = 2.0eV$ GaAs $E_g = 1.42\ eV$. $\Delta E_g = 0.58\ eV$ $\Delta E_c = \frac{2}{3}\Delta E_g = 0.387\ eV$ $\Delta E_v = \frac{1}{3}\Delta E_g = 0.193\ eV$

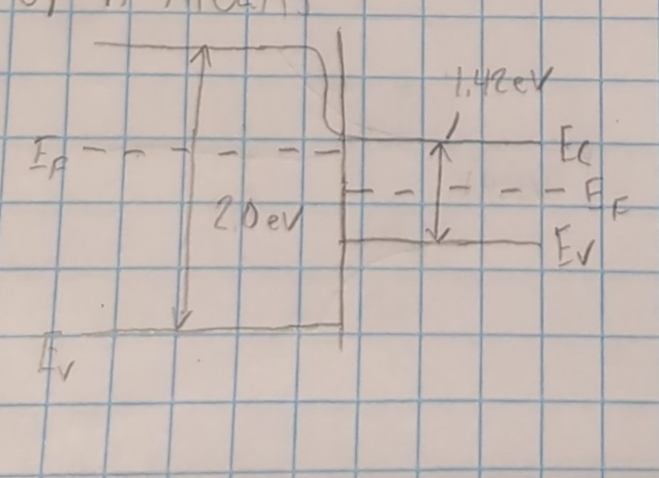
a)



b)



c) n+-AlGaAs



4) $A = 4cm$ $I_{th} = 32\,nA$ $g_{op} = 10^{18}\,EHP/cm^3\text{-}s$ $L_p = L_n = 2\mu m$ $W = 1\mu m$

$I_{op} = qAg_{op}(L_p + L_n + W) = \boxed{32.04\,nA}$

$V_{oc} = \frac{kT}{q}\ln\left(\frac{I_{op}}{I_{th}} + 1\right) = \boxed{17.97\,mV}$

5) $E_g = 2.5eV$ $\lambda = \frac{1.24}{E_g} = \boxed{496\,nm}$

$E_{900} = \frac{hc}{\lambda(\mu m)} = 1.38\,eV \rightarrow$ Can't detect 900nm photons (1.38 < 2.5)

$E_{100} = \frac{hc}{\lambda(\mu m)} = 12.4\,eV \rightarrow$ Can detect 100nm photons (12.4 > 2.5)

6) a) For carrier multiplication to occur, the diode needs a high electric field and/or special materials the p-i-n diode does not have. Gain is the ability for carrier multiplication to occur, so the diode has no gain.

b) To increase p-i-n diode sensitivity, the thickness of the intrinsic region needs to be increased. This additional width would cause an increase in carrier transit time, and thus decrease the device's speed.

c) To pick the best material we first need to compare the band gap, which determines the maximum wavelength a material can detect. Since E_g of GaAs < E_p and E_g of CdS > E_p, GaAs would be the better material.

7) $T = 300K$ $N_a = 10^{16}\,cm^{-3}$ $N_d = 10^{15}\,cm^{-3}$ $D_n = 25\,cm^2/s$ $D_p = 10\,cm^2/s$

$\tau_{n0} = 10^{-6}\,s$ $\tau_{p0} = 5\times10^{-7}\,s$ $A = 5\,cm^2$ $g_{op} = 5\times10^{21}\,cm^{-3}s^{-1}$ $n_i = 1.5\times10^{10}\,cm^{-3}$

a) $L_n = \sqrt{D_n \tau_n} = 0.005\,cm$ $L_p = \sqrt{D_p \tau_p} = 0.0022\,cm$

$V_{bi} = \frac{kT}{q} \ln\left(\frac{N_a N_d}{n_i^2}\right) = 0.635\,V$ $\varepsilon_s = \varepsilon \cdot \varepsilon_0 = 1.036\times10^{-12}\,F/cm$

$W = \sqrt{\frac{2\varepsilon_s V_{bi}}{q}(N_A^{-1} + N_D^{-1})} = 9.5\times10^{-5}\,cm = 950\,nm$

$I_{sc} = qAg_{op}(L_n + L_p + W) = 4.185\times10^{-6}\,A = \boxed{4.185\,\mu A}$

b) $V_{oc} = \frac{kT}{q} \ln\left(\frac{L_p + L_n + W}{(L_p/\tau_p)p_n + (L_n/\tau_n)n_p} \cdot g_{op} + 1\right) = 0.01329\,V = \boxed{13.29\,mV}$

c) $\frac{V_{oc}}{V_{bi}} = \frac{0.01329}{0.635} = \boxed{0.020929}$