EE 232 Lightwave Devices **HW#5 Solutions** **Prof. Ming C. Wu**

$h\_bar := 1.05459 \cdot 10^{-34}$ (J-sec) $q := 1.6 \cdot 10^{-19}$ (Coul)

$m0 := 9.11 \cdot 10^{-31}$ (kg)

$nm := 10^{-9}$ (m) $eV := q$

$m\_e := 0.067 \cdot m0$ $m\_h := 0.5 \cdot m0$ $m\_r := \frac{m\_e \cdot m\_h}{m\_e + m\_h}$

$\varepsilon 0 := 8.854 \cdot 10^{-12}$ (F/m)

$kT := 0.026eV$

$c := 3 \cdot 10^{8}$ (m/sec)

1. $Ep := 25.7 \cdot eV$ $L := 10nm$ $n\_r := \sqrt{13}$ $Eg := 1.42 \cdot eV$

$$En(m) := \frac{h\_bar^2}{2 \cdot m\_e} \cdot \left(\frac{m\pi}{L}\right)^2 \qquad Eh(m) := -\frac{h\_bar^2}{2 \cdot m\_h} \cdot \left(\frac{m\pi}{L}\right)^2$$

$Eg\_eff := En(1) + Eg - Eh(1)$ $\frac{Eg\_eff}{q} = 1.484$

$\omega := \frac{Eg\_eff}{h\_bar}$ $n\_r = 3.606$

$\omega = 2.251 \times 10^{15}$

$$C0 := \frac{\pi \cdot q^2}{n\_r \cdot c \cdot \varepsilon 0 \cdot m0^2 \cdot \omega}$$ $\frac{m\_r}{m0} = 0.059$

$$\rho r\_2d0 := \frac{m\_r}{\pi \cdot h\_bar^2 \cdot L}$$ $C0 = 4.495 \times 10^{9}$

$$g\_m := C0 \cdot \left[\left(\frac{3}{2}\right) \cdot \left(\frac{m0}{6} \cdot Ep\right)\right] \cdot \rho r\_2d0$$

$g\_m = 6.485 \times 10^{5}$ [m^{-1}]

$\rho r\_2d(x) := \left[\Phi[x - (Eg + En(1) - Eh(1))] + \Phi[x - (Eg + En(2) - Eh(2))]\right]$

$$\left.\begin{aligned} \frac{m_e}{\pi\hbar^2 L}\left(F_c - E_{n1}\right) &= \frac{m_h}{\pi\hbar^2 L}\left(E_{h1} - F_V\right) \\ F_C - F_V + E_g &= \Delta F \end{aligned}\right\} \Rightarrow \begin{cases} F_V = \dfrac{\Delta F - E_g - E_{n1} - \dfrac{m_h}{m_e}E_{h1}}{1 - \dfrac{m_h}{m_e}} \\ F_C = \Delta F - E_g + F_V \end{cases}$$

$$Fv(\Delta F) := \frac{\Delta F - Eg - En(1) - \frac{m\_h}{m\_e}\cdot Eh(1)}{1 - \frac{m\_h}{m\_e}} \qquad \frac{Fv(0.05eV + Eg\_eff)}{eV} = -0.018$$

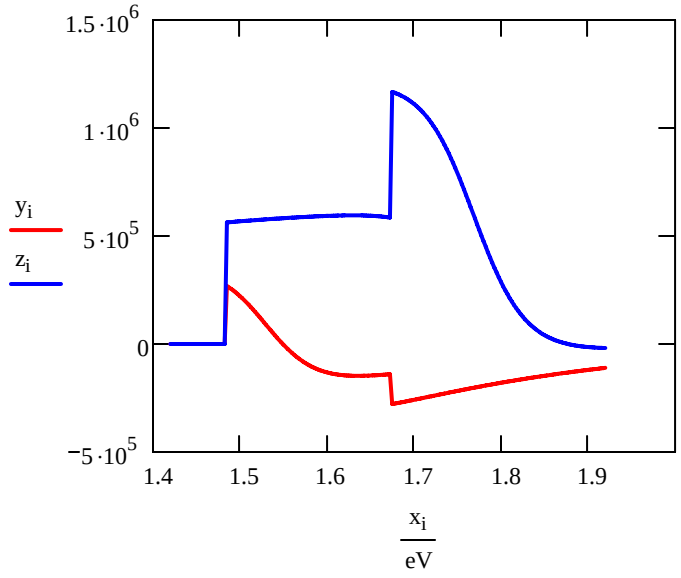
$$Fc(\Delta F) := \Delta F - Eg + Fv(\Delta F) \qquad \frac{Fc(0.05eV + Eg\_eff)}{eV} = 0.096$$

$$f\_c(hv, \Delta F) := \frac{1}{1 + \exp\left[\frac{En(1) + (hv - Eg\_eff)\cdot\frac{m\_r}{m\_e} - Fc(\Delta F)}{kT}\right]}$$

$$f\_v(hv, \Delta F) := \frac{1}{1 + \exp\left[\frac{Eh(1) + (hv - Eg\_eff)\cdot\frac{m\_r}{m\_h} - Fv(\Delta F)}{kT}\right]}$$

$$g(E, \delta) := g\_m\cdot\rho r\_2d(E)\cdot\left(f\_c(E, \delta + Eg\_eff) - f\_v(E, \delta + Eg\_eff)\right)$$

$$i := 0 .. 200 \qquad x_i := Eg + \frac{i}{200}\cdot 0.5\cdot eV \qquad y_i := g(x_i, 0.05eV) \qquad z_i := g(x_i, 0.3eV)$$



2(a) $n\_c := \frac{m\_e \cdot kT}{\pi \cdot h\_bar^2 \cdot L}$ $n\_c = 7.267 \times 10^{23}$ $[m^{-3}]$

$n\_v := \frac{m\_h \cdot kT}{\pi \cdot h\_bar^2 \cdot L}$ $n\_v = 5.423 \times 10^{24}$ $[m^{-3}]$

(b) Initial value of n_tr $n\_tr := 10^{23}$ $[m^{-3}]$

Given $1 - \exp\left(\frac{-n\_tr}{n\_c}\right) = \exp\left(\frac{-n\_tr}{n\_v}\right)$

$Find(n\_tr) = 1.184 \times 10^{24}$ $[m^{-3}]$