EECE 480 Mid-Term October 20, 2009

1. $m_e^* \propto \frac{1}{d^2E/dk^2}$ (2.28)

For A $dE/dk = 2\alpha k$ $d^2E/dk^2 = 2\alpha$ $m^*_{e,A} \propto \frac{1}{2\alpha}$

For B $E_B - 1.4 = 2\alpha\left(k^2 - 2kk' + k'^2\right)$

$dE/dk = 2\alpha\left(2k - 2k'\right)$ $d^2E/dk^2 = 4\alpha$ $\therefore m^*_{e,B} \propto \frac{1}{4\alpha}$

2 $\therefore m^*_{eB} = \frac{1}{2} m^*_{eA}$

2 $\mu_e = \frac{q\tau}{m_e^*}$ $\therefore \mu_{e,B} > \mu_{e,A}$ (5.16)

1 2 a) $E_g \equiv 112\,mm = 1120\,meV = 1.12\,eV$ $\therefore$ Si

2 b) $n = N_c \exp - \frac{(E_c - E_{fn})}{k_BT}$ (4.14) $E_c - E_{fn} \equiv 9\,mm = 90\,meV = 0.09\,eV$

$N_c = 3.2\times10^{19}\,cm^{-3}$ $\therefore n \approx N_D = 3.2\times10^{19}\,e^{-\frac{0.09}{0.0259}}$

$= 9.9\times10^{17}\,cm^{-3}$

2 c) $p = N_V \exp - \frac{(E_{fp} - E_V)}{k_BT}$ (4.15) $E_{fp} - E_V \equiv 13\,mm = 130\,meV = 0.13\,eV$

$N_V = 1.8\times10^{19}\,cm^{-3}$ $\therefore p \approx N_A = 1.8\times10^{19}\,e^{-0.13/0.0259}$

$= 1.19\times10^{17}\,cm^{-3}$

2 d) $E_{fn} - E_{fp} = -qV_a$ $V_a = -\frac{(E_{fn} - E_{fp})}{q} = -0.8V$

1 FORWARD

1 3. a) $\nabla^2 \psi = q\left(n - p + N_A - N_D\right).$ (5.24)

$J_e = q n D_e \nabla n - q n \mu_e \nabla \psi$

$J_h = -q p D_h \nabla p - q p \mu_h \nabla \psi$

$\frac{\partial n}{\partial t} = +\frac{1}{q} \nabla \cdot J_e - \frac{n - n_{op}}{\tau_e}$

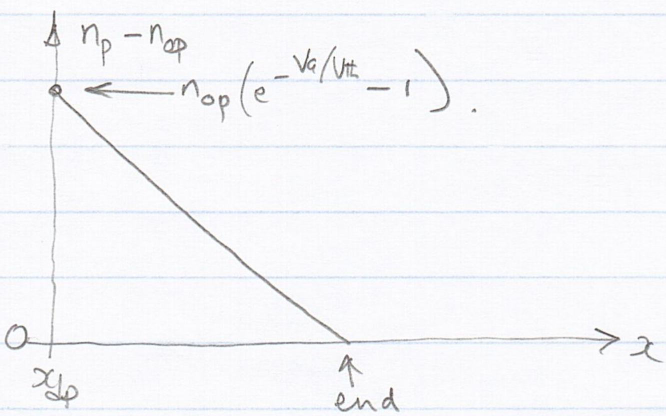
$\frac{\partial p}{\partial t} = -\frac{1}{q} \nabla \cdot J_h - \frac{p - p_{op}}{\tau_e}$

1 b) $J_e = q n D_e \nabla n$ $\qquad \frac{\partial n}{\partial t} = \underset{\uparrow}{0} + \frac{1}{q}\frac{dJ_e}{dx} - \left(\frac{n - n_{op}}{\tau_e}\right).$

steady-state

2 c) $n_p(x_p) = n_{op} e^{-V_a/V_{th}}$ $\qquad n_p(\text{end}) = n_{op}$ (6.29)

2 d) (i)



$$\text{or } -q D_e \frac{dn}{dx} = -q D_e \left(\frac{-n_{0B} e^{-V_a/V_{th}} + n_{0B}}{W} \right)$$

2 (ii) $$J_e(\text{short}) = -q \frac{D_e}{\cancel{L_e}} \exp(-V_a/V_{th})\, n_{op} \cdot \frac{\cancel{L_e}}{W_B}. \quad \times$$

Need $D_e\,(10^{17}\,cm^{-3}) = 21.4\ cm^2 s^{-1}$

$$n_{op} = \frac{n_i^2}{N_A} = \frac{(9.5)^2 \times 10^{18}}{10^{17}} = 902\ cm^{-3}.$$

$$J = -1.6\times10^{-19} \times 21.4 \times 902 \times \exp\left(\frac{0.8}{0.0259}\right) \frac{1}{100\times10^{-7}}\ A\,cm^{-2}$$

$$= 8\times10^{3}\ A/cm^{2}.$$

Bonus for determining $L_e \gg W_B$

$$D_e(10^{17}) = \frac{kT}{q}\mu(10^{17}) = 0.0259 \times 825 = 21.4\ cm^2 s^{-1} \qquad (5.30)$$

From (3.21) $$\tau_e(10^{17}) = \frac{5\times10^{-7}}{1+2} = 1.67\times10^{-7}\ s. \qquad (3.21)$$

$$L_e = \sqrt{D_e \tau_e} = 1.89\times10^{-5}\ m$$

$$\therefore W_B/L_e = 5.29\times10^{-3} \quad \& \quad \coth\left(\frac{W_B}{L_e}\right) \approx L_e/W_B$$