

VE320 Homework6

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Ex 6.1

(a)

(i)

$$n_{p0} = \frac{n_i^2}{N_a} = \frac{(1.5 \times 10^{10} \text{ cm}^{-3})^2}{5 \times 10^{16} \text{ cm}^{-3}} = 4.5 \times 10^3 \text{ cm}^{-3}$$

$$p_{n0} = \frac{n_i^2}{N_d} = \frac{(1.5 \times 10^{10} \text{ cm}^{-3})^2}{5 \times 10^{15} \text{ cm}^{-3}} = 4.5 \times 10^4 \text{ cm}^{-3}$$

$$p_n(x_n) = p_{n0} \exp \frac{V_a}{V_t}$$

$$V_a = V_t \ln \frac{p_n(x_n)}{p_{n0}} = V_t \ln \frac{0.1 N_d}{p_{n0}} = 0.599 \text{ V}$$

(ii)

$n_{p0} < p_{n0}$, so n-region concentration is the factor.

(b)

(i)

$$n_{p0} = \frac{n_i^2}{N_a} = \frac{(1.5 \times 10^{10} \text{ cm}^{-3})^2}{7 \times 10^{15} \text{ cm}^{-3}} = 3.214 \times 10^4 \text{ cm}^{-3}$$

$$p_{n0} = \frac{n_i^2}{N_d} = \frac{(1.5 \times 10^{10} \text{ cm}^{-3})^2}{3 \times 10^{16} \text{ cm}^{-3}} = 7.5 \times 10^3 \text{ cm}^{-3}$$

$$n_p(-x_p) = n_{p0} \exp \frac{V_a}{V_t}$$

$$V_a = V_t \ln \frac{n_p(-x_p)}{n_{p0}} = V_t \ln \frac{0.1 N_a}{n_{p0}} = 0.617 \text{ V}$$

(ii)

$n_{p0} > p_{n0}$, po n-region concentration is the factor.

Ex 6.2

(a)

$$J_s = en_i^2 \left(\frac{1}{N_a} \sqrt{\frac{D_n}{\tau_{n0}}} + \frac{1}{N_d} \sqrt{\frac{D_p}{\tau_{p0}}} \right) = 5.145 \times 10^{-11} \text{ A/cm}^2$$
$$I_s = AJ_s = 2 \times 10^{-4} \text{ cm}^2 \cdot 5.145 \times 10^{-11} \text{ A/cm}^2 = 1.029 \times 10^{-14} \text{ A}$$

(b)

(i)

$$I = I_s \exp \frac{V_a}{V_t} = 1.029 \times 10^{-14} \text{ A} \exp \frac{0.45 \text{ V}}{0.0259 \text{ V}} = 3.615 \times 10^{-7} \text{ A}$$

(ii)

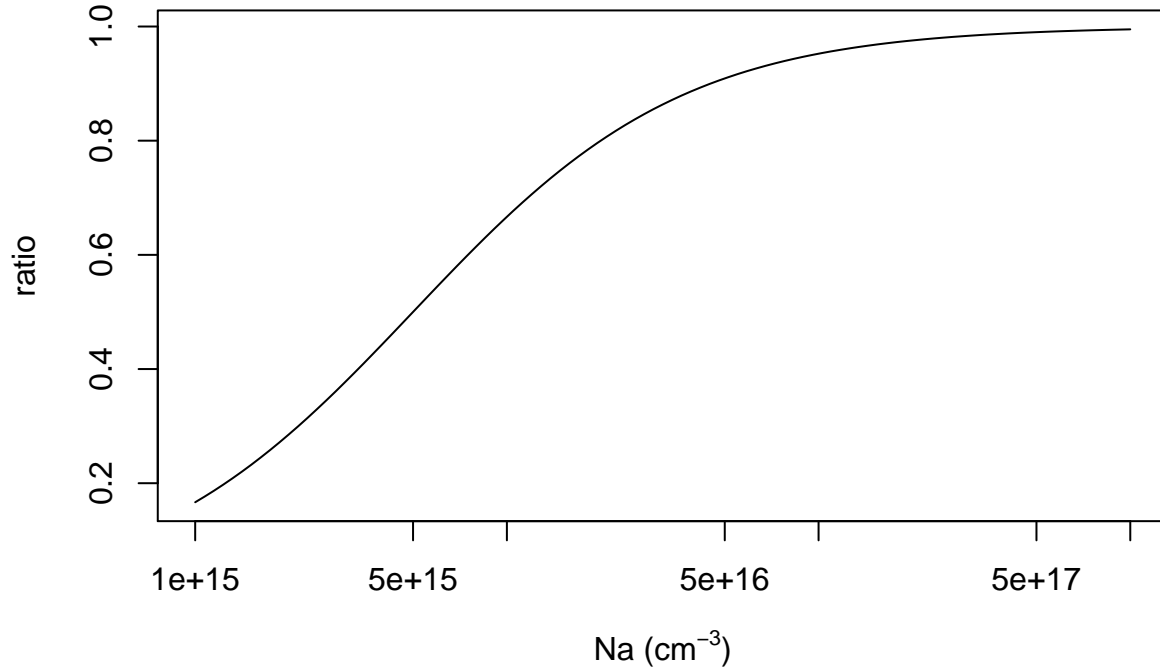
$$I = I_s \exp \frac{V_a}{V_t} = 1.029 \times 10^{-14} \text{ A} \exp \frac{0.55 \text{ V}}{0.0259 \text{ V}} = 1.717 \times 10^{-5} \text{ A}$$

(iii)

$$I = I_s \exp \frac{V_a}{V_t} = 1.029 \times 10^{-14} \text{ A} \exp \frac{0.65 \text{ V}}{0.0259 \text{ V}} = 8.160 \times 10^{-4} \text{ A}$$

Ex 6.3

```
func <- function(Na) {  
  Jn <- 1 / Na * sqrt(25 / 1e-6)  
  Jp <- 1 / 1e16 * sqrt(10 / 1e-7)  
  return(Jp / (Jn + Jp))  
}  
curve(func, from = 1e15, to = 1e18, xlab = TeX('Na (cm^{-3})'), ylab = 'ratio', log = 'x')
```



Ex 6.4

$$\frac{I_f}{I_s} = \exp \frac{V_a}{V_t}$$

$$V_t = \frac{V_a}{\ln(I_f/I_s)} = \frac{0.5 \text{ V}}{\ln 2^4} = 5.049 \times 10^{-2} \text{ V}$$

$$T = \frac{300V_T}{0.0259} = 5.848 \times 10^2 \text{ K}$$

$$\tau_{n0} = \tau_{p0} = 5 \times 10^{-7} \text{ s}$$

$$I_s = Aen_i^2 \left(\frac{1}{N_a} \sqrt{\frac{D_n}{\tau_{n0}}} + \frac{1}{N_d} \sqrt{\frac{D_p}{\tau_{p0}}} \right)$$

$$1.2 \times 10^{-6} = 1.432 \times 10^{-34} n_i^2$$

$$n_i^2 = N_c N_v \exp \frac{-E_g}{kT}$$

$$n_i^2 = 8.379 \times 10^{27} = 2.8 \times 10^{19} \cdot 1.04 \times 10^{19} \cdot \left(\frac{T}{300} \right)^3 \cdot \exp \frac{-1.12}{0.0259 \cdot T/300}$$

$$T \approx 502.46 \text{ K}$$

So the maximum temperature is 502.46 K, J_s is the limiting factor.

Ex 6.5

Ex 6.6

Ex 6.7

Ex 6.8

(a)

$$\begin{aligned}n_{E0} &= \frac{n_i^2}{N_E} = \frac{(1.5 \times 10^{10} \text{ cm}^{-3})^2}{5 \times 10^{17} \text{ cm}^{-3}} = 4.5 \times 10^2 \text{ cm}^{-3} \\p_{B0} &= \frac{n_i^2}{N_B} = \frac{(1.5 \times 10^{10} \text{ cm}^{-3})^2}{10^{16} \text{ cm}^{-3}} = 2.25 \times 10^4 \text{ cm}^{-3} \\n_{C0} &= \frac{n_i^2}{N_C} = \frac{(1.5 \times 10^{10} \text{ cm}^{-3})^2}{10^{15} \text{ cm}^{-3}} = 2.25 \times 10^5 \text{ cm}^{-3}\end{aligned}$$

(b)

$$\begin{aligned}p_B(0) &= p_{B0} \exp \frac{V_{EB}}{V_t} = 2.25 \times 10^4 \text{ cm}^{-3} \exp \frac{0.615 \text{ V}}{0.0259 \text{ V}} = 4.619 \times 10^{14} \text{ cm}^{-3} \\n_E(0) &= n_{E0} \exp \frac{V_{EB}}{V_t} = 4.5 \times 10^2 \text{ cm}^{-3} \exp \frac{0.615 \text{ V}}{0.0259 \text{ V}} = 9.239 \times 10^{12} \text{ cm}^{-3}\end{aligned}$$

(c)

Ex 6.9

$$\begin{aligned}i_C &= \frac{-eD_n A_{BE}}{x_B} \cdot n_{B0} \exp \frac{v_{BE}}{V_t} \\A_{BE} &= \frac{|i_C| x_B}{eD_n n_{B0} \exp \frac{v_{BE}}{V_t}} = 9.877 \times 10^{-2} \cdot |i_C|\end{aligned}$$

(a)

$$A_{BE} = 9.877 \times 10^{-2} \cdot 2 \times 10^{-3} = 1.975 \times 10^{-4} \text{ cm}^2$$

(b)

$$A_{BE} = 9.877 \times 10^{-2} \cdot 5 \times 10^{-3} = 4.939 \times 10^{-4} \text{ cm}^2$$

Ex 6.10**(a)**

$$\gamma = \frac{1}{1 + \frac{N_B}{N_E} \cdot \frac{D_E}{D_B} \cdot \frac{x_B}{x_E}}$$

$$k = \frac{N_{B0}}{N_E} \cdot \frac{D_E}{D_B} \cdot \frac{x_{B0}}{x_E}$$

$$\gamma_A = \frac{1}{1 + k}$$

$$\gamma_B = \frac{1}{1 + 2k}$$

$$\gamma_C = \frac{1}{1 + k/2}$$

(i)

$$\frac{\gamma_B}{\gamma_A} = \frac{1 + k}{1 + 2k}$$

(i)

$$\frac{\gamma_C}{\gamma_A} = \frac{1 + k}{1 + k/2}$$

(b)