Lista de Exercícios (10, 12, 14, 15, 17, 23, 29)
RAZAVI - CAP 2 pg 48

2.10

$ND = 5 \cdot 10^{17}$ $\quad T = 300K$ $\quad K = 1{,}38 \cdot 10^{-23} J/K$

$NA = 4 \cdot 10^{16}$ $\quad Eg = 1{,}2\ eV = 1{,}792 \cdot 10^{-19} J$ $\quad q = 1{,}6 \cdot 10^{-19} C$

a) n e p?

$$ni = 5{,}2 \cdot 10^{15} T^{3/2} \cdot \exp\left(\frac{-Eg}{2KT}\right) \Rightarrow \boxed{ni = 1{,}0776 \cdot 10^{10}\ cm^{-3}}$$

* Lado P

$p = NA \Rightarrow \boxed{p = 4 \cdot 10^{16}}\ cm^{-3}$

$n = \frac{ni^2}{p} \Rightarrow \boxed{n = 2{,}903 \cdot 10^{3}\ cm^{-3}}$

* Lado N

$n = ND \Rightarrow \boxed{n = 5 \cdot 10^{17}\ cm^{-3}}$

$p = \frac{ni^2}{n} \Rightarrow \boxed{p = 232{,}24\ cm^{-3}}$

b) Vo?

+ T = 250K

$\rightarrow ni = 5{,}2 \cdot 10^{15} T^{3/2} \exp\left(\frac{-Eg}{2KT}\right) \Rightarrow ni = 1{,}081 \cdot 10^{8}\ cm^{-3}$

$\rightarrow Vo = \frac{KT}{q} \cdot \ln \frac{NA \cdot ND}{ni^2} \Rightarrow \boxed{Vo(250) = 0{,}9053V}$

+ T = 300K $\Rightarrow ni = 1{,}0776 \cdot 10^{10} cm^{-3} \Rightarrow \boxed{Vo(300) = 0{,}8482V}$

+ T = 350 $\Rightarrow ni = 2{,}9897 \cdot 10^{11} cm^{-3} \Rightarrow \boxed{Vo(350) = 0{,}7884V}$

$$Vo = \frac{KT}{q} \cdot \left[\ln NA + \ln ND - \ln \underset{5{,}02 \cdot 10^{15} \cdot T^{3/2} \exp\left(-\frac{Eg}{2KT}\right)}{ni^2}\right]$$

$$Vo = \frac{KT}{q}\left[\ln NA + \ln ND - \ln(5{,}02 \cdot 10^{15})^2 - \ln T^3 - \ln\left[\exp\left(-\frac{Eg}{2KT}\right)\right]\right]$$

$$Vo = \frac{KT}{q} \cdot \left[\ln NA + \ln ND - 2\ln(5{,}02 \cdot 10^{15}) - 3\ln T + \frac{Eg}{2KT}\right]$$

$\frac{dV}{dT}$

$$\frac{dVo}{dT} = \frac{K}{q} \cdot \left[\ln NA + \ln ND - 2\ln(5{,}02 \cdot 10^{15}) - 3\ln T + \cancel{\frac{Eg}{2KT}}\right] +$$

$$+ \frac{K\cancel{T}}{q} \cdot \left[0 + 0 - 2 \cdot 0 - 3 \cdot \frac{1}{\cancel{T}} \cdot \cancel{\frac{Eg}{2KT^2}}\right]$$

$$\frac{dVo}{dT} = \frac{K}{q} \cdot \left[\ln NA + \ln ND - 2\ln(5{,}02 \cdot 10^{15}) - 3\ln T - 3\right]$$

$$\frac{dVo}{dT} = \frac{K}{q} \cdot \left[\ln(NA \cdot ND) - \ln\left[(5{,}02 \cdot 10^{15})^2 \cdot T^3\right] - 3\right]$$

$\Rightarrow$ Se $\ln(NA \cdot ND) < \ln\left[(5{,}02 \cdot 10^{15})^2 \cdot T^3\right] - 3$, Vo decai com a temperatura
$\hookrightarrow$ caso Atual

(2.13) $T = 300K$ ~~C_{J0} = ...~~

$NA = 2 \cdot 10^{16} cm^{-3}$ $\varepsilon_{si} = 1{,}04 \cdot 10^{-12} F/cm$ $E_g = 1{,}2 eV = 1{,}92 \cdot 10^{-19} J$

$ND = 9 \cdot 10^{15} cm^{-3}$ $V_R = 1{,}6V$ $q = 1{,}6 \cdot 10^{-19} C$

$k = 1{,}38 \cdot 10^{-23} J/K$

a) $+\ n_i = 5{,}2 \cdot 10^{15} \cdot T^{3/2} \cdot \exp\left(-\frac{E_g}{2kT}\right) \Rightarrow \underline{n_i = 1{,}0776 \cdot 10^{10}}$

$+\ V_0 = \frac{kT}{q} \ln \frac{NAND}{n_i^2} \Rightarrow \underline{V_0 = 0{,}6979 V}$

$+\ C_{J0} = \sqrt{\frac{\varepsilon_{si}}{2} \frac{NAND}{NA+ND} \cdot \frac{1}{V_0}} \Rightarrow$ ~~$C_{J0} = ...$~~

$C_{J0} = 1{,}4951 \cdot 10^{-8} F/cm^2$

$+\ C_J = \frac{C_{J0}}{\sqrt{1+\frac{V_R}{V_0}}} \Rightarrow \boxed{C_J = 8{,}2395 \cdot 10^{-9}} F/cm^2$

b) $C_J' = 2 \cdot C_J$

$$\frac{\sqrt{\frac{\varepsilon_{si}}{2} \cdot \frac{NA'ND}{NA'+ND} \cdot \frac{1}{V_0}}}{\left(1+\frac{V_R}{V_0}\right)} = 2C_J \Rightarrow \text{Só utilizando método numérico}$$

$$\boxed{\frac{NA'}{NA} \sim 5{,}125}$$

(2.14) $V_D = 750 mV$ $V_T \sim 26 mV$

$I_D = 1 mA$

a) $I_D = I_S \exp\left(\frac{V_D}{V_T}\right) \Rightarrow$ ~~$I_S = I_D \exp\left(\frac{V_D}{V_T}\right)$~~

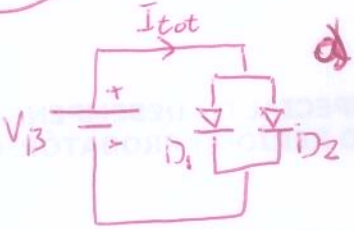
$I_S = I_D \exp -\frac{V_D}{V_T} \Rightarrow \boxed{I_S = 2{,}9667 \cdot 10^{-13} mA}$

b) $I_S = A q n_i^2 \left(\frac{D_n}{N_A L_n} + \frac{D_p}{N_D \cdot L_p}\right)$

$I_S \propto A \Rightarrow$ dobra a área $\Rightarrow I_S' = 2 \cdot I_S$

$V_d = V_T \cdot \ln \frac{I_D}{I_S'} \Rightarrow V_D = V_T \cdot \ln \frac{I_D}{2 \cdot I_S} \Rightarrow \boxed{V_D = 731{,}9782 mV}$

2.15



a) $I_{tot} = I_{D1} + I_{D2} = I_{S1}\left(\exp\left(\frac{V_B}{V_T}\right)-1\right) + I_{S2}\left(\exp\left(\frac{V_B}{V_T}\right)-1\right)$

$$I_{tot} = \underbrace{(I_{S1}+I_{S2})}_{I_{Seq}}\left[\exp\left(\frac{V_B}{V_T}\right)-1\right]$$

↳ dispositivo exponencial

b) $V_{D1} = V_{D2}$

$$V_T \cdot \ln \frac{I_{D1}}{I_{S1}} = V_T \ln \frac{I_{D2}}{I_{S2}} \Rightarrow \boxed{\frac{I_{D1}}{I_{S1}} = \frac{I_{D2}}{I_{S2}}} \quad (1)$$

$$\cancel{I_{tot} = I_{D1} + I_{D2} = I_{D1} + \frac{I_{D1} I_{S2}}{I_{S1}} \Rightarrow I_{D2} = I_{tot} \cdot I_{S1}}$$

$$+I_{tot} = I_{D1} + I_{D2} \Rightarrow \boxed{I_{D2} = I_{tot} - I_{D1}} \quad (2)$$

(2) -> (1)

$$\frac{I_{D1}}{I_{S1}} = \frac{I_{tot} - I_{D1}}{I_{S2}} \Rightarrow I_{D1} I_{S2} = I_{S1} I_{tot} - I_{D1} I_{S1}$$

$$I_{D1}(I_{S1}+I_{S2}) = I_{S1} I_{tot}$$

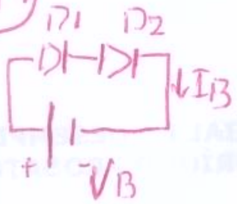
$$\Rightarrow \boxed{I_{D1} = \frac{I_{S1} I_{tot}}{I_{S1}+I_{S2}}} \quad (3)$$

(3) -> (2) $\boxed{I_{D1} = I_{tot} - I_{D2}}$ (4)

(4) -> (1)

$$\frac{I_{tot} - I_{D2}}{I_{S1}} = \frac{I_{D2}}{I_{S2}} \Rightarrow \boxed{I_{D2} = \frac{I_{S2} \cdot I_{tot}}{I_{S1}+I_{S2}}} \quad (5)$$

2.17



I_B, V_{D1}, V_{D2} ?

$$V_B = V_{D1} + V_{D2}$$

$$V_B = V_T \ln \frac{I_B}{I_{S1}} + V_T \ln \frac{I_B}{I_{S2}}$$

$$\boxed{V_B = V_T \ln \frac{I_B^2}{I_{S1} \cdot I_{S2}}}$$

$$\Rightarrow \frac{V_B}{V_T} = \ln \frac{I_B^2}{I_{S1} \cdot I_{S2}} \Rightarrow \frac{I_B^2}{I_{S1} I_{S2}} = \exp \frac{V_B}{V_T} \Rightarrow \boxed{I_B = \sqrt{I_{S1} I_{S2} \exp \frac{V_B}{V_T}}}$$

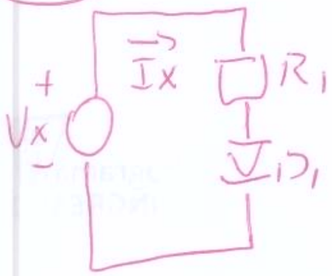
$$\Rightarrow V_{D1} = V_T \ln \frac{I_B}{I_{S1}} \Rightarrow V_{D1} = V_T \ln \frac{\sqrt{I_{S1} I_2 \exp(\frac{V_B}{V_T})}}{I_{S1}}$$

$$V_{D1} = V_T \ln \frac{I_{S1}^{1/2} I_{S2}^{1/2} \cdot \exp \frac{V_B}{2V_T}}{I_{S1}} \Rightarrow V_{D1} = V_T \left[\ln \frac{I_{S2}^{1/2}}{I_{S1}^{-1/2} \cdot I_{S1}} + \ln \exp(\frac{V_B}{2V_T}) \right]$$

$$\boxed{V_{D1} = V_T \ln \sqrt{\frac{I_{S2}}{I_{S1}}} + \frac{V_B}{2}}$$

$$\Rightarrow V_{D2} = V_T \ln \frac{I_B}{I_{S2}} \Rightarrow \boxed{V_{D2} = V_T \ln \sqrt{\frac{I_{S1}}{I_{S2}}} + \frac{V_B}{2}}$$

2.23



I_x (mA)	V_x (V)
0,2	1
0,5	2

$V_T = 26\,mV$

$$V_{D1} = V_T \ln \frac{I_x}{I_S}$$

$$V_{D1} = V_x - R_1 I_x$$

$$V_x - R_1 I_x = V_T \ln \frac{I_x}{I_S}$$

$$\Rightarrow \begin{cases} 1 - R_1 0{,}2 \cdot 10^{-3} = 26 \cdot 10^{-3} \ln \dfrac{0{,}2 \cdot 10^{-3}}{I_S} & (1) \\ 2 - R_1 0{,}5 \cdot 10^{-3} = 26 \cdot 10^{-3} \ln \dfrac{0{,}5 \cdot 10^{-3}}{I_S} & (2) \end{cases}$$

$$(2) - (1) \Rightarrow 1 - R_1 (0{,}5 - 0{,}2) \cdot 10^{-3} = 26 \cdot 10^{-3} \ln \frac{0{,}5 \cdot \cancel{10^{-3}}}{\cancel{I_S}} \cdot \frac{\cancel{I_S}}{0{,}2 \cdot \cancel{10^{-3}}}$$

$$1 - 0{,}3 \cdot 10^{-3} R_1 = \underbrace{26 \cdot 10^{-3} \underbrace{\ln \frac{0{,}5}{0{,}2}}_{0{,}9163}}_{0{,}0238}$$

$$R_1 = \frac{0{,}0238 - 1}{-0{,}3 \cdot 10^{-3}} \Rightarrow \boxed{R_1 = 3{,}2539 \cdot 10^{+3}\,\Omega}$$

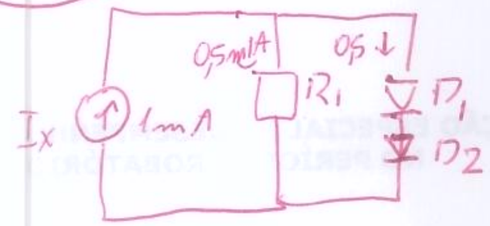
$$\boxed{R_1 = 3{,}2539\,k\Omega}$$

$$I_S = I_D \exp\left(-\frac{V_D}{V_T}\right) = I_D \exp\left(\frac{-(V_x - R_1 I_x)}{26 \cdot 10^{-3}}\right)$$

$$= 0{,}2 \cdot \exp\left(\frac{-(1 - 0{,}2 \cdot 10^{-3} \cdot 3{,}2539 \cdot 10^{3})}{26 \cdot 10^{-3}}\right)$$

$$\boxed{I_S = 2{,}9362 \cdot 10^{-10}\,A}$$

(2.29)



$I_S = 5 \cdot 10^{-16} A$

R_1?

$$\boxed{V_D = V_T \ln \frac{I_D}{I_S}}$$

$V_T \to 26mV$, $I_D \to 0,5 \cdot 10^{-3} A$

$$2 \cdot V_D = R_1 \cdot 0,5 \cdot 10^{-3}$$

$$\boxed{V_D = 0,25 \cdot 10^{-3} R_1}$$

$$0,25 \cdot 10^{-3} R_1 = 26 \cdot 10^{-3} \ln \frac{0,5 \cdot 10^{-3}}{5 \cdot 10^{-16}} \Rightarrow R_1 = \frac{26 \cdot 10^{-3}}{0,25 \cdot 10^{-3}} \ln \frac{0,5 \cdot 10^{-3}}{5 \cdot 10^{-16}}$$

$$\boxed{R_1 = 2,87 K\Omega}$$