EEL315 — ELETRÔNICA I — PROVA PARCIAL #1 — 08/05/2018 — GABARITO

① a) $n_i = 1.66\times10^{15}(300)^{3/2}\exp\left(\frac{-0.66\times1.6\times10^{-19}}{1.38\times10^{-23}\times600}\right) = 1.66\times10^{15}\times5.1962\times10^{3}\times2.89\times10^{-6} = 2.49\times10^{13}/cm^3$

$(e^{-12.754} = 2.89\times10^{-6})$

$np = n_i^2 \Rightarrow p = \frac{(2.49)^2\times10^{26}}{2\times10^{17}} \Rightarrow \boxed{p = 3.1\times10^{9}/cm^3}$; $\boxed{n = 2\times10^{17}/cm^3}$

b) $E = 5/(5\times10^{-6}m) = 5/(5\times10^{-4}cm) = 10^{5} V/cm$

Material dopado: $J = 1.6\times10^{-19}(\underbrace{3900\times2\times10^{17}}_{7.8\times10^{20}} + \underbrace{1900\times3.1\times10^{9}}_{5.89\times10^{12}})\times10^{5} = 1.6\times10^{-19}\times7.8\times10^{20}\times10^{5} = 12.48\times10^{6} A/cm^2$

$A = 50\times10^{-7}(cm)\times50\times10^{-7}(cm) = 2.5\times10^{3}\times10^{-14} = 2.5\times10^{-11} cm^2$

$I = 12.48\times10^{6}\times2.5\times10^{-11} \longrightarrow I = 31.2\times10^{-5} \longrightarrow \boxed{I = 312\,\mu A}$

Sem dopagem: $J = 1.6\times10^{-19}(\underbrace{(3900+1900)\times2.49\times10^{13}}_{1.44\times10^{17}})\times10^{5} = 2.30\times10^{3} A/cm^2$

$I = 2.30\times10^{3}\times2.5\times10^{-11} \longrightarrow 5.75\times10^{-8} = I \longrightarrow \boxed{I = 57.5\,nA}$

A corrente no material dopado é $312000/57.5 = \boxed{5426 \text{ vezes}}$ a corrente do material não dopado.

② a) Do lado n: $N_D = \boxed{10^{17}/cm^3 = n_n}$ (elétrons = portadores majoritários)

$np = n_i^2 \Rightarrow p = \frac{1.664\times10^{20}}{10^{17}} \Rightarrow \boxed{p_n = 1.664\times10^{3}/cm^3}$ (lacunas = portadores minoritários)

Do lado p: $N_A = \boxed{10^{16}/cm^3 = p_p}$ (lacunas = portadores majoritários)

$np = n_i^2 \Rightarrow n = \frac{1.664\times10^{20}}{10^{16}} \Rightarrow \boxed{n_p = 1.664\times10^{4}/cm^3}$ (elétrons = portadores minoritários)

b) $T = 250\,K$: $V_0 = \frac{kT}{q}\ln\left(\frac{10^{16}10^{17}}{n_i^2}\right) = 21.67\ln(0.857\times10^{17}) = 21.67\times38.99 = \boxed{845\,mV}$

$\frac{kT}{q}$: ~~27~~ 26 mV — 300 K
kT/q — 250 K
$kT/q = \frac{26\times250}{300} = 21.67\,mV$

$(1.08)^2\times10^{16} \Leftarrow 5.2\times10^{15}\underbrace{(250)^{3/2}}_{3.953\times10^{3}}\exp\left(\underbrace{\frac{-1.12\times1.6\times100}{1.38\times2\times2.5}}_{-25.971}\right) = n_i = 1.08\times10^{8}/cm^3$

$T = 350\,K$: $V_0 = \frac{kT}{q}\ln\left(\frac{10^{16}10^{17}}{n_i^2}\right) = 30.33\ln\left(\frac{10^{33}}{2.99^2\times10^{22}}\right) = 30.33\ln(0.112\times10^{11}) = 30.33\times23.14 = \boxed{702\,mV}$

26 mV — 300 K
kT/q — 350 K
$kT/q = 26\times350/300 = 30.33\,mV$

$(2.99)^2\times10^{22} \Leftarrow 5.2\times10^{15}\underbrace{(350)^{3/2}}_{6.548\times10^{3}}\exp\left(\underbrace{\frac{-1.12\times1.6\times100}{1.38\times2\times3.5}}_{-18.551}\right) = 2.99\times10^{11}/cm^3$

③ a) Começando por $I_D = \frac{0.6 - V_D}{1000}\Big|_{V_D = 0.5V} = 0.1\,mA = 10^{-4}A$,

temos $V_D = 26\,mV\times\ln\left(\frac{I_D}{10^{-15}}\right) = 26\times25.33 = 0.66\,V$ ⟶ maior que 0.6 V ⟶ não vai convergir!

— Mudando o sistema de equações, temos: $I_D = 10^{-15}\exp\left(\frac{V_D}{26\,mV}\right)\Big|_{V_D = 0.5V} = 225\,nA$

$V_D = 0.6 - 1000 I_D = 0.6 - 1000\times225\,nA = 600\,mV - 0.225\,mV = 599.8\,mV$

$I_D = 10^{-15}\exp(599.8/26) = 10443\,nA = 10.4\,\mu A$

$V_D = 0.6 - 1000\times10.4\times10^{-6} = 589.6\,mV$

$I_D = 10^{-15}\exp(589.6/26) = 7054\,nA = 7.05\,\mu A$

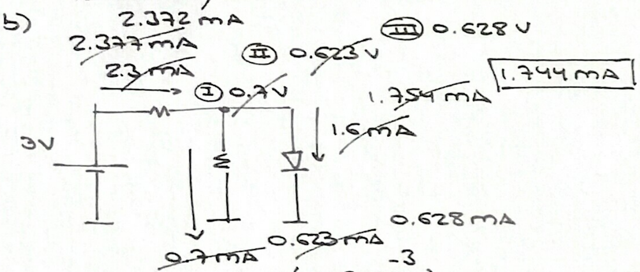
$V_D = 600\,mV - 7.1\,mV = 593\,mV$

$I_D = 10^{-15}\exp(593/26) = 8\,\mu A \longrightarrow V_D = 592\,mV$

$I_D = 10^{-15}\exp(592/26) = \cancel{7\,\mu A}\ 7.7\,\mu A \longrightarrow V_D = 592.3\,mV$

$\boxed{I_D = 7.8\,\mu A} \longrightarrow \boxed{V_D = 592.8\,mV}$

b)

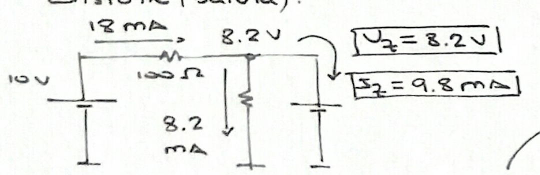


I: $V_D = 52\,mV\times\ln\left(\frac{1.6\times10^{-3}}{10^{-8}}\right) = 52\,mV\times11.98 = 623\,mV$

II: $V_D = 52\,mV\times\ln\left(\frac{1.754\times10^{-3}}{10^{-8}}\right) = 52\,mV\times12.07 = 628\,mV$

III: $V_D = 52\,mV\times\ln\left(\frac{1.744\times10^{-3}}{10^{-8}}\right) = 52\,mV\times12.07 = \boxed{628\,mV}$

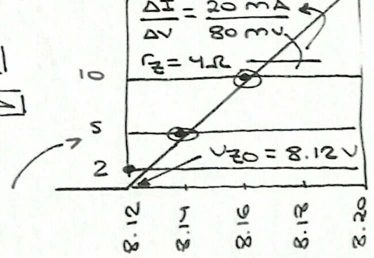
④ a) Solução com voltagem constante (bateria):



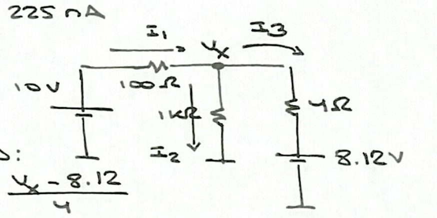
$\boxed{V_Z = 8.2V}$

$\boxed{I_Z = 9.8\,mA}$

Solução com modelo com bateria V_{Z0} e resistência r_Z:



④ Continuação:



$I_1 = I_2 + I_3$, então:

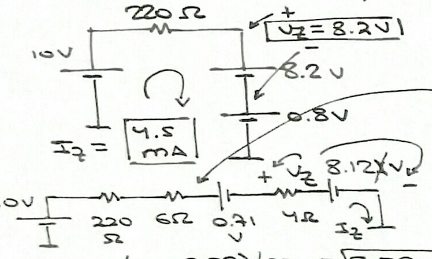
$\frac{10 - V_X}{100} = \frac{V_X}{1000} + \frac{V_X - 8.12}{4}$

$100 - 10V_X = V_X + 250V_X - 250\times8.12$

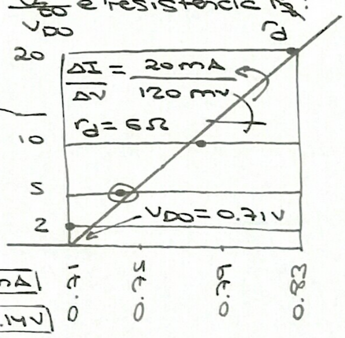
$261V_X = 100 + 250\times8.12 \longrightarrow V_X = 2130/261$

$\boxed{V_X = 8.1609\,V} \longrightarrow I_Z = \frac{8.1609 - 8.12}{4} = \boxed{10.23\,mA}$

b) Solução com voltagem constante (bateria):



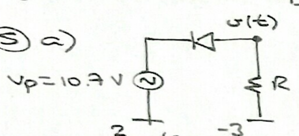
Solução com bateria V_{DO} e resistência r_d:



$I_Z = (10 - 8.83)/220 = \boxed{5.09\,mA}$

$V_Z = 8.12 + 4\times5.09\times10^{-3} = \boxed{8.14V}$

⑤ a)



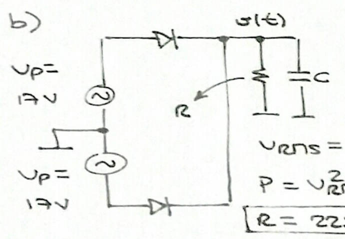
$V_{DC} = -10/\pi = \boxed{-3.18\,V}$

$V_{RMS} = 10/2 = \boxed{5V}$

$V_{AC,RMS} = \boxed{3.86\,V}$

$P = V_{RMS}^2/R = 10^{-3} \longrightarrow \boxed{R = 25\,k\Omega}$

b)



$V_{DC} = \frac{16.3 + 13.7}{2} = \boxed{15\,V}$

$V_{AC,RMS} = \frac{1.3}{\sqrt{3}} = \boxed{0.75\,V}$

$V_{RMS} = \sqrt{15^2 + 0.75^2} = \boxed{15.02\,V}$

$P = V_{RMS}^2/R = 1\,mW$

$\boxed{R = 225\,k\Omega}$ (o valor exato seria 225.6 kΩ)