Universidade Federal do Rio de Janeiro
Escola Politécnica

DATA: 10/10/2018

GRAUS

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Aluno(a): Prova Parcial #1 — Gabarito

Disciplina: Eletrônica I

Turma: 2018/2

Professor(a): José Gabriel

① a) $\boxed{n = 2\times10^{16}\ \text{elétrons/cm}^3}$ $(=N_D)$

$n_i^2 = 1.1664\times10^{20}/\text{cm}^6 \longrightarrow p = n_i^2/n \longrightarrow \boxed{p = 5.832\times10^{3}\ \text{lacunas/cm}^3}$

b) $E = 10/(2\times10^{-4}\ \text{cm}) = 5\times10^{4}\ \text{V/cm}$

$J = 1.6\times10^{-19}\times(\underbrace{1350\times2\times10^{16}}_{})\times5\times10^{4} = 1.6\times1.35\times2\times5\times10^{4} = 2.16\times10^{5}\ \text{A/cm}^2$

(note que $\mu_n n \gg \mu_p p$)

$A = (100\times10^{-7}\ \text{cm})\times(100\times10^{-7}\ \text{cm}) = 10^{-10}\ \text{cm}^2$

$I = 2.16\times10^{-5}\ \text{A} \longrightarrow \boxed{I = 21.6\ \mu\text{A}}$

② a) $n_i = 1.66\times10^{15}\times350^{1.5}\ \underbrace{\exp\left(\frac{-0.66\times1.6\times10^{-19}}{2\times1.38\times10^{-23}\times350}\right)}_{} = 1.66\times6.548\times10^{18}\times1.79\times10^{-5}$

$\exp\left(\frac{-0.66\times1.6\times100}{2\times1.38\times3.5}\right) = \exp(-10.93) = 1.79\times10^{-5}$

Então: $n_i = 1.946\times10^{14}/\text{cm}^3$

$kT/q = 1.38\times10^{-23}\times350/(1.6\times10^{-19}) = 30.19\ \text{mV}$

$V_0 = 30.19\times10^{-3}\times\ln\left(\frac{2\times10^{34}}{3.787\times10^{28}}\right) = 30.19\times10^{-3}\times\underbrace{\ln(5.281\times10^{5})}_{13.18} \Rightarrow \boxed{V_0 = 398\ \text{mV}}$

b) $\frac{N_A N_D}{N_A+N_D} = \frac{2\times10^{34}}{3\times10^{17}} = 6.67\times10^{16}$ (usando ε_{Si} mesmo, em vez de ε_{Ge}) (*)

$C_{j0}^2 = \frac{11.7\times8.85\times10^{-14}\times1.6\times10^{-19}\times6.67\times10^{16}}{2}\times\frac{1}{0.398} = \frac{1105.03\times10^{-17}}{0.796} = 138.82\times10^{-16}$

$C_{j0} = 11.78\times10^{-8}\ \text{F/cm}^2$

$C_j = \frac{11.78}{\sqrt{1+2/0.398}} = \frac{11.78}{2.455} = 4.8\times10^{-8}\ \text{F/cm}^2$

$1\ \mu\text{m}^2 = 10^{-8}\ \text{cm}^2$

$C = 4.8\times10^{-16}\ \text{F} \longrightarrow \boxed{C = 0.48\ \text{fF}}$

(*) Usando $\varepsilon_{Ge} = 16\times8.85\times10^{-14}\ \text{F/cm}$, temos:

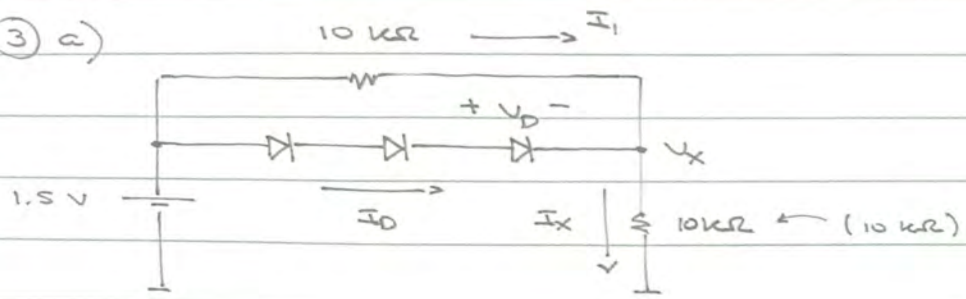
$C_{j0}^2 = 189.84\times10^{-16}\ \text{F}^2/\text{cm}^4$

$C_{j0} = 13.78\times10^{-8}\ \text{F/cm}^2$

$C_j = 5.6\times10^{-8}\ \text{F/cm}^2$

$C = 0.56\ \text{fF}$ //

(3) a)



$$\frac{1.5 - V_x}{10^4} + I_D = \frac{V_x}{10^4} \qquad \underline{\underline{e}} \qquad V_x = 1.5 - 3V_D$$

$$1.5 - V_x + 10^4 I_D = V_x$$

$$10^4 I_D = 2V_x - 1.5 \longrightarrow 10^4 I_D = 3 - 6V_D - 1.5 \longrightarrow V_D = \frac{1.5 - 10^4 I_D}{6}$$

Chute inicial : $V_D = 0.25$ V

1) $I_D = 10^{-8} \exp(0.25/0.052) = 1.22\,\mu A$

$V_D = (1.5 - 1.22 \times 10^{-2})/6 = 0.248$ V

2) $I_D = 10^{-8} \exp(0.248/0.052) = 118 \times 10^{-8} = 1.18\,\mu A$

$V_D = (1.5 - 1.18 \times 10^{-2})/6 = 0.248 \text{ V} \longrightarrow \boxed{V_D = 0.248 \text{ V}}$ e $\boxed{I_D = 1.18\,\mu A}$

Obs.: com chute inicial $V_D = 0.5$ V, teríamos :

$I_D = 10^{-8} \exp(0.5/0.052) = 15 \times 10^{-5} = 150\,\mu A$

$V_D = (1.5 - 0.15)/6 = 0.225$ ... e assim por diante (converge corretamente)

b) Chute inicial : $V_D = 0.7$ V (usamos o mesmo diagrama do item (a), com 20 V)

1) $V_x = 20 - 3V_D \Rightarrow V_x = 17.9$ V

$I_x = 1.79$ mA

$I_1 = (20 - 17.9)/10\text{ k}\Omega = 0.21$ mA

$I_D = I_x - I_1 = 1.58$ mA

$V_D = (52 \text{ mV}) \times \ln(1.58 \times 10^{-3}/10^{-8})$

$V_D = (52 \text{ mV}) \times 11.97 = 622$ mV

2) $V_x = 20 - 3V_D \Rightarrow V_x = 18.13$ V

$I_x = 1.81$ mA

$I_1 = 1.866/10\text{ k}\Omega = 0.19$ mA

$I_D = I_x - I_1 = 1.62$ mA

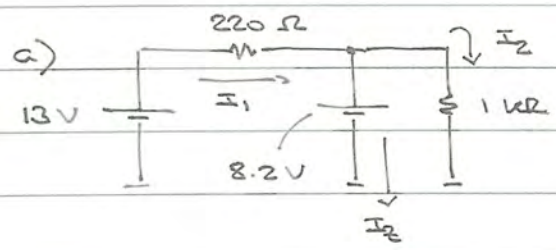
$V_D = (52 \text{ mV}) \times \ln(1.62 \times 10^{-3}/10^{-8})$

$V_D = (52 \text{ mV}) \times 12 = 624$ mV

3) $V_x = 20 - 3V_D \Rightarrow V_x = 18.13$ V (mesmo V_x da iteração 2)

Então : $\boxed{V_D = 0.624 \text{ V}}$ e $\boxed{I_D = 1.62 \text{ mA}}$

(4) a)



$I_1 = (13 - 8.2)/220 = 21.8$ mA

$I_2 = 8.2/1000 = 8.2$ mA

$I_D = I_1 - I_2 \Rightarrow \boxed{I_D = 13.6 \text{ mA} \quad V_D = 8.2 \text{ V}}$

(modelo bateria)

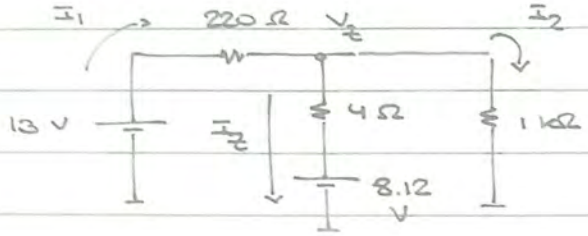
Para corrente em torno de 13.6 mA, vamos usar o seguinte modelo : (com V_{D0} e r_d)

8.16 V — 10 mA

8.2 V — 20 mA

$r_z = \Delta V_z / \Delta I_z = 0.04/0.01 \longrightarrow r_z = 4\,\Omega$

$V_{z0} + r_z I_z = V_z \longrightarrow V_{z0} + 4 \times 0.02 = 8.2 \longrightarrow V_{z0} = 8.12\,V$



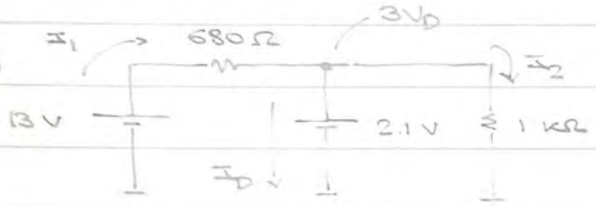
$I_2 + I_z = I_1$:

$$\frac{V_z}{1000} + \frac{V_z - 8.12}{4} = \frac{13 - V_z}{220}$$

$V_z\,(4 \times 220 + 220 \times 1000 + 4 \times 1000) = 13 \times 4 \times 1000 + 8.12 \times 220 \times 1000$

$V_z = 1838400/224880 \longrightarrow \boxed{V_z = 8.175\,V}$ e $\boxed{I_z = 13.8\,mA}$

b)



$I_1 = (13 - 2.1)/680 = 16\,mA$

$I_2 = 2.1/1000 = 2.1\,mA$

$I_D = I_2 - I_1 \Rightarrow \boxed{I_D = 13.9\,mA \quad V_D = 0.7\,V}$

(modelo bateria)

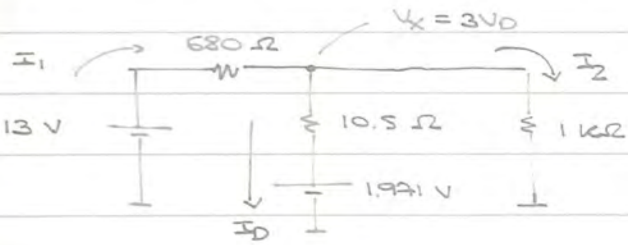
Para corrente em torno de 13.9 mA, vamos usar

o seguinte modelo (V_{D0}, r_d): $0.692\,V$ — $10\,mA$

$0.727\,V$ — $20\,mA$

$r_d = \Delta V_D / \Delta I_D = 0.035/0.01 \longrightarrow r_d = 3.5\,\Omega$

$V_{D0} + r_d I_D = V_D \longrightarrow V_{D0} + 3.5 \times 0.02 = 0.727 \longrightarrow V_{D0} = 0.657\,V$



$I_2 + I_D = I_1$

$$\frac{V_x}{1000} + \frac{V_x - 1.971}{10.5} = \frac{13 - V_x}{680}$$

$V_x\,(10.5 \times 680 + 1000 \times 680 + 1000 \times 10.5) = 13 \times 10.5 \times 1000 + 1.971 \times 680 \times 1000$

$V_x = 1476780/697640 = 2.117 \longrightarrow \boxed{V_D = 0.706\,V}$ e $\boxed{I_D = 14\,mA}$

5) a) $(1 + \sqrt{3} \times 0.04)\,V_{DC} = 9.3 \longrightarrow V_{DC} = 8.7\,V$

$I_{DC} = 8.7/470 \longrightarrow I_{DC} = 18.5\,mA$

$$C = \frac{I_{DC}}{2\sqrt{3}\,f\,r\,V_m} = \frac{18.5 \times 10^{-3}}{2 \times 1.7 \times 60 \times 0.04 \times 9.3} = 244\,\mu F \Rightarrow \boxed{C = 330\,\mu F}$$

(meia onda) $\longrightarrow 2\sqrt{3}\,f\,r\,V_m$

(valor comercial)

b) $r = 18.5 \times 10^{-3} / (2 \times 1.7 \times 60 \times 9.3 \times 330 \times 10^{-6}) = 3\%$

$(1 + \sqrt{3} \times 0.03)\,V_{DC} = 9.3 \longrightarrow V_{DC} = 8.84\,V \longrightarrow I_{DC} = \frac{8.84}{470} = 18.8\,mA$

$r = 18.8 \times 10^{-3} / (2 \times 1.7 \times 60 \times 9.3 \times 330 \times 10^{-6}) \Rightarrow r = 3\%$ $(v_{RL}(t))$

Com relação a $v_{IN}(t)$: $\boxed{V_{DC} = 0\ V}$; $V_{AC,RMS} = V_{RMS} = V_P/\sqrt{2} = \boxed{7.1\ V}$

$r = V_{AC,RMS}/V_{DC}$, então $\boxed{r \longrightarrow \infty}$

Com relação a $v_{RL}(t)$: $\boxed{V_{DC} = 8.84\ V}$; $\boxed{r = 3\%}$

$V_{AC,RMS} = r \cdot V_{DC} \longrightarrow \boxed{V_{AC,RMS} = 0.265\ V}$

$V_{RMS} = \sqrt{V_{DC}^2 + V_{AC,RMS}^2} \longrightarrow \boxed{V_{RMS} = 8.84\ V}$

$P = \dfrac{V_{RMS}^2}{R_L} = \dfrac{8.84^2}{470} \longrightarrow \boxed{P = 166\ mW}$

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