11)

a) $V_0 = \frac{K_B T}{e} \ln\left(\frac{N_a N_d}{n_i^2}\right) = 26.10^{-3} \ln\left(\frac{4.10^{17} \cdot 10^{16}}{(1,5.10^{10})^2}\right) \Rightarrow \boxed{V_0 = 0,85\ V}$

b) $l = \left[\frac{2\,\epsilon.\epsilon_0.V_0}{e}\left(\frac{1}{N_a} + \frac{1}{N_d}\right)\right]^{1/2} = \left[\frac{2.11,8.8,85.10^{-12}.0,85}{1,6.10^{-19}}\left(\frac{1}{4.10^{17}} + \frac{1}{10^{22}}\right)\right]^{1/2} = \boxed{333.10^{-9}}$

$l_p = \frac{N_d}{N_d + N_a} l = \frac{10^{16}}{10^{16} + 4.10^{17}} \cdot 333.10^{-9} = 0,0248 \cdot 333.10^{-9} = \boxed{8,2.10^{-10}}$

$l_n = \frac{N_a}{N_d + N_a} l = \frac{4.10^{17}}{10^{16} + 4.10^{17}} \cdot 333.10^{-9} = \boxed{332\ nm}$

c) $Q = e N_d V = e N_d l_n A = 1,6.10^{-19} \cdot 10^{22} \cdot 332.10^{-9} \cdot 2.10^{-4} = \boxed{1,06.10^{-10} C}$

d) $\mathcal{E}_0 = \frac{2 V_0}{l} = 2.\frac{0,85}{333.10^{-9}} = \boxed{5,1.10^6\ V/m}$

e) $C = \frac{\epsilon.\epsilon_0.A}{l} = \frac{11,8.8,85.10^{-12}.2.10^{-7}}{333.10^{-9}} = \boxed{6,27.10^{-11}\ F}$

2)

a) $V_0 = \frac{K_B T}{e} \ln\left(\frac{N_a N_d}{n_i^2}\right) = 0,026 \cdot \ln\left(\frac{10^{17} \cdot 10^{15}}{(1,5 \cdot 10^{10})^2}\right) = 0,7\,V$

$l = \left(\frac{2 \cdot \varepsilon \cdot \varepsilon_0 \cdot (V_0 - V)}{e}\left(\frac{1}{N_a} + \frac{1}{N_d}\right)\right]^{1/2} = \left(\frac{2 \cdot 11,8 \cdot 8,85 \cdot 10^{-12} \cdot (0,7 - 0,5)}{1,6 \cdot 10^{-19}}\left(\frac{1}{10^{23}} + \frac{1}{10^{21}}\right)\right]^{1/2} =$

$l = 511\ nm$

$C = \frac{\varepsilon \cdot \varepsilon_0 \cdot A}{l} = \frac{11,8 \cdot 8,85 \cdot 10^{-12} \cdot 10^{-6}}{511 \cdot 10^{-9}} = 200\ pF$

b)

$L_p = \sqrt{D_p \tau_p} = \sqrt{12,5 \cdot 0,1 \cdot 10^{-6}} = 0,0012$

$L_n = \sqrt{D_N \tau_0} = \sqrt{35 \cdot 0,1 \cdot 10^{-6}} = 0,0018$

$I_s = e A n_i^2 \left(\frac{D_p}{L_p N_d} + \frac{D_n}{L_n N_a}\right) = 1,6 \cdot 10^{-19} \cdot 10^{-6} \cdot 2,25 \cdot 10^{20} \left(\frac{1,35 \cdot 10^{-3}}{1,12 \cdot 10^{-3} \cdot 10^{15}} + \frac{3,5 \cdot 10^{-3}}{1,87 \cdot 10^{-3} \cdot 10^{17}}\right) = 4,068 \cdot 10^{-12}$

$I = I_S\left(e^{\frac{eV}{K_B T}} - 1\right) = 4,06 \cdot 10^{-12}\left(e^{\frac{1}{0,026} \cdot 0,5} - 1\right) = 1,01 \cdot 10^{-3}$

3)

a)

$L_p = \sqrt{12,5 \cdot 0,1 \cdot 10^{-6}} = 1,18 \cdot 10^{-3}$

$L_n = \sqrt{35 \cdot 0,1 \cdot 10^{-6}} = 1,87 \cdot 10^{-3}$

$I = I_S\left(e^{\frac{eV}{K_B T}} - 1\right) \Rightarrow I_S = \frac{I}{e^{eV/K_B T} - 1} = \frac{0,9 \cdot 10^{-3}}{e^{\frac{1}{0,026} \cdot 0,5} - 1} = 4\,pA$

$2l = \sqrt{D_p \tau_p} = cm = 10^{-2}\,m$

$2,32 \cdot 10^{22}$
$3,210 \cdot 10^{3}$
$4,92 \cdot 10^{15}$

b)

$I_S = e A n_i^2 \left(\frac{D_p}{L_p N_a} + \frac{D_n}{L_n N_d}\right) \Rightarrow A = \frac{I_S \cdot D_p}{e n_i^2 L_p N_d} = \frac{4 \cdot 10^{-12} \cdot 12,5}{1,6 \cdot 10^{-19} \cdot 2,25 \cdot 10^{20} \cdot 1,18 \cdot 10^{-3} \cdot 10^{15}} = 10^{-6}\,m^2$

c)

$n_i^2 = N_c N_v e^{\frac{-(E_g) e}{K_B T}} = 2,8 \cdot 10^{39} \cdot 1,02 \cdot 10^{39} \cdot e^{\frac{-1,11 \cdot 1,6 \cdot 10^{-19}}{1,38 \cdot 10^{-23} \cdot 3,20}} \Rightarrow 4,82 \cdot 10^{16}\,m^{-3} = n_i$

$I_S = e A n_i^2 \left(\frac{D_p}{L_p N_a} + \frac{D_n}{L_n D_p}\right) = 1,6 \cdot 10^{-19} \cdot 10^{-6} \cdot (4,82 \cdot 10^{16})^2 \left(\frac{12,5 \cdot 10^{-4}}{1,18 \cdot 10^{-3} \cdot 10^{21}}\right) = 39,37$

d)

$I = I_S\left(e^{\frac{eV}{K_B T}} - 1\right)$

a) $\frac{C_1}{C_2} = \frac{\varepsilon A/l_1}{\varepsilon A/l_2} \Rightarrow \frac{C_1}{C_2} = \frac{l_2}{l_1} \Rightarrow C_1 l_1 = C_2 l_2 \Rightarrow C_1 \left(\frac{2\varepsilon(V_0+3,2)}{e}\left(\frac{1}{N_a}+\frac{1}{N_d}\right)\right)^{1/2} = C_2 \left(\frac{2\varepsilon(V_0+8,2)}{e}\left(\frac{1}{N_a}+\frac{1}{N_d}\right)\right)^{1/2}$

$\Rightarrow C_1^2 (V_0 + 3,2) = C_2^2 (V_0 + 8,2) \Rightarrow (18.10^{-12})^2 (V_0 + 3,2) = (12.10^{-12})^2 (V_0 + 8,2) \Rightarrow$

$\boxed{V_0 = 0,8V}$

b)

$C_1 = \frac{\varepsilon . \varepsilon_0 A}{l_1} \Rightarrow l_1 = \frac{\varepsilon . \varepsilon_0 . A}{C_1} = \frac{11,8 . 8,85.10^{-12} . 10^{-3} . 10^{-4}}{18.10^{-12}} = 1,6\ 928\ nm$

$V_0 = \frac{K_B T}{e} \ln\left(\frac{N_a N_d}{n_i^2}\right) \Rightarrow \frac{N_a N_d}{n_i^2} = 2,3.10^{13} \Rightarrow N_a N_d = 2,3.10^{13} . (1,5.10^{16})^2 \Rightarrow$

$N_a N_D = 5,2.10^{45}$

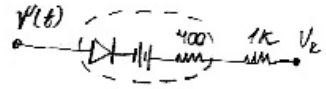
$l_1^2 = \frac{2\varepsilon\varepsilon_0 (V_0 + 3,2)}{e}\left(\frac{1}{N_a} + \frac{1}{N_d}\right) \Rightarrow \left(\frac{N_a + N_d}{N_a N_d}\right) = \frac{e . l_1^2}{2\varepsilon . \varepsilon_0 (V_0 + 8,2)} \Rightarrow$

$N_a + N_d = \frac{1,6.10^{-19} . (928.10^{-9})^2 . 5,2.10^{45}}{2 . 11,8 . 8,85.10^{-12} . 4} \Rightarrow N_a + N_d = 8,58.10^{23}$

$\begin{cases} N_a + N_d = 8,68.10^{23} \\ N_a . N_d = 5,2.10^{45} \end{cases} \Rightarrow N_a = 8,5.10^{17}\ cm^{-3}$

$N_d = 6,07.10^{15}\ cm^{-3}$

5)

a) 

$(V(t)_{MAX} - \varepsilon_0) = R_{eq} I_{MAX} \Rightarrow (2 - 0,6) = 1,4.10^3 I_{MAX} \Rightarrow$

$\boxed{I_{MAX} = 1mA}$ $\boxed{V_{1K} = 1V}$

b)