Electronics I 903261
Student Name:
Answers should be written in ink

University of Jordan
Elect. Eng. Dept.
First Exam
Reg. N
Exam Duration: 70 min

Sunday 3/3/2019
Mark out of 30

19

Useful information : for silicon , μ_n =1350 cm^2/V–s and μ_p = 480 cm^2/V–s.
n_i =1.5×10^{10} cm^{-3}. V_T = 0.026 V at 300K.
Use the linearized diode model with r_f = 0 ohm unless otherwise mentioned.

Q1 a) Consider n-type ~~GaAs~~ silicon at T =300 K doped to a concentration of N_d =5×10^{15} cm^{-3}. Assume mobility values of μ_n = ~~6800~~ 1350 cm^2/V–s and μ_p = ~~300~~ 480 cm^2/V–s.
Determine the conductivity of the material.

$n_i^2 = B T^{3/2} . e^{(-E}$

$n_i^2 = n_0 P_0$

because of $N_d > n_i$

$N_d = P_0 = 5 \times 10^{15}$

$\sigma = e n \mu_n + e P \mu_p$

$n_0 = \frac{n_i^2}{P_0} = \frac{(2.25 * 10^{20})}{5 * 10^{15}}$

$n = 45 * 10^3$

~~$\sigma = (1.6 \times 10^{-19})(\ldots)(6800) + (1.6 \times 10^{-19})(5 \times 10^{15})(300)$~~

$\sigma = (1.6 * 10^{-19})(45 * 10^3)(1350) + (1.6 * 10^{-19})(5 * 10^{15})(480)$

$= 9.72 * 10^{-12} + 384 * 10^{-3} = 0.384 (cm\text{-}\Omega)^{-1}$

Determine the applied electric field that induces a drift current density of 175 A/cm^2.

$J = \sigma E$

$\frac{175}{0.384} = E \Rightarrow E = 455.72 \frac{A . \Omega}{cm^3}$

3.5

b) A silicon pn junction at T =300 K is doped with N_d =10^{16} cm^{-3} and N_a =10^{15} cm^{-3}. The junction capacitance is to be 0.8 pF when a reverse bias voltage of of **13** V is applied. Find the zero-biased junction capacitance.

$C_j = C_{j0} \left(1 + \frac{V_R}{V_{bi}}\right)^{-\frac{1}{2}}$

$V_{bi} = V_T \left(\ln \left(\frac{N_a N_d}{n_i^2} \right) \right)$

$C_j = 0.8$ pf

$V_R = 13$ V

$0.8 = C_{j0} \left(1 + \frac{13}{V_{bi}}\right)^{-\frac{1}{2}}$

$V_{bi} = 0.026 \ln \left(\frac{10^{16} . 10^{15}}{(1.5 * 10^{10})^2} \right)$

$= 0.026 \ln \left(\frac{1 \times 10^{31}}{2.25 * 10^{20}} \right)$

$= 0.637$

$0.8 = C_{j0} \left(1 + \frac{13}{0.637}\right)^{-\frac{1}{2}}$

$\frac{0.8}{0.216} = \frac{C_{j0}(0.216)}{0.216}$

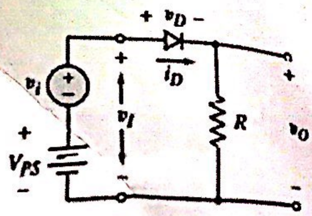
final answer

$C_{j0} = 3.70$ PF

2

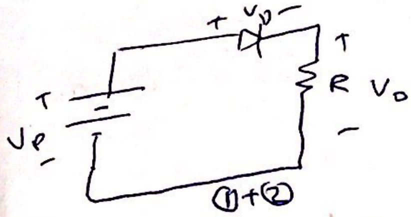
Scanned with CamScanner

Q3 a) The circuit and diode parameters for the circuit shown are $V_{PS} = 9.7$ V, $R = 9.9$ K ohm, $V\gamma = 0.7$ V, $r_f = 100$ ohm and $v_i = 0.2\sin\omega t$ V.



Calculate the <u>time-varying</u> diode **current** and **voltage**.

first kill Vi source: we get a DC-circuit



$V_{PS} = I_D \cdot R + V_D$

$9.7 = 9.9 I_D + V_D$ --- ①

this is the equation of V_D

$V_D = I_D r_f + V_\gamma$

$V_D = 100 I_D + 0.7$

$-0.7 = 100 I_D - V_D$ --- ②

$9.7 = 9.9 I_D + V_D$

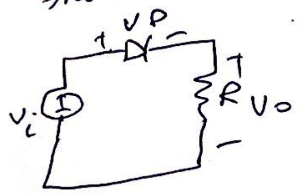
$-0.7 = 100 I_D - V_D$

$9 = 109.9 I_D$ ⟹ $I_D = 0.08$ mA (8.18 * 10^{-5}), $V_D = 8.77$ V (11.97 V)

2.5

$r_d = \frac{V_T}{I_D} = \frac{0.026}{0.08} = 0.325$ (317.98)

then when we switch of vi



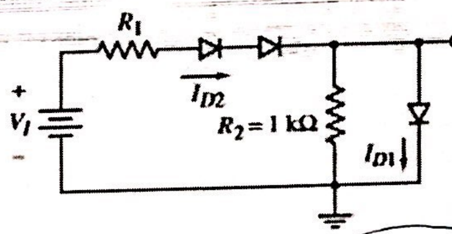
$v_i = i_d(R + r_d)$

then $i_d = \frac{v_i}{R + r_d} = \frac{0.2\sin(wt)}{9.9 + 0.325} = 1.957 * 10^{-5} \sin(wt)$ A

time varying current

$V_d = r_d i_d$

b) Assume each diode in the circuit shown has a cut-in voltage of $V\gamma = 0.7$ V, $r_f = 50$ ohm and $V_I = 6.1$ V. Determine the value of R_1 required such that I_{D1} is one-half the value of I_{D2}.



$V_\gamma = 0.7 = V_{D1}$ because of the sign V_{PS} "forward bias"

$I_{R_2} = \frac{V_{D1}}{R_2} = \frac{0.7}{1 \times 10^3} = 7 * 10^{-4}$ A $= I_{D2}$ → then $V_{D2} = \frac{I_{D2}}{r_f} = \frac{7 * 10^{-4}}{50} = 1.4 * 10^{-5}$

if we apply KVL

$-V_1 + V_{R_1} + 2V_{D2} + V_{R2} = 0$

$-6.1 + V_{R_1} + 1.4 * 10^{-5} + 0.7 = 0$

and $V_{R_2} = V_\gamma = 0.7$

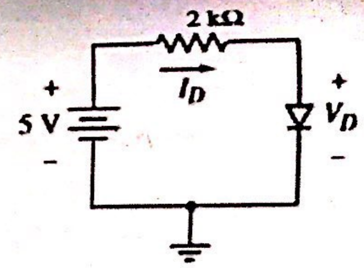
$V_{R_1} = 5.39$ V

2.5

then $R_1 = \frac{V_{R_1}}{I_{D2}} = \frac{5.39}{7 * 10^{-4}} = 7700\ \Omega$

5

Q2 a) Consider the following circuit , where $I_s = 10^{-12}$ A. Determine V_D, and I_D, using the **diode equation** and the **trial and error method** .



$V_{PS} = R I_D + V_D$

$5 = 2*10^3 \cdot \left(I_s\left[e^{\left(\frac{V_D}{V_t}\right)} - 1\right]\right) + V_D$

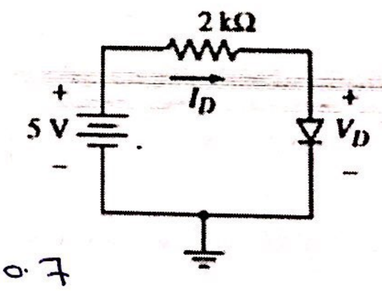
$5 = 2*10^3 \left(10^{-12}\left[e^{\left(\frac{V_D}{0.026}\right)} - 1\right]\right) + V_D$

after many trials

$V_D = 0.5596$ v , $I_D = 2.2$ mA

4

b) Consider the circuit shown . Assume $V_\gamma = 0.7$ V , $r_f = 20$ ohm, and $I_D = 1.2$ mA. Use the piecewise linear model to calculate the voltage drop on the **2 K** ohm resistor.



$V_D = I_D r_f + V_\gamma$

$V_D = (1.2*10^{-3})(20) + 0.7$

$= 0.724$ V

6

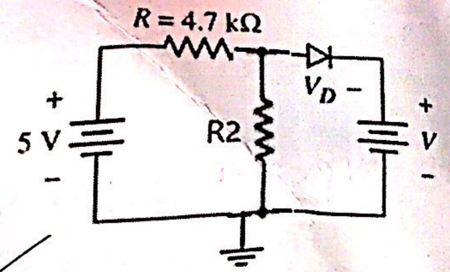
2

What is the power dissipated in the diode?

$P = I_D V_D = 8.688 * 10^{-4}$ w

Scanned with CamScanner

Q4 Consider the circuit shown, where $V\gamma = 0.7$ V, $r_f = 50$ ohm and **R2** = 2 *K* ohm.



i)Fnd the supply voltage V such that the diode current is *0.2mA*.

$V_D = I_D \cdot r_f + V_\gamma$

$= (0.2 * 10^{-3})(50) + 0.7 = 0.71$ V

4.7 KΩ

$V_{R2} = V + 0.71 \Rightarrow$ 5V, R_2, $V + 0.71$

by applaying KVL:

$-5 + 4.7 * 10^3 I_1 + 2 * 10^3 I_1 = 0$

$\frac{5}{6700} = \frac{6700 I_1}{6700}$

$I_1 = 7.46 * 10^{-4}$ A

$V_{R2} = \frac{I_1}{R_2} = \frac{7.46 * 10^{-4}}{2 * 10^3}$

$= 3.73 * 10^{-3}$ V

$V_{R2} = V + 0.71$

$V = 0.71$ V

2.5

ii) Calculate the current in the **R2** resistance when $V = 2$ V.

according to this relation that we determie in the previous question:

$V_{R2} = V + 0.71 \Rightarrow V_{R2} = 1.42$ V

$I_{R2} = \frac{V_{R2}}{R_2} = \frac{1.42}{2 * 10^3} = 7.1 * 10^{-4}$ A

0

2.5

Scanned with CamScanner