Answers should be written in ... Exam Duration: 70 min

Useful information : for silicon , μ_n =1350 cm²/V–s and μ_p = 480 cm²/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) cm²/V–s and μ_p = 300 (480) cm²/V–s.
Determine the conductivity of the material.

$$P_0 = \frac{(n_i)^2}{5\times10^{15}} \Rightarrow 45000\ cm^{-3}$$

$$\sigma = (n\mu_n + p\mu_p)e$$

$$\sigma = (1.6\times10^{-19}) \times ((5\times10^{15}\times1350) + (45000\times480))$$

$$\sigma = 1.08\ (\Omega\text{-}cm)^{-1}$$

6

Determine the applied electric field that induces a drift current density of 175 A/cm².

$$J = \sigma E$$

$$E = \frac{J}{\sigma} = \frac{175}{1.08} = 162.03$$

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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.

$N_d = 10^{16}$, $N_a = 10^{15}$, $C_j = 0.8$, $V_R = 13$

$$V_{bi} = 0.026 \ln\left(\frac{10^{15}\times10^{16}}{(1.5\times10^{10})^2}\right)$$

$$V_{bi} = 0.637$$

$$C_j = \frac{C_{jo}}{\sqrt{1+\frac{V_R}{V_{bi}}}}$$

$$C_{jo} = C_j \times \sqrt{1+\frac{V_R}{V_{bi}}} \Rightarrow$$

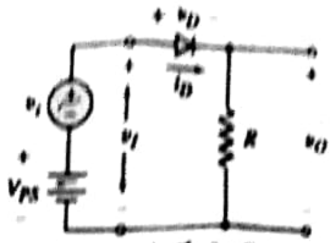
$$C_{jo} = 0.8 \times \sqrt{1+\frac{13}{0.637}}$$

$$C_{jo} = 3.7015\ pF$$

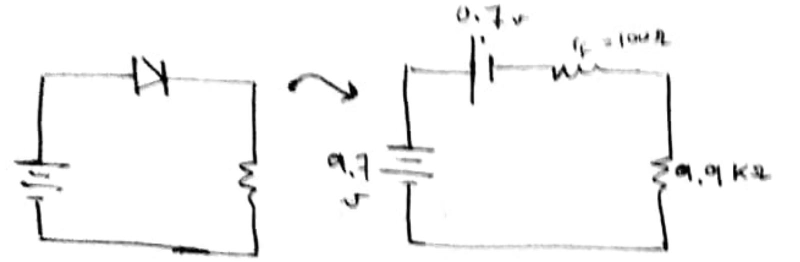
2

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 **time-varying diode current and voltage**.



DC Analysis



$I_D = I_{DQ} + i_D$

$V_D = V_{DQ} + v_D$

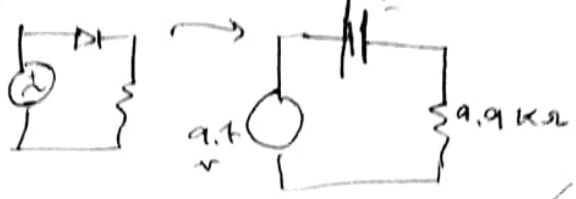
I_{DQ}: $-9.7 + 0.7 + 100 I_{DQ} + 9.9\times10^3 I_{DQ} = 0$

$9 = 10000 I_{DQ}$

$I_{DQ} = 9\times10^{-4}$ A

$V_{DQ} = 0.052 \ln\left(\frac{9\times10^{-4}}{I_S}\right)$

AC Analysis



$r_d = \frac{0.026}{I_{DQ}} = \frac{0.026}{9\times10^{-4}} = 28.88\ \Omega$

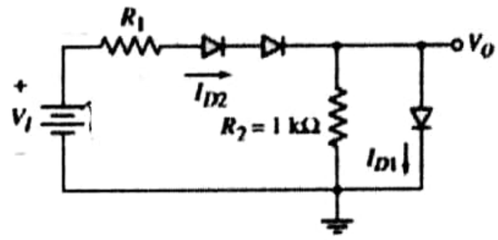
$i_d = \frac{I_{DQ}}{0.026} v_d$

$v_d = \frac{0.026}{I_{DQ}} i_d$

$v_d = 28.88\, i_d$

2

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}.



$I_{D1} = 1.5 I_{D2}$

① — $6.1 = R_1 I_{D2} + 1.4 + 100 I_{D2} + 1\times10^3 (I_{D2} - I_{D1})$

$1.5 I_{D2}$

$0 = 0.7 + 50 I_{D1} + 1\times10^3 (I_{D1} - I_{D2})$ — ②

$4.7 = I_{D2}(R_1 + 100 + 1\times10^3 - 1500)$ — [1]

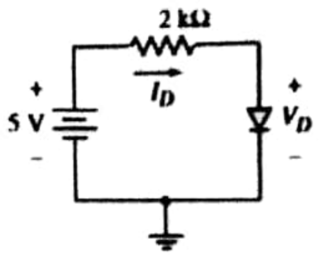
$-0.7 = 75 I_{D2} + 1500 I_{D2} - 1\times10^3 I_{D2}$

$I_{D2} = -2.718 \downarrow = 2.718 \uparrow$

$R = -401.729\ \Omega$

3

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** .



$I_D = I_s\left(e^{\frac{V_D}{0.026}} - 1\right)$

$-5 + 2I_D + V_D = 0$

$5 = 2I_D + V_D$

$5 = 2\left(I_s\left(e^{\frac{V_D}{0.026}} - 1\right)\right) + V_D$

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

$V_D = 0.738$ v

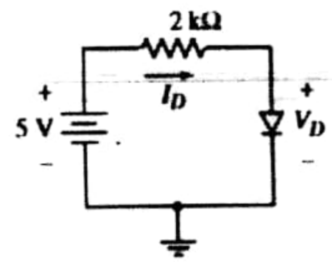
$I_D = 2.131$ A

4.5

0

3

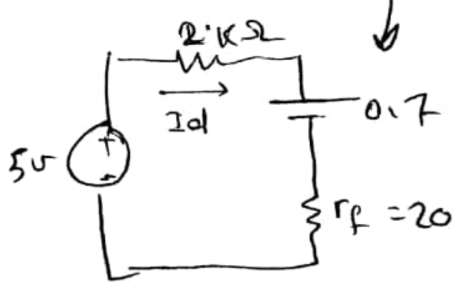
b) Consider the circuit shown . Assume $V\gamma = 0.7$ V , $r_f = 20$ ohm, and $I_D = 1.2$ mA. Use the piecewise linear model to calculate the voltage drop on the **2 K** ohm resistor. V_R = ?



$I_D = 1.2$

$V = I_D R$

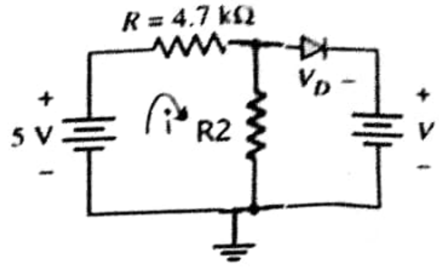
$= 1.2 \times 10^{-3}(2 \times 10^{3}) = 2.400$ v



1.5

What is the power dissipated in the diode?

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*.

$I_D = 0.2$ mA

$5 = 4.7\times10^3 \times i + 2\times10^3(i - I_D)$

$5.2 = i(4.7\times10^3 + 2\times10^3) \longrightarrow i = 7.76$

~~$2\times10^3 \times (I_D + V_D + V = 0$~~

$(0.7 + (50\times I_D))$

$0.4 + 0.7 + 0.01 + V = 0$

$-1.11 = V$

1.5

1.5

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

$(2\times10^3 \times I_D) + 0.7 + (50\times I_D) + 2 = 0$

$I_D = -1.31707A$

0