Some useful Constants:		
$B(Si) = 5.23 \times 10^{15}\ cm^{-3}K^{-3/2}$	$E_g(Si) = 1.1\ eV$	$k = 86 \times 10^{-6} eV/K$
$e = 1.6 \times 10^{-19} C$		
$\mu_n(Si) = 1350\ cm^2/V-s$	$\mu_p(Si) = 480\ cm^2/V-s$	

Question 1: [20-points] 15

A Silicon semiconductor material is to be designed at temperature $330K$, such that the majority carrier hole concentration is $4.5 \times 10^{16}\ cm^{-3}$. Answer the following questions clearly:

a) What is the intrinsic carrier concentration for this sample?

3

$T = 330K$ $\quad p_o = 4.5 \times 10^{16}$

$n_i = B T^{3/2} e^{\frac{-E_g}{2kT}} = 5.23 \times 10^{15} \times (330)^{\frac{3}{2}} e^{\left(\frac{-1.1}{2 \times 86 \times 10^{-6} \times 330}\right)}$

$= 1.2 \times 10^{11}\ cm^{-3}$

b) Should donor or acceptor impurity atoms be used to achieve this concentration?

3

acceptor impurity should be used

c) Determine the minority carrier concentration.

5

$n_o = \frac{n_i^2}{p_o} = \frac{(1.2 \times 10^{11})^2}{4.5 \times 10^{16}} = 3.2 \times 10^5\ cm^{-3}$

d) An applied electric field $E = 15\ V/cm$ is applied to the designed sample, determine the drift current if you know that the cross sectional area for it is $2 \times 10^{-4} cm^2$.

2

$A =$

$J = AE\sigma$ ×2

$\sigma = -e \mu_p p_o + e\mu_n n_o$ too small

$= -(1.6 \times 10^{-19})(480)(4.5 \times 10^{16})$

$J = (2 \times 10^{-4})(15)(-3.456)$

$= -3.456$

$J = -0.01\ A/cm^2$

$= (-)3.456$

?

e) True or False: As impurity concentration increase, the electron mobility decrease. False

0

20

Question 2: [20-points]

For a Silicon pn junction, let $N_a = 5 \times 10^{15}$ and $N_d = 8 \times 10^{17}$ answer the following questions:

a) Determine the built-in potential barrier of the generated pn junction at room temperature.

10

$V_{bi} = V_T \ln\left(\frac{N_a N_d}{n_i^2}\right)$ $n_i(si) = 1.5 \times 10^{10}$

$= 0.026 \ln\left(\frac{5 \times 10^{15} \times 8 \times 10^{17}}{(1.5 \times 10^{10})^2}\right)$ n_i

~~$V_{bi} = 0.4486$ V~~

$V_{bi} = 0.79323$ V

b) If this pn junction diode is operating in forward-bias region, determine the increase in forward bias voltage that will cause a factor of 22 increase in current.

10

$\frac{I_{D2}}{I_{D1}} = e^{\left(\frac{V_{D2} - V_{D1}}{V_T}\right)}$ $\frac{e^{\left(\frac{V_{D2}}{V_T}\right)}}{e^{\frac{V_{D1}}{V_T}}}$

$\Delta V = V_T \ln\left(\frac{I_{D2}}{I_{D1}}\right)$

$= 0.026 \ln(22)$

$\Delta V = 0.08$ V → increase in forward bias voltage

15

Question 3: [20-points]

Part 3.1: For the diode circuit shown in Figure Q.3.Part 1, it has a reverse-saturation current of $I_S = 5 \times 10^{-13}$, assume $T = 300K$, answer the following questions:

a) What is the input voltage V_{PS} that will produce $V_D = 0.5V$.

0 $V_D = V_{PS}\left(\frac{R_2}{R_1+R_2}\right)$

$0.5 = V_{PS}\left(\frac{20}{60}\right)$

$V_{PS} = 1.5V$

R+b = 0.33

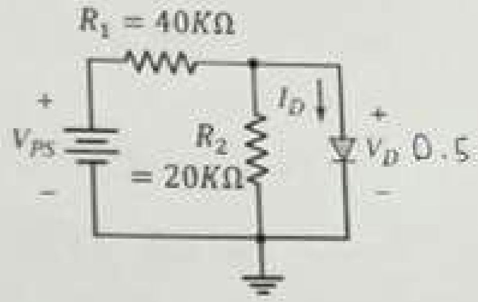


Figure Q.3.Part 1

5 b) Determine the I_D value

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

$= 5\times10^{-13}\left(e^{\frac{0.5}{0.026}} - 1\right)$

$I_D = 1.12\times10^{-4}$

Part 3.2: For the circuit shown in Q.3.Part 2, assume $V_\gamma = 0.6V$, find I and V_O.

10 $I = \frac{12 - 0.6}{22\,K\Omega} = 0.518mA$

$V = .6 + (0.518 \times 12)\,mA\,K - 3 = 3.816\,V$

3.82

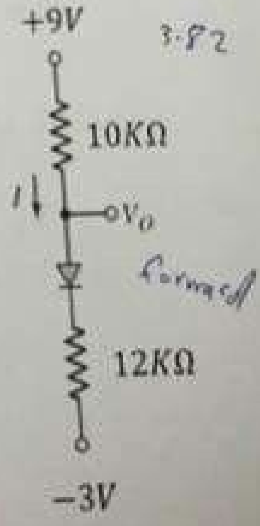


Figure Q.3.Part 2

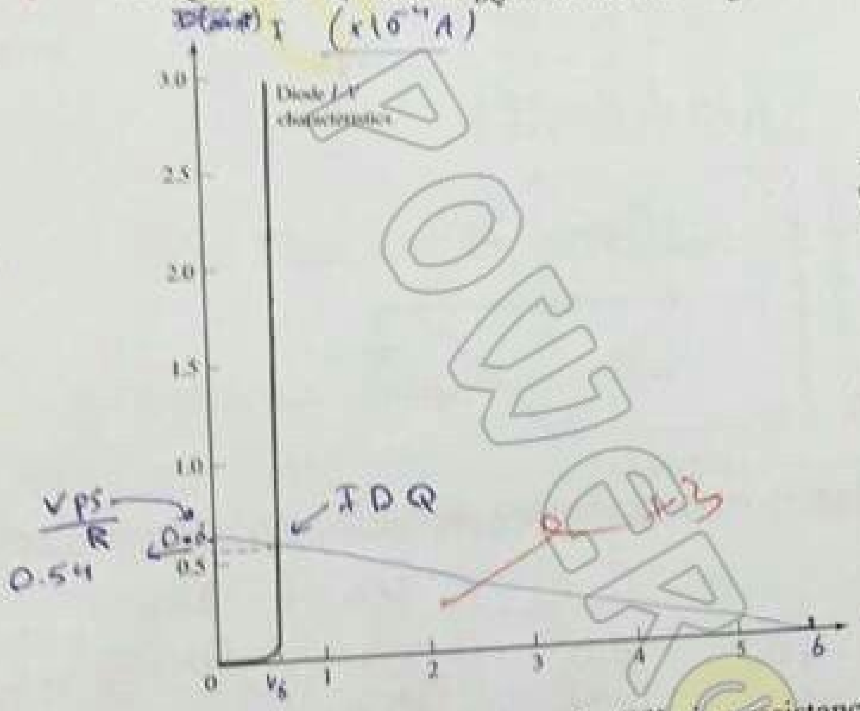
17

Question 4: [20-points]

For the circuit shown in Figure Q.4, at room temperature, assume circuit parameters: $V_{PS} = 6V$, and $R = 1k\Omega$. The diode $V_\gamma = 0.6V$. A sinusoidal voltage is superimposed on V_{PS} such that $v_i = 0.2\sin(\omega t)$. As you learned in the class, do the following:

a) For this circuit, draw the related load line over the diode characteristic curve given in the figure below, what is I_{DQ} from the drawing?

7



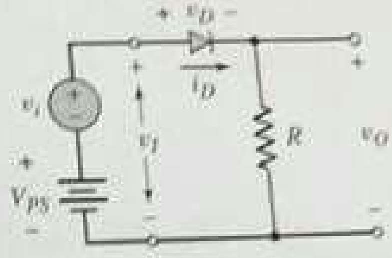


Figure Q.4

$\frac{6}{1K} = 6\times10^{-4}$

b) Calculate the small-signal diode diffusion resistance, assume $T = 300K$.

6

$r_d = \frac{V_T}{I_{DQ}} = \frac{0.026}{5.4\times10^{-3}} = 4.814\ \Omega$

$I_{DQ} = \frac{V_{PS} - V_\gamma}{R} = \frac{6-0.6}{1K\Omega} = 5.4\ mA$ (+4)

c) What is the "only" ac component of the output voltage v_o?

4

$i_d = \frac{v_i \times R}{r_d + R} = \frac{0.2\sin(\omega t) \times R}{(4.8 + 1K)} = 1.99\times10^{-4}\ \sin(\omega t) \times R$

$v_o = 0.199 \sin(\omega t)\ v$

−2

12

Question 5: [20-points]
For the full-bridge rectifier circuit shown in Figure Q.5, if the turns ratio of the attached transformer is 22, the input voltage v_I was $220V_{RMS}$, each diode has the following cut-in voltages shown in the table, answer the following questions:

D1	$V_\gamma = 0.5$
D2	$V_\gamma = 0.6$
D3	$V_\gamma = 0.7$
D4	$V_\gamma = 0.8$

$V_S = \frac{220 \times \sqrt{2}}{22} = 10\sqrt{2} = 14.14\,V$

$\frac{N_1}{N_2} = 22$

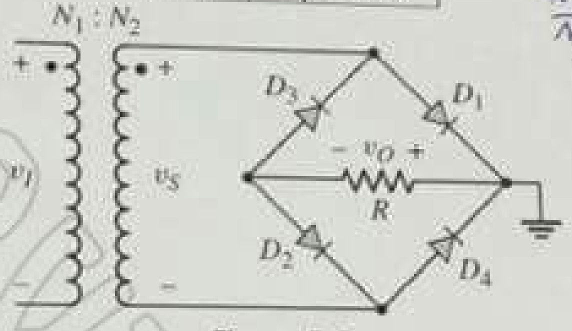


Figure Q.5

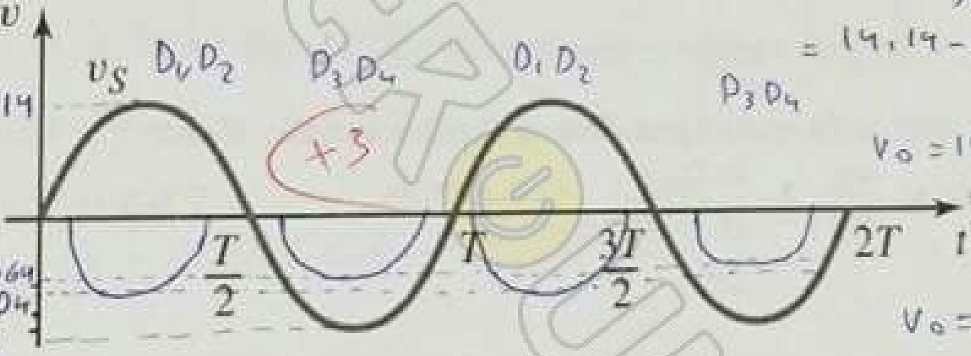
$V_S = 14.14\,V$ ×5

(10) a) Draw the output voltage v_O on the graph below showing the real values of v_S and v_O voltages.

$V_O = -(V_S - 2V_\gamma)$

$D_1 D_2$: $= 14.14 - (0.5 + 0.6)$

$D_3 D_4$: $V_O = 14.14 - (0.7 + 0.8)$



$= $

$V_O =$

+3

+1 −12.64

+1 −13.04

b) Determine the peak inverse voltage rating for each diode in the circuit.

+2

$PIV = V_S - V_\gamma$

$D_1: 14.14 - 0.5 = 13.64$

$D_2: 14.14 - 0.6 = 13.54$

$D_3: 14.14 - 0.7 = 13.44$

$D_4: 14.14 - 0.8 = 13.34$

PIV