ASSIGNMENT - 02

PH3104 Electronics SABARNO SAHA

Q1

1. Find the bias for which the reverse current in a silicon (Si) pn junction diode is half its saturation value at room temperature. [4]

We have

$$I_D = I_S \left[e^{V_D/NV_T} - 1 \right]$$

where $V_T = \frac{k_B T}{e}$ $N :=$ emission coefficient

we want V_D for which $I_D = -\frac{I_S}{2}$

$$-\frac{I_S}{2} = I_S \left(e^{V_D/NV_T} - 1 \right)$$

$$\Rightarrow \frac{1}{2} = e^{V_D/NV_T}$$

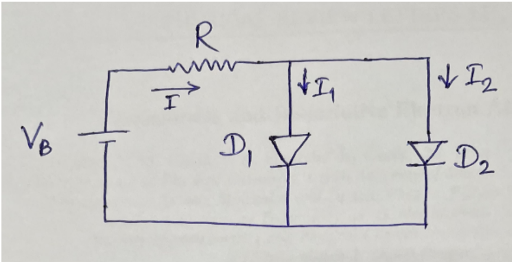
$$\Rightarrow V_D = N V_T \ln(1/2)$$

At room temperature and using the fact that Silicon has $N = 2$

$$\boxed{V_D \approx -35.54 \text{ mV}}$$

Q

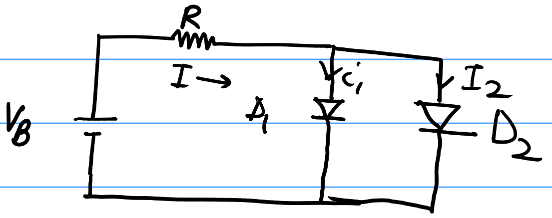
2. Consider the following network with R = 500 Ω and V_B = 5 V:



The cutin voltage and forward resistance for diode D_1 and D_2 are 0.7 V & 0.6 V and 50 Ω & 75 Ω, respectively. Calculate (a) the currents I_1, I_2 and I; (b) the voltage V_0; and (c) the powers delivered to D_1 and D_2. [4+2+4]

Ans:-

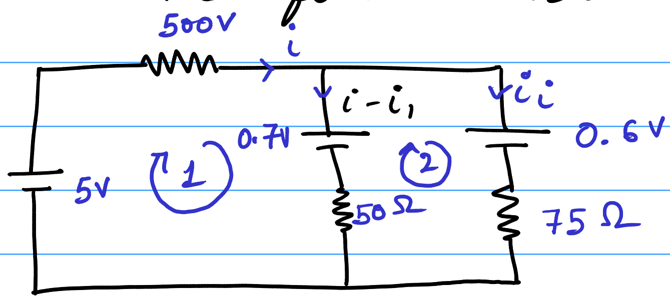
a)



We have $R = 500\,\Omega$

$V_B = 5\,\Omega$

Now we know the Diodes to be forward biased, we can replace the diode with a cell of the cutin voltage and a resistor with the forward resistance



L2 → $0.7 - 0.6 - 75\, i_1 + 50(i - i_1) = 0$

L1 → $5 - 500\, i - 0.7 - 50\,(i - i_1) = 0$

L2 $125 i_1 - 50 i = 0.1 \Rightarrow 250 i_1 - 100 i = 0.2$

L1 $550 i - 50 i_1 = 4.3 \Rightarrow 2750 i - 250 i_1 = 21.5$

$\Rightarrow 2650 i = 21.7 \Rightarrow i = 8.188$ mA

$$125 i_1 - 50\, i = 0.1$$

$$\Rightarrow i_1 = \frac{0.1 + 50\, i}{125} = 4.075 \text{ mA}$$

We also have $\quad I_1 = i - i_1$

$I_2 = i_2$

$I = i$

$$\boxed{I = 8.188 \text{ mA}, \quad I_1 = 4.113 \text{ mA}, \quad I_2 = 4.075 \text{ mA}}$$

b) Voltage across Diode $= V_o$

$$V_o = 5V - 500\, i$$

$$= 0.906 \text{ V}$$

$$\boxed{V_o = 0.906 \text{ V}}$$

c) Powers Delivered to D_1 and D_2 $\qquad i_1 = I_1$

$$P_{D_1} = V_{D_1} i_1 + i_1^2 R_{D_1}$$

$$= 0.7 \times 4.113 + (4.112)^2 \times 10^{-3} \times 50 \quad \text{mW}$$

$$= 3.73 \text{ mW}$$

$$P_{D_2} = V_{D_2} i_2 + i_2^2 R_{D_2}$$

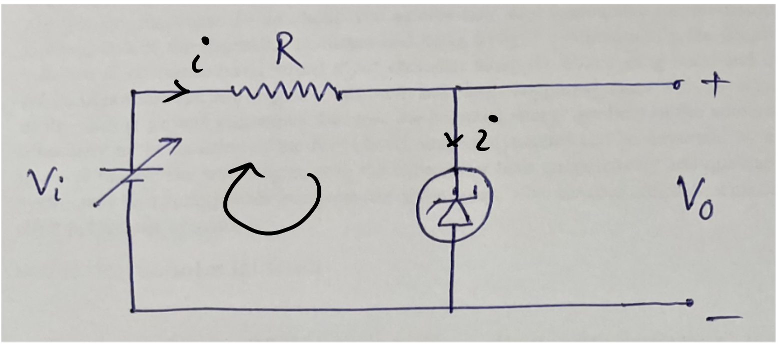
$$= 0.6 \times 4.075 + (4.075)^2 \times 10^{-3} \times 75 \text{ mW}$$

$$= 3.69 \text{ mW}$$

$$\boxed{P_{D_1} = 3.73 \text{mW}, \quad P_{D_2} = 3.69 \text{ mW}}$$

Q3)

3. Considering the following circuit with R = 800 Ω.



Also consider that the Zener diode is non-ideal, having a knee voltage V_{z0} = 9 V and a dynamic resistance r_z = 5 Ω. If the input voltage varies from 15 V to 30 V, determine the range of variation of the output voltage V_o. Comment on the result. [5+1]

The Zener Diode is reverse biased.

We use the Linear Zener Diode Model working in Reverse Bias

$$V_Z = V_{Z0} + i_Z R_Z$$

$$\Rightarrow V_Z = 9 + i\,5$$

Using Kirchoff's Voltage Law we have,

$$V_i - iR - V_Z = 0$$

$$\Rightarrow V_i = iR + V_Z$$

$$= (V_Z - V_{Z0})\frac{R}{R_Z} + V_Z$$

The output voltage of the Zener Diode under a linear model ranges bet

$9.03V \leq V_o \leq 9.13V$

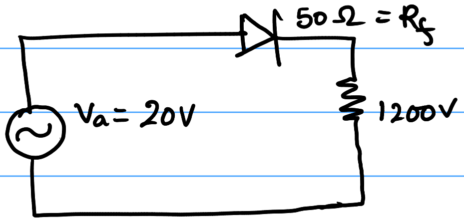
$$\Rightarrow V_Z = \left(V_i + V_{Z0}\,R/R_Z\right)\left(\frac{1}{1+\frac{R}{R_Z}}\right)$$

$$\Rightarrow 9.03 \leq V_Z \leq 9.13$$

The voltage variation should be const for an ideal zener diode, but since it is non ideal, there is slight variation.

4. A diode having forward resistance of 50 Ω, supplies power to a load resistance 1200 Ω from a 20 V (rms) source. Calculate (a) the dc load current, (b) the ram value to ac load current, (c) the dc voltage across the diode, (d) the dc output power, (e) the conversion efficiency, and the percentage regulation. [6]

Q4)



$V_p = \sqrt{2}\, V_{rms} = 20\sqrt{2}\,V$

$I_p = V_p / R_f + R_L = 22.6\,mA$

a) DC Load Current :-

Due to the Diode, we modify our current fxn to be

$$i = \begin{cases} i_p \sin(\varepsilon) & 0 < \varepsilon \leq \pi \\ 0 & \pi \leq \varepsilon \leq 2\pi \end{cases}$$

$$i_{dc} = \frac{1}{2\pi}\int_0^{2\pi} i^2\, d\varepsilon$$

$$= \frac{i_p}{2\pi}\int_0^{\pi} \sin(\varepsilon)\, d\varepsilon$$

$$\Rightarrow \frac{i_p}{2\pi} \cos(\varepsilon)\Big|_{\pi}^{0} \Rightarrow i_{dc} = \frac{i_p}{\pi} \approx \boxed{7.19\,mA}$$

b) $$i_{rms} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} i^2\, d\varepsilon} = \sqrt{\frac{I_p}{2\pi}\int_0^{\pi} \sin^2\varepsilon\, d\varepsilon}$$

$$= I_p/2 \qquad i_{rms} = I_p/2$$

Rms value to AC current $= \sqrt{\frac{I_p^2}{4} - i_{dc}^2} \approx \boxed{8.7\,mA}$

c) From KVL we have,

$$V_{dc} = \frac{1}{2\pi}\left(\int^{\pi} (V_p - i_p R_L) \sin\varepsilon\, d\varepsilon + \int^{2\pi} V_p \sin\varepsilon\, d\varepsilon\right)$$

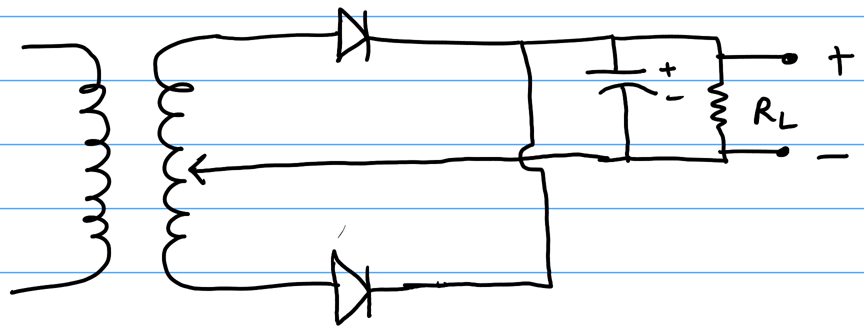
(d) Dc output power = $P_{dc} = i_{dc}^2 \times R_L \approx 62.2\ mW$

(e) Conversion Efficiency $= \dfrac{40.6}{1 + R_f/R_L} \approx 39\%$

(f) Percentage regulation $= \dfrac{R_f \times 100}{R_L} = 4.17\%$

Q5)

5. The output voltage across a load resistance R_L = 100 Ω of a capacitor filter with C = 1100 μF connected to a full-wave rectifier supply with a line frequency of 50 Hz has a dc value of 9 V and a peak-to-peak ripple voltage of 0.8 V. Calculate the ripple factor from the voltage values and compare it with the theoretical value expected from the filter components. [2 + 2]



$R_L = 100\,\Omega$ $\quad C = 1100\ \mu F$ $\quad f = 50\ Hz$

$V_{dc} = 9V$ $\quad V_{rpp} = 0.8\ V$

$$r_{expt} = \frac{V_{rpp}}{2\sqrt{3}\ V_{dc}} = \frac{2}{45\sqrt{3}} = 0.257$$

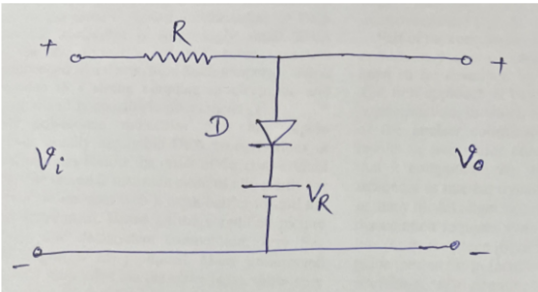
$$r_{Th} = \frac{1}{4\sqrt{3}\ fCR_L} = 0.0262$$

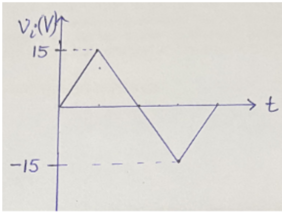
Comparing the values, we have,

$$\Rightarrow \frac{|0.0262 - 0.257|}{0.0262} \times 100\% = 2.22\%$$

Q6)

6. Consider the following Clipping circuit with R = 4kΩ, V_R = 3 V and the diode is an ideal one. The input voltage v_i has the waveform of as given below:





Fine the output voltage (v_o) and the diode current (i) waveforms. [2+2]

During the ⊕ve half cycle $V_i(t) \geqslant 0$

When $v_i < 3$ diode is at reverse bias, so V_o measures v_i

When $v_i \geqslant 3$ → forward bias, there is constant voltage = 3V ($\forall t$ s.t $t \geqslant 3$)

During -ve half

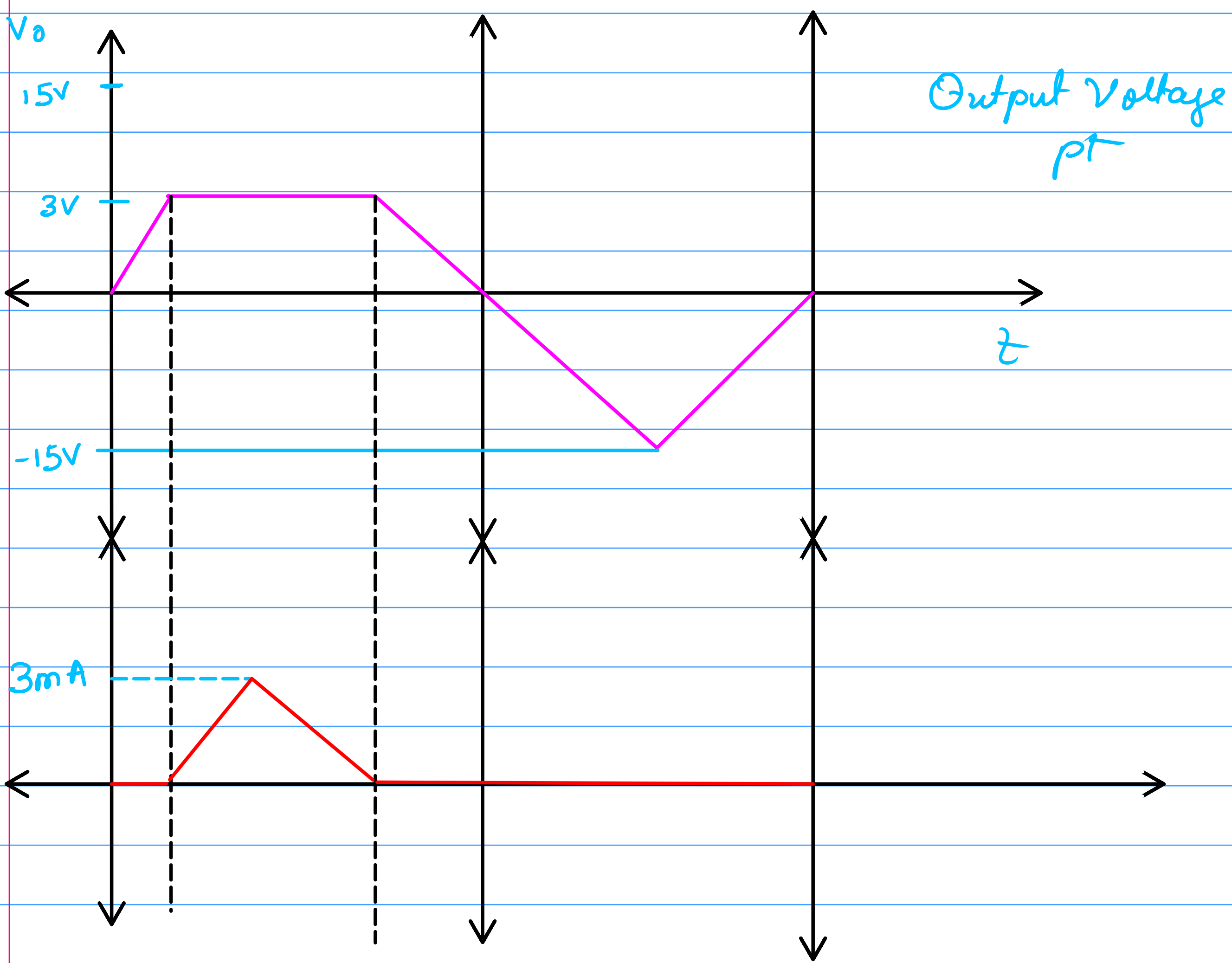
The diode is always at reverse bias, so the measured voltage is always V_i

Diode current (+ve half)

When $v_i \leq 3$, no current flows

When $v_i > 3$ $\quad i = \frac{v_i - 3}{R}$

When in One half → i=0 is always reversed bias.



Let t_1 and t_2 be such that

$\forall \; t \in [t_1, t_2]$

$v_i(t) \geq 3$

Then

$$V_o(t) = \begin{cases} 60t/T & 0 \leq t \leq t_1 \\ 3 & t_1 \leq t \leq t_2 \\ 30 - 60t/T & t_1 \leq t \leq 3T/4 \\ \frac{60t}{T} - 60 & 3T/4 \leq t \leq T \end{cases}$$

Diode current

$$I_{dc} = \begin{cases} 0 & 0 \leq t \leq t_1 \\ \frac{60t}{TR} - \frac{3}{R} & t_1 \leq t \leq T/4 \\ \frac{27}{R} - \frac{60t}{R} & T/4 \leq t \leq t_2 \\ 0 & t_2 \leq t \leq T \end{cases}$$