8th September, 2016

<u>Home Assignment – 6</u>

1. For the circuit shown in **Fig. 1,** using ideal diodes, find the voltage (V_0) and current (I) indicated.

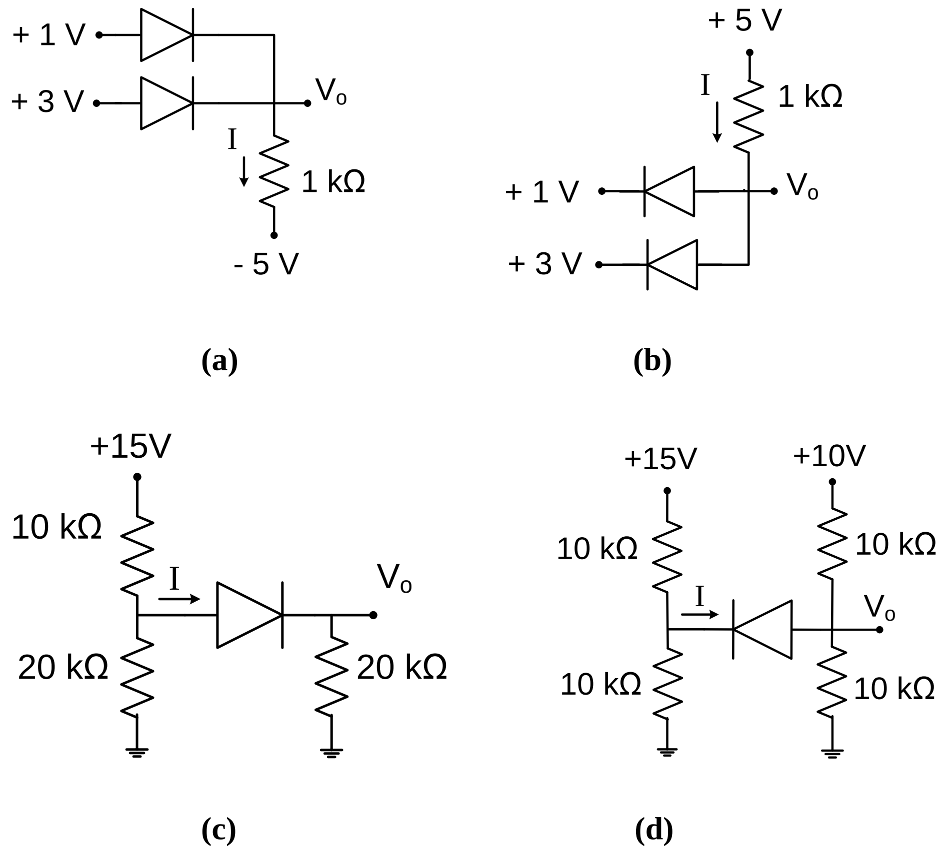


Fig. 1

2. For the circuit shown in **Fig. 2**, sketch the output voltage waveform with time. When diode conducts, voltage drop is 0.7 V and forward resistance is 50 **Ω**. In OFF state diode is open circuit. Assume $V_i = 15\sin(\omega t)\,\text{V}$.

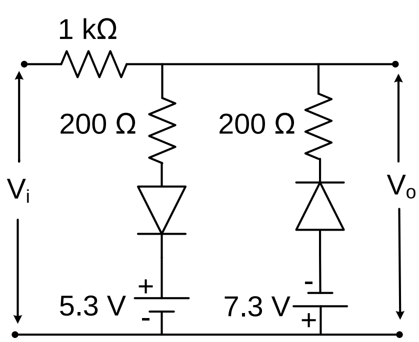


Fig. 2

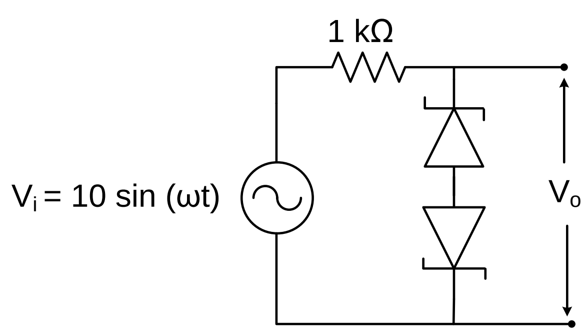


Fig. 3

3. The Zener diodes used in **Fig. 3** have the following characteristics: Forward drop = 0.7 V; Zener voltage = - 7 V; R_f (Forward Resistance) = 20 Ω ; R_z (Resistance in Zener region) = 10 Ω. Sketch the output waveform V_o with time.

4. (a) Determine $\mathbf{V_L}$, $\mathbf{I_L}$, $\mathbf{I_Z}$ and $\mathbf{I_R}$ for the voltage regulator network shown in **Fig. 4** if $\mathbf{R_L}$ **= 180 Ω**.
   (b) Repeat part (a) if $\mathbf{R_L}$ **= 470 Ω**.
   (c) Determine the value of $\mathbf{R_L}$ that will establish maximum power conditions in the Zener diodes.
   (d) Determine the minimum value of $\mathbf{R_L}$ to ensure that the Zener diode in "ON" state.

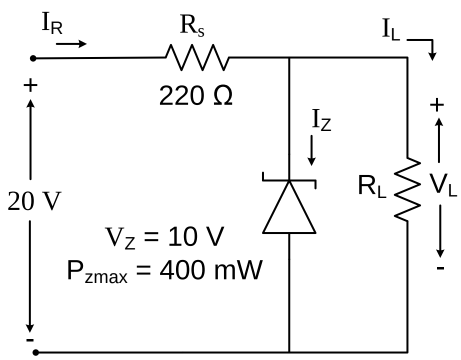


Fig. 4

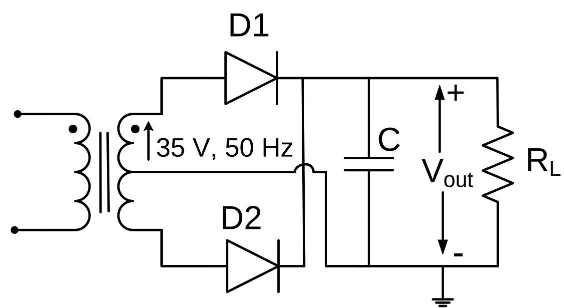


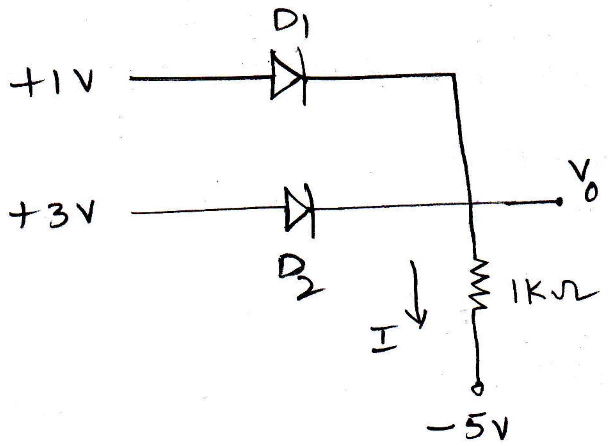
Fig. 5

5. A Full Wave Rectifier is shown in **Fig. 5.** The center tapped transformer voltage is 35 V rms, 50 Hz. A 160 µF capacitor is connected in the output to filter out the load voltage ripple. A load of 250 Ω is connected in parallel with filter capacitor. Assume that the cut-off voltage of diode is 0.7 V and forward biased resistance is zero.
   (a) Plot the output voltage $\mathbf{V_o}$ and diode current $\mathbf{i_D}$ at steady state.
   (b) Calculate the ripple voltage and maximum diode current.
   (c) Calculate the peak inverse voltage.

6. A Full Wave Bridge Rectifier is used to design a dc power supply that provides an average dc output voltage of 15 V on which a maximum of ±1 V ripple is allowed. The rectifier feeds a load of 150 Ω. The rectifier is fed from the line voltage (120 V rms, 60 Hz) through a transformer. The diodes available have 0.7 V drop when conducting.
   (a) Specify the **rms** voltage that must appear across the transformer secondary.
   (b) Find the required value of the filter capacitor.
   (c) Find the **PIV rating** of the diode.

Soln. 1

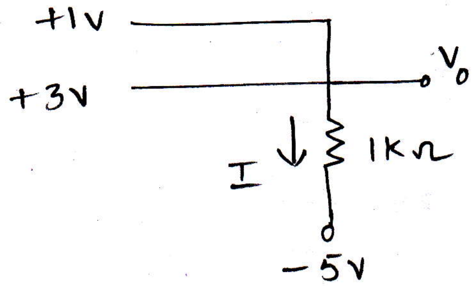
(a)



case (i) :-

Assume both D_1 and D_2 are ON.

Then the circuit reduces to,

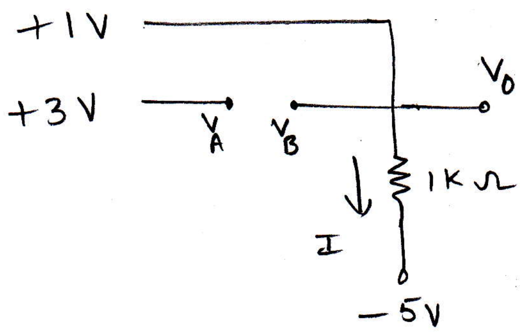


In can be seen that the case is contradicting. This implies D_1 & D_2 cannot be 'ON' simultaneously. Hence, the assumption is false.

case (ii) :-

Assume D_1 is ON and D_2 is OFF.

Then the circuit reduces to,



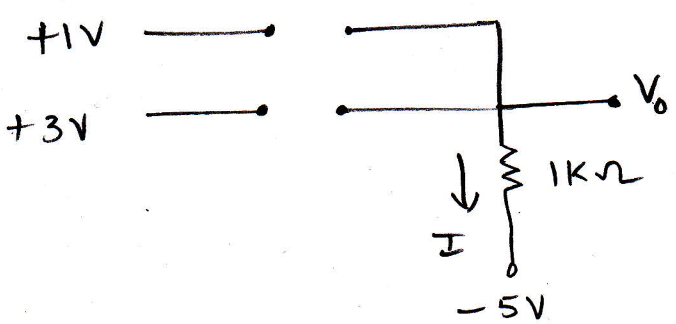
Here, $V_0 = +1V = V_B$

But $V_A = 3V >> V_B \Rightarrow D_2$ must be ON.

Hence, our assumption is False.

case (iii) :-

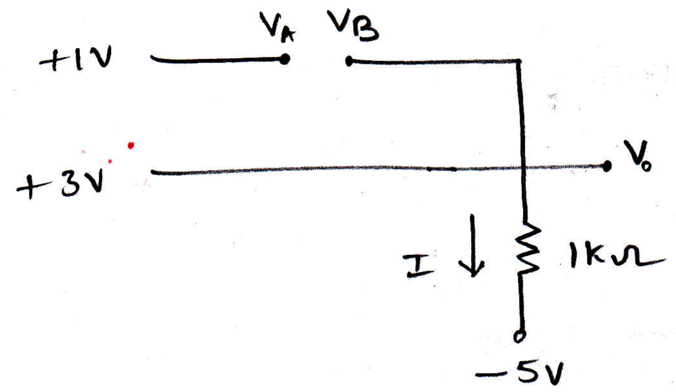
Assume both D_1 and D_2 are OFF.



Here $V_0 = -5V \Rightarrow$ this implies D_1 and D_2 must be ON [∵ as in case (i)]. Again the assumption fails.

case (iv):- Assume D_1 is OFF and D_2 is ON.

Then the circuit reduces to,



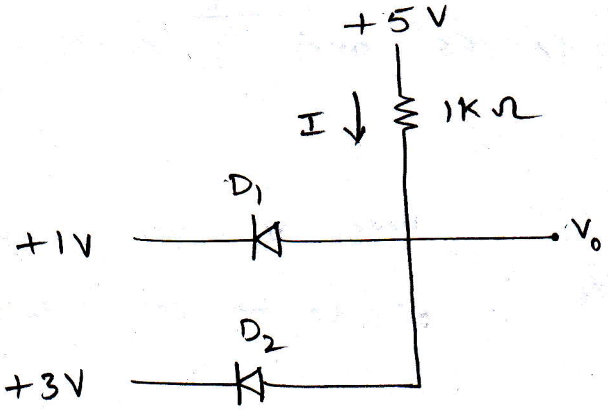
Here, $V_0 = +3V \Rightarrow$ which implies D_1 is OFF $[V_B > V_A]$

Hence the assumption is True.

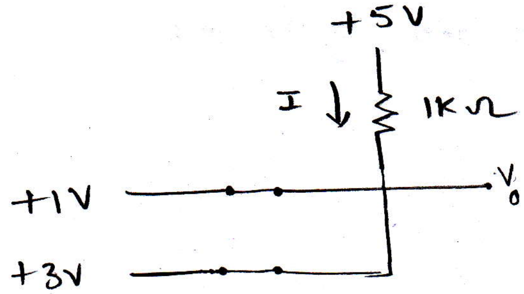
$$\Rightarrow I = \frac{V_0 - (-5V)}{1K\Omega} = \frac{3V - (-5V)}{1K\Omega} = 8\,mA$$

$$\therefore \boxed{\begin{aligned} V_0 &= 3V \\ I &= 8\,mA \end{aligned}}$$

(b)



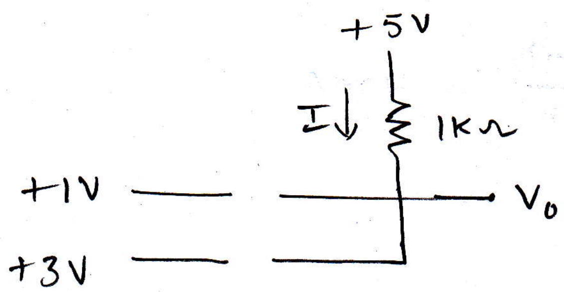
Case (i):- Assume both D_1 & D_2 are 'ON'



It can be seen that the case is contradicting and the two diodes cannot be 'ON' simultaneously.

Hence, the assumption is False.

Case (ii):- Assume both D_1 & D_2 are OFF.

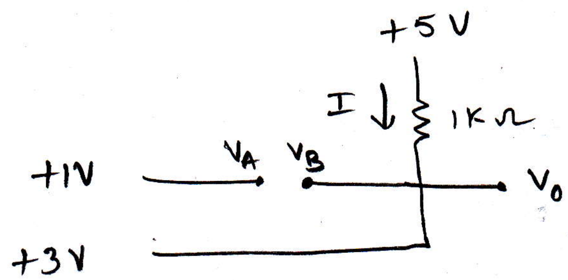


Then $V_o = 5V$, which forces D_1 and D_2 to be forward biased; which again is a malcondition.

So, the assumption fails.

Case (iii) :-

Assume D_1 is OFF and D_2 is ON.

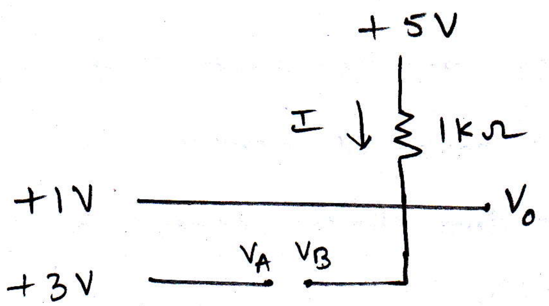


Here, $V_o = 3V$ which forces D_1 to be ON. $[V_B > V_A]$

Hence, the assumption is incorrect.

Case (iv) :-

Assume D_1 is ON and D_2 is OFF.



Here, $V_o = 1V$ which forces D_2 to be OFF. $[V_B < V_A]$

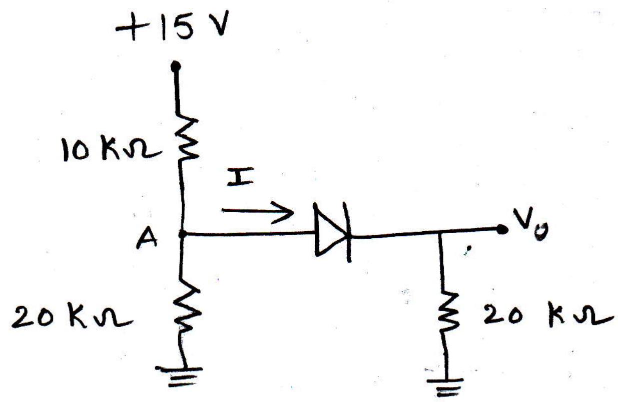
So the assumption is correct.

Now,

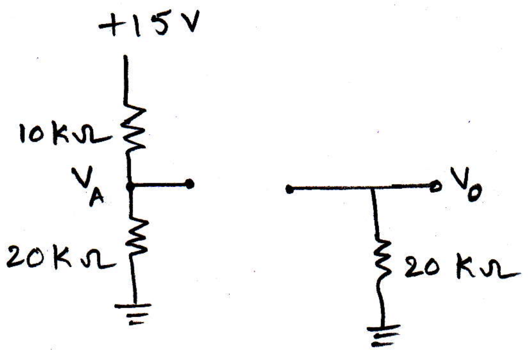
$$I = \frac{5 - V_0}{1K} = \frac{5-1}{1K} = 4mA.$$

$$\therefore \boxed{\begin{aligned} V_o &= 1\,V \\ I &= 4mA \end{aligned}}$$

(c)



Assume the diode is OFF. Then,



$$V_A = 15 \times \frac{20\,K}{20K + 10K}$$

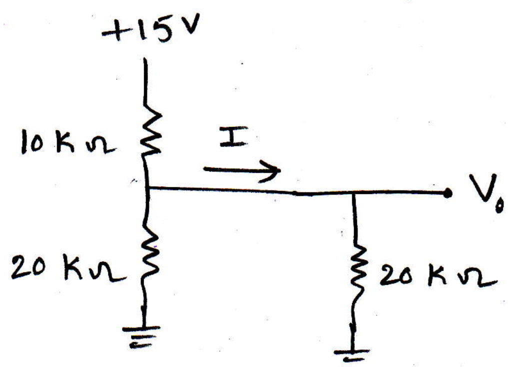
$$= 15 \times \frac{20}{30} = 10\,V$$

and $V_0 = 0$

since $V_A > V_0 \Rightarrow$ Diode is Forward Biased.

So the assumption is False.

when the diode is ON,



$$V_0 = 15 \times \frac{(20K \parallel 20K)}{10K + [20K \parallel 20K]}$$

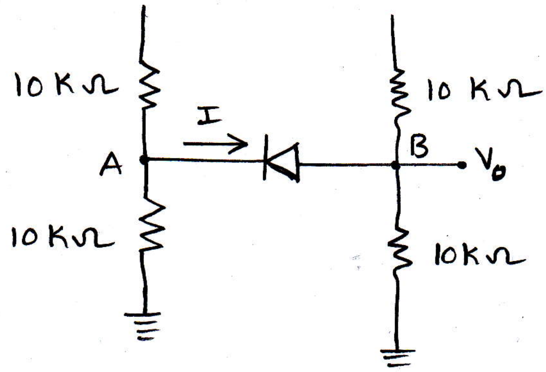
$$= 15 \times \frac{10K}{20K} = 7.5\,V$$

and,

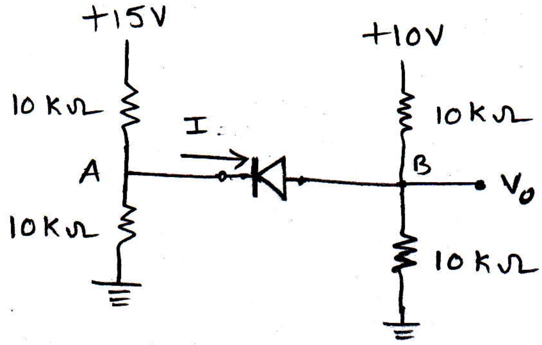
$$I = \frac{V_0}{20K} = \frac{7.5}{20K\Omega} = 0.375\,mA$$

$\therefore$ $$\boxed{\begin{array}{l} V_0 = 7.5\,V \\ I = 0.375\,mA \end{array}}$$

(d)



Assume that, the diode is OFF. Then,



Now,

$$V_A = 15 \times \frac{10K}{10K + 10K} = \frac{15}{2} = 7.5V$$

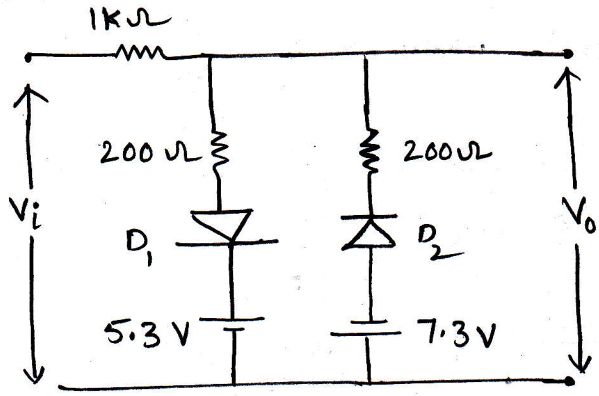
$$V_B = 10 \times \frac{10K}{10K + 10K} = 10 \times \frac{1}{2} = 5V \Rightarrow V_B = 5V$$

Since $V_A > V_B$ ie., Diode is reverse biased i.e, OFF.

So, the assumption is correct and as the diode is reverse-biased, no current will flow through it i.e, $I = 0$.

$\therefore V_o = V_B = 5V$

$\therefore$ $\boxed{\begin{array}{l} V_o = 5V \\ I = 0A \end{array}}$

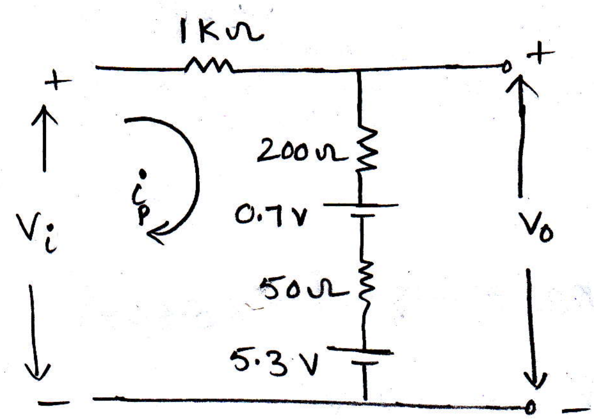


$V_i = 15 \sin(\omega t)$

→ During +ve half cycle of 'V_i',

D_1 conducts and D_2 gets OFF.

Then the circuit reduces to,



$$i_p = \frac{V_i - 0.7 - 5.3}{1000 + 200 + 50} = \frac{V_i - 6}{1250}$$

for $V_i < 6V \Rightarrow V_o = V_i$ (D_1 will conduct when $V_i \geq 6V$)

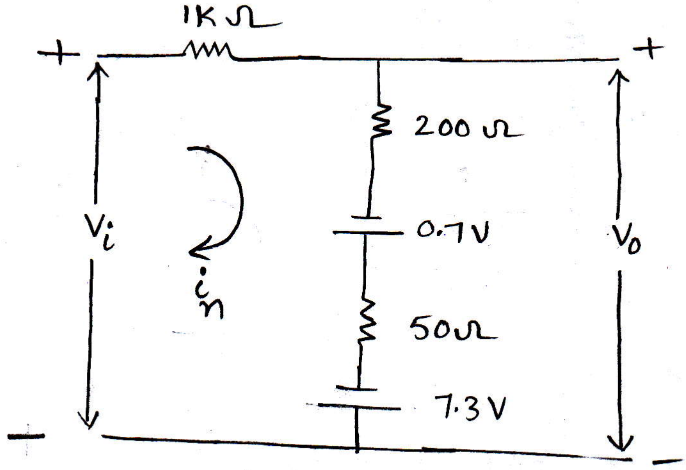
$$i_{p\,max} = \frac{V_{i,max} - 6}{1250} = \frac{15-6}{1250} = \frac{9}{1250} = 7.2\text{ mA}$$

$$V_{o,max} = 15 - (1K \times 7.2 \times 10^{-3}) = 7.8\text{ V}$$

→ During −ve half cycle of 'V_i'

D_2 conducts and D_1 gets OFF.

Then the circuit reduces to,



$$i_n = \frac{+V_i + 7.3 + 0.7}{1000 + 200 + 50} = \frac{V_i + 8}{1250} \Rightarrow \begin{array}{l}\text{For } -8V \le V_i \le 0V \\ V_o = V_i\end{array}$$

(D_2 will conduct for $V_i \leq (-8V)$)

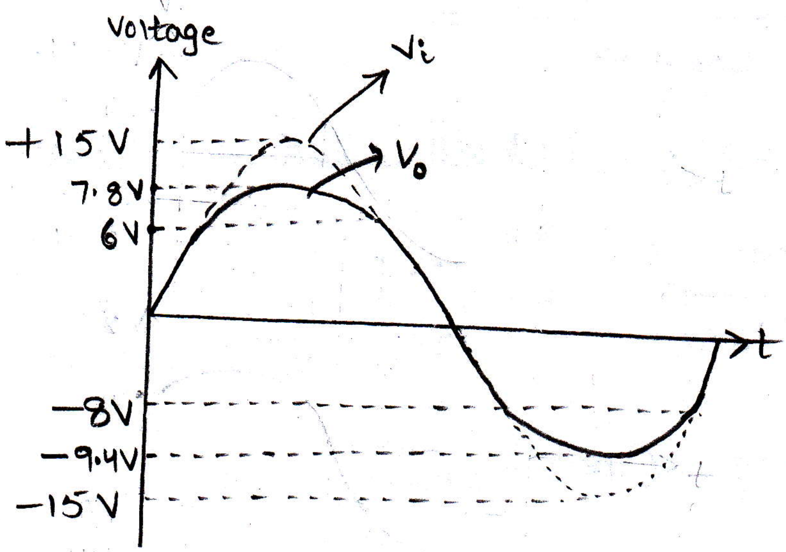
when $V_i = -15V \Rightarrow i_{n,min} = \dfrac{-15+8}{1250} = -\dfrac{7}{1250}$

$= -5.6$ mA

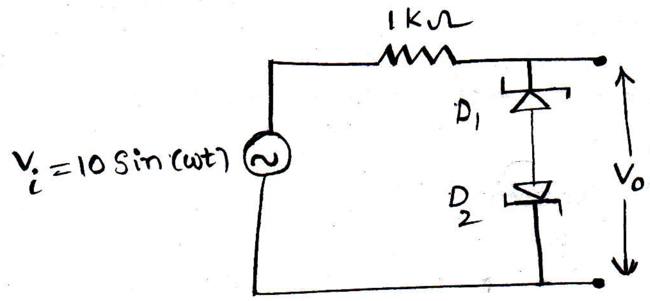
$\therefore V_{o,min} = -15 - i_{n,min} \cdot 1K\Omega = -15 + [1K \times 5.6mA]$

$= (-15 + 5.6)V = -9.4$ V

The desired waveforms are sketched below.



For $-8V \le V_i \le 6V$
D_1 and D_2 are OFF
$\Rightarrow V_o = V_i$



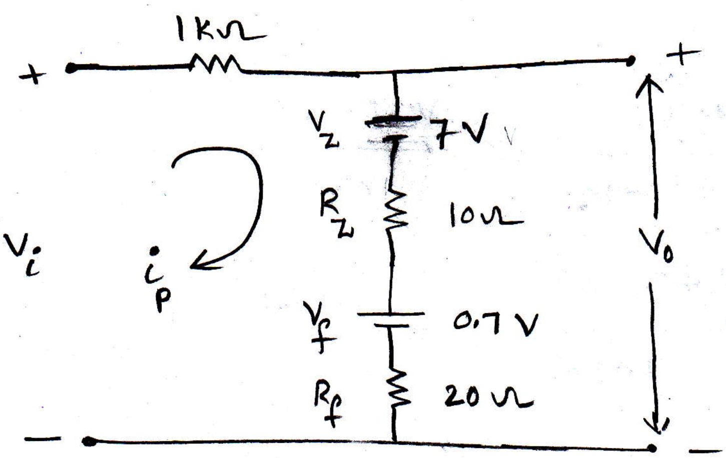
given $V_f = 0.7\,V$; $V_z = -7\,V$; $R_f = 20\,\Omega$

and $R_z = 10\,\Omega$

→ During +ve half cycle,

D_1 acts as a zener and D_2 acts as a normal diode

The circuit reduces to,



when $V_i < (7+0.7 = 7.7V) \Rightarrow V_o = V_i$

when $V_i \geq 7.7\,V$,

$$i_p = \frac{V_i - 0.7 - 7}{1000+10+20} = \frac{V_i - 7.7}{1030}$$

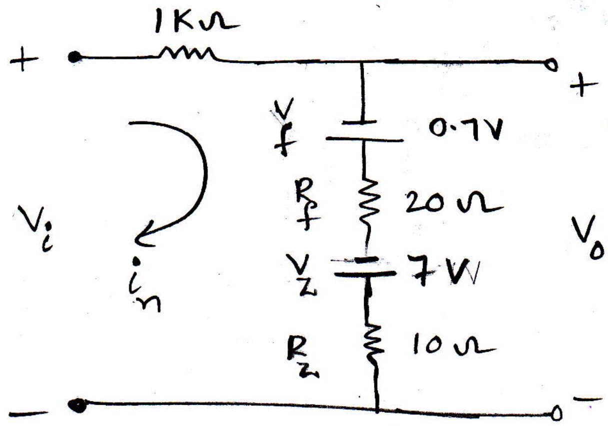
$$\Rightarrow i_{P,max} = \frac{V_{i,max} - 7.7}{1030} = \frac{10 - 7.7}{1030} = 2.23\,mA$$

$$\therefore V_{o,max} = V_{i,max} - [1K \times i_{P,max}] = 10 - 2.23 = 7.77\,V$$

During −ve half cycle,

D_1 acts as a normal diode

and D_2 acts as a zener.



For $-7.7V < V_i < 0$; $V_o = V_i$

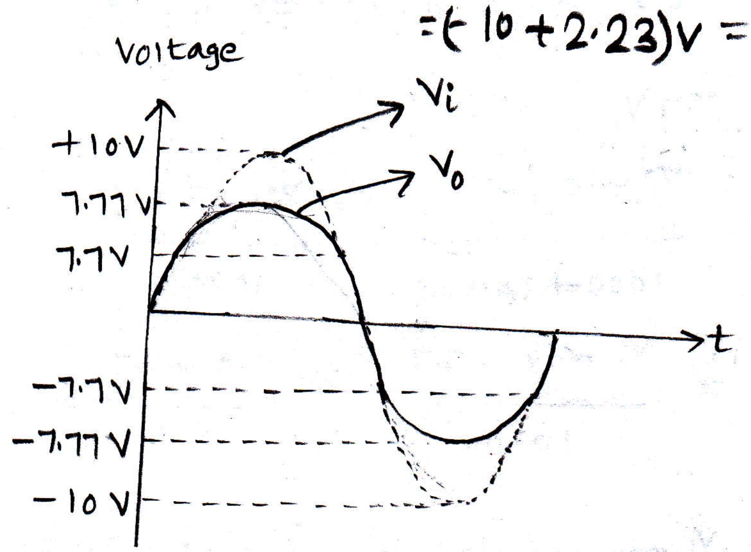
for $V_i < -7.7V$,

$$i_n = \frac{V_i + 7.7}{1000+20+10} = \frac{V_i + 7.7}{1030}$$

$$\Rightarrow i_{n,min} = \frac{V_{i,min} + 7.7}{1030} = \frac{-10+7.7}{1030} = -2.23mA.$$

$$V_{o,min} = -10 - i_n \cdot 1K\Omega = -10 + [2.23 \times 10^{-3} \times 1 \times 10^{3}]$$

$$= (-10 + 2.23)V = -7.77V$$



a) $\because$ In the absence of Zener diode.

$$V_L = 20 \times \frac{R_L}{R_L + R_s} = 20 \times \frac{180}{180+220}$$

$= 9V.$

$\because V_Z = 10V \Rightarrow V_L < V_Z.$

so Zener diode is not conducting.

$$\therefore I_L = \frac{20}{R_s + R_L} = \frac{20}{180+220} = 50\ mA.$$

$\Rightarrow I_L = I_R = 50\ mA.$ so $I_Z = 0\ A.$

$V_L = 9\ V$

b) $\because R_L = 470\Omega.$

so in absence of Zener diode

$$V_L = 20 \times \frac{R_L}{R_L + R_s} = 20 \times \frac{470}{470+220} = 13.62\ V.$$

$\because V_L > V_Z$, so Zener diode is ON.

$\therefore V_L = 10V.$ $\therefore I_L = \frac{10}{470} = 21.27\ mA.$

$$\Rightarrow I_R = \frac{20-10}{220} = 45.45\ mA.$$

$\Rightarrow I_Z = I_R - I_L = 24.18\ mA.$

c) $\because P_{Z\,max} = 400\ mW = V_Z \cdot I_{Z\,max}$

$$\Rightarrow I_{Z\,max} = \frac{400 \times 10^{-3}}{10} = 40\ mA.$$

$\Rightarrow I_{L\,min} = I_R - I_{Z\,max} = 45.45\ mA - 40\ mA$

$= 5.45\ mA$

$$\therefore \quad R_{L,max} = \frac{V_L}{I_{L\,min}} = \frac{10}{5.45\times10^{-3}} = 1.82\ k\Omega.$$

d) Minm, voltage required for the Zener to be ON = 10V.

$V_L = 10V$

$$\Rightarrow \quad 10 = 20\times \frac{R_L}{R_L+220}$$

$$\Rightarrow \quad R_L + 220 = 2R_L$$

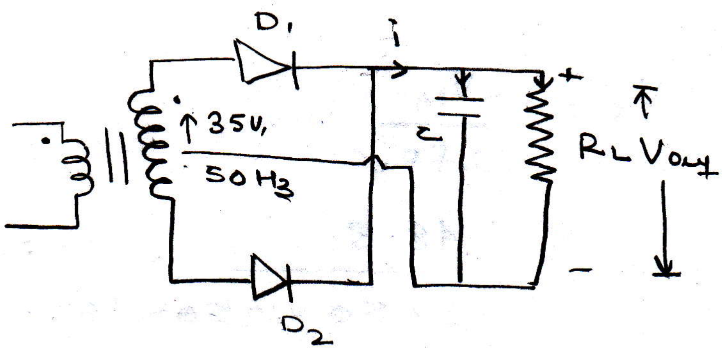
$$\Rightarrow \quad R_{L,min} = 220\ \Omega.$$

SOLN. 5

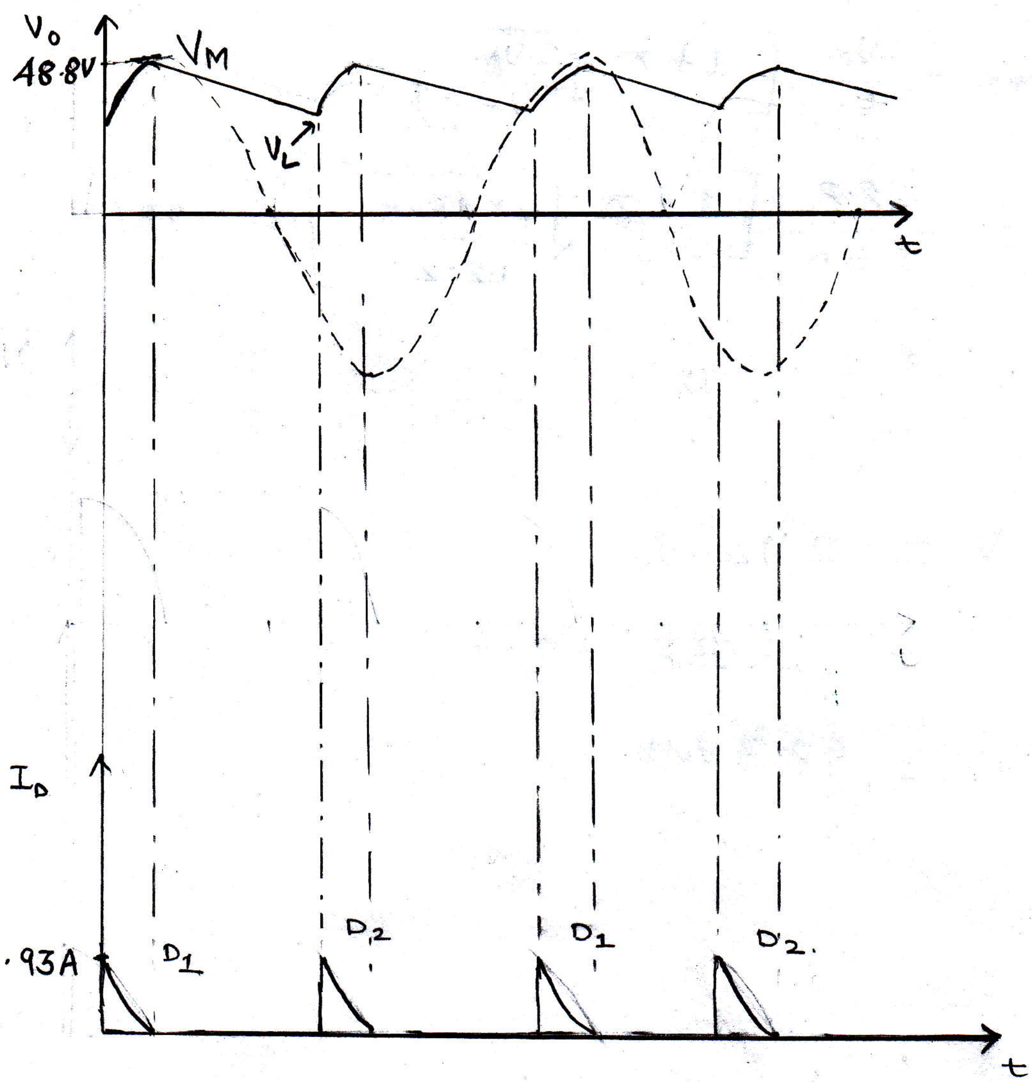
$\because V_i = 35\sqrt{2}\sin\omega t$

$C = 160\ \mu F$

$R_L = 250\ \Omega$



a)



b) $V_m = 35\sqrt{2}\ V$

$V_M = 35\sqrt{2} - 0.7 = 48.8\ V.$

$(V_m \sin\omega t) \rightarrow$ Input voltage to diode.

$V_M \rightarrow$ Maximum voltage at output

$V_M = V_m - V_\gamma$

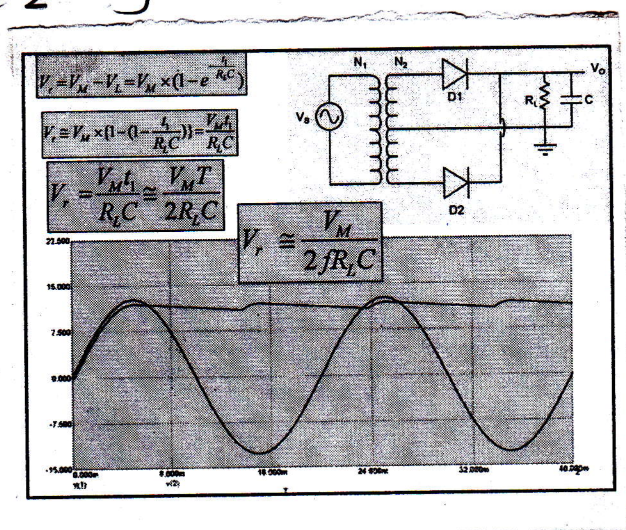
⇒ $$V_r = \frac{V_M}{2fR_LC}$$

$$= \frac{48.8}{2\times 50\times 250\times 160\times 10^{-6}}$$

$$= 12.2 \text{ Volt}$$

⇒ $$I_{D,max} = \frac{V_m}{R_L}\left[1+\pi\sqrt{\frac{2V_M}{V_r}}\right]$$

$$= \frac{48.8}{250}\left[1+\pi\sqrt{\frac{2\times 48.8}{12.2}}\right] = 1.93A$$

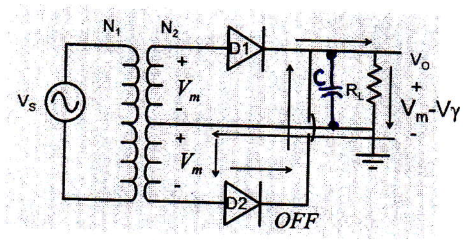


c) $$PIV = 2V_m - V_\gamma$$

$$= (2\times 35\sqrt{2}) - 0.7$$

$$= 98.3 \text{ Volt.}$$

Peak Inverse Voltage

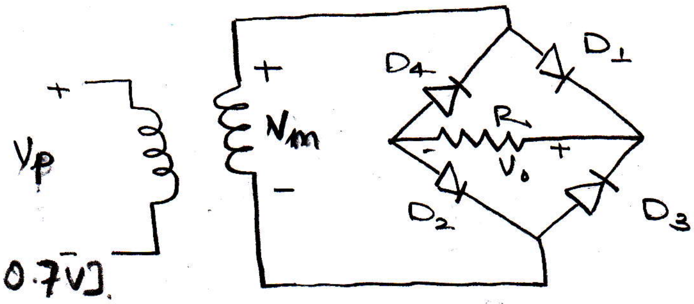


$V_m + V_D + V_m - V_\gamma = 0$

$$V_D = -(2V_m - V_\gamma) \qquad PIV = 2V_m - V_\gamma$$

$V_p = 120$ Vrms.

$V_o = 15 \pm 1$V.



$\because V_m = V_o + 2V_\gamma$ [$V_\gamma = 0.7$V].

$= 16 + 1.4 = 17.4$ V

a) $\Rightarrow V_S = \frac{V_m}{\sqrt{2}} = \frac{17.4}{\sqrt{2}} = 12.3$ V. [rms Voltage appearing across transformer secondary]

b) $\because V_r = \frac{V_M}{2fCR_L}$ $\Rightarrow 2 = \frac{16}{2 \times 60 \times C \times 150}$ [$V_M = 16$ V and $V_r = 2$V]

ripple voltage

$\Rightarrow C = 444.44\ \mu F$

c) for the diodes,

$PIV = V_o + V_\gamma$

$= (16 + 0.7)$V

$= 16.7$V.