Diode circuits:

Dc analysis of diode circuit:-

unilateral

Switch → i) It allows current only from p to n

ii) It never allows current to flow from n to p

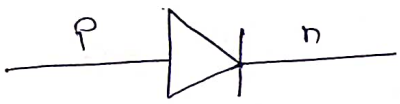
i) $V_p > V_n$ → Diode is said to forward biased.

ii) $V_n > V_p$ → Diode is said to be Reverse biased.

Ideal diode →

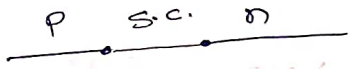
$V_\gamma = 0$, $R_f = 0$, $R_r \to \infty$

i) FB



F.B ($V_p > V_n$)

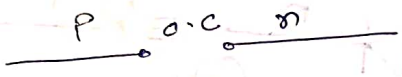
≡



ii) RB

R.B ($V_p < V_n$)

≡



Practical diode :-

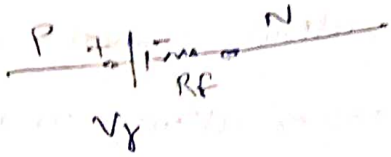
V_γ , R_f , $R_r \to \infty$

F.B. practical diode

i)

i) $V_p > V_n \longrightarrow$ diode is F.B

$(V_p - V_n) > V_\gamma \xrightarrow[\text{ON}]{\text{Proportionally}} \equiv$



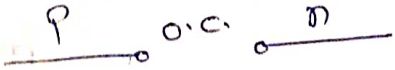
ii) $V_p > V_n \longrightarrow$ F.B.

$(V_p - V_n) \leq V_\gamma \xrightarrow{\text{off}} \equiv$

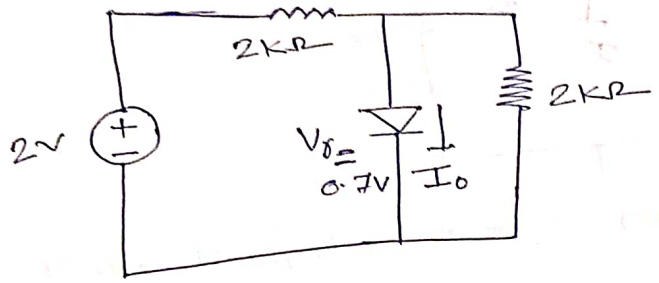
2) Reverse Bias diode

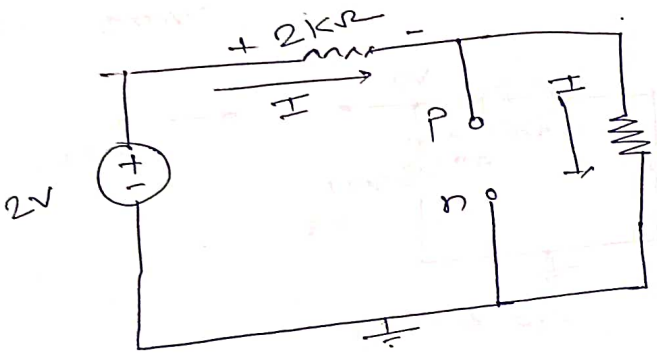
$V_n > V_p$

$\equiv$



Open circuit test :-





ⓐ $V_p > V_n \rightarrow$ F.B.

i) $(V_p - V_n)_{o.c} \geq V_\gamma \rightarrow$ ON

ii) $(V_p - V_n)_{o.c} < V_\gamma \rightarrow$ off

ⓑ If $V_p < V_n \rightarrow$ R.B $\rightarrow$ off

By VDR $= \dfrac{2 \times 2}{4} = V_x$

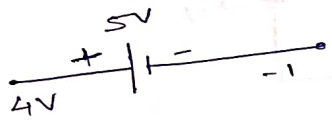
$V_x = 1V$

$V_p = 1V$, $V_n = 0$

$V_p > V_n \rightarrow$ F.B

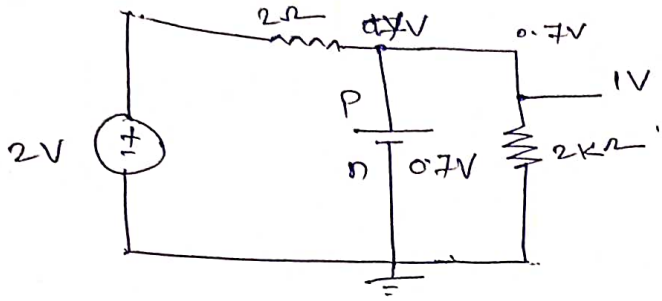
$(V_p - V_n)_{oc} = 1 > 0.7V$

$\rightarrow$ ON



$V_+ - V_- = 5V$

$V_+ = V_- + 5$



$$I = \frac{0.7 - 0}{2} = 0.3\ mA$$

Voltage → volt

Resistance → KΩ

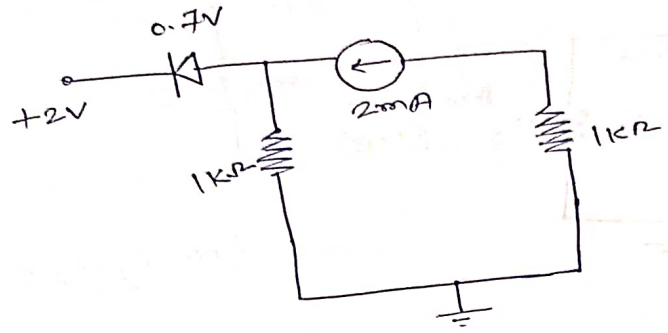
$$\text{current} = \frac{\text{volt}}{\text{KΩ}} = mA$$

Steps :

1. O.C → open diode
2. check V_p & V_n
3. $V_p > V_n$ FB

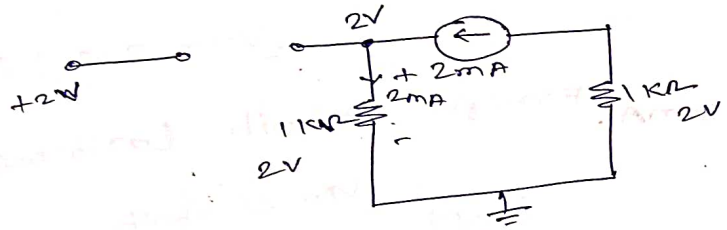
   $(V_p - V_n) > V_\gamma$

2)



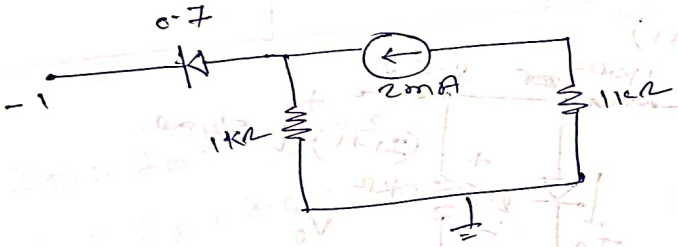
Power dissipation across Diode _____ mW.

Sol:- 0mW



$p - n \geq 0.7$

$0 \ngeq 0.7$

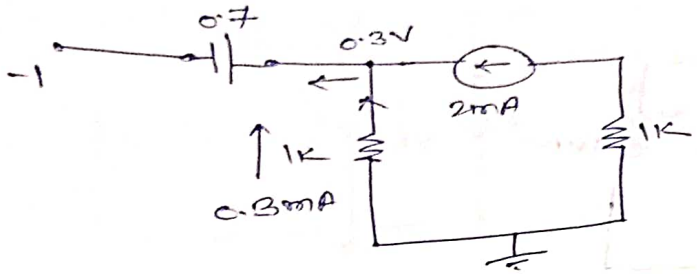


$V_p - V_n \geq V_\gamma$

$2 + 1 = 3 > 0.7$

→ ON

→ FB



$-1 + 0.7 = -0.3V$

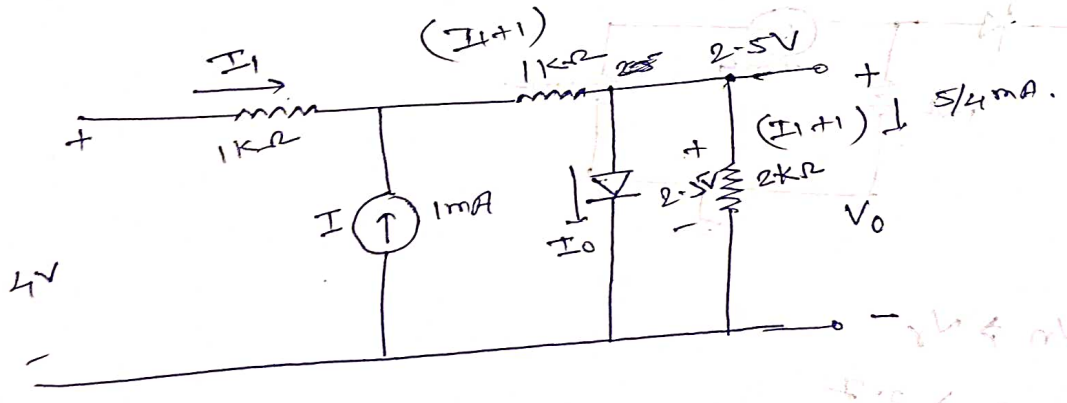
$\frac{V}{R} = \frac{0.3}{1000} = 0.3mA$

$0.3mA + 2mA = 2.3mA.$

$\therefore P = V \times I = 0.7 \times 2.3mA$

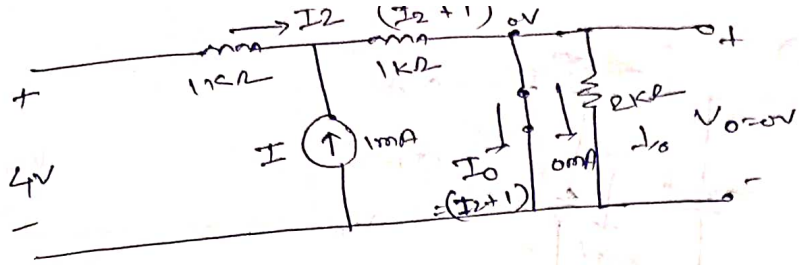
$= 1.61 mW.$

2)



i) ideal diode

ii) practical diode having $V_\gamma = 0.7V$



$4 - I_2 - (I_2+1) = 0$

$B = 2I_2$

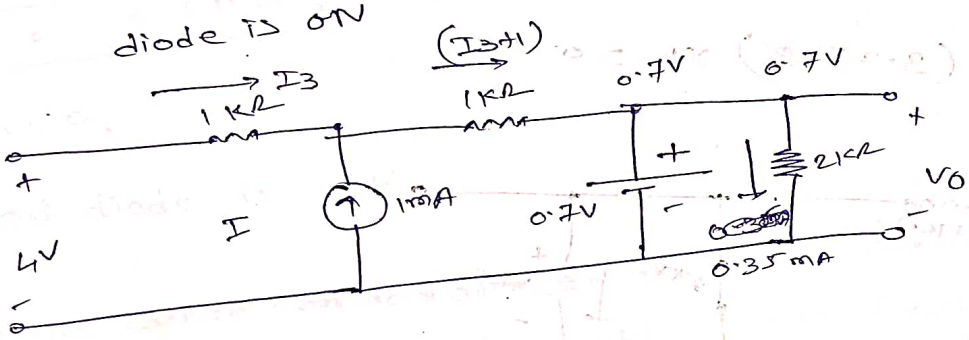
$I_2 = 1.5mA$

$I_D = I_2+1 = 2.5mA.$

$V_o = 0-0 = 0V.$

2) practical diode $V_\gamma = 0.7V$

diode is 0V



$I_D = I_3+1-0.35$

$= I_3 + 0.65.$

$4 - I_3 - (I_3+1) - 0.7 = 0$

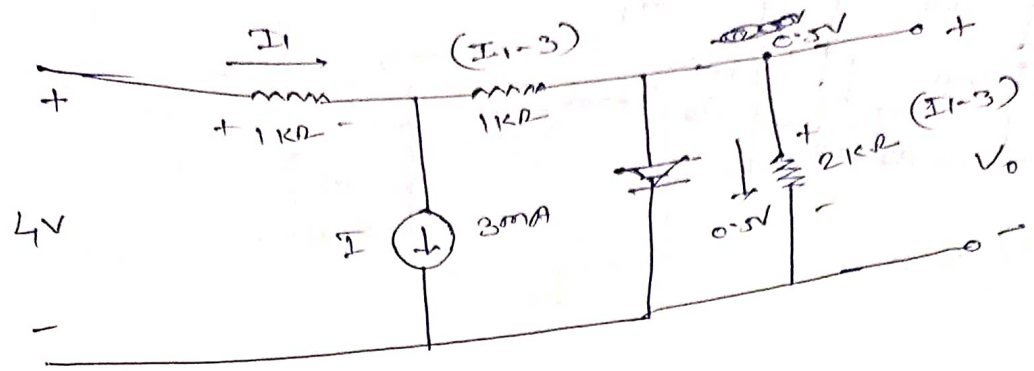
$2.3 = 2I_3$

$\boxed{I_3 = 1.15mA}$

$I_D = 1.15+1-0.35$

$= 1.8mA.$

Q)



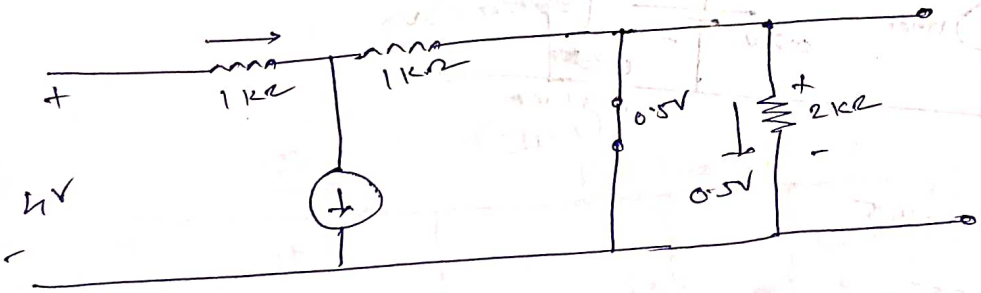
Lect- 3.

$4 - I_1 - (I_1-3) - 2(I_1-3) = 0$

$4I_1 = 13$

$I_1 = 3.25$ mA

$(I_1-3) \times 2 = (3.25-3) \times 2 = 0.5V$

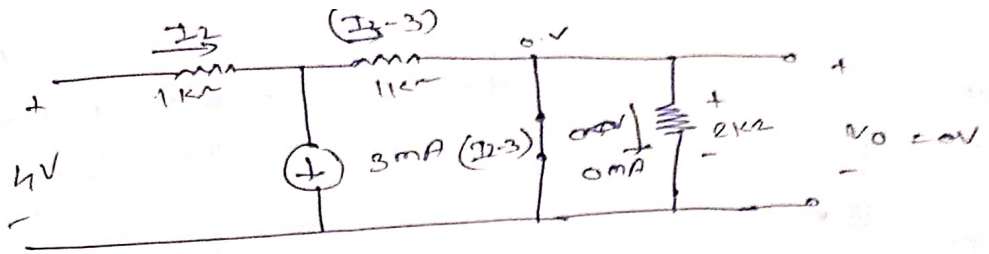


In ideal case

$V_p > V_n$

In practical

$V_p - V_n > V_r$.



$$4 - I_2 - (I_2 - 3) = 0$$

$$4 + 3 + 2I_2 = 0$$

$$\frac{7}{2} = I_2$$

$$\boxed{3.5\ mA = I_2}$$

$$I_D = I_2 - 3$$

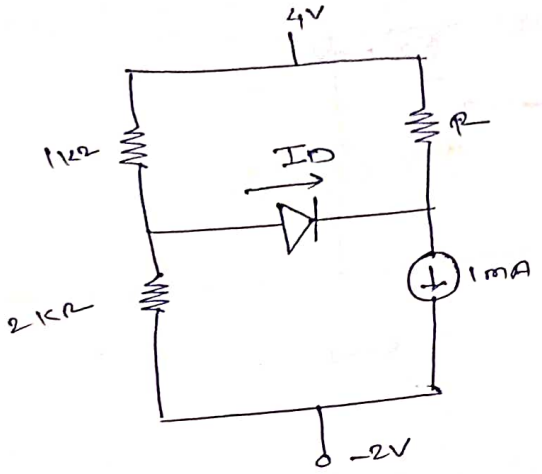
$$\boxed{I_D = 0.5\ mA}$$

$$V_o = 0.$$

Practical diode is off.

Never use source transformation in diode is ~~represent~~ in ckt while we use source transform after known diode is ON/off.

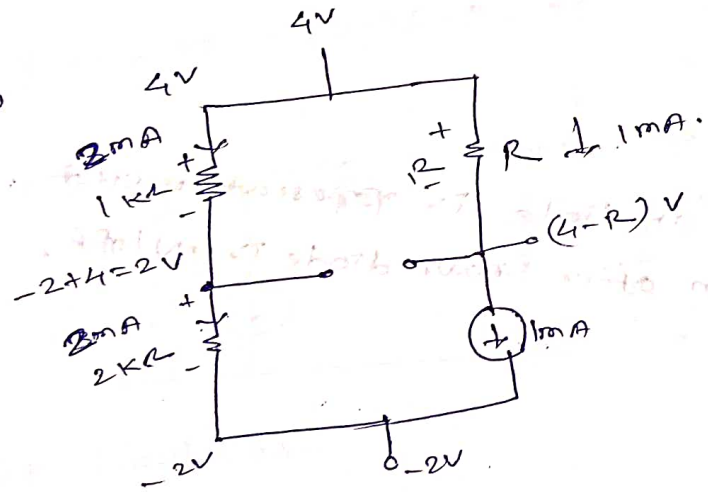
Q)

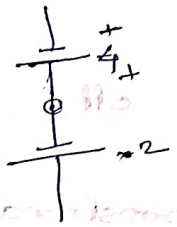


i) minimum value of R for which diode D will be ON ____ kΩ
ideal

ii) practical diode
with $V_\gamma = 0.7V$.

Sol^n ①





$4+2=6$

$\frac{6}{3k\Omega} = 2mA$

$2 > (4-R) \rightarrow F.B$

$2-(4-R) > V_\gamma$

i)

$-2+R > 0$

$R > 2K\Omega$

$2-4+R > 0$

$R > 2K\Omega$

$R_{min} = 2K\Omega$

ii) $-2+R > 0.7$

$R > 2.7K\Omega$

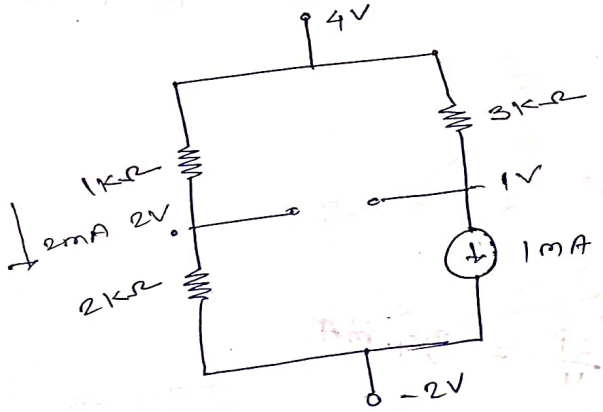
$\boxed{R_{min} = 2.7K\Omega}$

(b) $R = 3K\Omega$

i) ideal diode I_D ____ mA

ii) practical diode I_D ____ mA

$V_\gamma = 0.7$

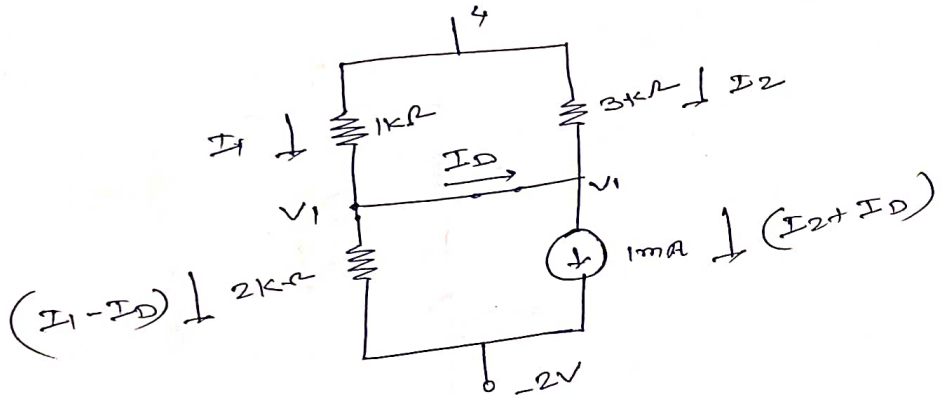


$\frac{6}{3} = 2mA$

p > n → on

2 > 1 → ON.

in ideal case.



$$\frac{4-V_1}{1} + \frac{4-V_1}{3} = \frac{V_1+2}{2} + 1$$

$$24 - 6V_1 + 8 - 2V_1 = 3V_1 + 6 + 6$$

$$11V_1 = 20$$

$$\boxed{V_1 = \frac{20}{11}\ V}$$

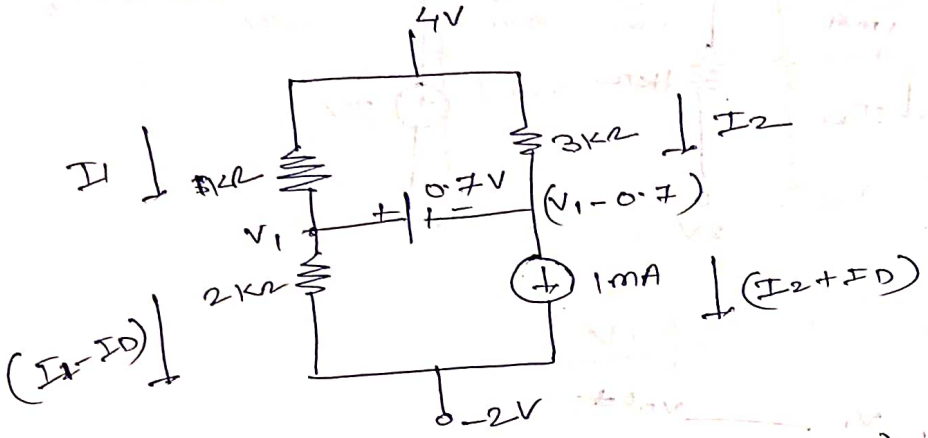
$$\frac{4-V_1}{1} = I_1$$

$$4 - \frac{20}{11} = \frac{24}{11}\ mA$$

$$I_1 - I_D = \frac{V_1+2}{2}$$

$$I_D = I_1 - \frac{21}{11} = \frac{24}{11} - \frac{21}{11} = 3/11\ mA.$$

In practical case



$$\frac{4 - V_1}{1} + \cancel{\frac{V_1 + 2}{2}} + \frac{4 - (V_1 - 0.7)}{3} = \frac{V_1 + 2}{2} + 1$$

$$\frac{4}{1} - \frac{V_1}{1} + \frac{4}{3} - \frac{V_1}{3} + \frac{0.7}{3} = \frac{V_1}{2} + 1 + 1$$

$$4 + \frac{4}{3} + \frac{0.7}{3} + 1 + 1 = \frac{V_1}{2} - \frac{V_1}{1} - \frac{V_1}{3}$$

$$\cancel{= V_1\left(\frac{1}{2} - 1 - \frac{1}{3}\right)}$$

$$\cancel{7.56 = V_1\left(-5/6\right)}$$

$$V_1 = \frac{-5/6}{7.56}$$

$$I_1 = \frac{4 - 1.95}{1}$$

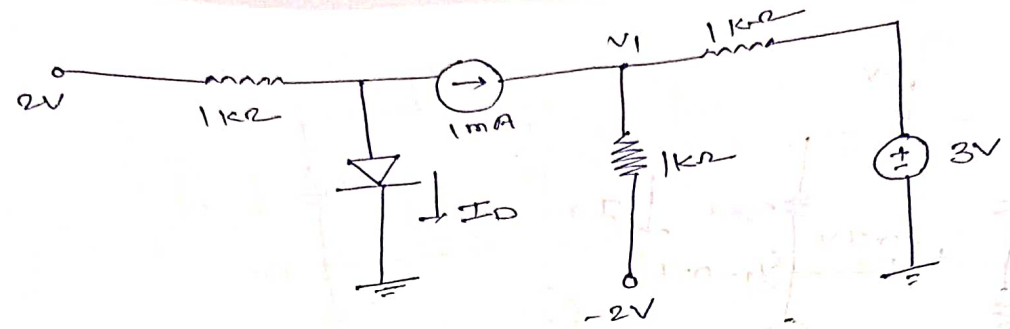
$$I_1 = 2.05$$

$\cancel{V_1 = 1.245}$ V

$V_1 = 1.945$

$I_D = 0.0825$ mA.

Q)



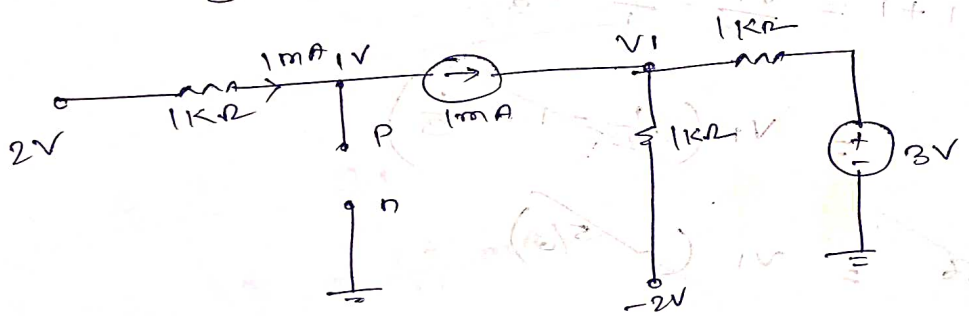
i) ideal diode

I_D ___ mA , V_1 ___ volt

ii) practical diode I_D ___ mA , V ___ volt.

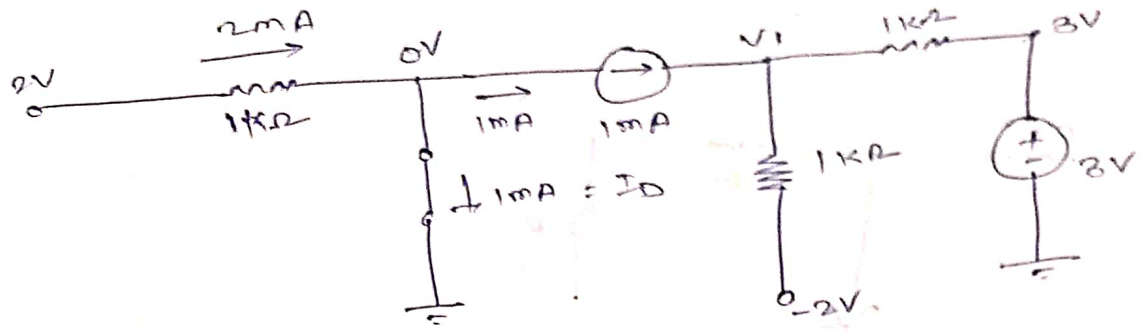
Soln:-

Diode - ON



P > n = F.B

= ON.



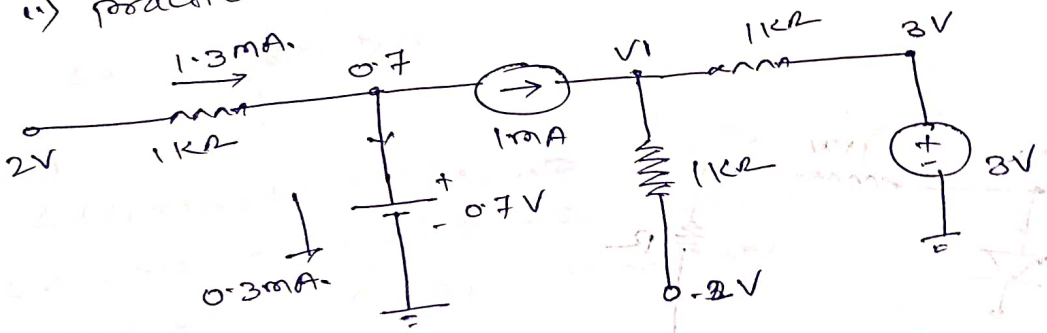
$$\frac{V_1+2}{1} + \frac{V_1-3}{1} = 1$$

$$2V_1 - 1 = 1$$

$$\boxed{V_1 = 1V}$$

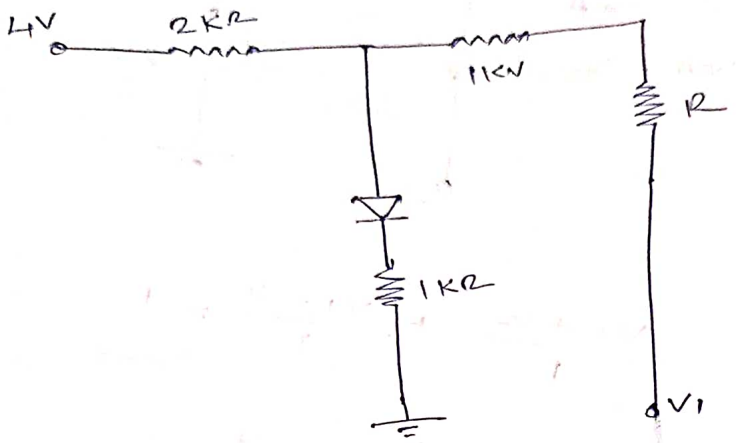
$I_D = 1mA$, $V_1 = 1V$

ii) practical diode



$I_D = 0.3mA$, $V_1 = 1V$.

Q)



for which combination of R & V1 Diode D will ON

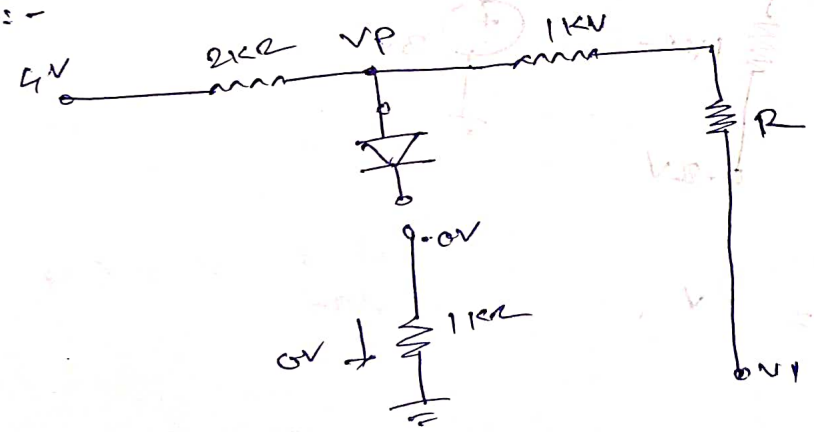
a) R = 1KΩ V1 = -5V

b) R = 2KΩ, V1 = -7V

c) R = 2.4KΩ, V1 = -2V

d) R = 2KΩ, V1 = -6.2V.

Sol^n:-



$$\frac{4-V_p}{2} = \frac{V_p - V_1}{1+R}$$

$$4 - V_p = \frac{2}{1+R}(V_p - V_1)$$

$$V_p = \frac{4 + 4R + 2V_1}{3+R}$$

$V_p - V_n > V_\gamma \rightarrow$ ON.

$V_p > V_n$

$V_p - V_n > 0$

$$\frac{4+4R+2V_1}{3+R} > 0$$

$4 + 4R + 2V_1 > 0$

Now

1) $4 + 4 \times 1000 + 2 \times (-5) > 0$ $\quad -2 > 0$ off

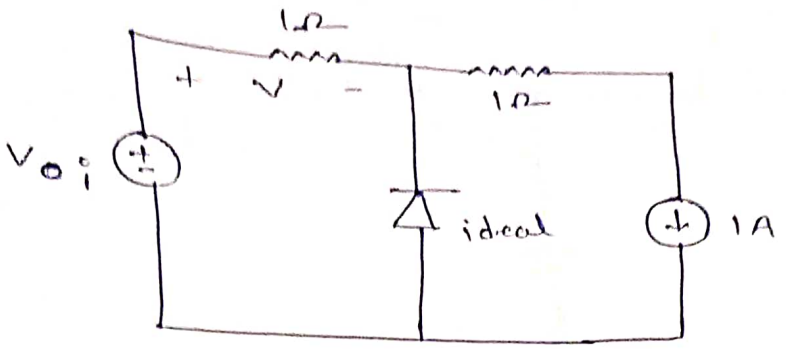
2) $4 + 4 \times 2 + 2(-7) > 0$ $\quad -2 > 0$ off

3) 9.6 ✓ $\quad 9.6 > 0$ ✓ Diode ON

4) -0.4 off.

Q)

Lect-4

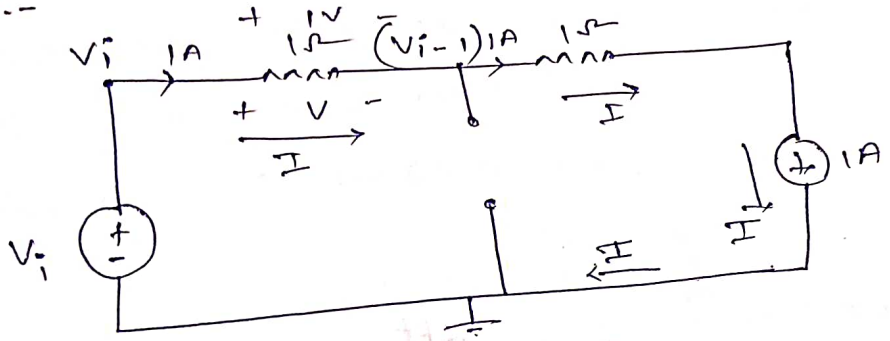


The value V will be be

a) min (V_i, 1) b) max (V_i, 1)

c) min (-V_i, 1) d) max (-V_i, 1)

Sol^n:-



$V_p = 0$

$V_n = (V_i - 1)$

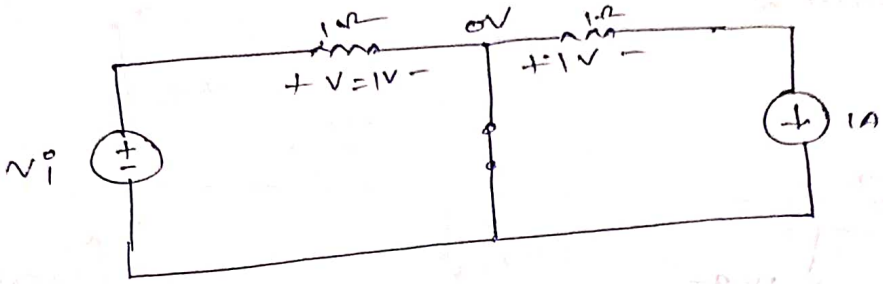
$V_p - V_n$

$[0 - (V_i - 1)]$

$(1 - V_i)_{oc} > 0 \rightarrow$ Diode ON $V_i < 1$

$(1 - V_i)_{oc} < 0 \rightarrow$ Diode off $\boxed{V = 1V}$

$\boxed{V_i > 1}$



$V = V_i \rightarrow V_i < 1$

$V = 1V, \; V_i > 1$

~~Vi~~

Summary

Steps :-

① check Diode ON/OFF

open circuit test

$p > n \rightarrow F.B$ — ideal

$(p-n) > V_\gamma \rightarrow ON$ practical

② Apply Network theory

ON → current → p to n

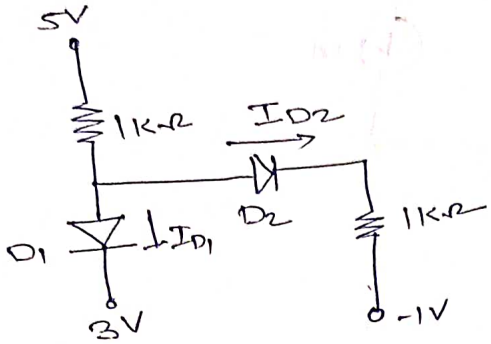
off → voltage → p-n voltage $> V_\gamma$

$< V_\gamma$

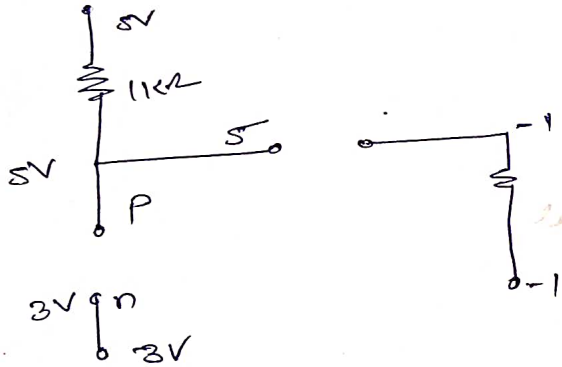
off → current → n to p

Multiple diode's

Q)



$I_{D1} + I_{D2}$ ——— mA.

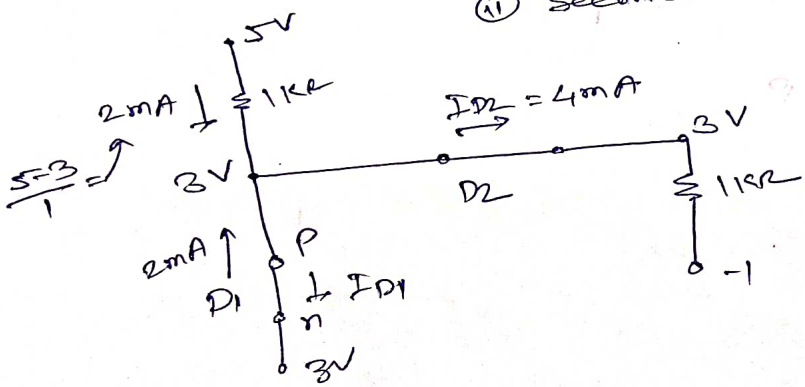


$V_p > V_n > V_\gamma$

$5 + 1 > V_\gamma$

$5 - 3 > V_\gamma$

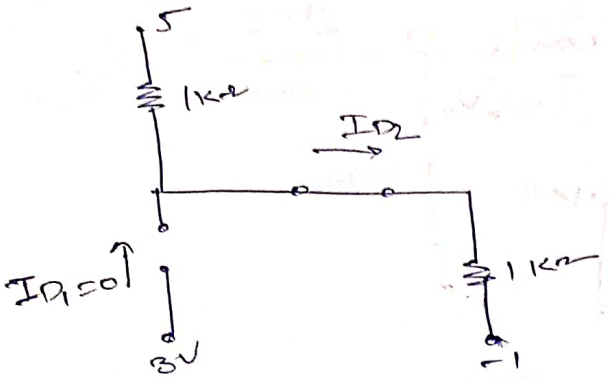
(11) second step verification



$\frac{3+1}{1} =$

$D_2 \rightarrow$ ON

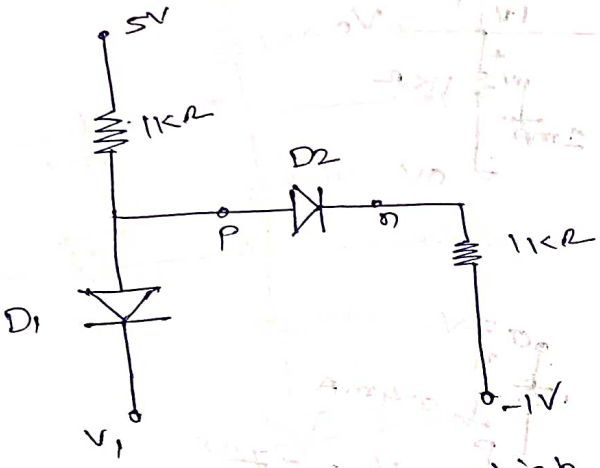
$D_1 \rightarrow$ OFF.



$$\frac{5+1}{2} = \frac{6}{2} = 3mA.$$

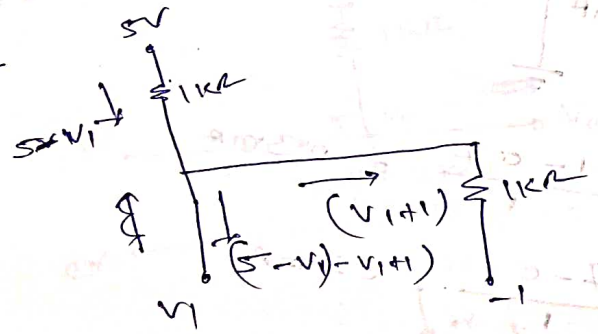
$$I_{D1} + I_{D2} = \underline{3mA}$$
$$\overset{\shortparallel}{0}$$

Q)



maximum value of V_1 for which both diodes will be on. 2 volt.

Sol:-



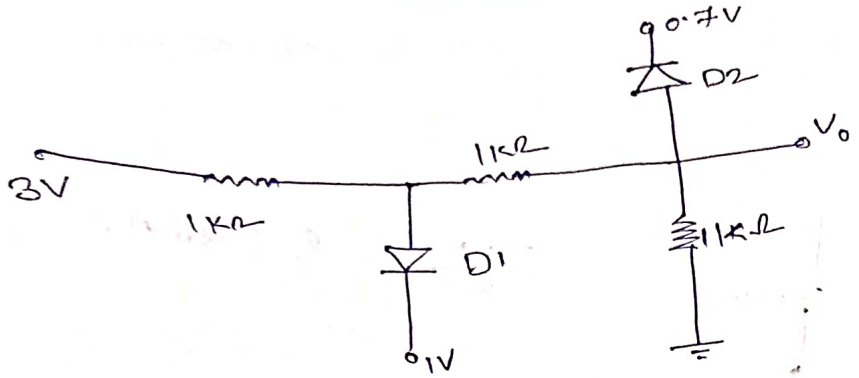
$4-2V > 0$

$4-2V_1 > 0$

$2V_1 < 4$

$\boxed{V_1 < 2}$

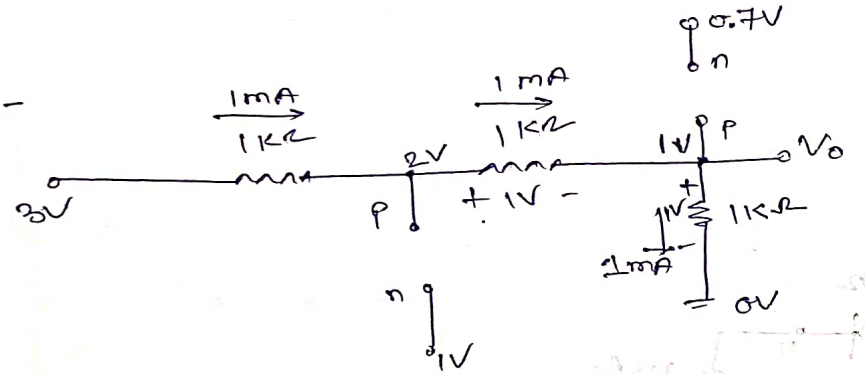
Q)



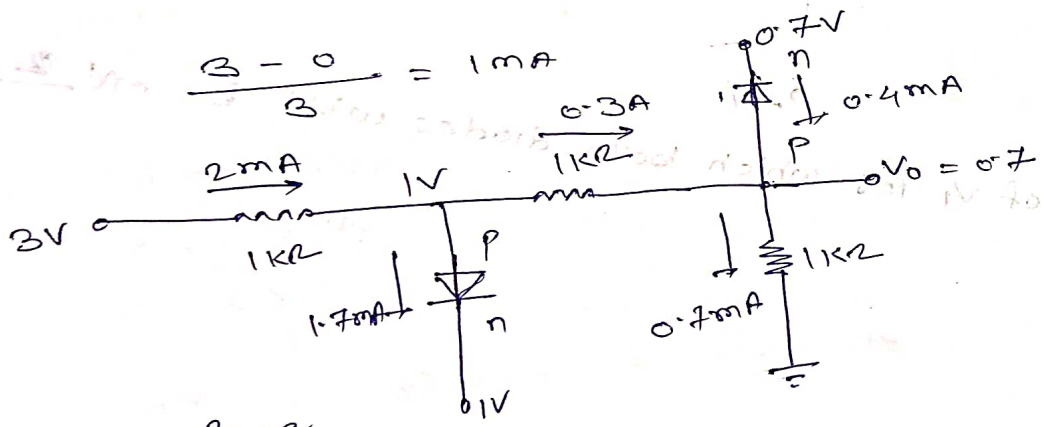
$I_{D1} + I_{D2} \rightarrow$ mA

$V_o \longrightarrow$ Volt

Soln:-



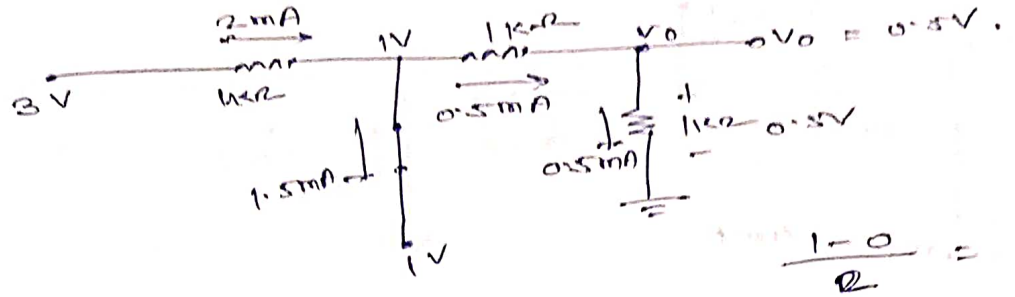
$\frac{3-0}{3} = 1mA$



$\frac{3-1}{1} = \frac{2}{1} = 2$

$\frac{1-0.7}{1} = 0.3mA$

$\frac{0.7-0}{1} = 0.7mA$

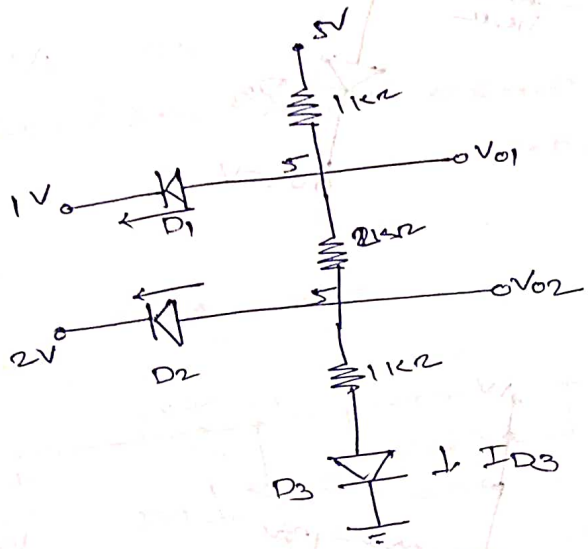


$$\frac{1-0}{2} = 0.5\,mA$$

$I_{D1} + I_{D2} = 1.5\,mA$

$V_o = 0.5V$ volt.

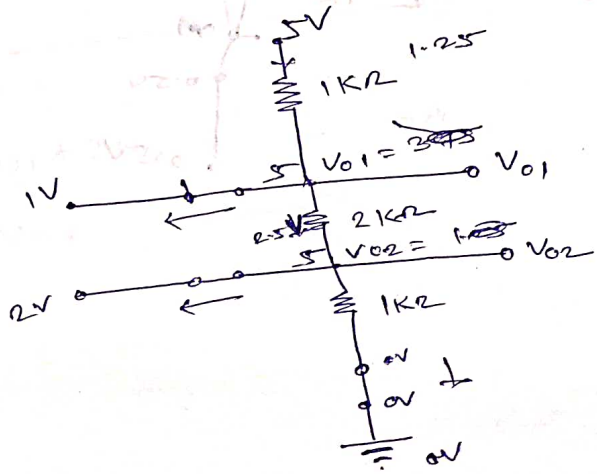
Q)



$I_{D1} + I_{D2} + I_{D3} =$ _____ mA

$V_{D1} + V_{o2} =$ _____ volt.

Soln:-



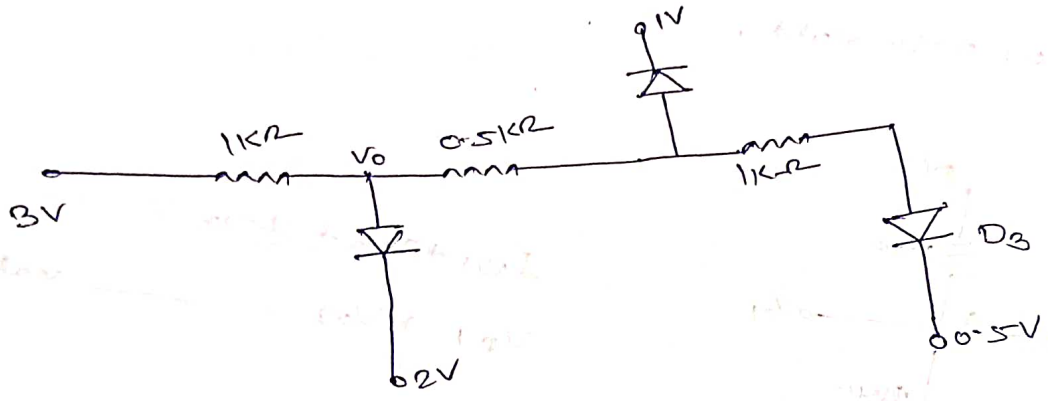
$$\frac{5-0}{4} = \frac{5}{4} = 1.25\,mA$$

D_1 = ON
D_2 = OFF
D_3 = ON

$2mA + 3.5 - 1.5mA = 4mA$

$V_{D1} + V_{D2} = 7V$
$4 + 3 = 7V.$

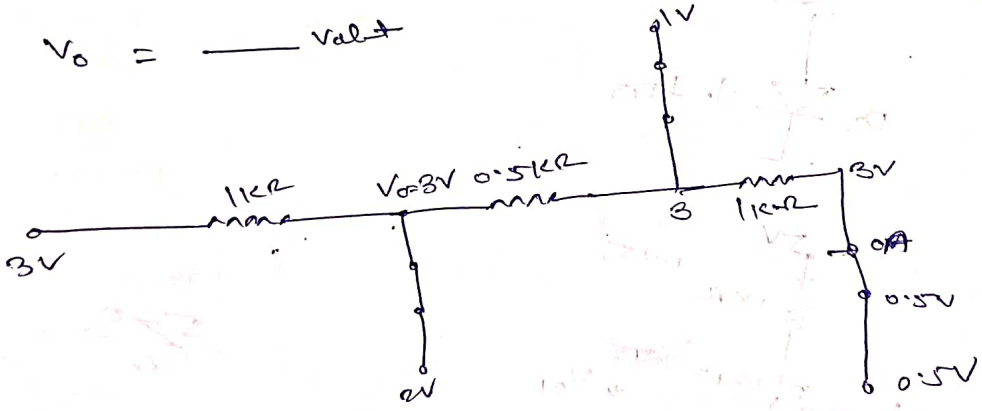
Q)

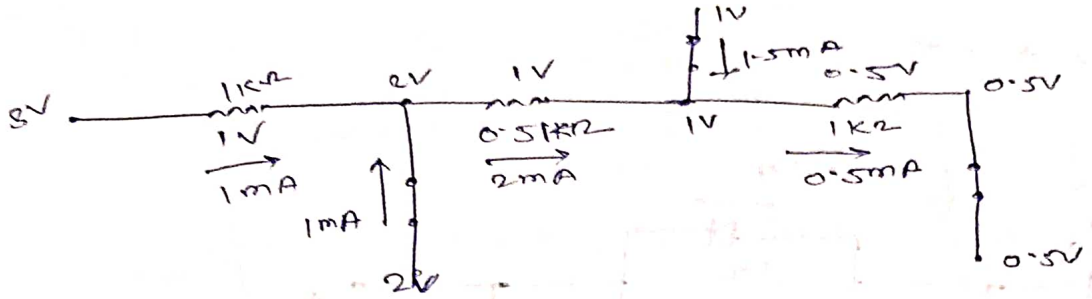


$I_{D1} + I_{D_2} + I_{D3} =$ ____ mA.

$V_o =$ ____ Volt

Sol^n:-





D_1 = off

D_2 = off

D_3 = ON

$V_o = 2V$

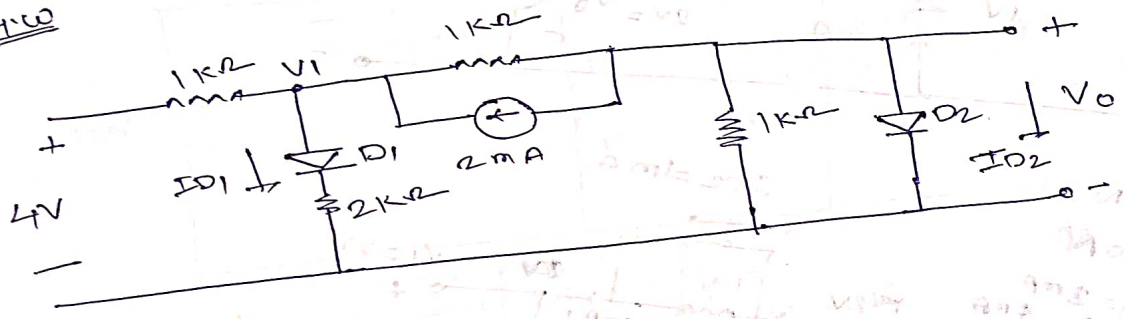
$I_{D1} + I_{D2} + I_{D3} = \cancel{0.5mA}. -1 - 1.5 + 0.5$

$= -2mA.$

Lect - 05

H.W

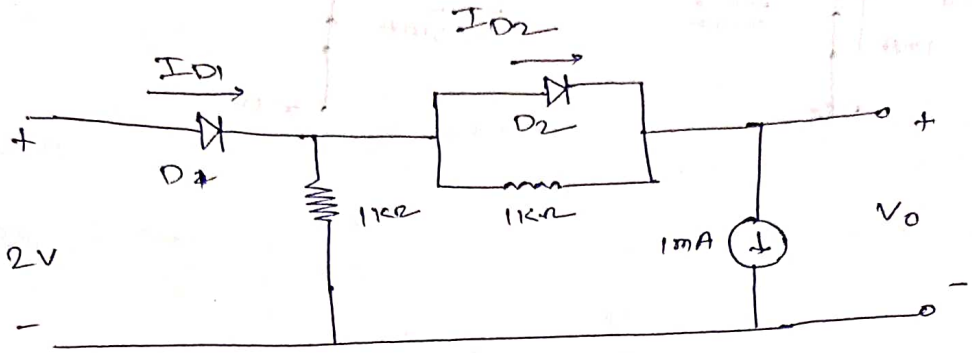
Q)



$I_{D1} + I_{D2} =$ ____ mA

$V_1 =$ ____ V

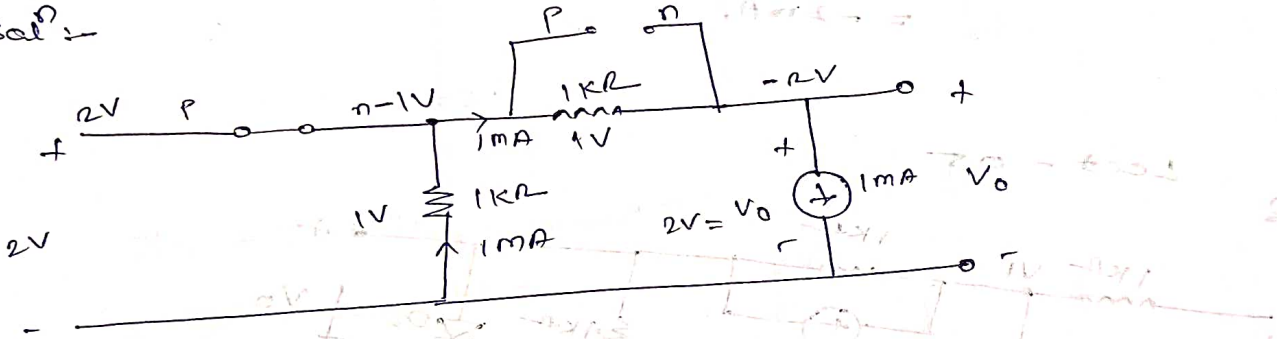
Q) Lect - 5



V_0 ——— volt

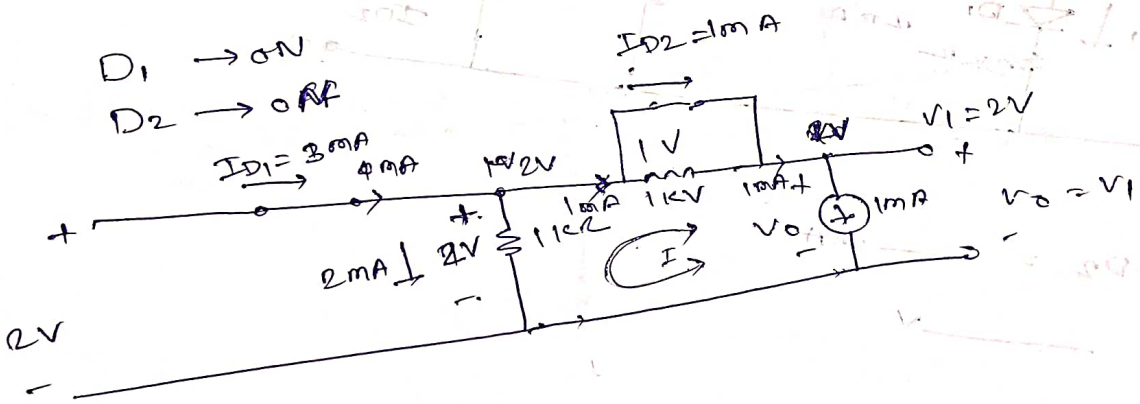
$I_{D1} + I_{D2}$ ——— mA

Sol^n:-



$D_1 \rightarrow$ ON

$D_2 \rightarrow$ ON



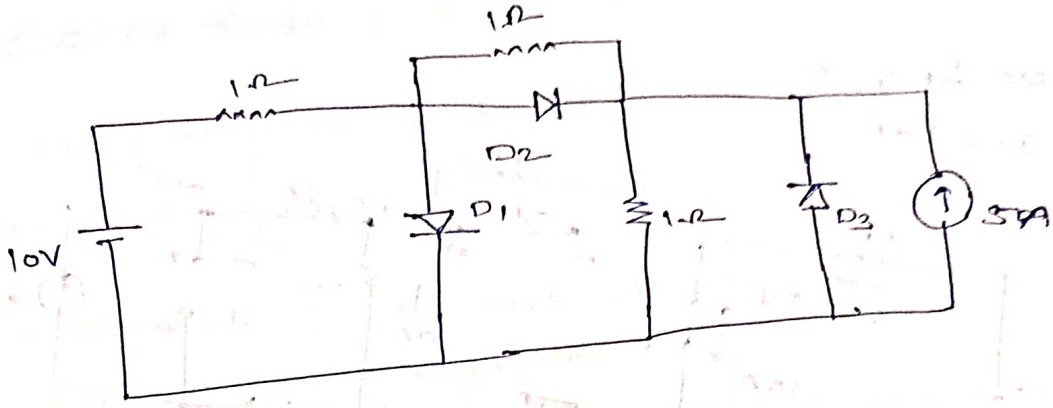
$D_1 \rightarrow$ ON

$D_2 \rightarrow$ ON

$V_0 = V_1 = 2V$

$3mA + 1mA = 4mA = I_{D1} + I_{D2}$.

Q)



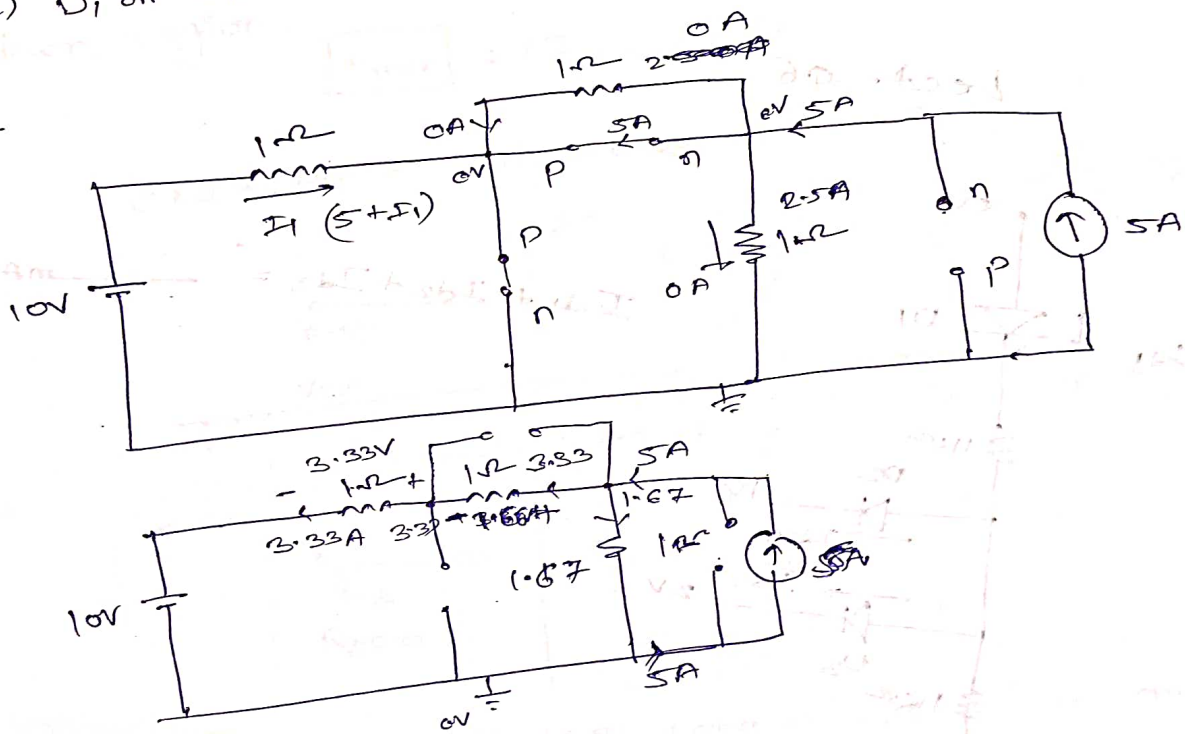
a) D1 ON, D2 off, D3 OFF

b) D1 off D2 ON D3 off

c) D1 ON D2 off D3 ON

d) D1 off D2 ON D3 ON

Sol^n:-



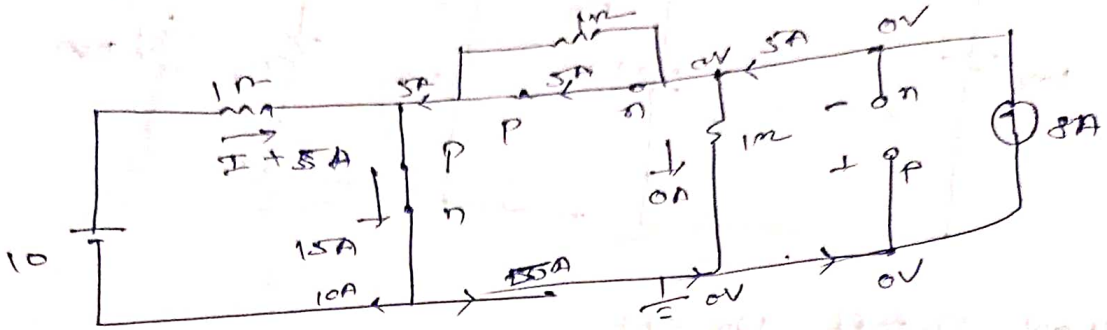
D2 = ON

D1 = ON

D3 = off

→ $10 - I_1 = 0$

$I_1 = 10A$



$D_1 = ON$

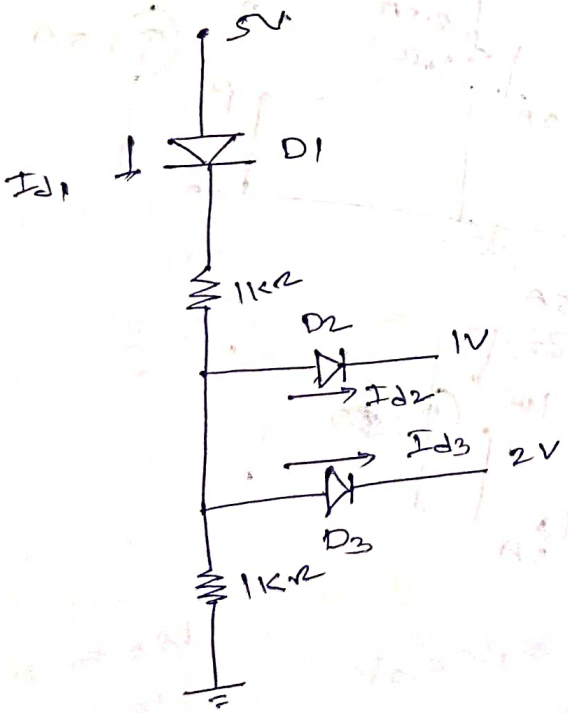
$D_2 = OFF$

$D_3 = OFF.$

Q) Lect - 06

H.W

Q)



$I_{d1} + I_{d2} + I_{d3} =$ _____ mA

Zener diode

1) specially designed diode that can work in reverse breakdown region

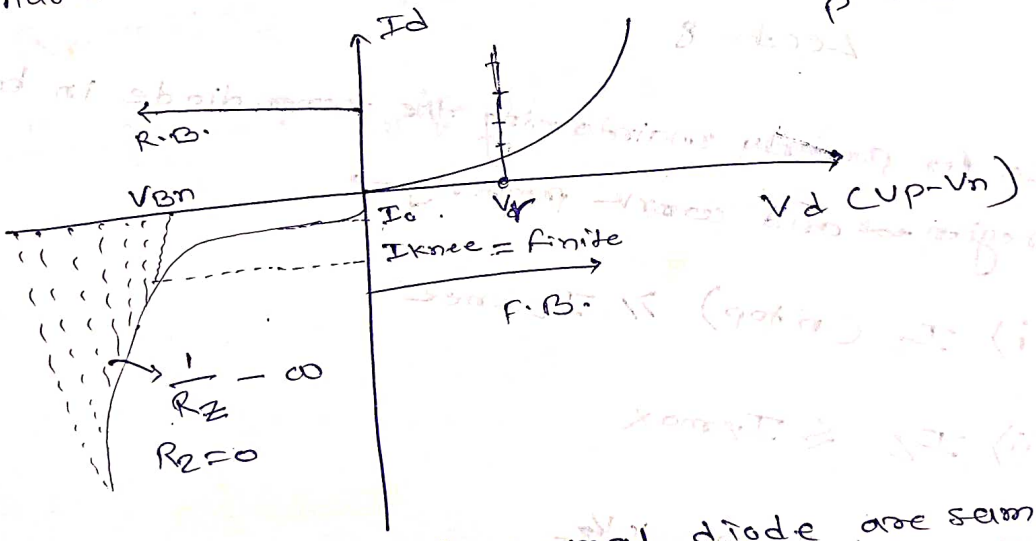
2) It is used as a constant voltage device in reverse breakdown region in regulator ckt.

Imp 3) for zener diode to remain in breakdown region the minimum current that should flow is called as knee current.

Imp 4) power ratting of zener diode is defined as the maximum power that zener diode can withstand in reverse break down region.

$$\boxed{P_{max}} = (I_{Zmax} \times V_Z)$$

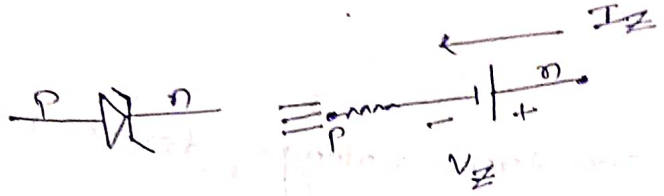
Characteristic of zener diode :→



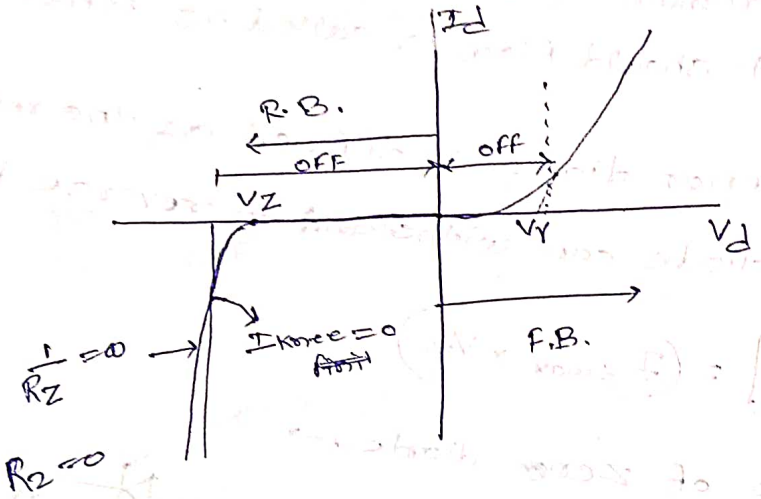
In FB region zener diode & normal diode are same.

Lect - 07

→ Zener diode in breakdown region



ideal diode



Lect - 8

5) So for properly maintaining the zener diode in breakdown region and work properly →

i) I_Z (n dop) ≥ $I_{Z\,knee}$

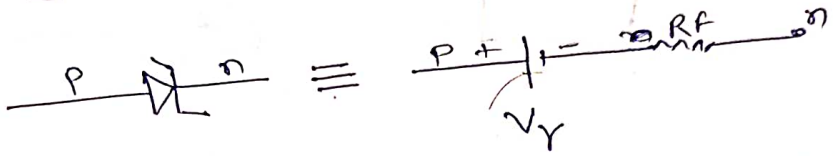
ii) $I_Z \leq I_{Zmax}$

$P_{max} = I_{Zmax} \times V_Z$

Equivalent circuit of zener diode:-

a) If $V_p > V_n \longrightarrow (V_p - V_n) > 0 \longrightarrow$ Diode is F.B.

i) $(V_p - V_n) > V_\gamma \longrightarrow$ diode is ON in F.B. region



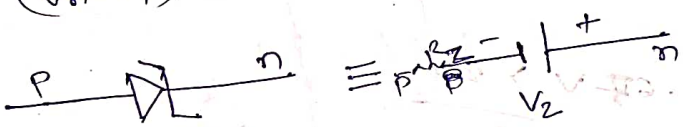
ii) $(V_p - V_n) < V_\gamma \longrightarrow$ diode is OFF in F.B region

b) If $V_p < V_n \Rightarrow (V_p - V_n) < 0 \longrightarrow$ diode is Reversed Biase.

$V_n - V_p > 0$

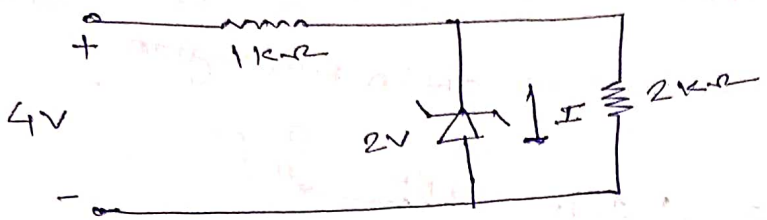
i) $(V_n - V_p) < V_Z \longrightarrow$ OFF in R.B. region

ii) $(V_n - V_p) > V_Z \longrightarrow$ ON in R.B. region

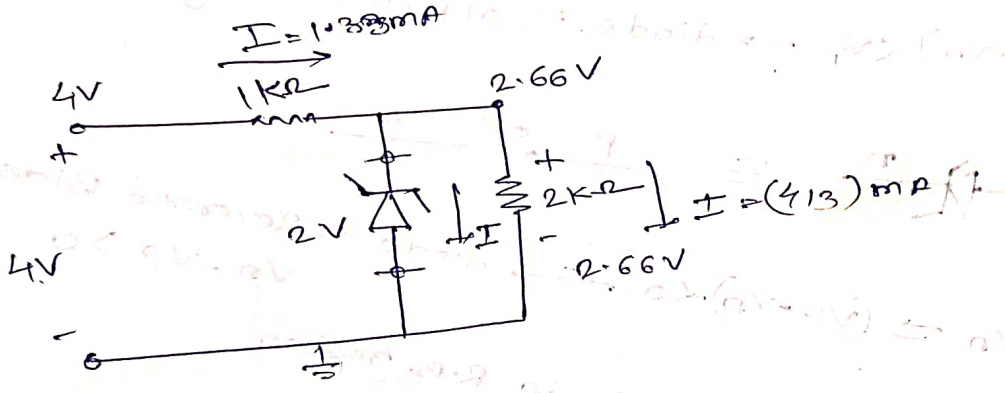


Lect-9

Q)



Soln:-

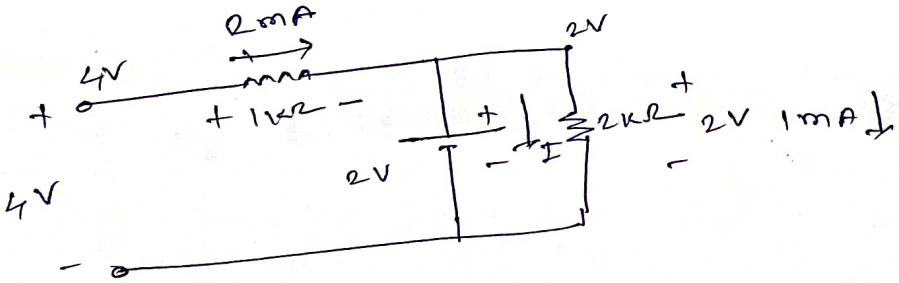


$4 - 3I = 0$

$\frac{4}{3} = I$ $\qquad V_p > V_n$

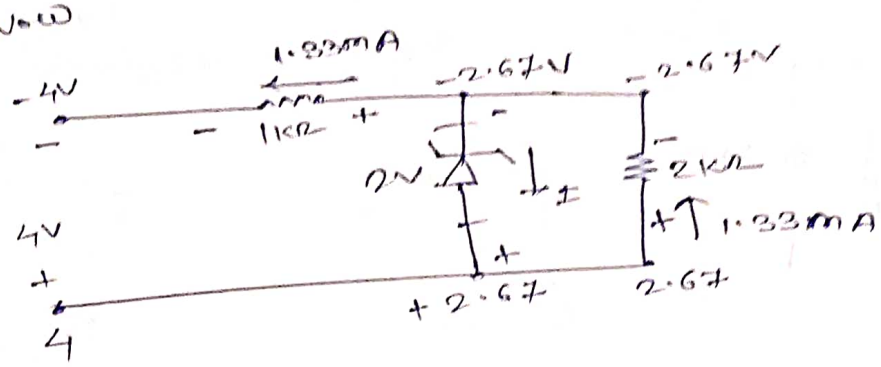
$(V_n - V_p) = 8/3 = 2.67V > 2V$

ON in R.B region



$I = 1mA.$

Now



$V_p > V_n$

$V_p - V_n > 2$

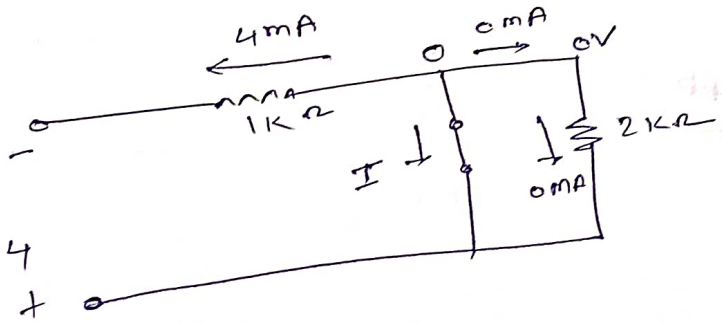
$V_p = 0$

$V_n = -8/3$

$V_p > V_n \rightarrow$ F.B.

$V_p - V_n = 8/3 > 2$

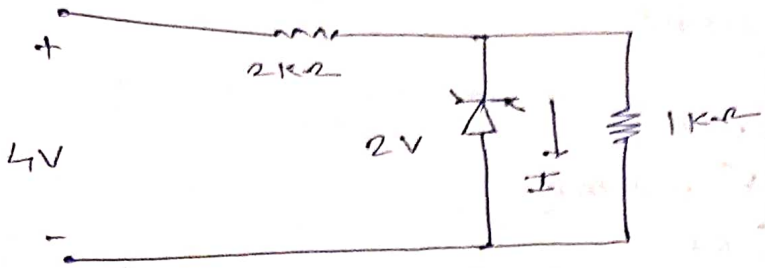
ON in F.B region



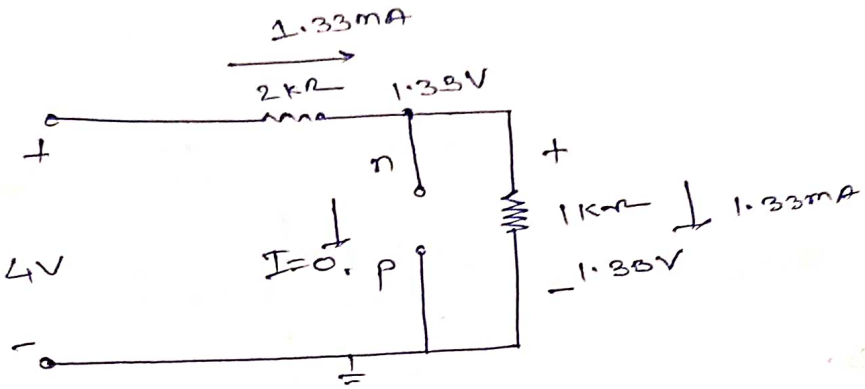
$4 + 0 + I = 0$

$\boxed{I = -4.0mA}$

2)



Soln:-



$\frac{4}{3} = I$

$p = 0$

$n = 1.33V$

$p \times n \longrightarrow$ ~~Diode as off.~~ Diode ▷ R.B

$V_p - V_n > 2$

$V_n - V_p = 4/3 < 2$

R.B $\longrightarrow$ off mode

$I = 0$

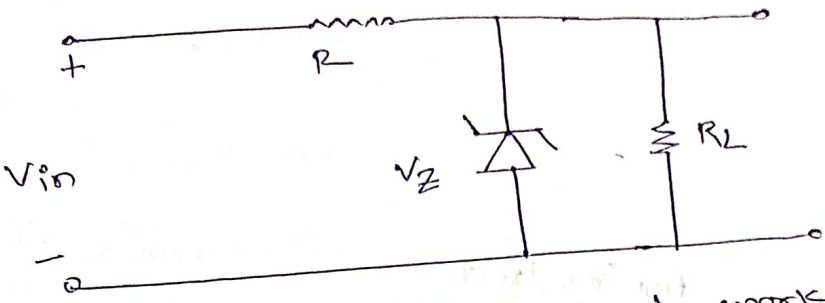
$\boxed{V_o = 4/3 V.}$

Lect-10

(Imp)

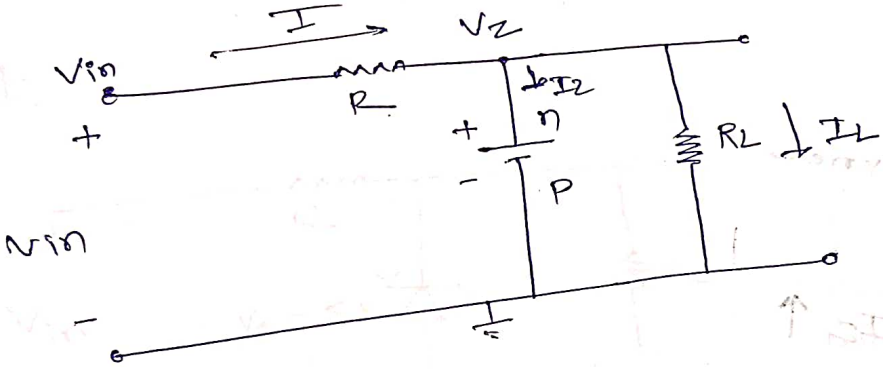
Analysis of Regulator circuit :→

→ To regulate const. voltage across load



1) So for regulator circuit to work properly zener diode must be in reverse breakdown region.

2) If regulator ckt working properly, then



$$I = I_Z + I_L$$

$$\frac{V_{in} - V_Z}{R} = I_Z + \frac{V_Z}{R_L}$$

$$\boxed{I_Z = \frac{V_{in} - V_Z}{R} - \frac{V_Z}{R_L}}$$

(Imp)

$$\left\{ \begin{array}{l} I_Z \geq I_{Z\,knee} \\ I_Z \leq I_{Z\,max} \end{array} \right\}$$

i) $V_{in} \rightarrow$ fix (know)

$R \rightarrow$ fix (value)

$\boxed{R_L \rightarrow \text{variable}}$

$R_L \downarrow$, $\frac{V_Z}{R_L} \uparrow$, $I_Z \downarrow$

$$\frac{V_{in} - V_Z}{R} - \frac{V_Z}{R_L} \geq I_{knee}$$ for $(R_L)_{min}$ calculation

$$\frac{V_Z}{R_L} \leq \frac{V_{in} - V_Z}{R} - I_{knee}$$

$$R_L \geq \frac{V_Z}{\left(\frac{V_{in} - V_Z}{R}\right) - I_{knee}}$$

ii) $R_L \uparrow$, $\frac{V_Z}{R_L} \downarrow$, $I_Z \uparrow$

$$\frac{V_{in} - V_Z}{R} - \frac{V_Z}{R} \leq I_{max}$$

$$\frac{V_Z}{R_L} \geq \frac{V_{in} - V_Z}{R} - I_{Zmax}$$

$$R_L \leq \frac{V_Z}{\frac{V_{in} - V_Z}{R} - I_{Zmax}}$$

ii) $V_{in} \rightarrow (V_{in})_{min} - (V_{in})_{max}$

$R \rightarrow$ fix (value)

$R_L \rightarrow$ variable

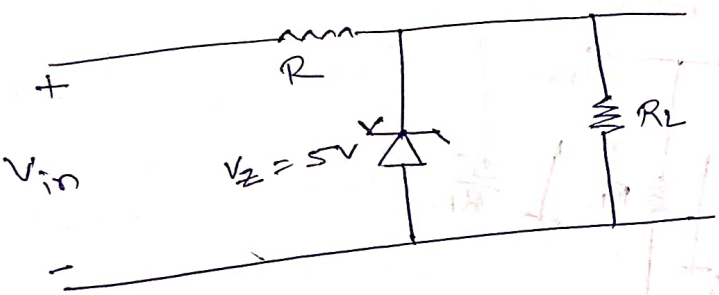
$I_Z \geq I_{Zknee}$

$$\frac{(V_{in})_{min} - V_Z}{R} - \frac{V_Z}{R_L} \geq I_{Zknee}$$

$$R_L \geq \frac{V_Z}{\frac{(V_{in})_{min} - V_Z}{R} - I_{Zknee}}$$

Lect - 11

Q)



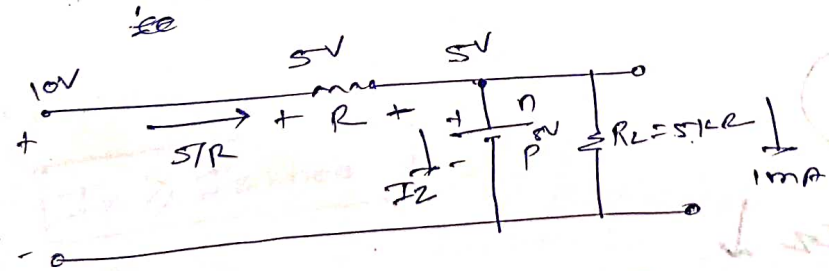
$V_{in} = 10V$

$R_L = 5K\Omega$

∴ The max. value of R for which this regulator ckt works properly.

R_{max} _____ $K\Omega$ (upto one decimal place)

Sol:-



$$I_Z = \frac{5}{R} - 1$$

$R\uparrow, I_Z\downarrow$

$I_Z \geq 0$

$\frac{5}{R} + 1 \geq 0$

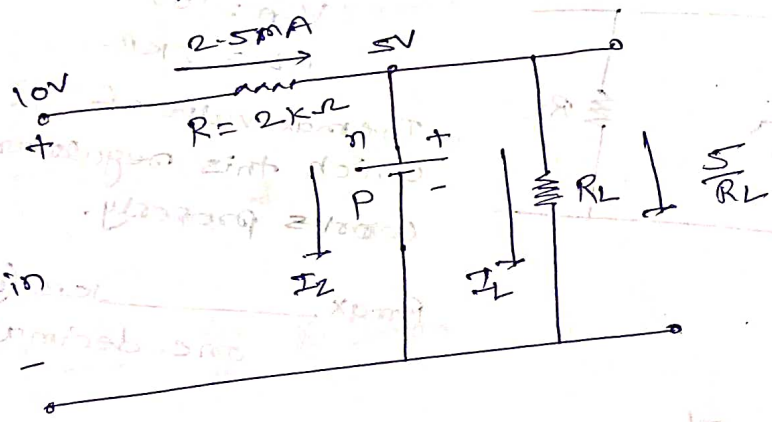
$R \leq 5/1$ $\boxed{R \leq 5k\Omega}$

$\boxed{R_{max} = 5.0\ k\Omega}$

Lect - 12

b) $V_{in} \rightarrow 10V$, $R = 2k\Omega$, the minimum value of R_L for which this ckt works properly. $2.01\ k\Omega$ upto 1 decimal place.

$I_Z = \frac{5}{R}$



$I_Z = \left(2.5 - \frac{5}{R_L}\right)$

$R_L\downarrow, \frac{5}{R_L}\uparrow, I_Z\downarrow$

$I_Z \geq I_{Zknee}$

$2.5 - \frac{5}{R_L} \geq 0$

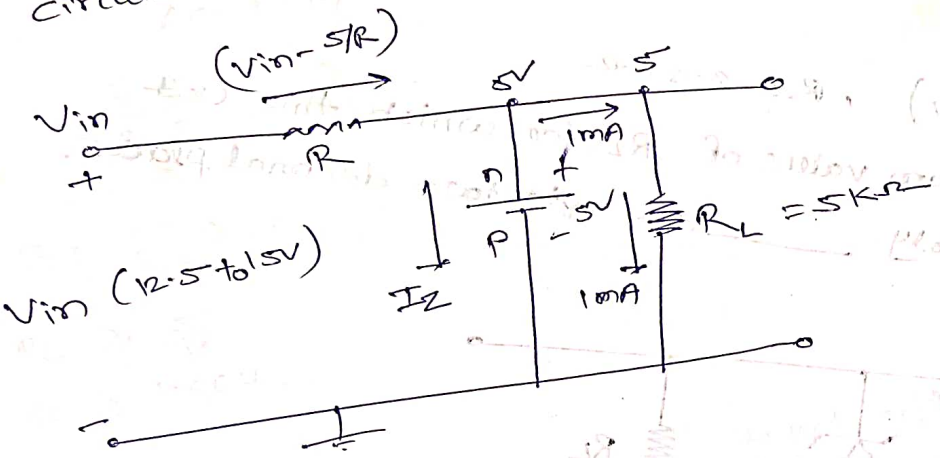
$\frac{5}{R_L} \leq 2.5$

$R_L \geq \frac{5}{2.5}$

$R_L \geq 2K\Omega$

c) V_{in} = (12.5V to 15 V)

$R_L = 5K\Omega$, then the maximum value of R for which this circuit works properly ____ $K\Omega$ upto one decimal place.



$I_Z = \frac{V_{in} - 5}{R} - 1$

$R\uparrow, I_Z\downarrow$

$\boxed{I_Z \geq I_{Z\,knee}}$

LCCt-18

$I_{Z\,min}$ w.r.to V_{in} $= \dfrac{(V_{in})_{min} - 5}{R} - 1$

$= \dfrac{7.5}{R} - 1$

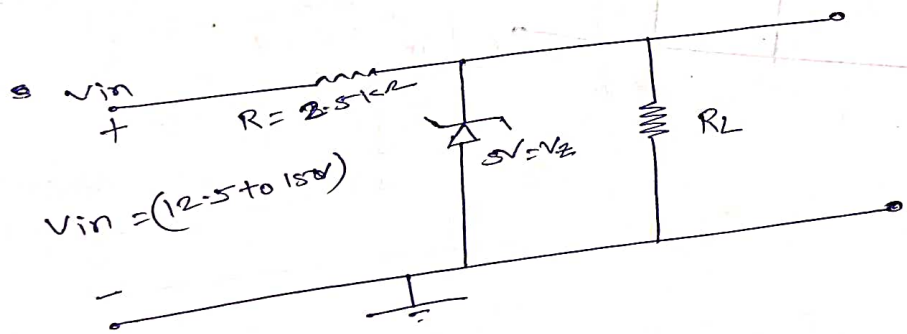
$I_Z \geq 0$

$\dfrac{7.5}{R} - 1 \geq 0$

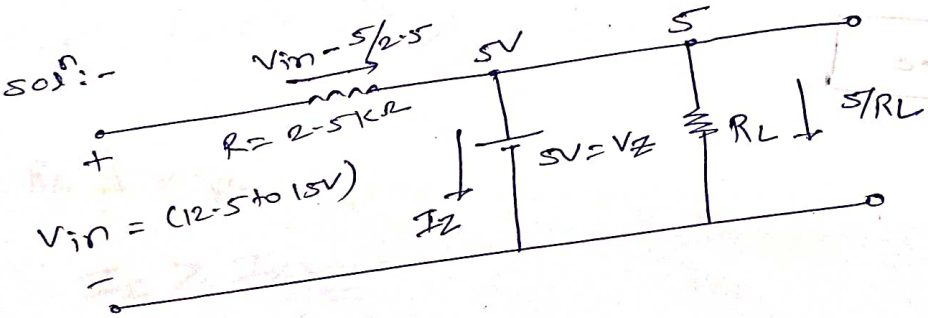
$\boxed{R \leq 7.5\ K\Omega}$

d) V_{in} (12.5 to 15V), $R = 2.5\ K\Omega$

then the minimum value of R_L for which this ckt works properly _____ $K\Omega$ upto two decimal places.



Sol^n:-



$$I_Z = \frac{V_{in}-5}{2.5} - \frac{5}{R_L} \quad \text{—(1)}$$

$R_L \downarrow$, $\frac{5}{R_L} \uparrow$, $I_Z \downarrow$

$$\left\{ \begin{array}{l} I_Z \geq I_{Zknee} \\ \boxed{I_Z \geq 0} \end{array} \right\}$$

$$(I_Z)_{min} = \frac{12.5-5}{2.5} - \frac{5}{R_L}$$

Lect-14

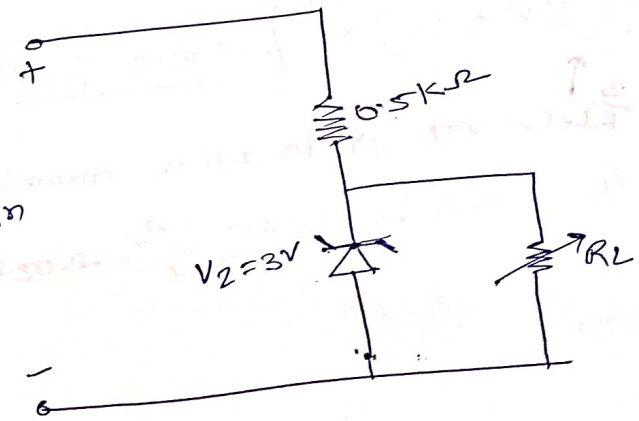
$$\frac{7.5}{2.5} - \frac{5}{R_L}$$

$$3 - \frac{5}{R_L} \geq 0$$

$$R_L \geq \frac{5}{3}$$

$$R_L \geq 1.667.$$

Q)



Input Vin = (10 to 10%) volt and power rating of zener diod is 24 mW. then for minimum value of RL for which circuit works properly is

a) 250Ω b) 187Ω
c) 750Ω d) 375Ω

$V_{in} = 10 \pm 10\%$

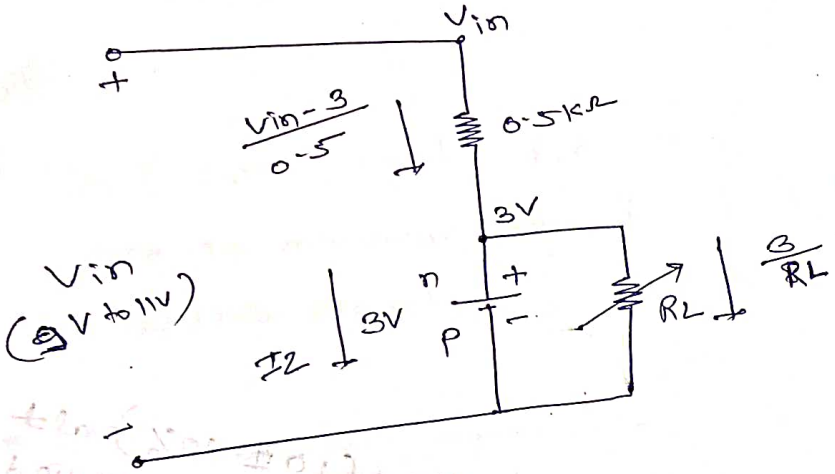
$= 10 \pm 1$

$V_{in} = (9 \text{ to } 11V)$

$P_{zmax} = 24\,mW$

$V_{z} \times I_{zmax} = 24\,mW$

$I_{zmax} = 8\,mA$ $\qquad V_z = 3V$



$$I_Z = \frac{V_{in} - 3}{0.5} - \frac{3}{R_L}$$

$R_L \downarrow$, $V_{in} \downarrow$, $I_Z \downarrow$, $\frac{3}{R_L} \uparrow$

$$\boxed{I_Z \geq I_{Z\,knee}}$$

$I_Z \geq 0$

$I_{Z\,min} = 12 - \frac{3}{R_L}$

$V_{in} = 9$

$12 - \frac{3}{R_L} \geq 0$

$12 \geq \frac{3}{R_L}$

$R_L \geq \frac{3}{12}$

$0.25\,k\Omega \leq R_L$

$V_{in} = 11$

$\frac{8}{0.5} - \frac{3}{R_L} \geq 0$

$R_L \geq \frac{8}{18}$

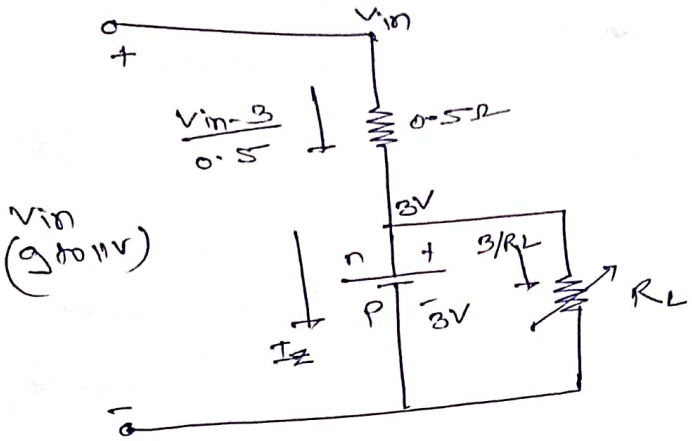
$R_L \geq 187\,\Omega$

Lect - 15

$\boxed{R_L \geq 250\,\Omega}$ min for $(10 \pm 10\%)$.

Q) maximum value of R_L for which ckt works properly

a) $750\,\Omega$, b) $375\,\Omega$. c) $500\,\Omega$ d) $250\,\Omega$



$R_L \rightarrow$ maximum value?

$$\boxed{I_{zmax} = 8mA}$$

$$I_z = \frac{V_{in}-3}{0.5} - \frac{3}{R_L}$$

$R_L \uparrow$, $\frac{3}{R_L} \downarrow$, $I_z \uparrow$

$$\boxed{I_z \leq I_{zmax}} \rightarrow I_z \leq 8mA$$

$$\frac{11-3}{0.5} - \frac{3}{R_L}$$

$$\frac{8}{0.5} - \frac{3}{R_L} \leq 8$$

$$16 \leq 8 + \frac{3}{R_L}$$

$$8 \leq \frac{3}{R_L}$$

$$R_L \leq \frac{3}{8}$$

$$\boxed{R_L = 375\Omega}$$

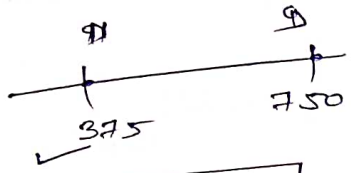
$\frac{9-3}{0.5} - \frac{3}{R_L} \leq 8$

$12 - 8 \leq \frac{3}{R_L}$

$4 \leq \frac{3}{R_L}$

$R_L \leq \frac{3}{4}$

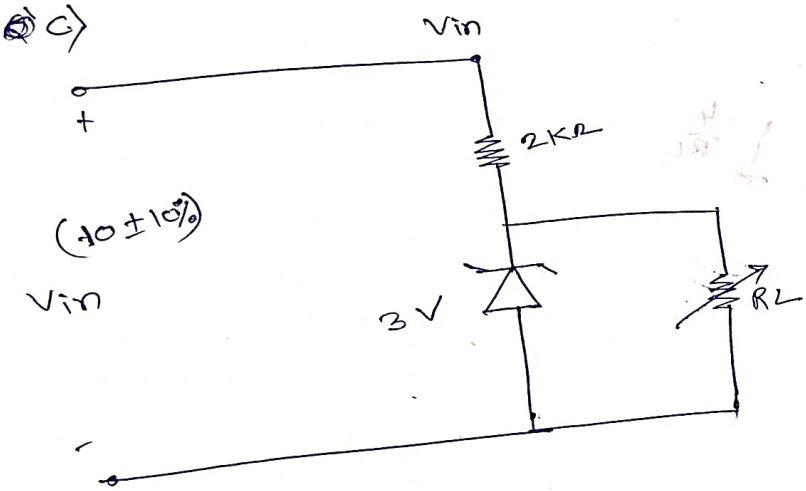
$\boxed{R_L \leq 750\Omega}$



$\boxed{R_L \leq 375\Omega}$ → max

$R_{Lmax} = 375$

c)

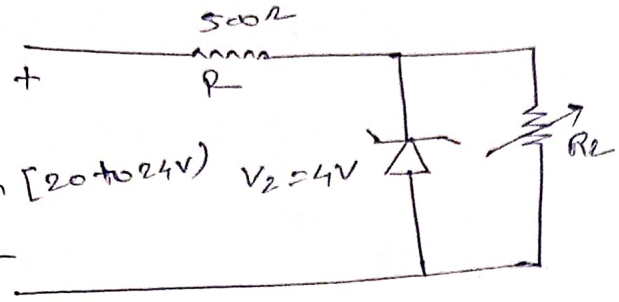


find R_L range $\underline{min < R_L < max}$

~~$R_{Lc} \geq 2000\Omega$~~

~~$R_{Lc} \leq 3750\Omega$~~

Q)



minimum value of RL & minimum power rating of zener diode will be

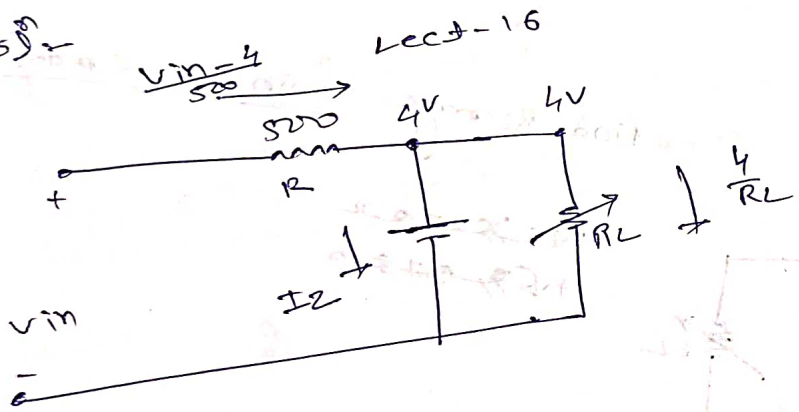
a) 125 Ω , 128 mW

✓ b) 125 Ω , 160 mW

c) 100 Ω , 128 mW

d) 100 Ω , 160 mW.

Sol:- Lect-16



Vin = 20

$I_Z = \frac{20-4}{500} - \frac{4}{R_L}$

$I_L \geq 0$

$0.032 - \frac{4}{R} \leq 0$

$R_L \geq 125\Omega$

$V_{in} = 24$

$\frac{0.04}{4}$ $\frac{4}{0.04} \geq R_L$

$\boxed{R_L \geq 100\Omega}$

$\therefore R_{L\,min} \geq 125\Omega$

$$I_Z = \frac{V_{in} - 4}{500} - \frac{4}{R_L}$$

$R_L \rightarrow \infty$ (o.c)

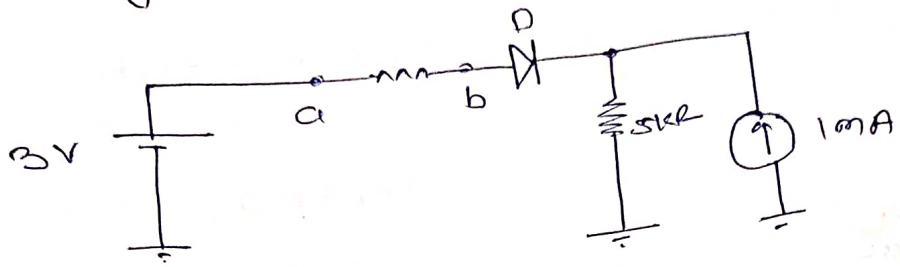
$$(I_{Z\,max}) = \frac{24-4}{0.5} = 40mA.$$

$$P_{max} = 4 \times 40mA = 160mW.$$

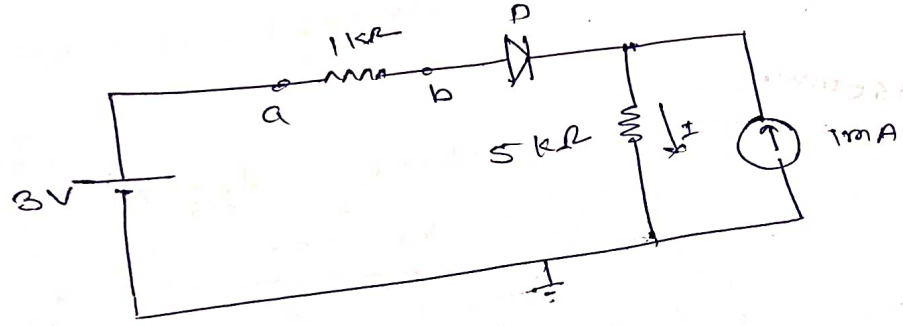
Discussion - 1

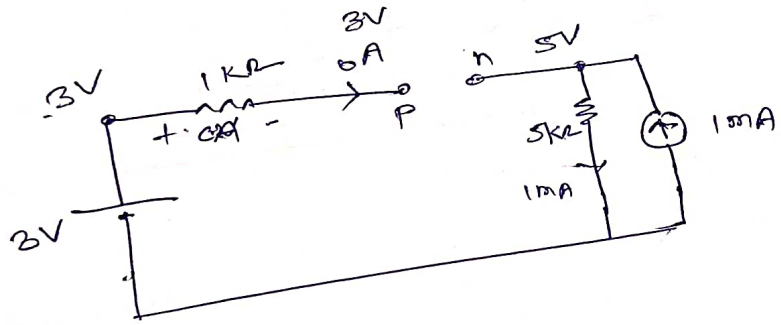
Category 01 (year Level)

Q1) The diode D used in the circuit below is ideal. the Voltage drop V_{ab} across the 1KΩ resistor in volt is



Sol^n:-

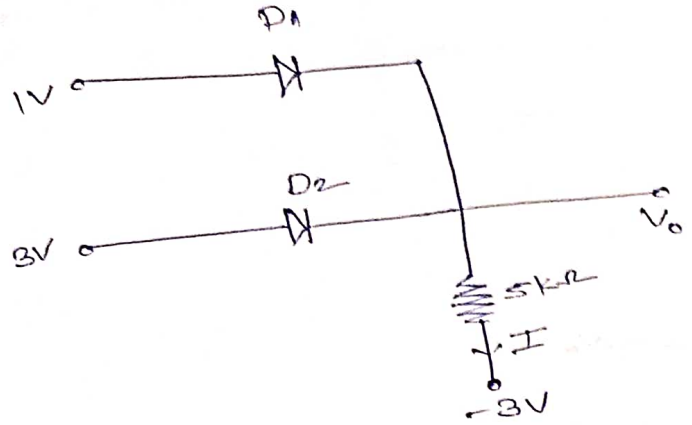




$\therefore V_{ab} = 0V$

$V_p - V_n = 3 - 5 = -2V \rightarrow$ Diode off.

(Q2) consider the circuit shown in the figure below



If diode D_1 & D_2 are made up of same material with the cutin voltage $V_\gamma = 0.7V$, then the value of current I is equal to

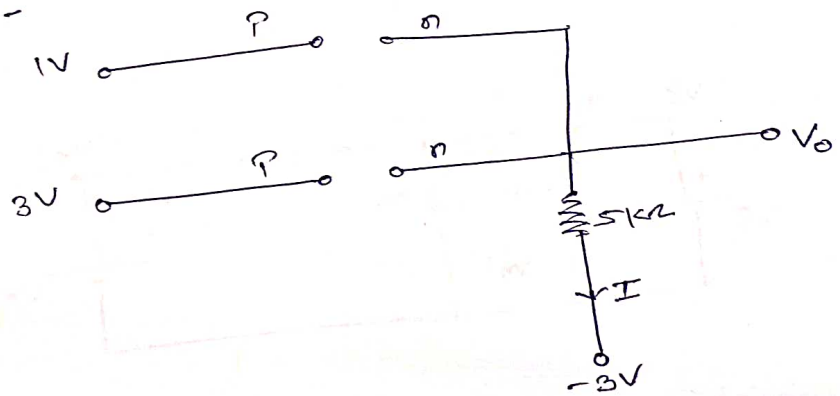
a) 0.46 mA

b) 0.99 mA

c) 0.59 mA

d) 1.06 mA

Sol:-



* KVL & KCL Never fail.

* n end connected to p end well known vice versa.

$(V_p - V_n - V_\gamma)$ highest

$V_n = V_o$

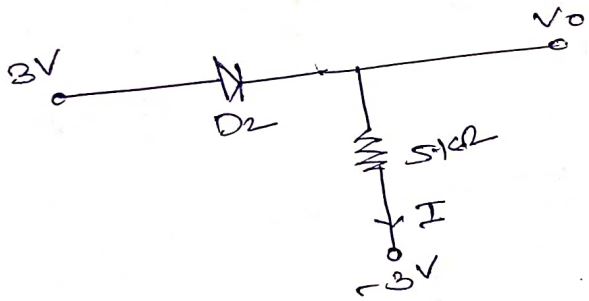
$V_{p1} = 1V$

$V_{p2} = 3V$

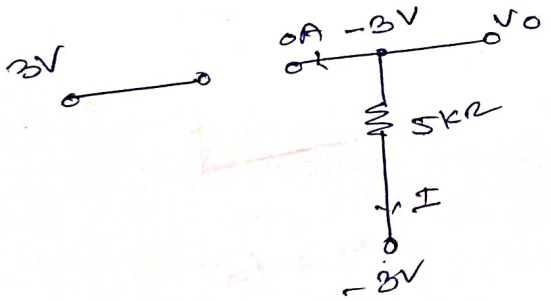
$V_{p1} - V_{n1} - V_\gamma = 1 - V_o - 0.7 = 0.3 - V_o$

$V_{p2} - V_{n2} - V_\gamma = 2.3 - V_o$ ✓ highest

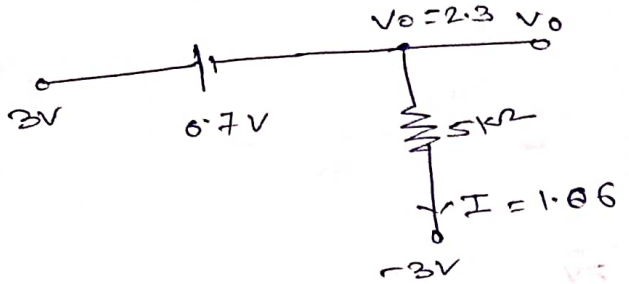
only condition is D_2 is ON.



oc test



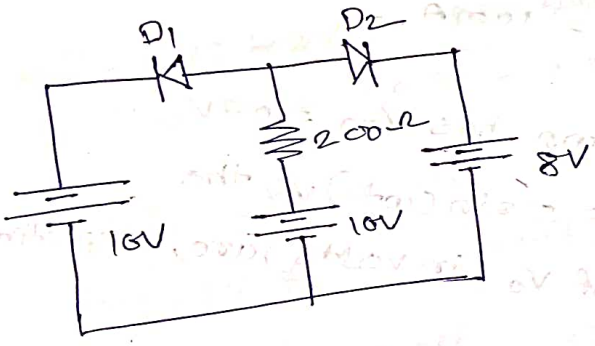
$V_p - V_n = 6V \times 0.7V/V_\gamma$



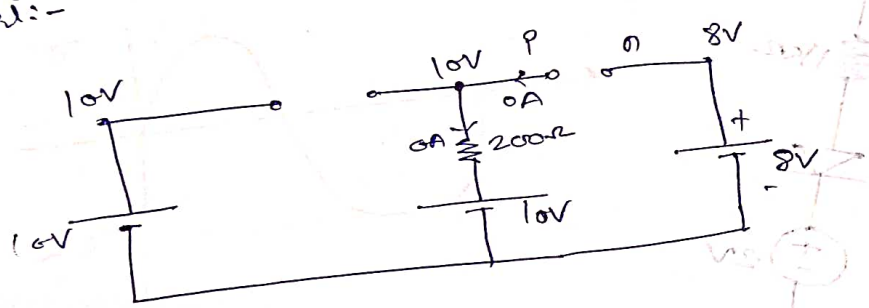
$$\frac{V_o - (-3)}{5} = \frac{2.3+3}{5} = 1.06\,mA.$$

$3 - 0.7 = 2.3$

Q3) for the circuit shown, assume ideal diode with zero forward resistance and zero forward voltage drop. The current through the diode D_2 in mA is ------.



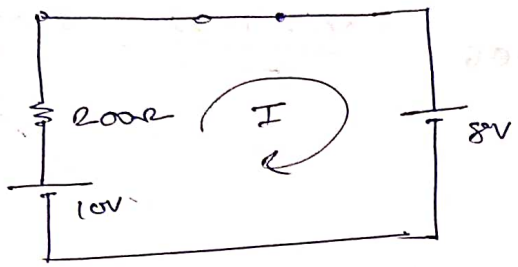
Soln:-



$p - n = 2V$

$(V_p > V_n) \rightarrow$ ON $\rightarrow D_2$

$D_1 \rightarrow$ off.



$10 - 8 - 200I = 0$

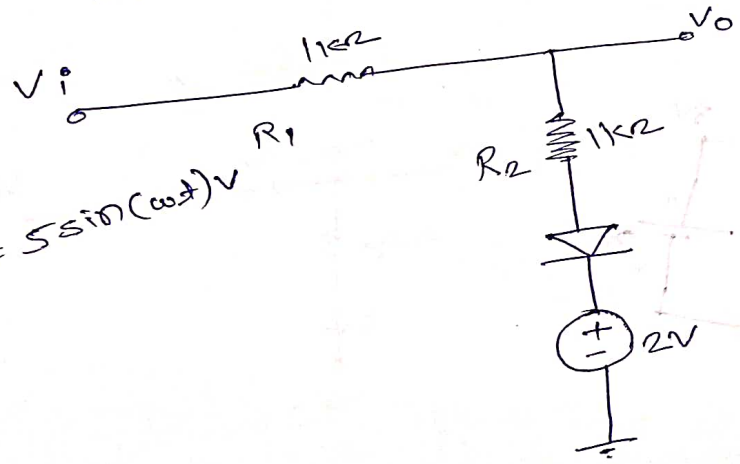
$\frac{2}{200} = I$

$0.01 = I$

$0.01 \times 1000 = 10mA.$

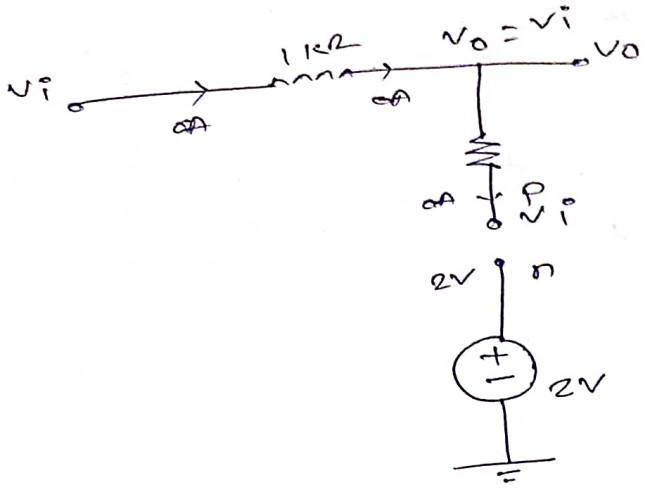
~~1mA~~

Q4) The diode in the circuit shown has $V_{on} = 0.7V$ but is ideal otherwise, If $v_i = 5\sin(\omega t)$ V, the minimum & maximum values of V_o (in volts) are, respectively,



$v_i = 5\sin(\omega t)V$

Sol:-



$V_p = V_i$

$V_n = 2V$

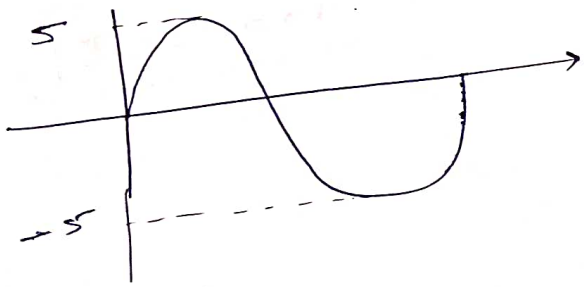
$V_p - V_n =$ ~~$V_i > 2V \Rightarrow V_i > 2V$~~

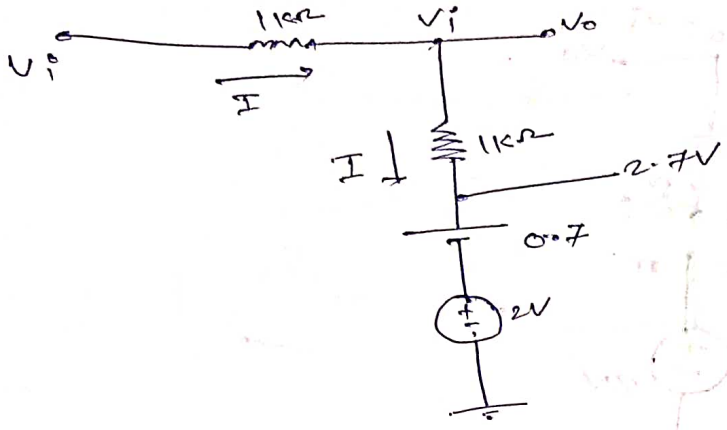
$V_i - 2 > 0.7 \rightarrow ON$

$V_i > 2.7 \rightarrow ON$

$V_i - 2V < 0.7 \rightarrow off.$

$V_i < 2.7 \rightarrow off. \Rightarrow V_o = V_i$ ✓





$$\frac{V_i - 2.7}{2} = I$$

Vo = 2.7 + I.1kΩ

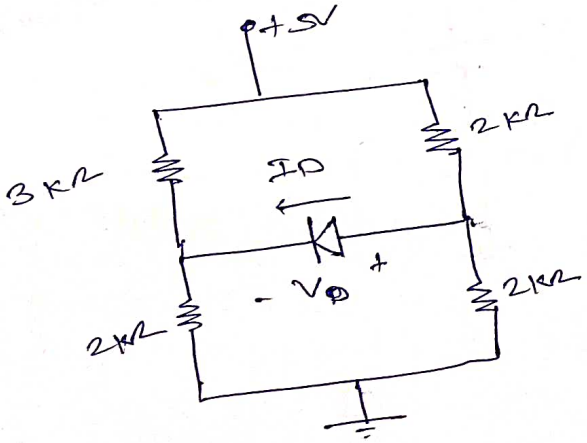
Vo = 2.7 + $\frac{V_i - 2.7}{2}$ $\boxed{V_i > 2.7}$

Vo = -5V

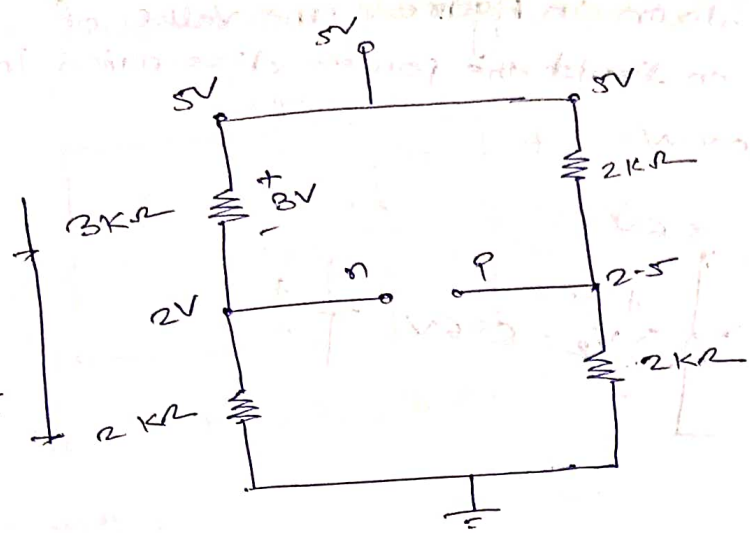
Vo = 2.7 + ↑

Vo = 3.85

Q5) Consider the circuit shown in figure. The value of diode current I_D for $V_\gamma = 0.6V$ is ----(in mA)



Sol:-



$V_\gamma = 0.6\,V$

$1mA = I$

$\frac{5-0}{4} = 1.25mA$

$\frac{5-0}{5} = 1mA$

$3 \times 1 = 3V$

$2 \times 1.25 = 2.5V$

$5 - 3 = 2$

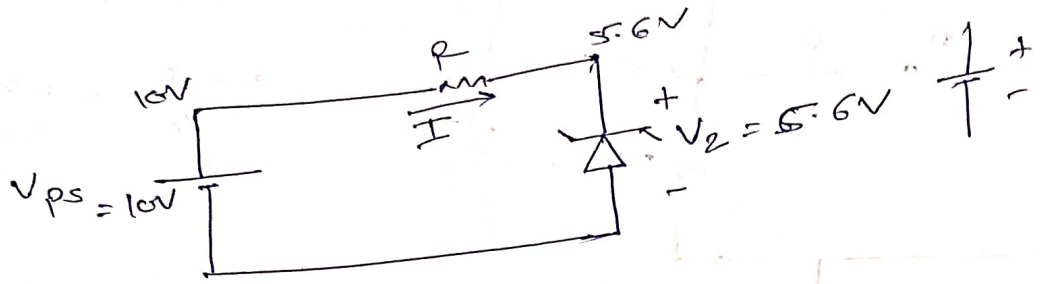
$p - n > 0.6$

$2.5 - 2 > 0.6$

$0.5 \not> 0.6 \rightarrow$ Diode off.

$\boxed{I_D = 0mA}$

Q6) Consider the circuit shown in figure. Find the power dissipation, resistance R required to limit the power dissipation of the zener diode to 10mW.



Sol:-

$P_z \leq 10mW$

$V_z \cdot I_z \leq 10mW$

$I = I_z \leq \frac{10}{5.6}$ mA

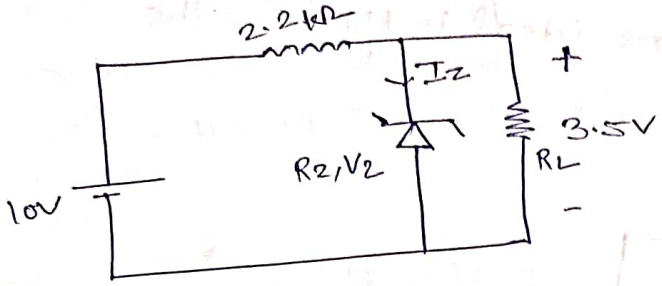
$\frac{10 - 5.6}{R} \leq \frac{10}{5.6}$

$R \geq \frac{4.4 \times 5.6}{10}$

$(R)_{min} \geq 2.464$

$\therefore$ more than this.

Q7) The current through the zener diode in figure is



$R_Z = 0.1 k\Omega$, $V_Z = 3.3V$

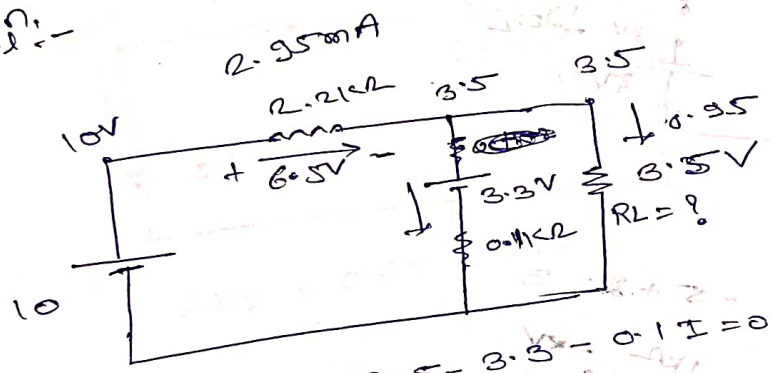
a) 3.3 mA

b) 4.3 mA

c) 2mA

d) 0mA

Sol:-



$3.5 - 3.3 - 0.1I = 0$

$\frac{0.2}{0.1} = 2mA = I$ ✓

$\therefore$ $2.95 - 2mA = 0.95mA$

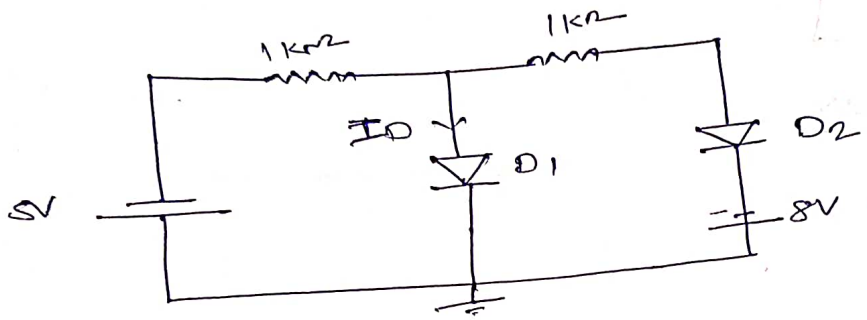
$\frac{V}{R} = I$

$R = \frac{V}{I}$

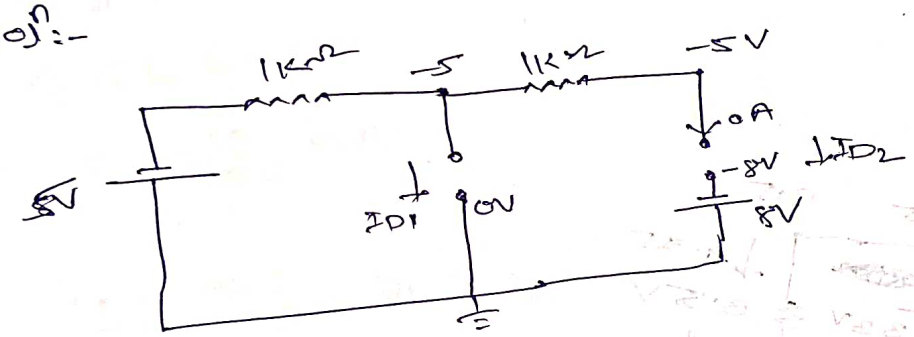
$R_L = \frac{3.5}{0.95} = 3.68 k\Omega$

Category 02 :- (your competitor level)

Q1) Assuming that the diode are ideal in figure, the current in diode D1 is

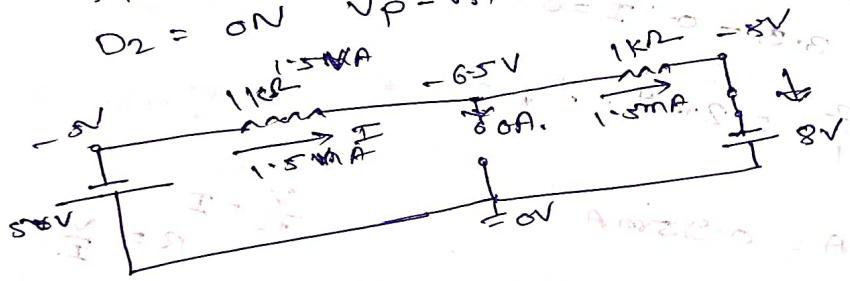


Soln:-



D1 = OFF

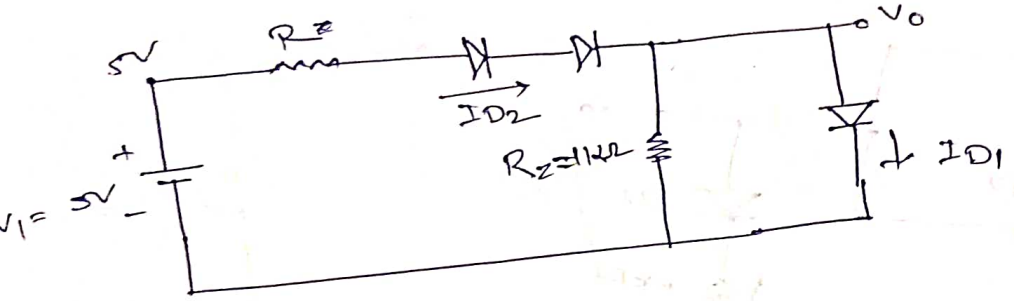
D2 = ON $V_p - V_n = -5 + 8 = 3$



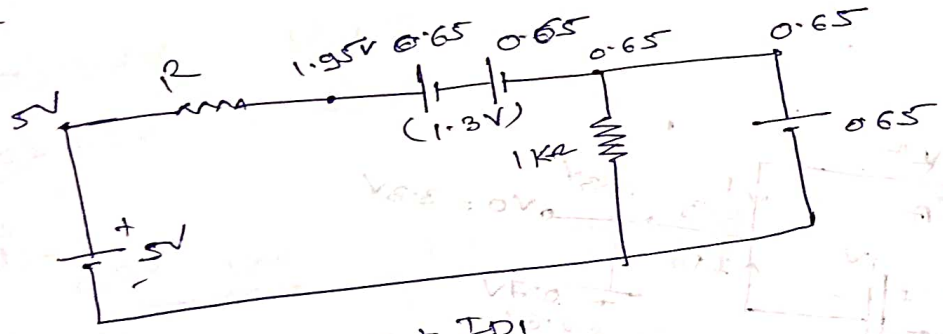
$$\frac{-5+8}{2} = \frac{3}{2} = 1.5mA$$

$\therefore D_1 = 0mA$

Q2) Assume each diode in the circuit shown in figure has a cut in voltage of $V_\gamma = 0.65V$. The input voltage is $V_1 = 5V$. The value of R_1 such that I_{D1} is one half the value of I_{D2} (in kΩ) is _____.



Soln:-



$$I_{D2} = 0.65 + I_{D1}$$

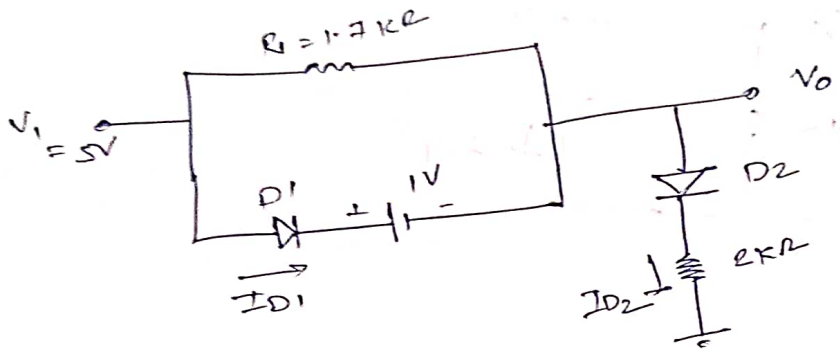
$$\frac{5 - 1.95}{R} = 1.3$$

$$R_1 = 2.34k\Omega$$

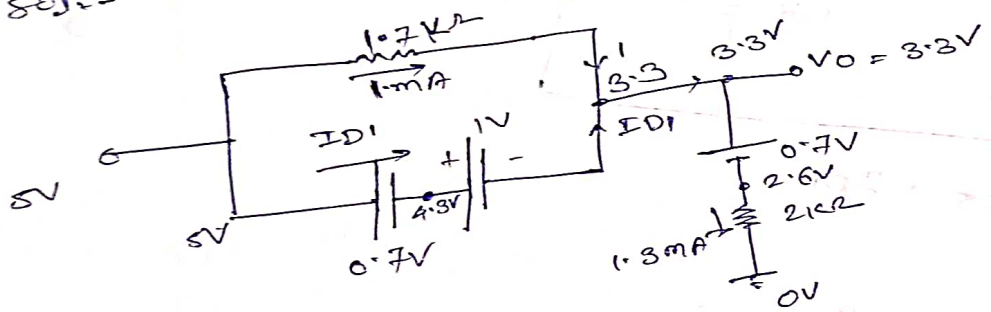
$$I_{D1} = \frac{1}{2} I_{D2}$$

$$\therefore 2.34 \times \frac{1}{2} = 1.3mA.$$

Q3) Consider the circuit shown in figure. The of each diode is $V_\gamma = 0.7V$. Let $V_1 = 5V$. Assume both diode are conducting. The the value of I_{D1} in mA is 0.3mA.



Sol:-



$5 - 0.7 = 4.3$

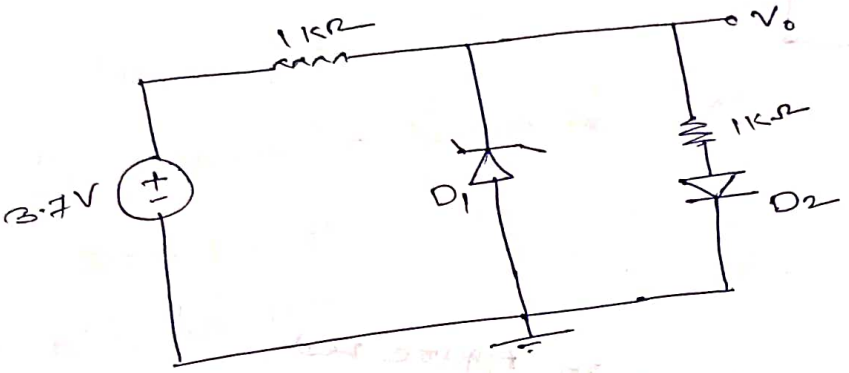
$4.3 - 1 = 3.3V$

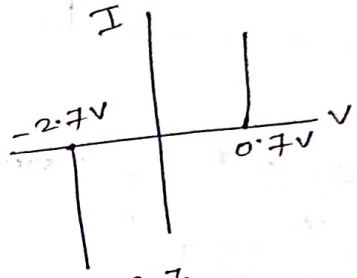
$I_{D1} + 1 = I_{D2}$

$I_{D1} + 1 = 1.3$

$I_{D1} = 0.3\,mA$

Q4) Assuming zener diode D_1 has current voltage characteristic as shown below. ~~reverse~~ Reverse voltage drop and forward voltage drop of diode D_2 is 0.7 V, the voltage V_0 in the circuit shown below is.





$V_n - V_p = 2.7$

$V_p - V_n = -2.7$

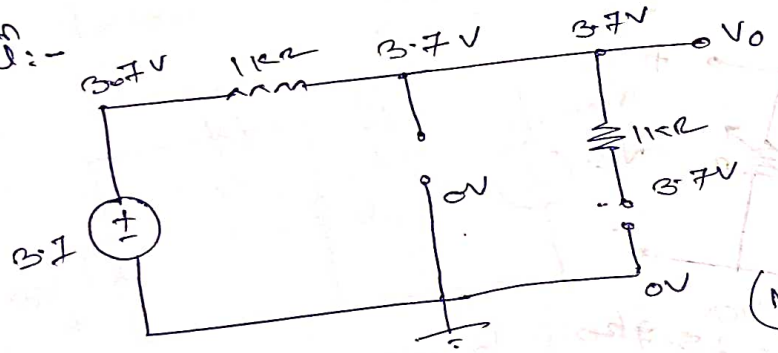
a) 3.7 V

b) 2.7 V

c) 2.2 V

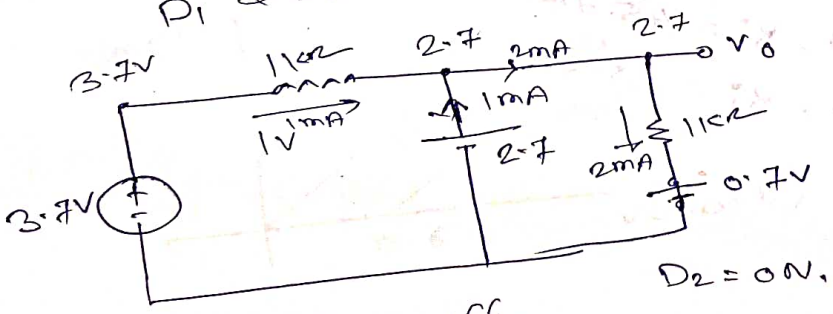
d) 0 V.

Sol^n:-



$(V_n - V_p) = 3.7 > 2.7$

D_1 & $D_2 \rightarrow$ ON

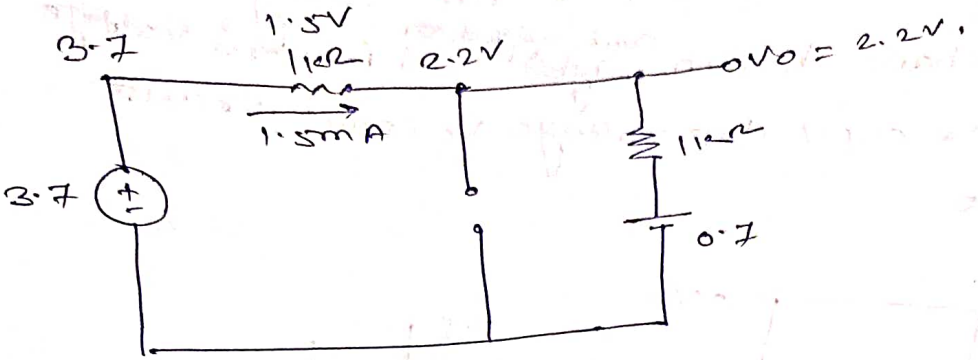


$2.7 - 0.7 - 1I = 0$

$I = 2mA$

$D_2 = ON.$

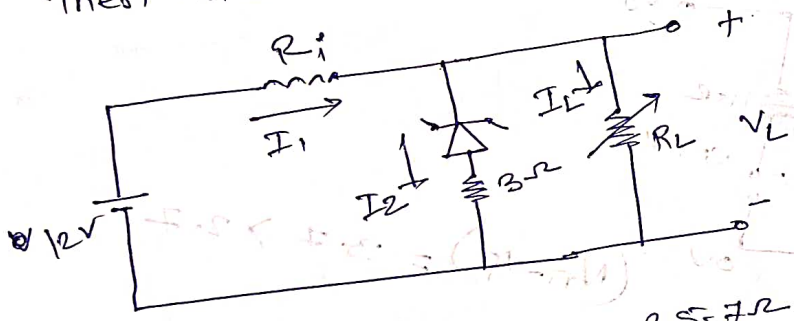
$D_1 = off.$



$$\frac{3.7 - 0.7}{2} = 1.5mA$$

$$\boxed{V_o = 2.2V}$$

Q5) consider the circuit shown in figure red $V_{PS} = 12V$. $V_{Z0} = 6.2V$, and $r_Z = 3\Omega$. The power rating of the diode is $P = 1W$. Then the value of $I_Z(max)$ and R_i are

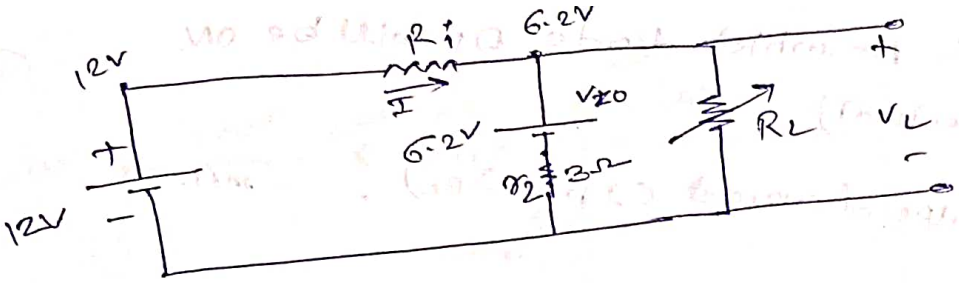


a) $I_Z(max) = 160\ mA$, $R_i = 25.7\Omega$

b) $I_Z(max) = 150mA$, $R_i = 35.7\Omega$

c) $I_Z(max) = 140mA$, $R_i = 45.7\Omega$

d) $I_Z(max) = 120mA$, $R_i = 25.7\Omega$



$P_{max} = 1W.$

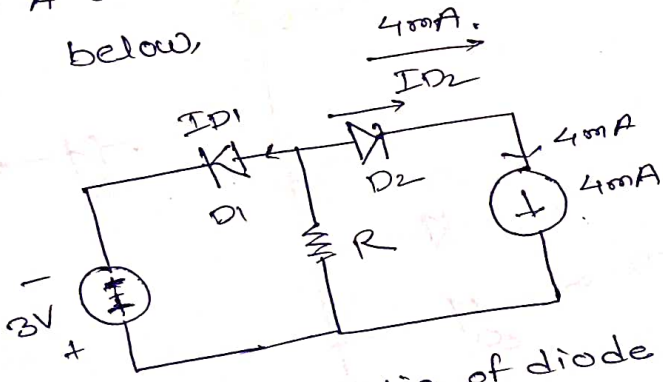
$(V_{z0} \times I_{Zmax}) + I_{Zmax}^2 r_z = 1W.$

$I_Z \leq 150mA$

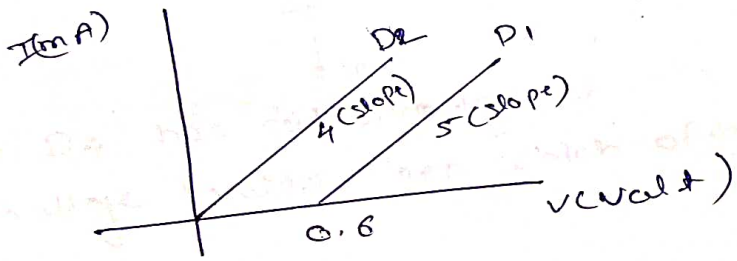
$R_i = 35.7\Omega$

Category 03 :- (G-20)

Q) A diode circuit is designed using diode D_1 & D_2 as shown below,



IV characteristic of diode D_1 & D_2 is given below



i) maximum value of R for which diode D1 will be ON

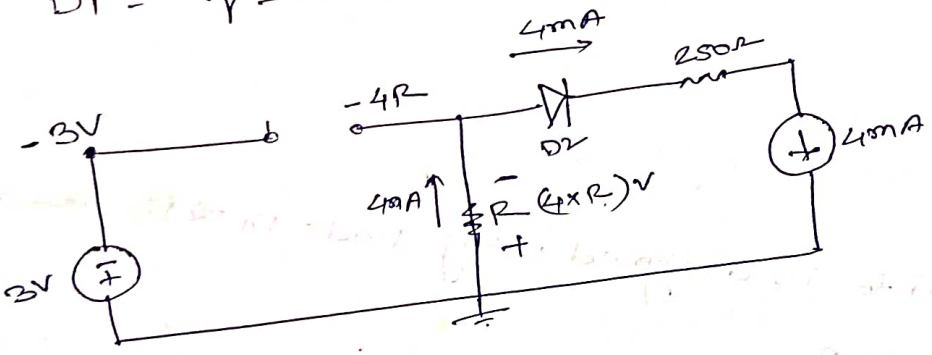
0.60 kΩ (upto two decimal)

ii) for R = 0.5 kΩ, value of current $(I_{D1} + I_{D2})$ ---- mA.

soln:-

① $D_2 = V_\gamma = 0$, $R_f = 250\Omega = \frac{1}{4}$

$D_1 = V_\gamma = 0.6$, $R_f = 200\Omega$



$-4R - (-3) > 0.6$

$-4R + 3 > 0.6$

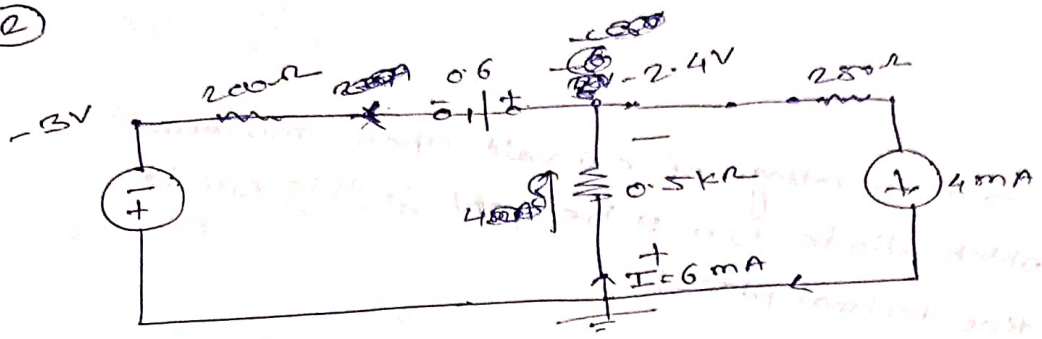
$3 > 0.6 + 4R$

$2.4 > 4R$

$\frac{2.4}{4} > R$

$\boxed{R < 0.6\,k\Omega}$

(2)



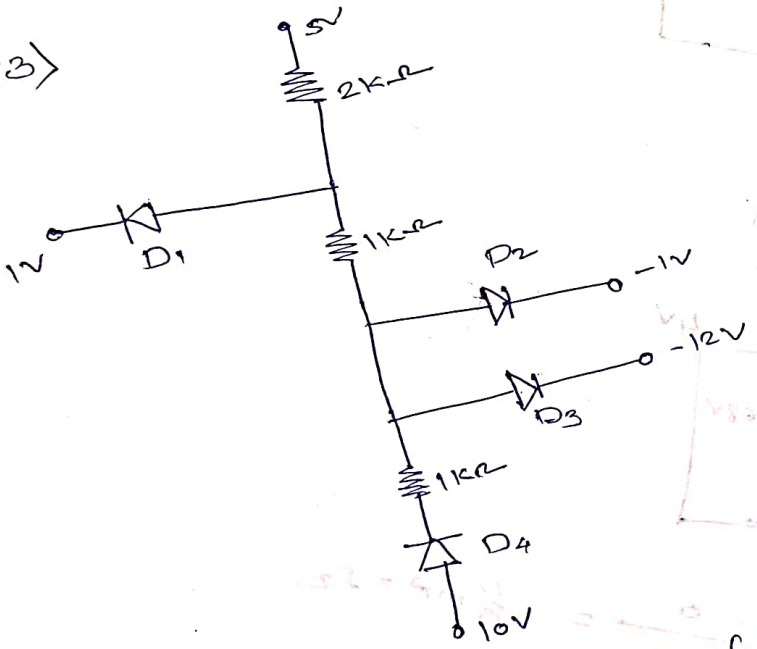
$4 \times 0.5 = 2V$

$-3V - 200 \times I - 0.6 - 2.4 = 0$

$V_p > V_n$

$R = 0.5k\Omega$ $\quad (I_{D_1} + I_{D_2} = 4.57$

Q3)



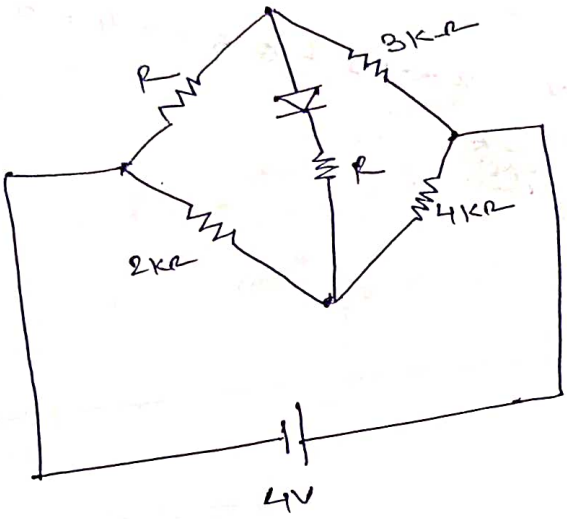
D_1, D_2, D_4 has cut in voltage of 0.6V while diode D_3 cut in voltage 1 volts. Then which of the following statements is true.

D_2, D_4 — ON

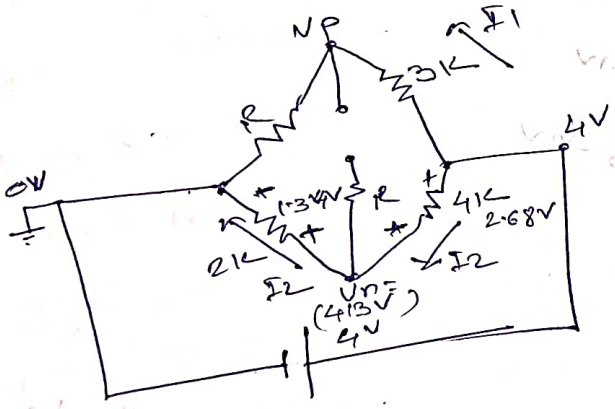
$D_3, D_1 \rightarrow$ off.

Q3) Diode D has cut in voltage of 0.6 volt. Then minimum value of R for which diode D will be ON in this circuit

_____ kΩ (upto two decimal place)



Sol^n --



$\frac{4-0}{3+R}$ mA $= I_1$, $\frac{4-0}{6} = \frac{4}{6}$ mA $= I_2$

$RI_1 = \frac{R4}{R+3} =$

$$V_p = \frac{4R}{R+3}$$

$$V_n = 4/3$$

$$(V_p - V_n) \geq 0.6$$

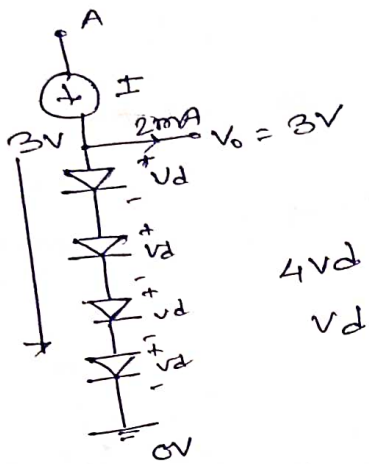
$$\frac{4R}{R+3} - \frac{4}{3} \geq 0.6$$

$$\frac{4R}{R+3} \geq 1.93$$

$$\boxed{R = 2.81\ k\Omega}.$$

ii) current I_d in ~~m~~ (μA) ——→ when $R = 3k\Omega$.

Q4) A diode circuit is as shown below



$4V_d = 3V$

$V_d = \frac{3}{4}$ Volt

All the diode are identical diodes with reverse saturation current of $I_s = 10^{-15}$ A. If the load connected as output V_o draws a current of 2mA then for V_o to be 3V, $V_T = 25m$ the value of I _____ mA.

Soln:- Given $\frac{KT}{q} = 25$ mA

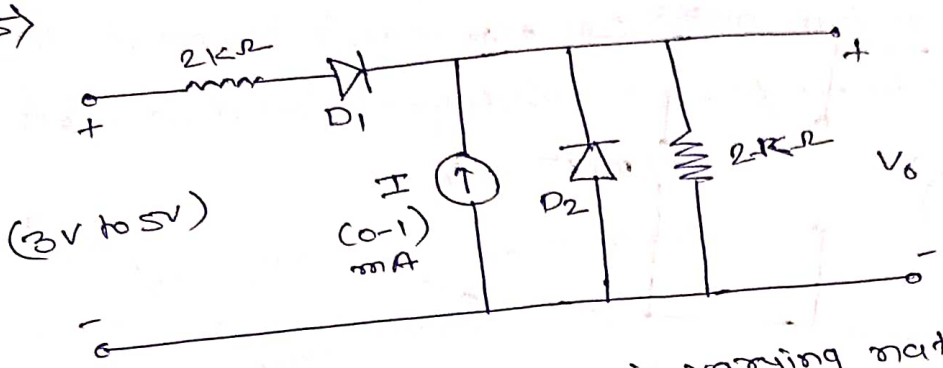
$$I_d = I_o\left[e^{V_d/V_T} - 1\right]$$

$$I_d = 10^{-15}\left[e^{750/25} - 1\right] A$$

$I_d = 0.0106A = \cancel{12.68mA}$ 10.68mA.

$I = (I_d + 2) = 12.68$ mA.

Q5)



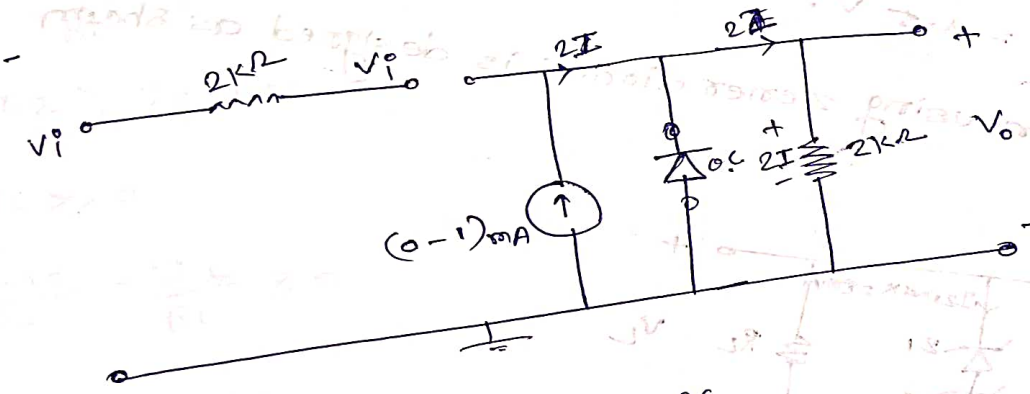
The input voltage source is varying nature and is varying from 3 to 5 V while current source I varying from (0-1)mA.

Then ($V_{o\,max}$, $V_{o\,min}$) will be

where $V_{o\,max}$ → maximum value of V_o

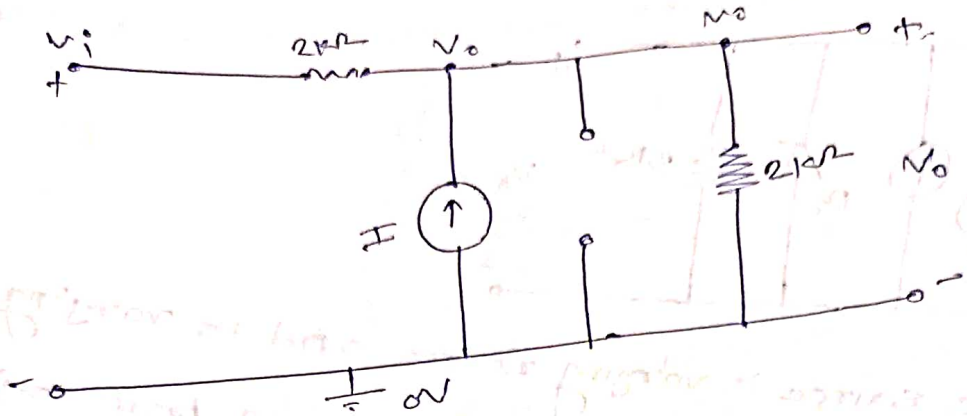
$V_{o\,min}$ → minimum value of V_o

sol:-



$(0-2I)_{o.c.}$ → D_2 → off

$(V_i - 2I)_{o.c}$ → $(3-2\times1) = 1V$ → ON. > V_γ.



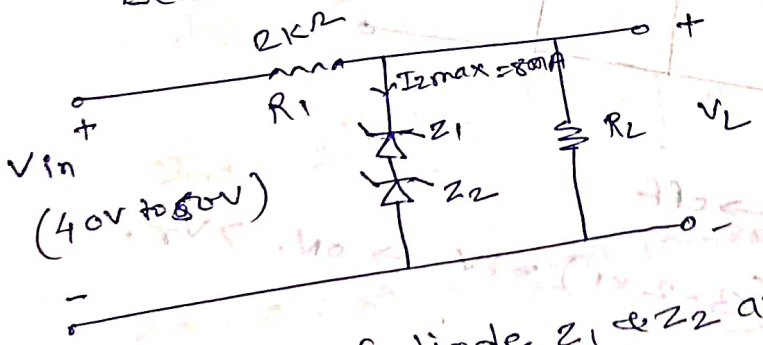
$$\frac{V_i - V_o}{2} + I = \frac{V_o - 0}{2}$$

$$V_o = \left(\frac{V_i}{2} + I\right)$$

$V_o\,max = 3.5V$

$V_o\,min = 1.5\ V.$

Q7) A regulator using zener diodes is designed as shown below.



specification of diode Z_1 & Z_2 are :-

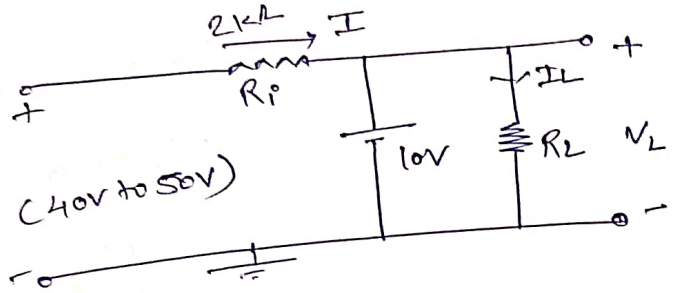
Z_1 : $V_Z = 4V$, $P_Z\,max = 40\,mwatt \longrightarrow I_Z\,max = 10mA$

Z_2 : $V_Z = 6V$, $P_Z\,max = 48\,mwatt. \longrightarrow I_Z\,max = 8mA.$

If $R_L max$ & $R_L min$ are maximum and minimum value of R_L for which this regulator circuit works perfectly then $\frac{R_L max}{R}$.

Sol^n:- $V_Z = 10V$, $I_Z max = 8 mA$.

$I_{Z\,knee} = 0 mA$.



$I_Z = I - I_L$

$\frac{10}{R_L}$,

$I_Z \geq I_{Z\,knee}$

$I - I_L \geq 0$

$\frac{V_{in} - 10}{2} - \frac{I_L}{R_L} \geq 0$

$\frac{V_{in} - 10}{2} - \frac{10}{R_L} \geq 0$

$R_L \geq 1.5 k\Omega$

$\boxed{R_L min = 0.67 k\Omega}$

$I_Z \leq I_{Zmax}$

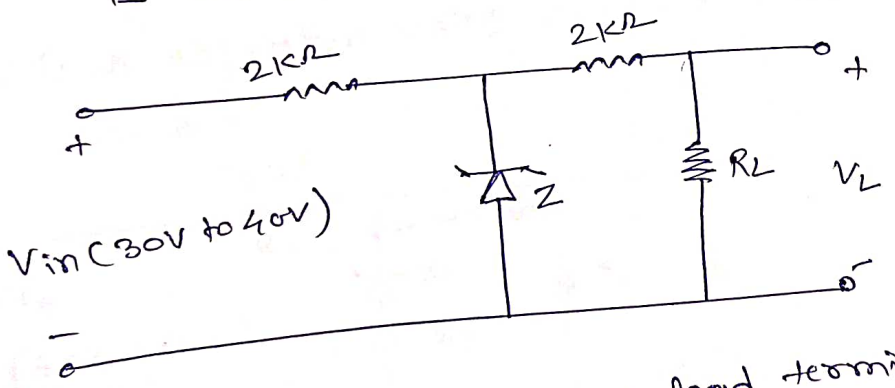
$$\frac{V_{in}-10}{2} - \frac{10}{R_L} \leq 8$$

$$\frac{50-10}{2} - \frac{10}{R_L} \leq 8$$

$R_L \leq 5/6\ K\Omega$

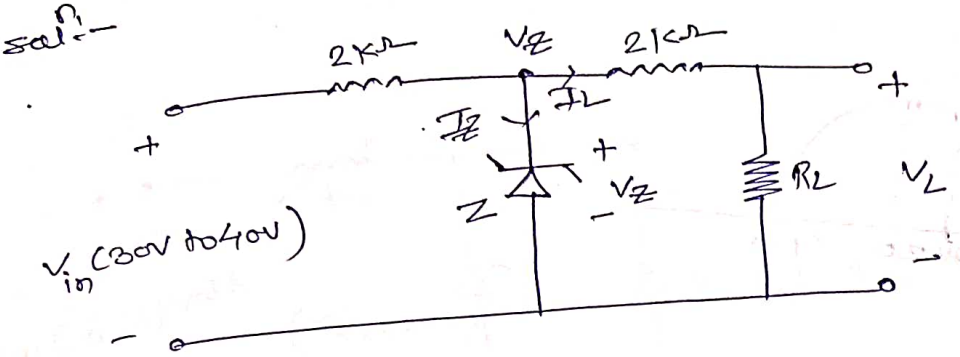
$$\frac{R_{Lmax}}{R_{Lmin}} = 1.25.$$

Q8) A regulator circuit designed using zener diode is shown below



If maximum voltage across load terminal should not exceed 12V then minimum power rating of zener diode Z should be _____ mWatt.

sol^n:-



$V_L(max) = V_Z$

$(V_L)_{max} \leq 12V$

$\boxed{V_Z \leq 12}$

$$I_{Z\,max} = \frac{V_{in} - V_Z}{2} = \frac{40 - V_Z}{2}$$

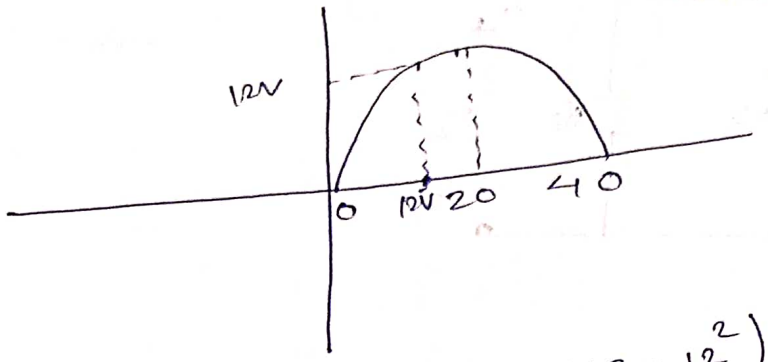
$$(P_{dissipation})_{max} = V_Z\left(\frac{4 - V_Z}{2}\right) = \frac{1}{2}\left(40V_Z - V_Z^2\right)$$

$$\frac{1}{2}\frac{d}{dV_Z}\left(40V_Z - V_Z^2\right) = 0$$

$$40 - 2V_Z = 0$$

$$\boxed{V_Z = 20V}$$

$\boxed{V_Z \leq 12}$



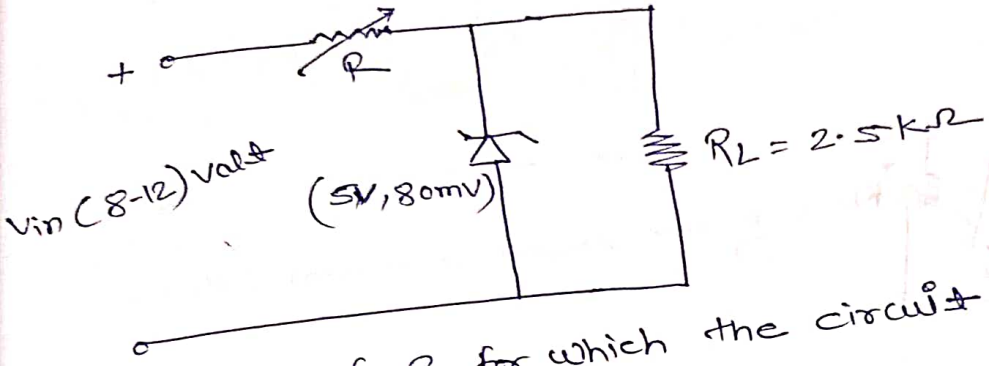
$$(P_{diss})_{max} = \frac{1}{2}(40 \times 12 - 12^2)$$

$$= 168\,mA.$$

Q6) A Applied R.B. voltage of $V_R = -2$ volt the current flowing through a diode is I. we want to have a current of $I_1 = I/2$ through diode then voltage applied will be ---- mVolt

Given $\frac{KT}{q} = 25$ mVolt.

Q)



The range of R for which the circuit works properly.

a) $167\Omega \leq R \leq 1500\Omega$ b) $389\Omega \leq R \leq 3500\Omega$

✓c) $389\Omega \leq R \leq 1500\Omega$ d) $167\Omega \leq R \leq 389\Omega$

Sol:-

$$I_Z = \frac{V_{in} - 5}{R} - \frac{5}{2.5}$$

$R\downarrow, I_Z\uparrow$

$I_Z \leq I_{Zmax}$

$$(I_Z)_{high} = \frac{12-5}{R} - 2$$

$$= \frac{7}{R} - 2 \leq 16$$

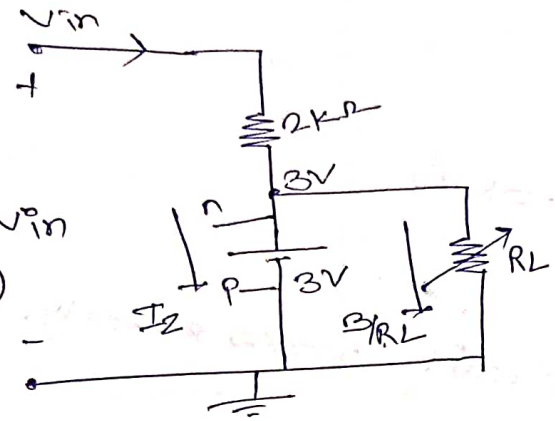
$$\frac{7}{R} \leq 18$$

$$R \geq 7/18 \ k\Omega$$

Q)

(20-22)

(9 to 11)



$$I_Z = \frac{V_{in} - 3}{2} - \frac{3}{R_L}$$

$R_L \downarrow$, $I_Z \downarrow$

$I_Z \geq I_{Zknee} \longrightarrow I_Z \geq 0$

$$3 - \frac{3}{R_L} \geq 0$$

$$\frac{3}{R_L} \leq 3$$

$$\boxed{R_L \geq 1k\Omega}$$

$R_L \uparrow$, $I_Z \uparrow$, $I_Z \leq I_{Zmax}$

$I_Z \leq 8mA$

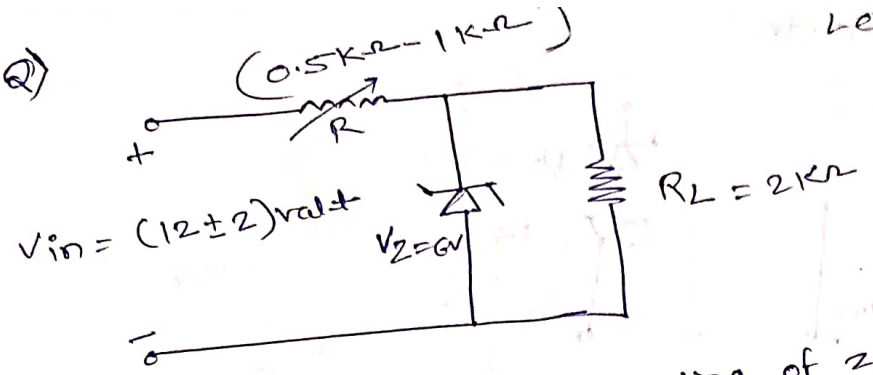
$$4 - \frac{3}{R_L} \leq 8$$

$$\boxed{\frac{3}{R_L} \not\geq -4}$$

Not properly framed question

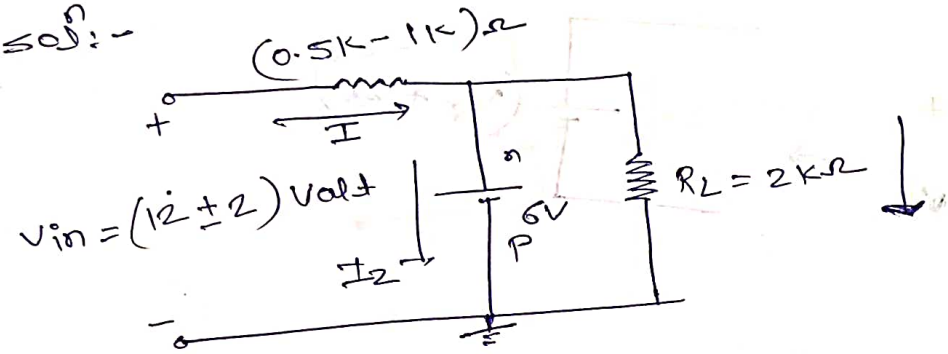
Lect - 18

Q)



Then the minimum power rating of zener diode should be ----

Sol:-



$$I_Z = \frac{V_{in} - 6}{R} - 3$$

$$(I_Z)_{high} = \frac{14-6}{0.5} - 3$$

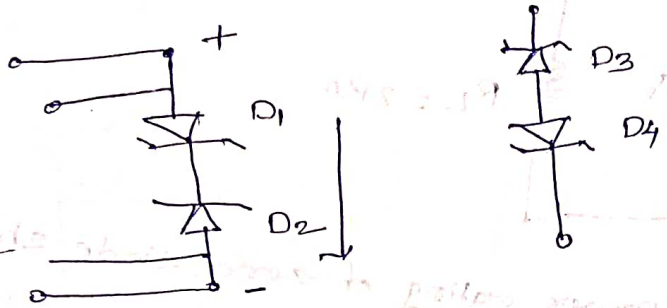
$$= 16 - 3 = 13\,mA$$

$$(P_Z)_{max} = 13\,mA \times 6V$$

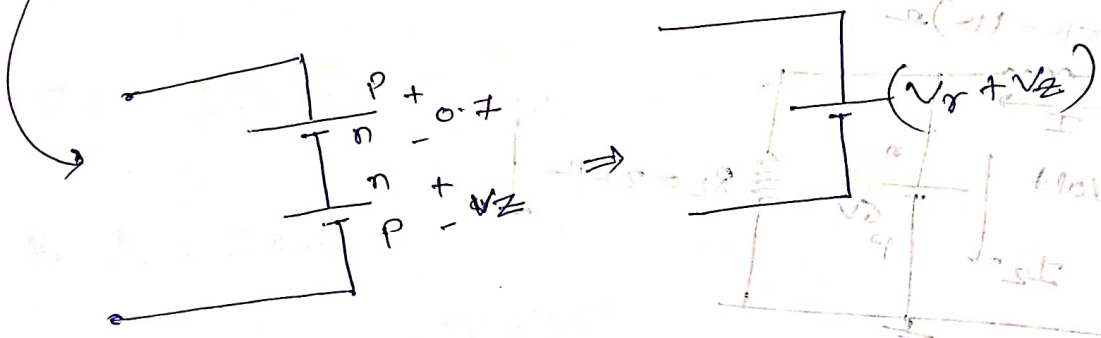
$$= 78\,mW.$$

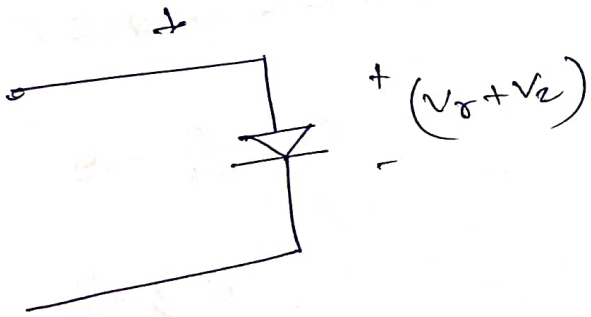
Multiple Zener diode

(1)

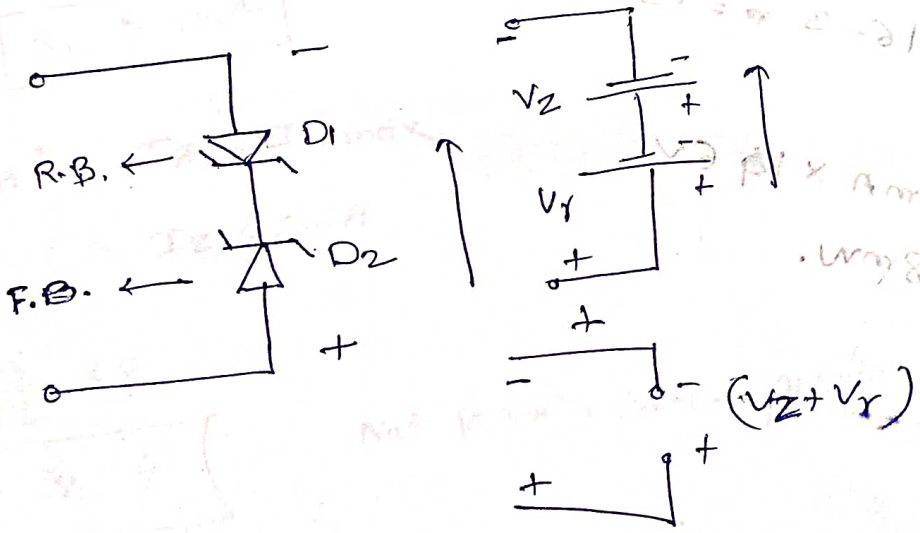


Lect-19

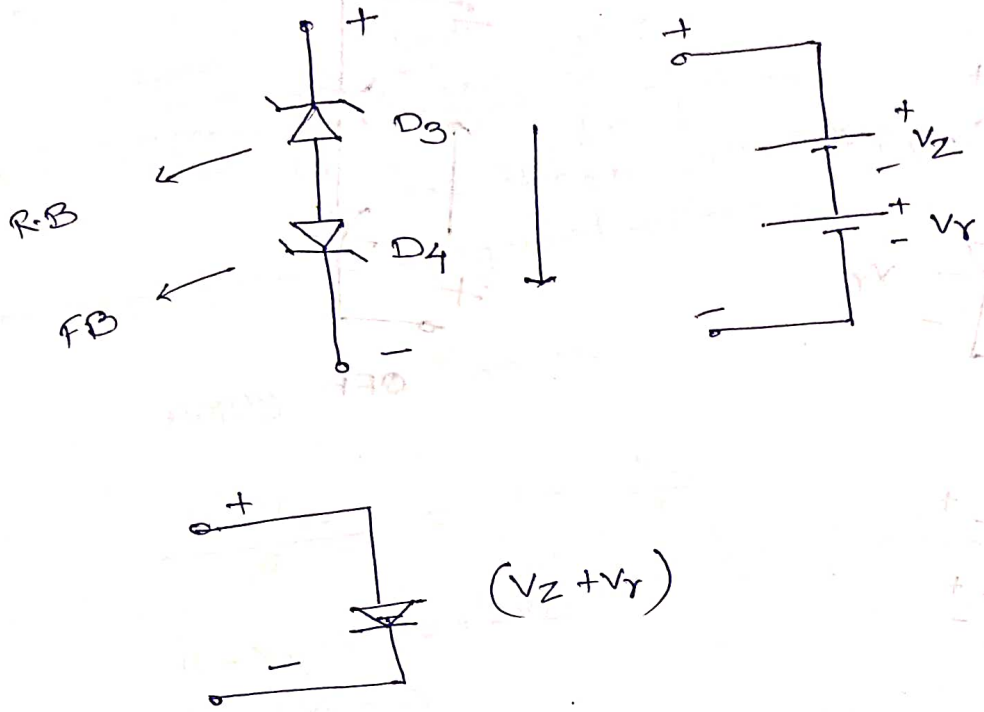




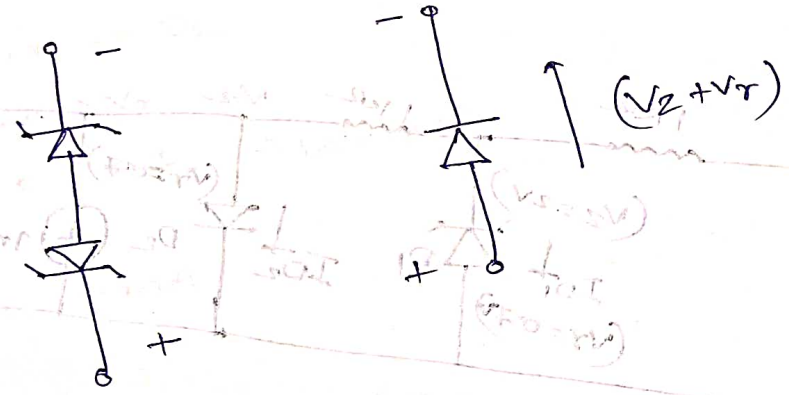
(2)



(3)

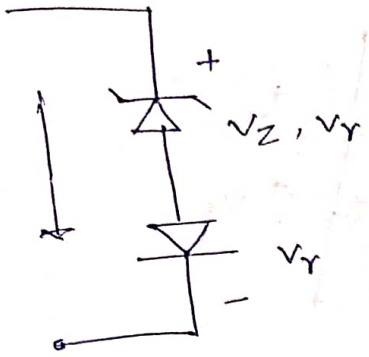


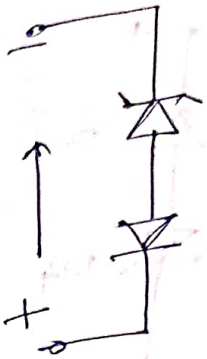
(4)



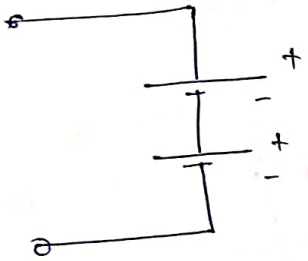
Lect-19

(4)



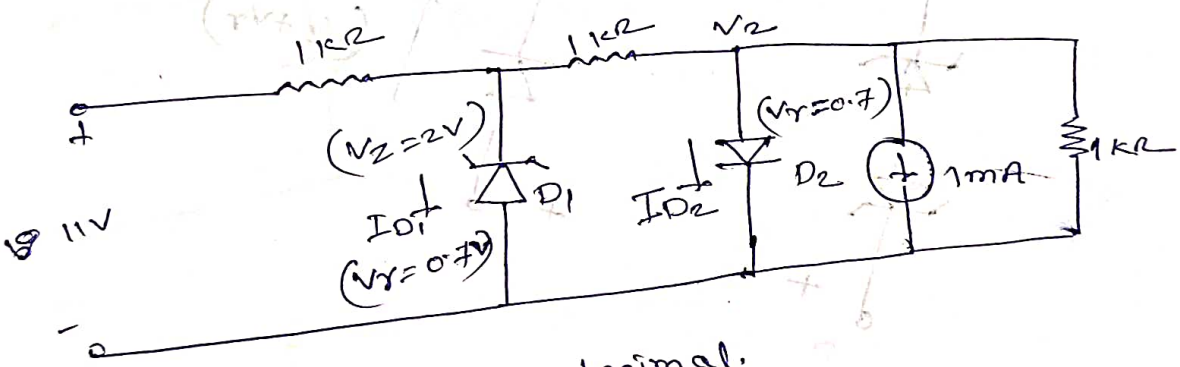


OFF



ON

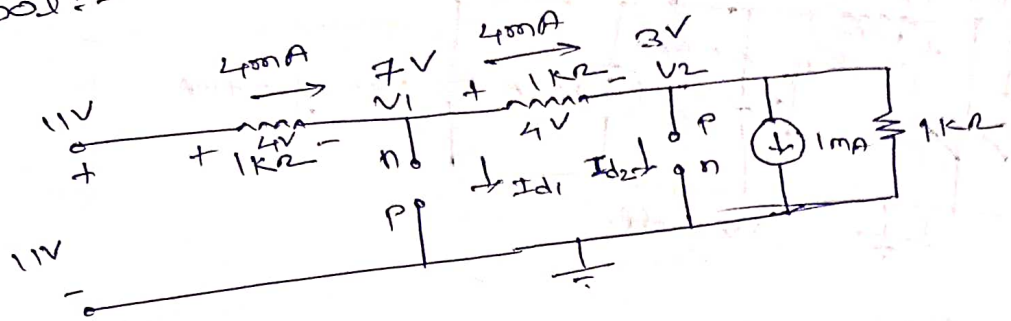
Q)



$V_1 + V_2 =$ ____?____ upto two decimal.

$I_{D1} + I_{D2} =$ ____ mA upto two decimal.

Sol:-



Apply KCL on V_2

$$\frac{11 - V_2}{2} = 1 + \frac{V_2}{1}$$

$$11 - V_2 = 2 + 2V_2$$

$$3V_2 = 9$$

$$\boxed{V_2 = 3V}$$

$p > n \rightarrow D_2$

$p > n > V_\gamma$

$3 - 0 > 0.7 \rightarrow D_2 = ON$

$$\frac{11 - 3}{2} = 4mA$$

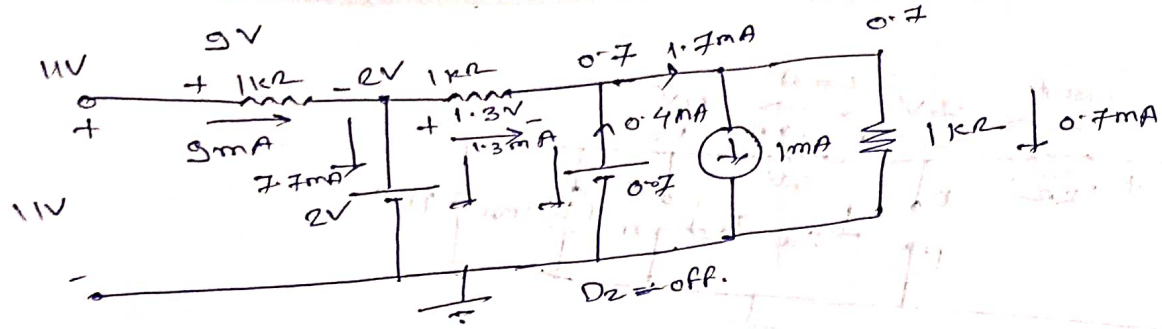
$11 - 4 = 7V$

D_1

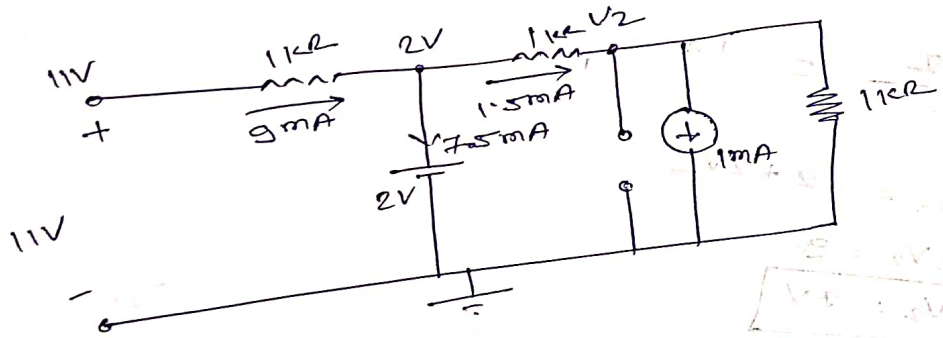
$V_n - V_p > V_Z$

$7 - 0 > 2V$

$7 > 2$. $D_1 = ON$



~~V1+V2 = 2+0.7 = 2.07~~



$$\frac{2-V_2}{1} = 1 + \frac{V_2}{1}$$

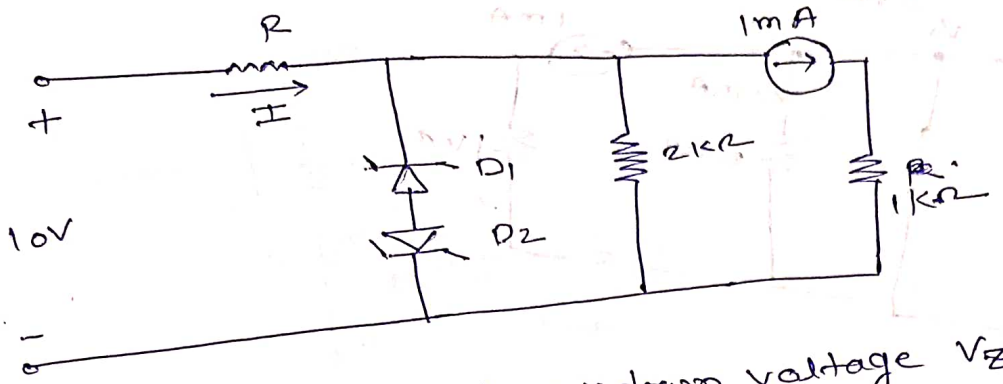
$$2 - V_2 = 1 + V_2$$

$$\boxed{V_2 = 0.5}$$

$I_1 + I_2 = 7.50mA$

$V_1 + V_2 = 2 + 0.5 = 2.50V.$

Q)

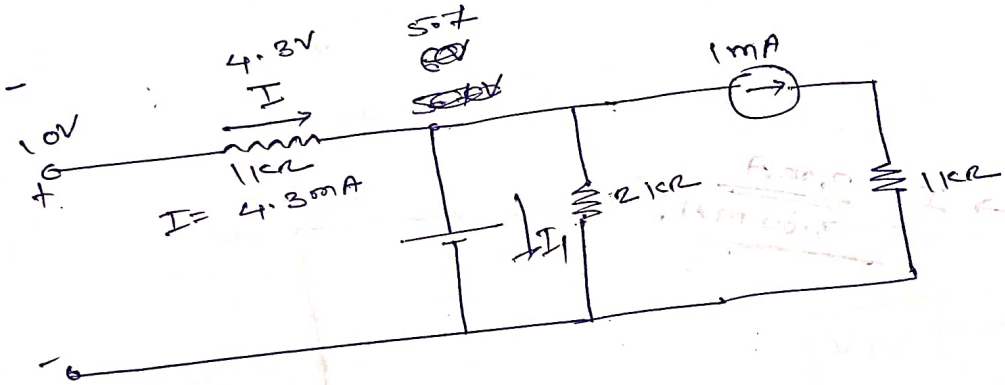


zener diode have breakdown voltage $V_Z = 5V$ and cut in voltage $V_\gamma = 0.7V$ then the value of current I _____ mA upto two decimal for

a) $R = 1K\Omega \rightarrow 4.30\,mA$

b) $R = 2K\Omega$

Sol^n:-



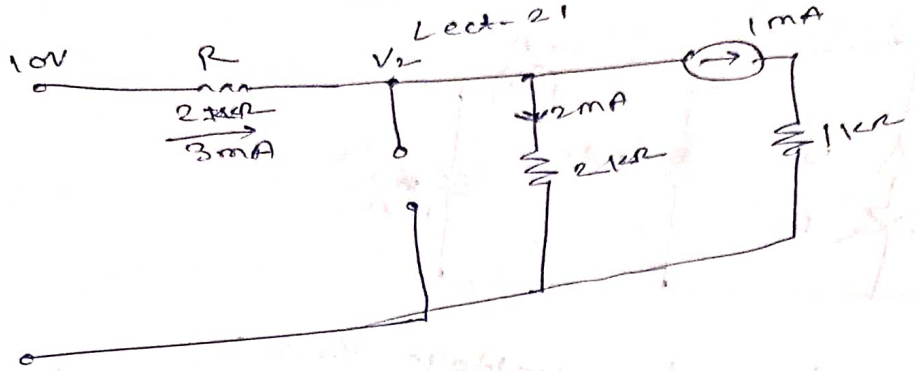
$$\frac{10 - V_1}{1} = \frac{V_1 - 0}{2} + 1$$

$$20 - 2V_1 = V_1 + 2$$

$$3V_1 = 18$$

$$\boxed{V_1 = 6V}$$

Lect-21



$$\frac{10-V_2}{2} = \frac{V_2}{2} + 1$$

$$10 - V_2 = V_2 + 2$$

$$2V_2 = 8$$

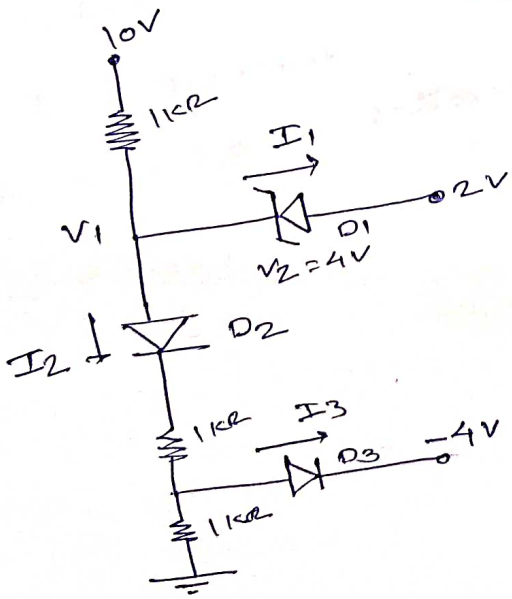
$$\boxed{V_2 = 4V}$$

$$V_2 + V_\gamma = 5.7$$

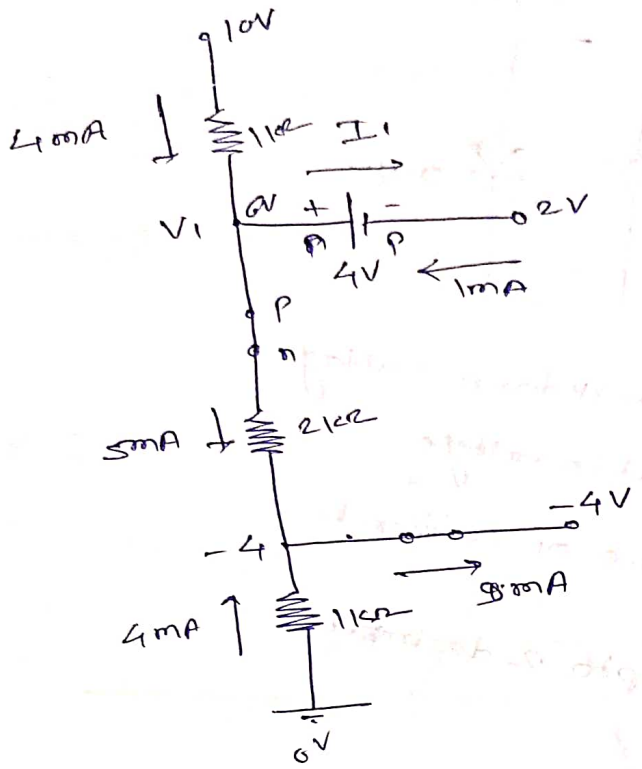
$$4.V < 5.7$$

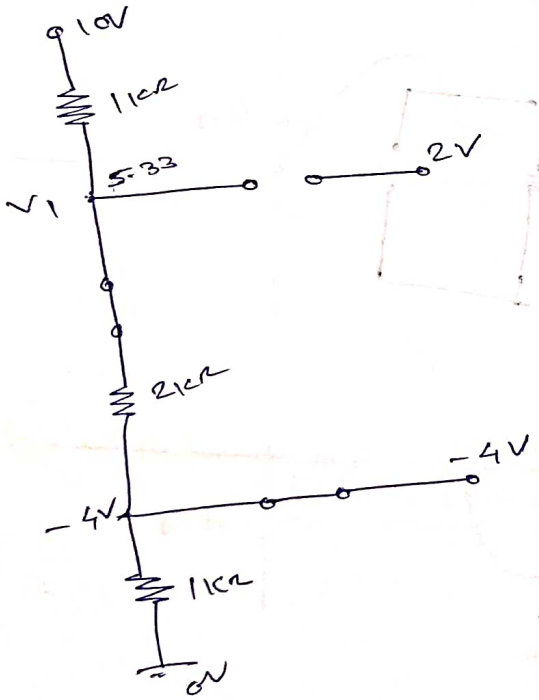
$$R_2 = 2k\Omega \rightarrow I = \frac{3mA}{3.00\,mA}.$$

Q)



Sol:-





$$\frac{10-V_1}{1} = \frac{V_1+4}{2}$$

$$\boxed{V_1 = \frac{16}{3} = 5.33 \text{ volt}}$$

$$\boxed{V_1+V_2 = 5.33-4 = 1.33\,V}$$

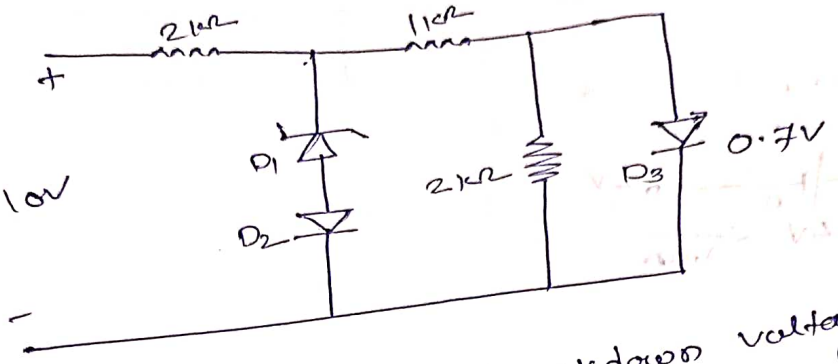
$$I_2 = \frac{9.33}{2}$$

$$I_3 = 4 + I_2$$

$$\boxed{I_2 + I_3 = 13.33\,mA}$$

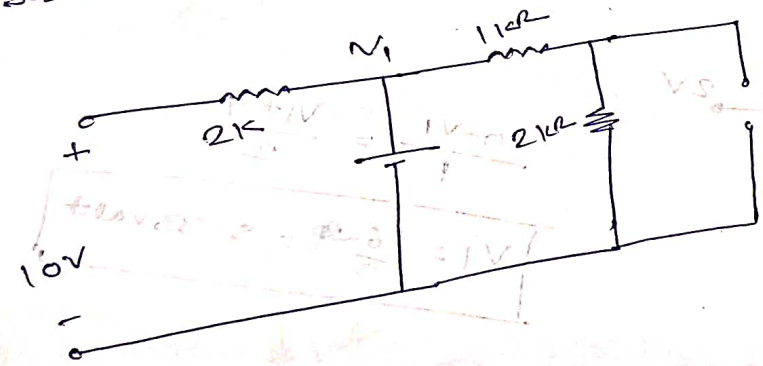
$$\boxed{I_1 = 0}$$

Q)



Zener diode D_1 has breakdown voltage of $\therefore V_Z = 2.3$ volt & cut in voltage $V_\gamma = 0.7V$. Then the value of current (I_1+I_2) _____ mA upto 2 decimal

Sol^n:-



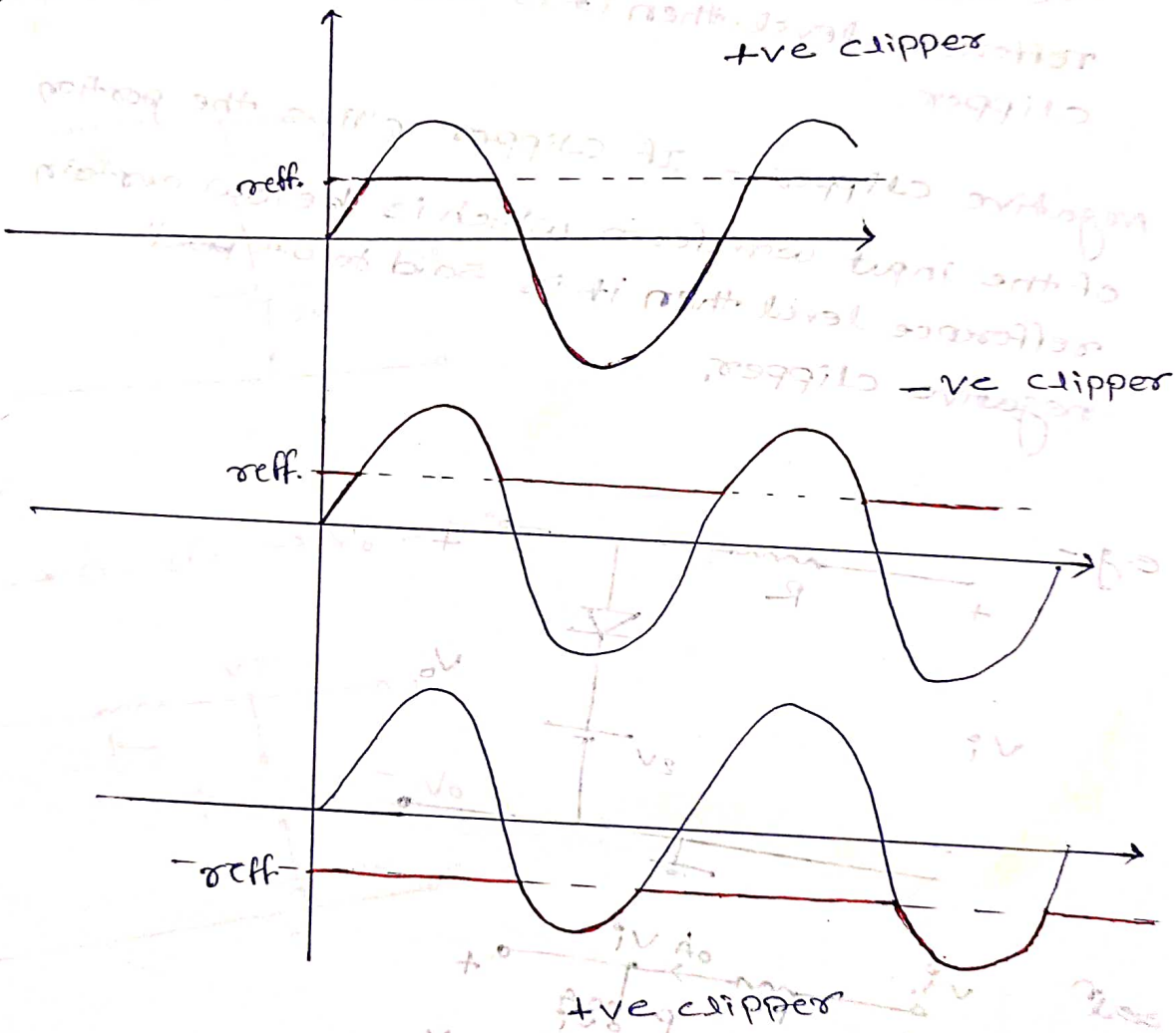
$V_Z = 2.3$

Lect-22 (Very Imp) (ask in gate every year)

Clipper & clamper

Wave shapping circuits
- clipper
- clamper

Clipper :→



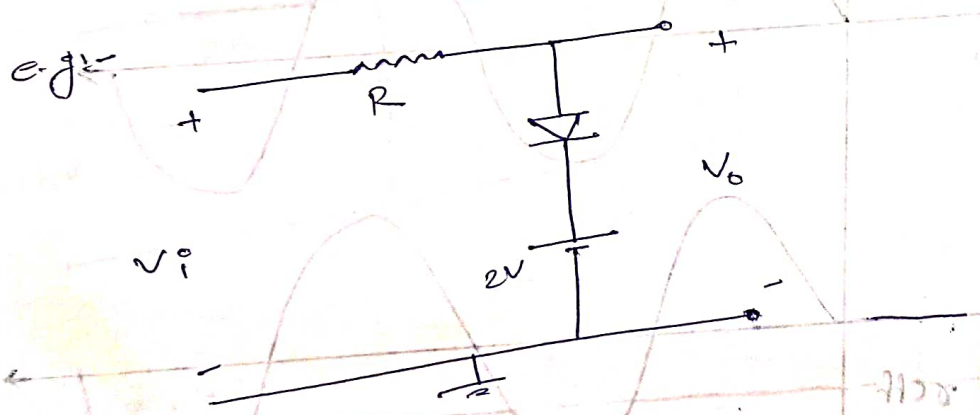
1) Clipper is basically used to ~~cut~~ clip unwanted portion of the input waveform

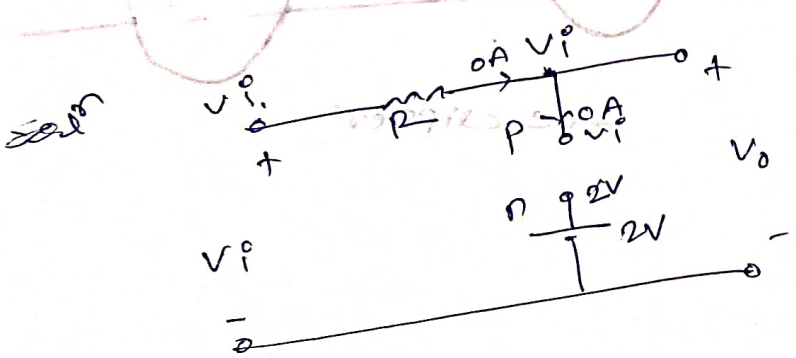
2) Clipper is also use to reduce the effect of noise (voltage fluctuation, sudden spikes).

Positive clipper :- If clipper clips the portion of the input waveform which is above certain refference level. then it is said to be positive clipper.

Negative clipper :- If clipper clips the portion of the input waveform which is below certain refference level then it is said to be ~~posi~~ negative clipper.

e.g :-





$V_p = V_i$

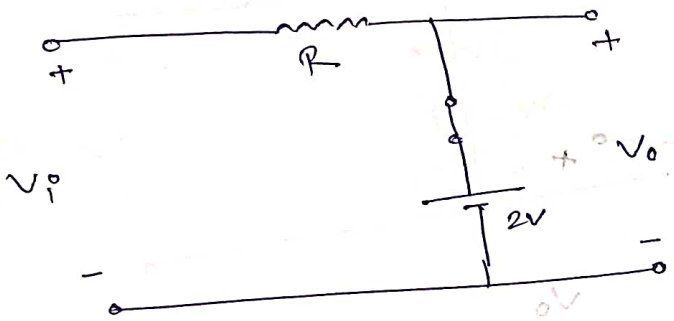
$V_n = 2V$

$(V_p - V_n)_{o.c} = V_i - 2$

$V_i - 2 > 0 \longrightarrow ON \longrightarrow V_i > 2 \longrightarrow D\text{-}ON$

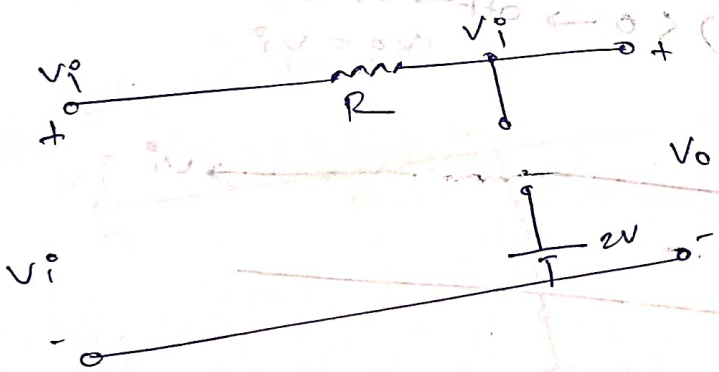
$V_i - 2 < 0 \longrightarrow off \longrightarrow V_i < 2 \longrightarrow D\text{-}off$

i) $V_i > 2 \longrightarrow D\text{-}ON \longrightarrow V_o = 2V$

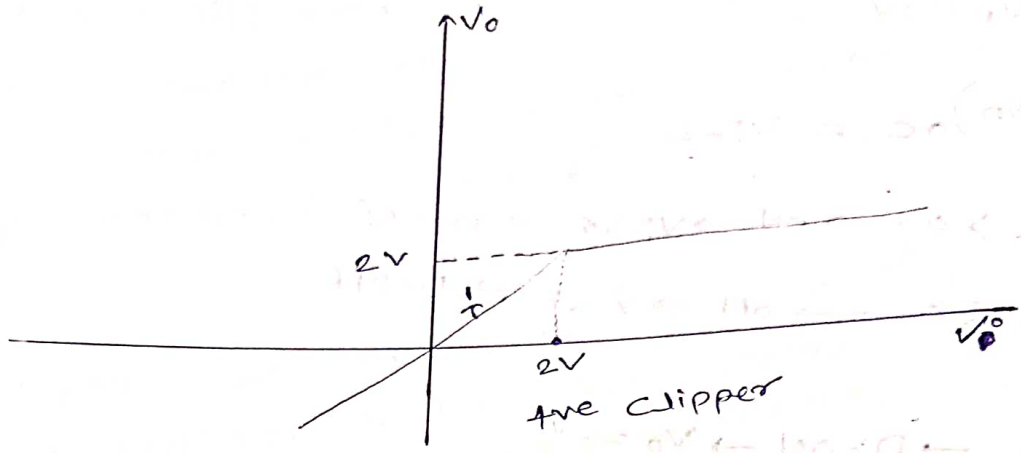


$V_o = 2V$.

ii) $V_i < 2 \longrightarrow D\text{-}off \longrightarrow V_o = V_i$

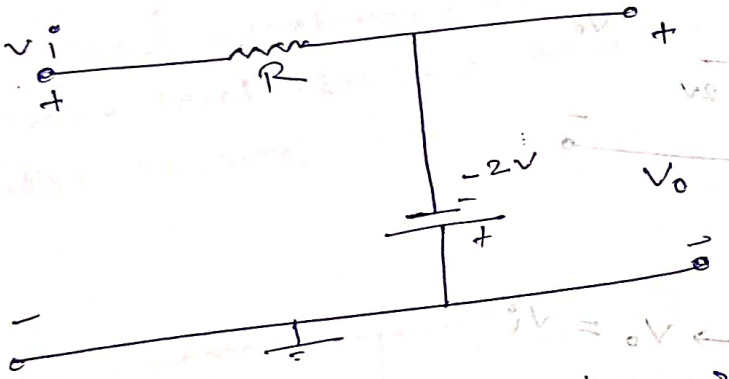


Lect-23



$y = mx + c \qquad c = 0$

$y = 1x + c$

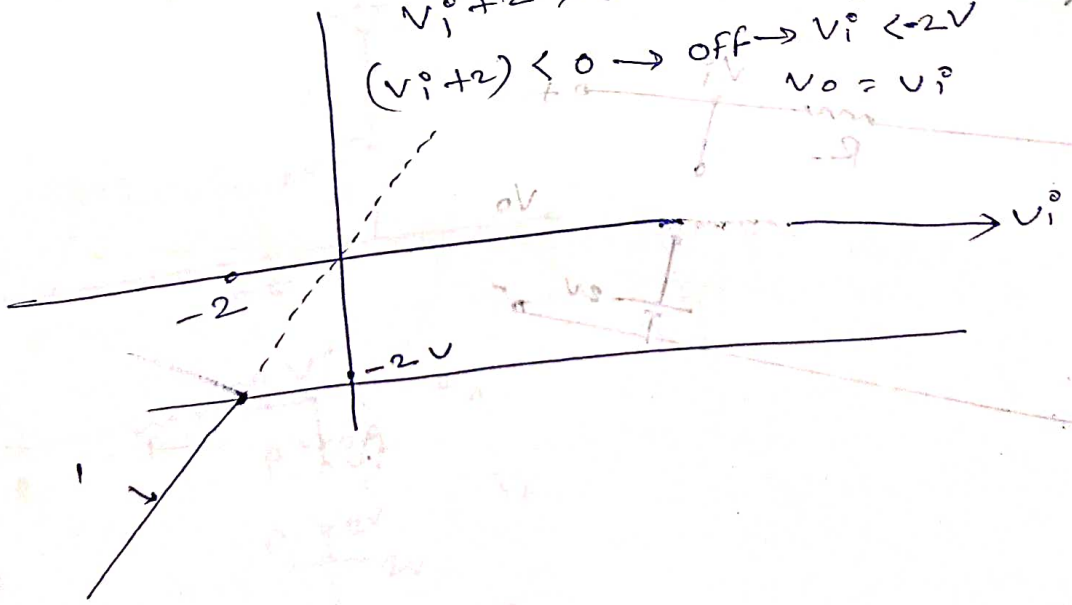


$V_o = -2V$

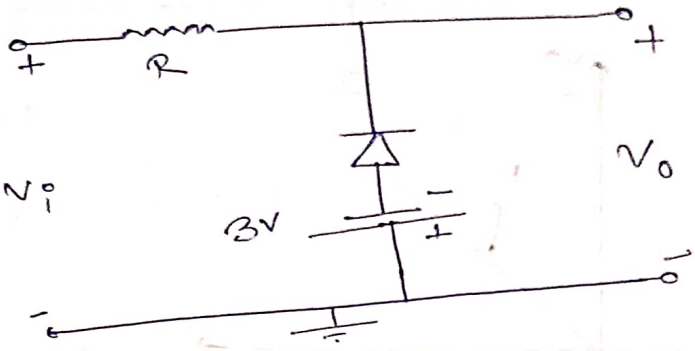
$V_i + 2 > 0 \longrightarrow$ on $\rightarrow V_i > -2V$

$(V_i + 2) < 0 \longrightarrow$ off $\rightarrow V_i < -2V$

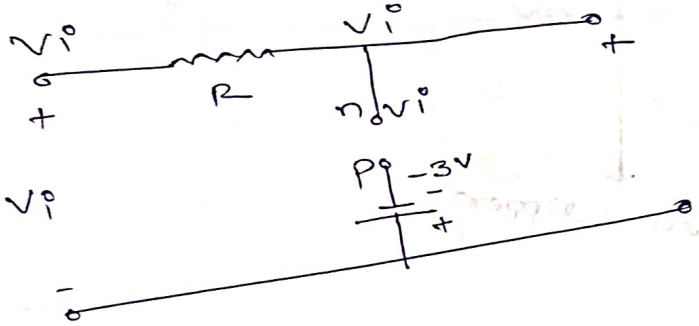
$V_o = V_i$



Q)



Sol^n:-



p-n > 0

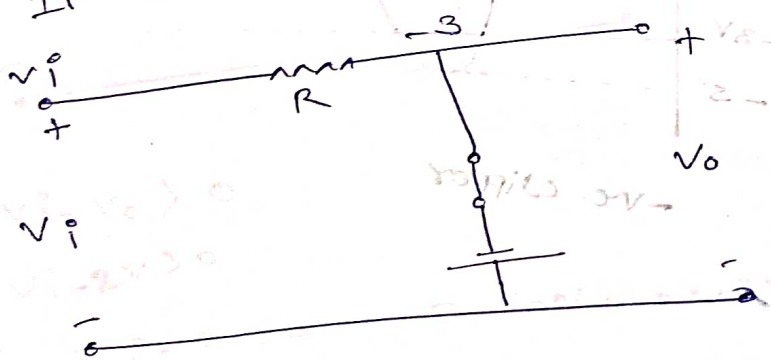
$-3 - V_i > 0 \longrightarrow$ ON

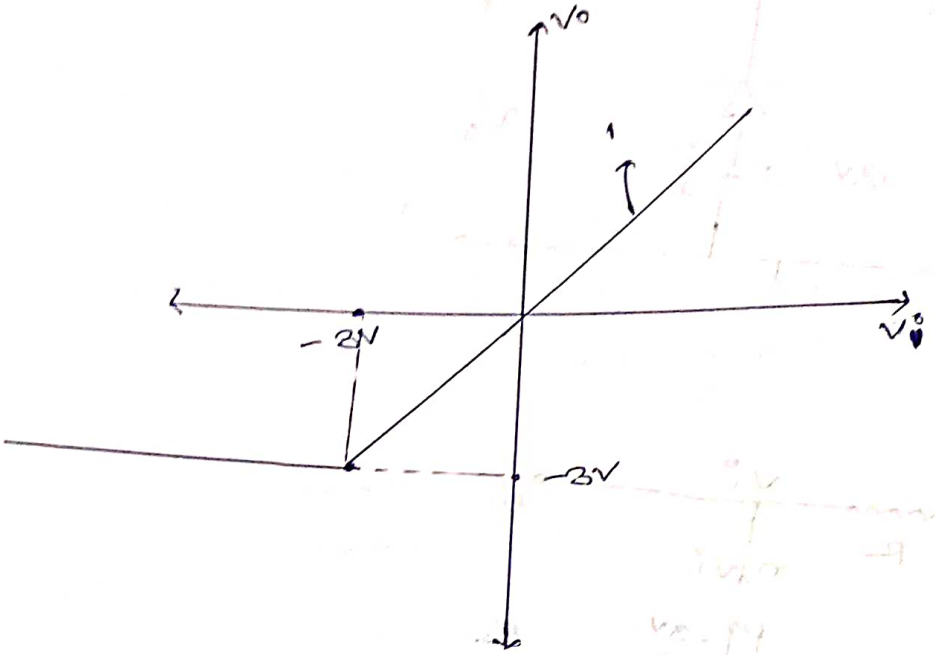
$-3 - V_i < 0 \longrightarrow$ off

$V_i < -3 \longrightarrow V_o = -3V$

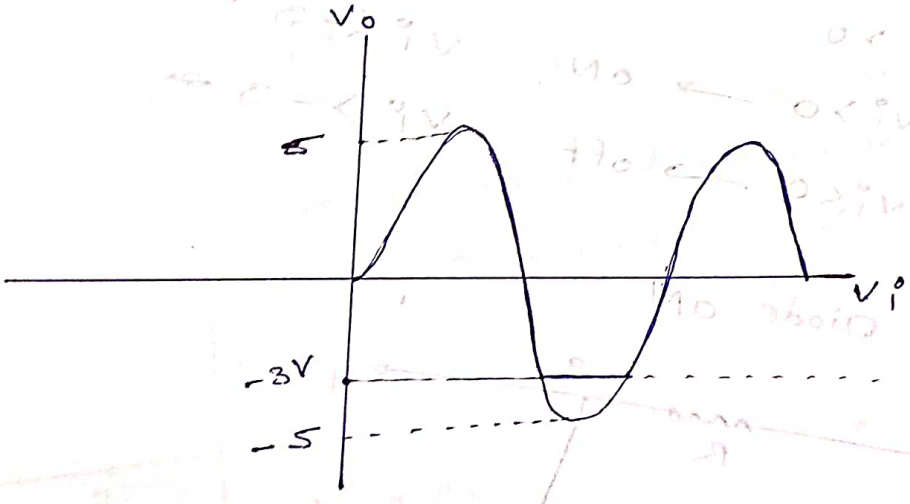
$V_i > -3$

If Diode ON



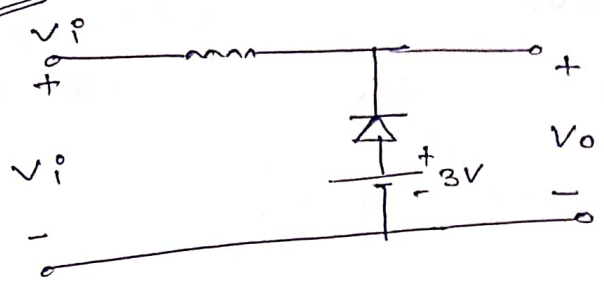


-ve clipper

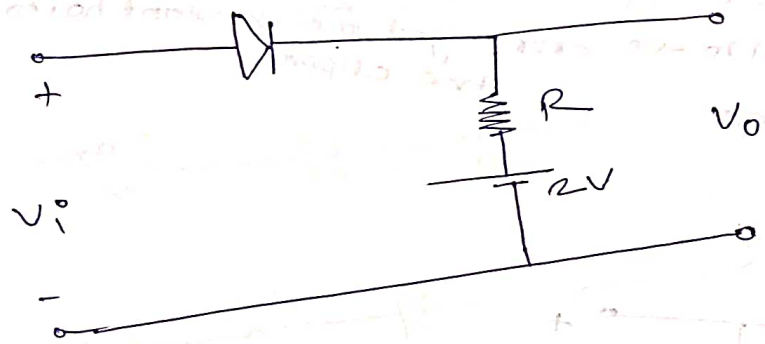


-ve clipper

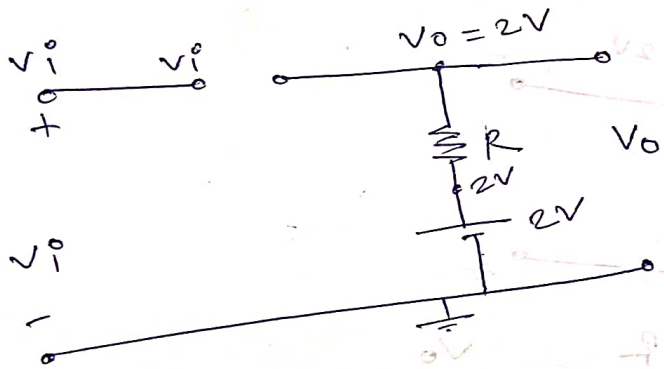
Q) H.W



Q)



Sol:-



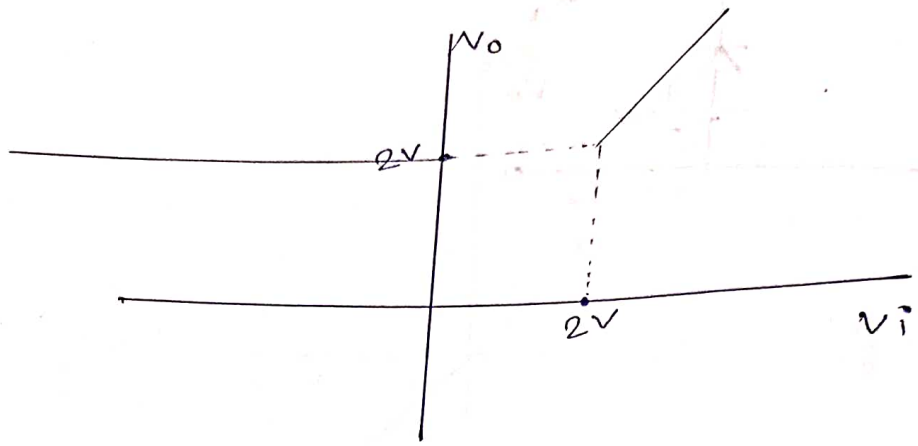
$V_i - V_o > 0$

$V_i - 2V > 0$

if $V_i - 2 > 0 \rightarrow D \rightarrow ON \rightarrow V_i > 2$, $V_o = V_i$

if $V_i - 2 < 0 \rightarrow D \rightarrow off \rightarrow V_i < 2$, $V_o = 2V$.

if → $V_o = V_i$

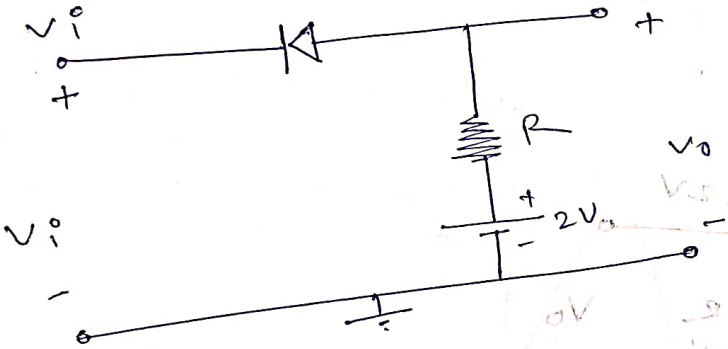


-ve clipper

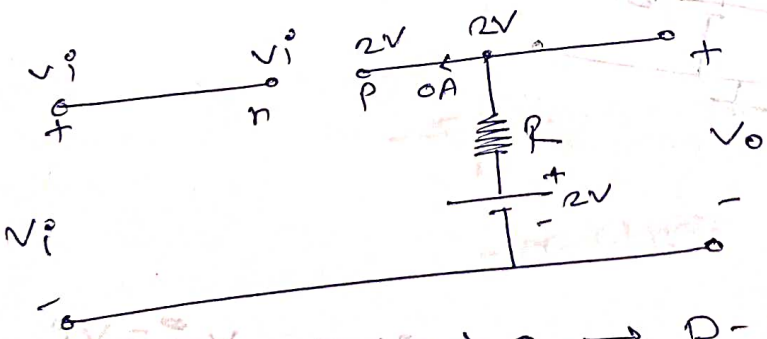
* reff. ke left me const. hai to -ve aur right me constant hai to +ve clipper.

~~if → Vo = 0V~~

Q)



Sol:-

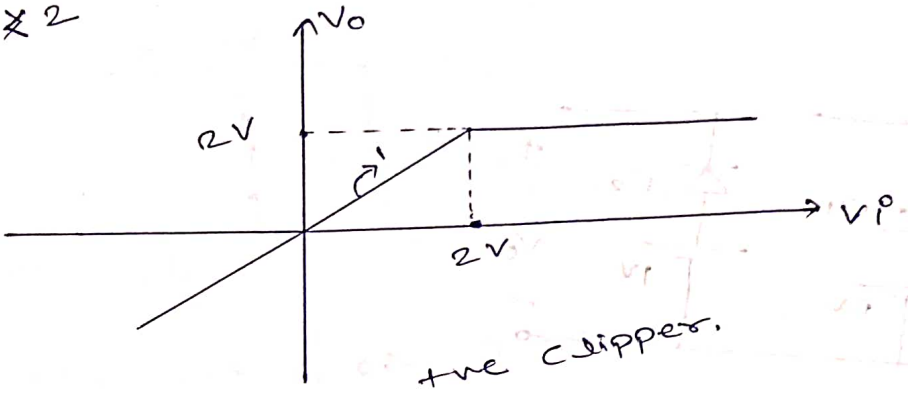


if $V_p - V_n > 0$, $2 - V_i > 0$ → D - ON

if $V_p - V_n < 0$, $2 - V_i < 0$, → D - off

if $2 - V_i > 0$

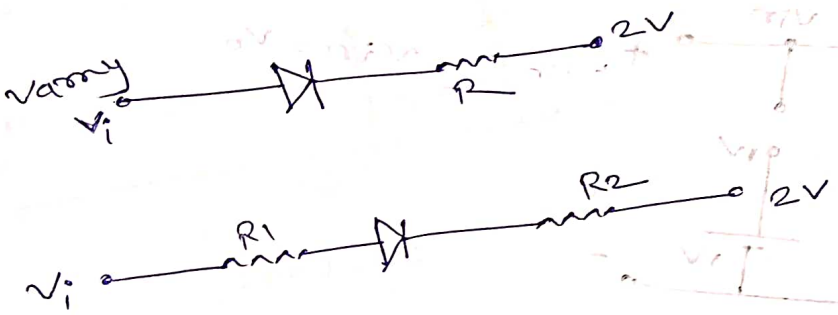
$V_i \not> 2$



+ve clipper.

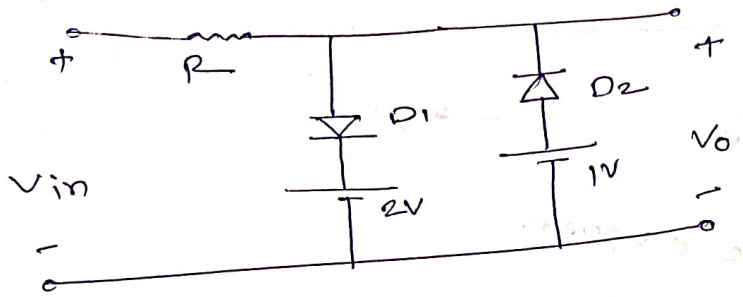
Lect-25

Q)

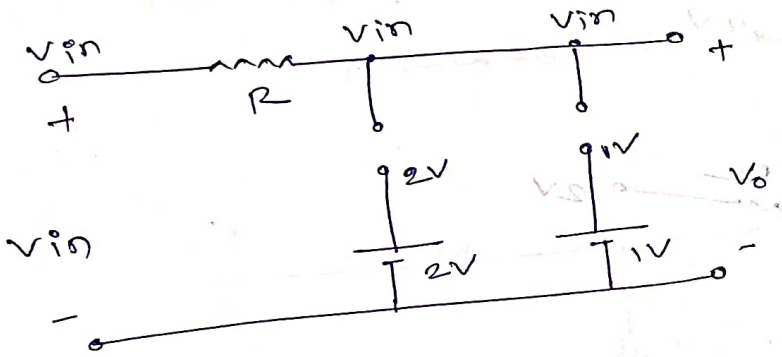


Multiple diode

Q)



Sol^n:-



$V_{in} = V_o$

for D1

$(V_p - V_n)_{o.c.}$ $D_1 = (V_i - 2)$

for D2

$(V_p - V_n)_{o.c.}$ $D_2 = (1 - V_i)$

$D_1 \rightarrow ON \rightarrow V_i - 2 > 0 \rightarrow V_i > 2$

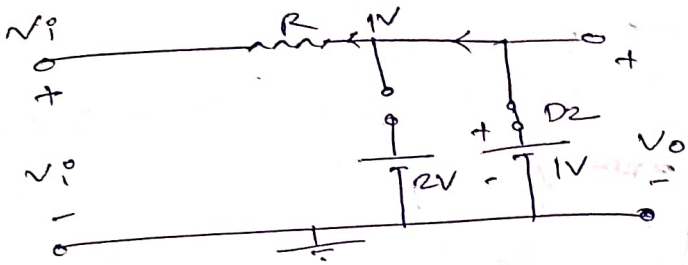
$off \rightarrow V_i - 2 < 0 \rightarrow V_i < 2$

$D_2 \rightarrow ON \rightarrow 1 - V_i > 0 \rightarrow V_i < 1$

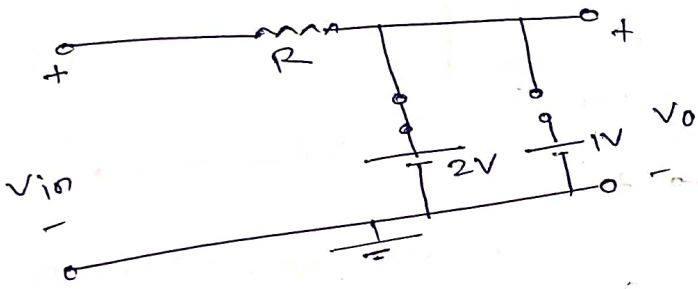
$off \rightarrow 1 - V_i < 0 \rightarrow V_i > 1$

$1 < V_i < 2 \rightarrow D_1, D_2$ off. $\rightarrow V_o = V_{in}$

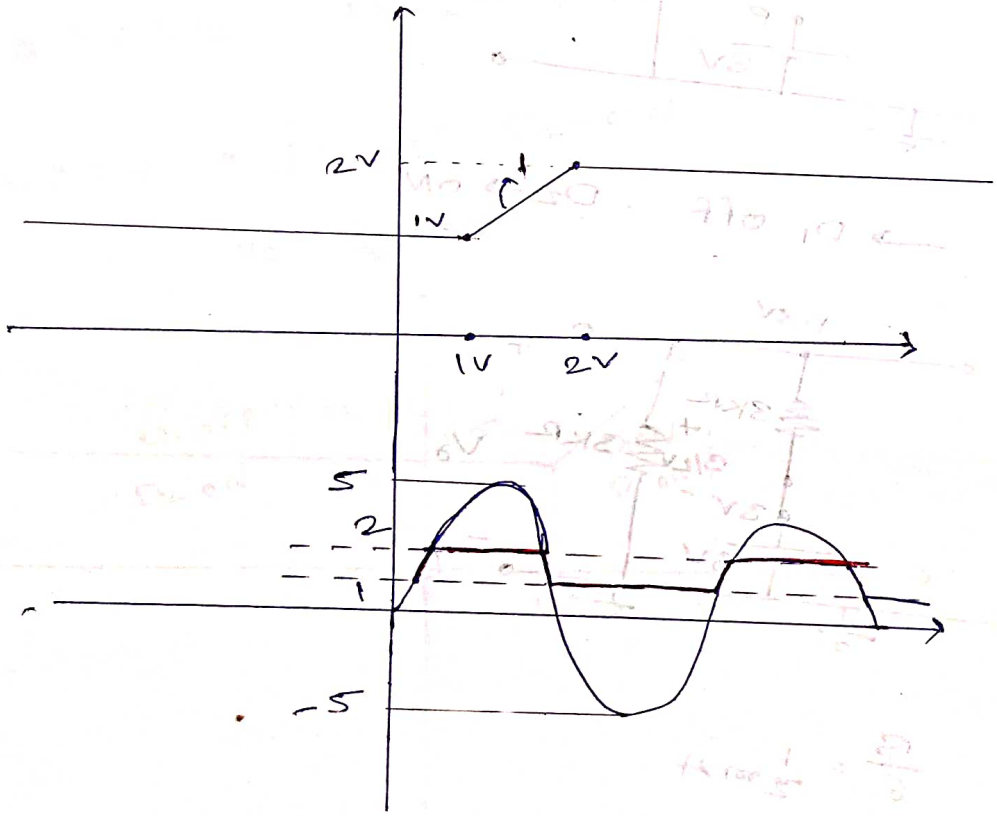
ii) $V_i < 1$, D_1 off, $D_2 \rightarrow ON \rightarrow V_o = 1V$



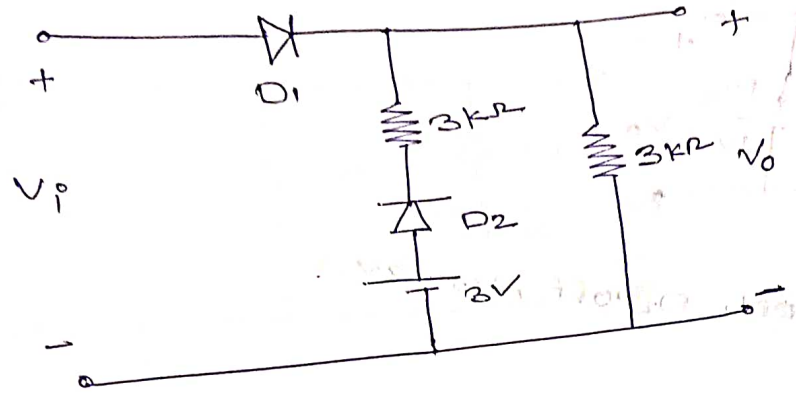
iii) $V_i > 2 \rightarrow D_1$ ON, $D_2 \rightarrow$ off, $V_o = 2V$.



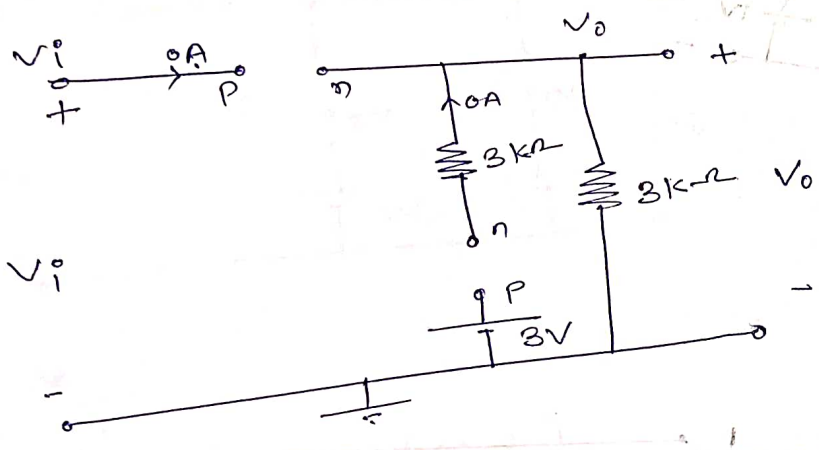
Lect-26



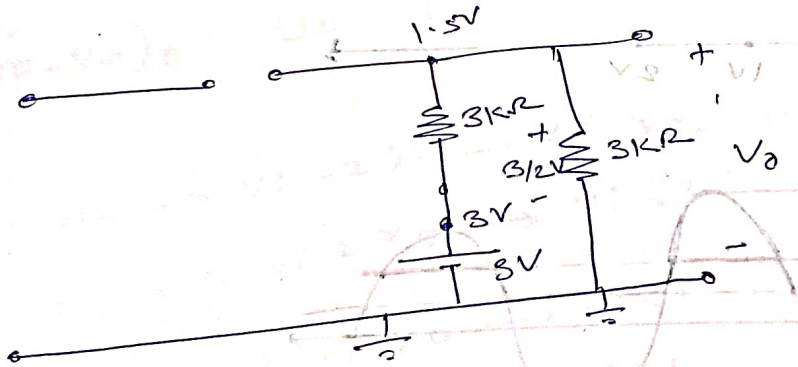
Q)



Soln:-



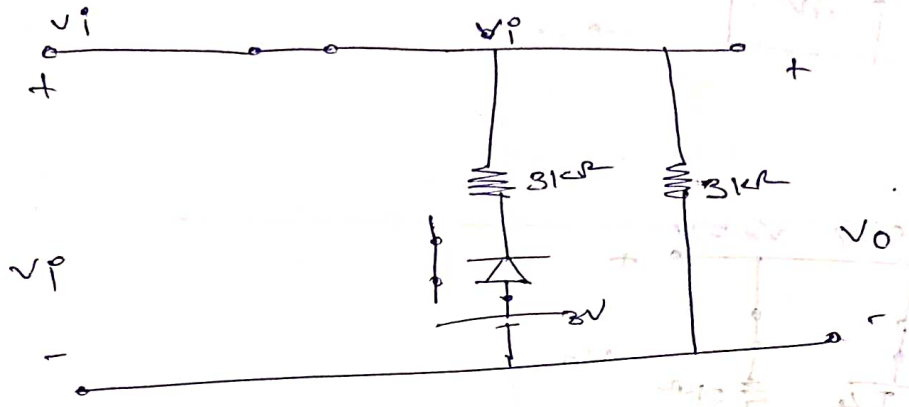
$V_i > 0 \longrightarrow D_1$ off , $D_2 \rightarrow$ ON



$\frac{3}{6} = \frac{1}{2}$ mA

$1.5V > V_i > 0 \longrightarrow D_1$ off, D_2 - ON.

*) $V_i > 1.5 \longrightarrow D_1$ ON, D_2 ON $V_o = 1.5$.

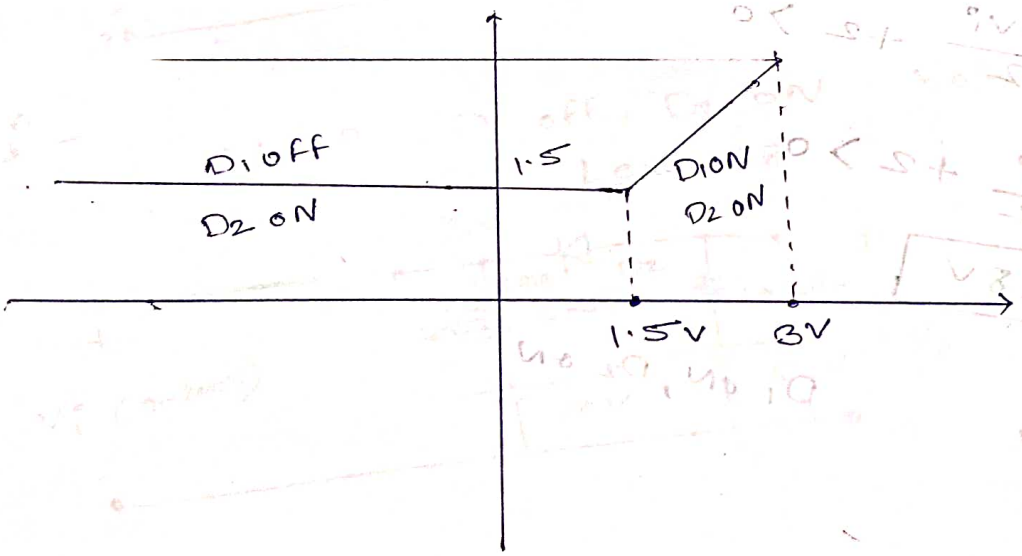


$3 > V_i > 1.5$ $V_o = V_i$ D_1 ON, D_2 ON.

*) $V_i > 3$ D_2 - off, D_1 - ON.

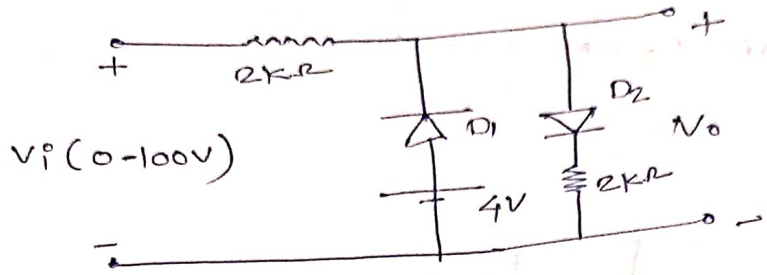
*) $V_i < 0 \longrightarrow D_1$ off, D_2 - ON

$V_o = \frac{3}{2}$ Volt



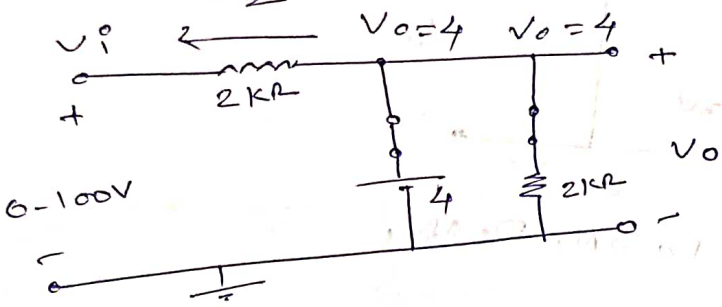
Lect-27

Q)



Sol:-

$\frac{4-V_i}{2} = I$



$\cancel{\frac{V_i - V_o}{2}}$

$V_i > 0$ D1 ON, D2 ON

$I = \frac{4-V_i}{2} + \frac{4-0}{2}$

$\frac{4-V_i}{2} + 2 > 0$

$2 - \frac{V_i}{2} + 2 > 0$

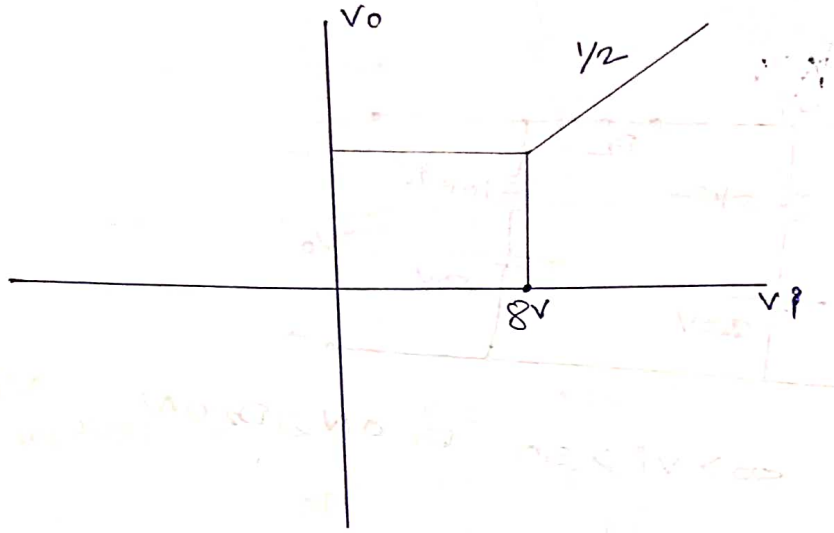
$\boxed{V_i < 8V}$

D1 ON, D2 ON

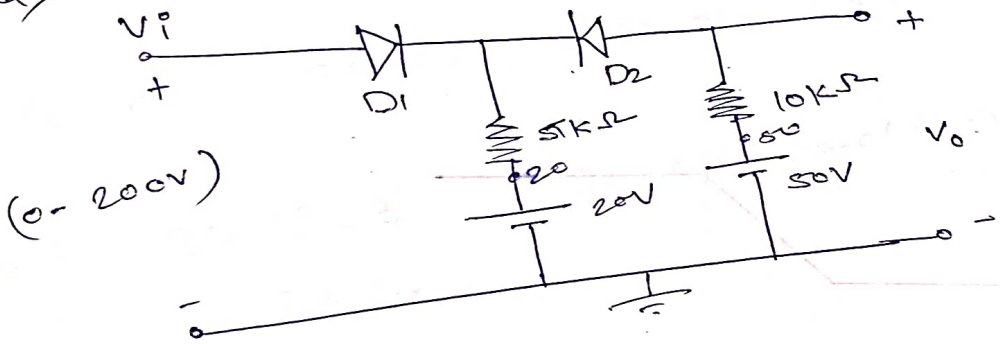
$8 > V_i > 0$

$V_i > 8 \longrightarrow D_1$ - off, D_2 - ON

$V_o = V_i/2$

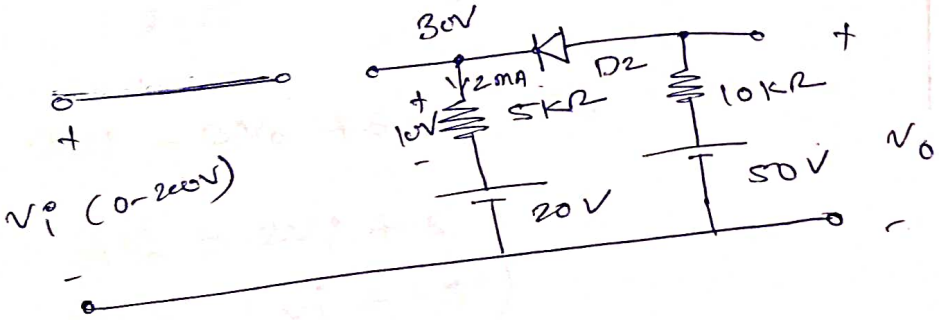


Q)



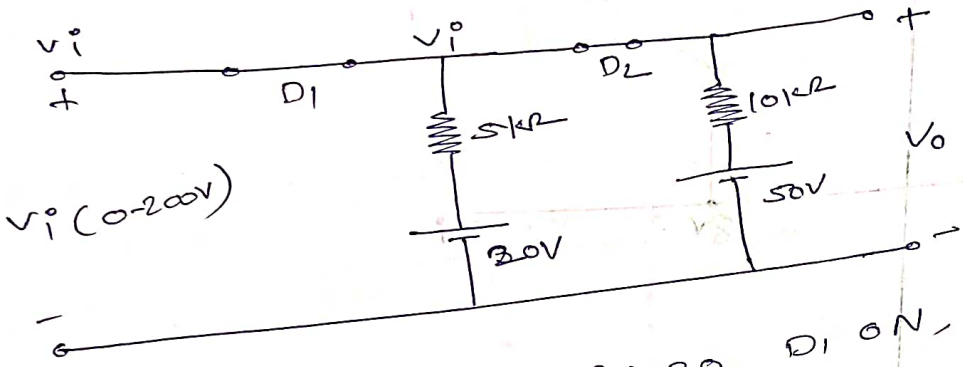
Soln:- $V_o > 0$, D_1 off, D_2 ON $\quad V_o = 30$

Lect - 28



$30 > V_o > 0$

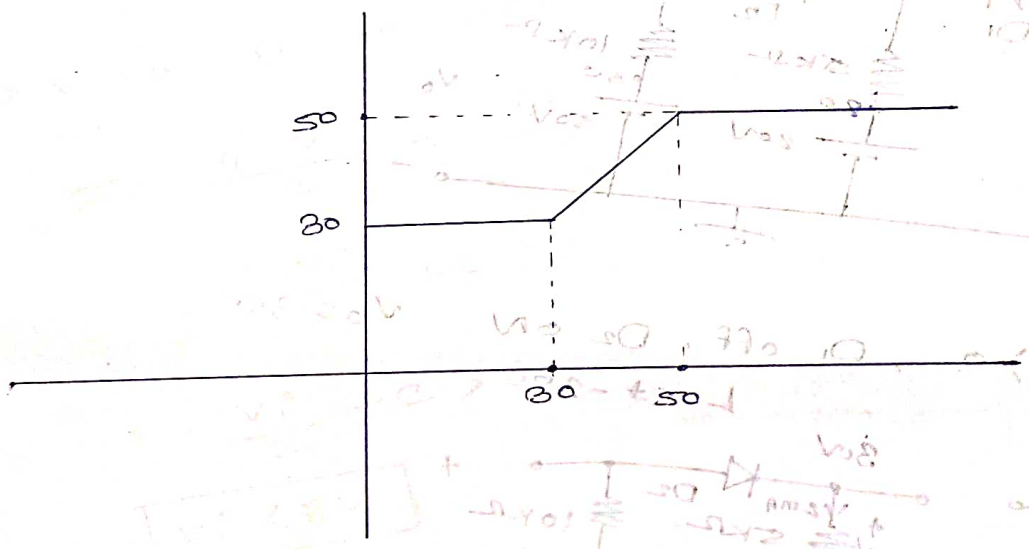
$V_i > 30$ D1 - ON , D2 - ON



$V_o = V_i$

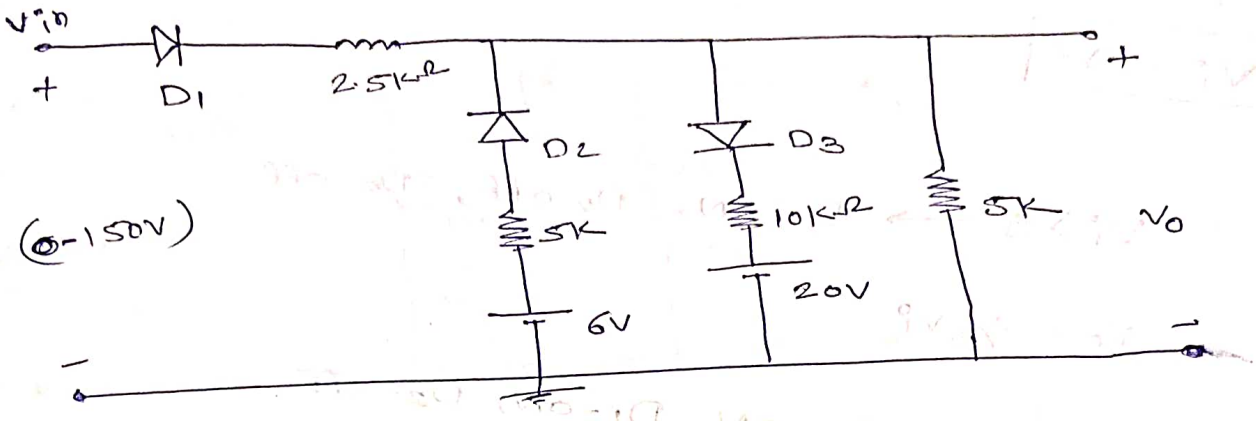
$\therefore$ ~~50<vi~~ $50 > V_i > 30$ D1 ON, D2 ON

$V_o = 50V$ $V_i > 50$, D1 ON, D2 OFF



Lect - 20

Q)



soln:-

assumption :-

D1	D2	D3
ON	ON	ON
off	off	off

$V_o = 3V$ $\quad 0 < V_i < 3$ $\quad$ D1 off, D3 off

D1 - ON, D3-off, D2-ON

~~Vi~~ $\quad 9 > V_i < 3$

$1/2 V_i + 3/2$

$$\frac{V_i - V_o}{2.5} + \frac{6 - V_o}{5} = \frac{V_o - 0}{5}$$

$$2V_i - 2V_o + 6 - V_o = V_o$$

$$4V_o = 2V_i + 6$$

$$V_o = \left(\frac{1}{2} V_i + 1.5\right)$$

$$\frac{1}{2} V_i + \frac{3}{2} = 6$$

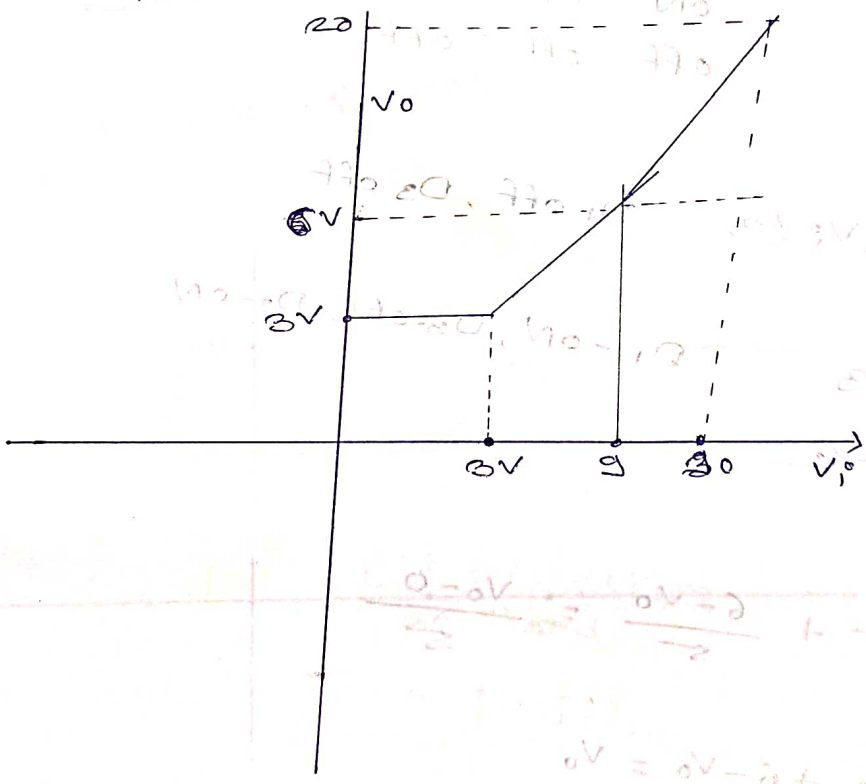
$$\boxed{V_i = 9V}$$

$V_i > 9 \longrightarrow D_1$ ON, D_2 off, D_3 off

$V_o = 2/3 V_i$

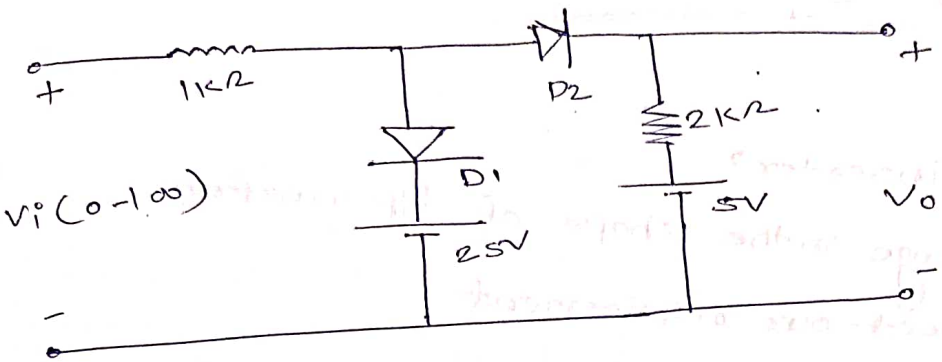
$V_i > 30$ D_3-ON, D_1-ON, D_2- off

$$V_o = \frac{4}{7} V_i + \frac{20}{7}$$

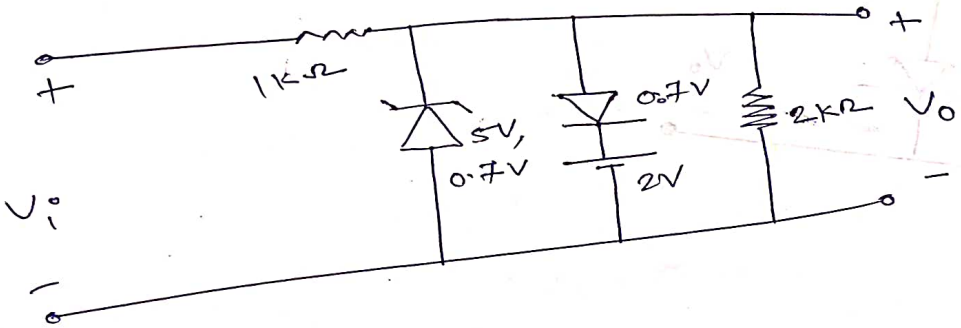


4.co

Q)



Q)



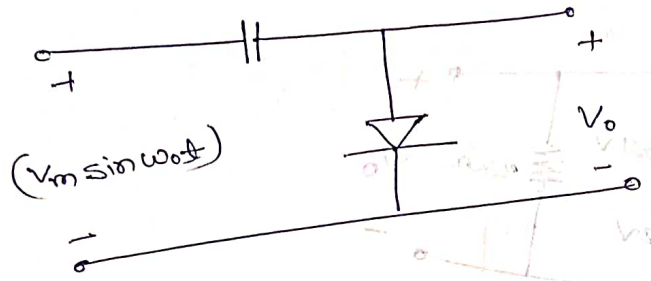
Lect-30

Clamper & Rectifier

Clamper :→ 'DC inserter'

:→ No change in the shape of i/p waveform

:→ To meet our requirement



RC → small
↓
charging
fast

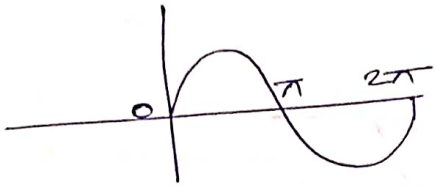
RC → 0
charging/discharging will be instantaneous

RC → very high → charging | discharging very slow

RC → ∞ → no charging | discharging

$V_m (V_+ - V_-) = V_m \sin\omega_0 t$

$\boxed{\omega_0 T = 2\pi}$



$V_C = -2$

$+$ 4V || $-$ 6V

8V 4V = +4V

Lect-31

$0 < \omega_0 < \pi$

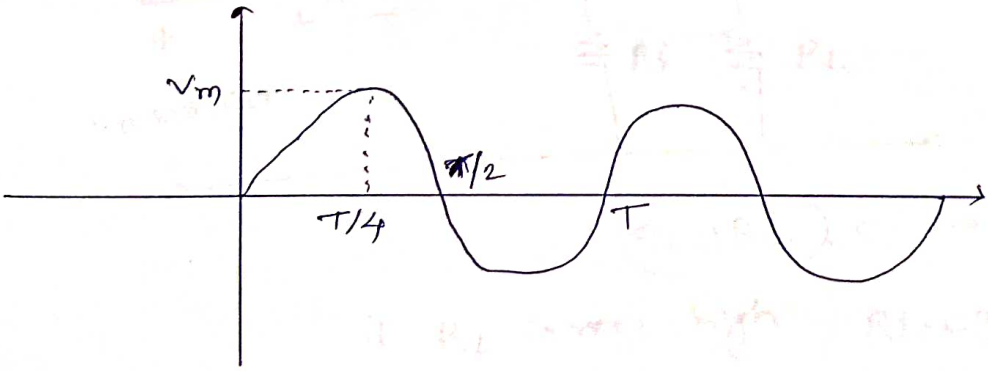
$\Rightarrow V_m \sin\omega_0 t$

$0 < t < T/2$

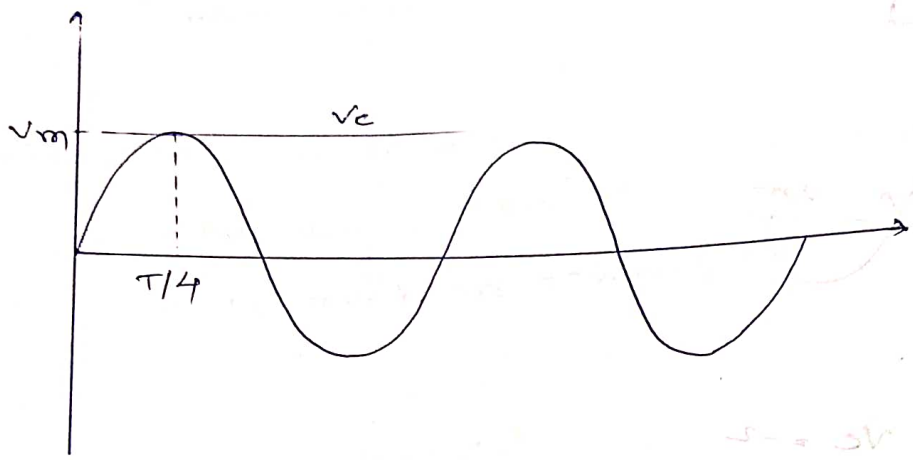
in first half diode is ON. $\rightarrow V_m \sin\omega_0 t = V_C$

~~Rf.C~~

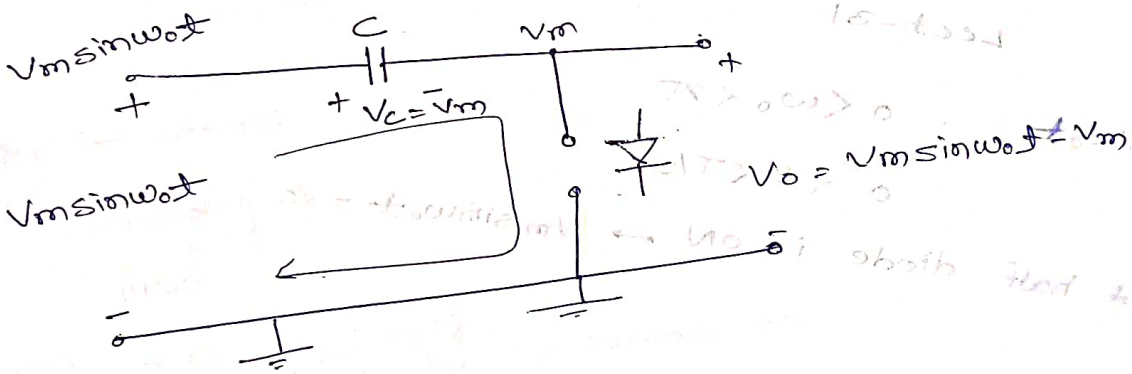
$R_f \cdot C = 0$

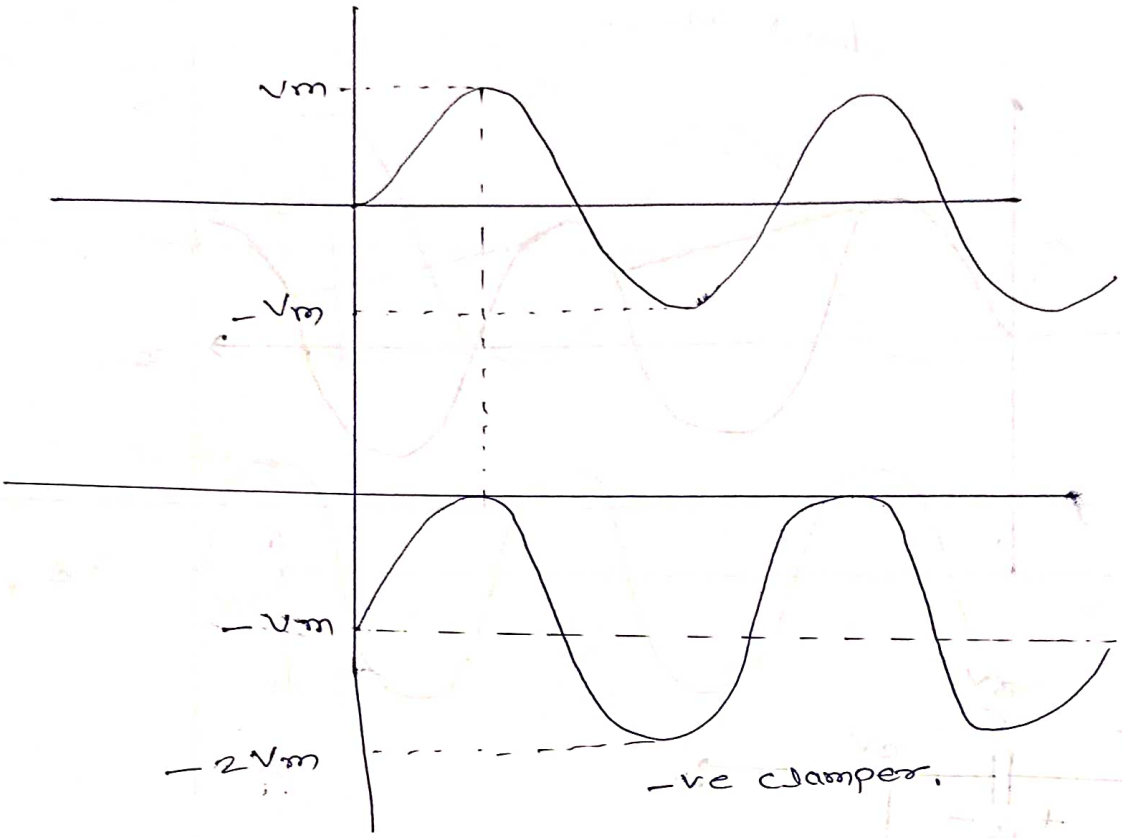


other half cycle Diode is off

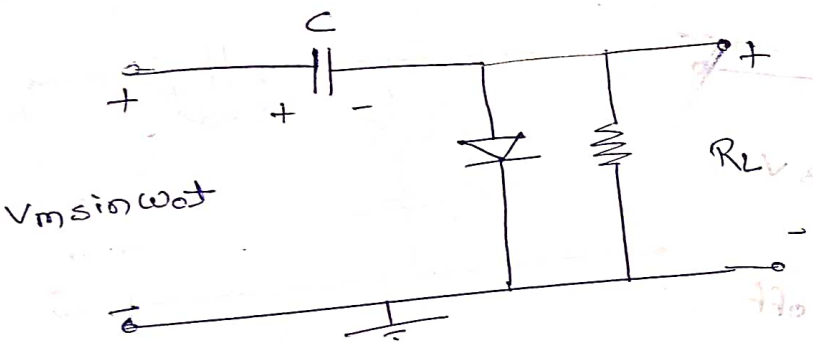


$V_o = V_m \sin\omega_o t - V_m$





-ve clamper.

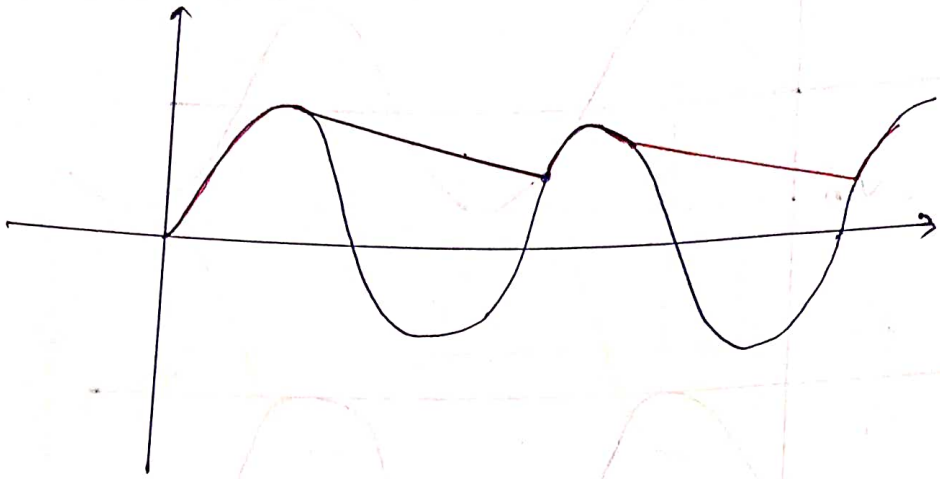


$R_L \gg R_f$

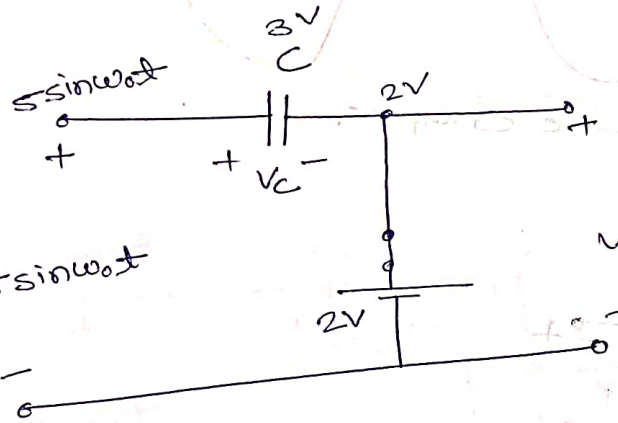
$(R_f \| R_L) \cdot C \rightarrow$ very small

if R_L is very high $R_L \cdot C \gg T$

Lect-32

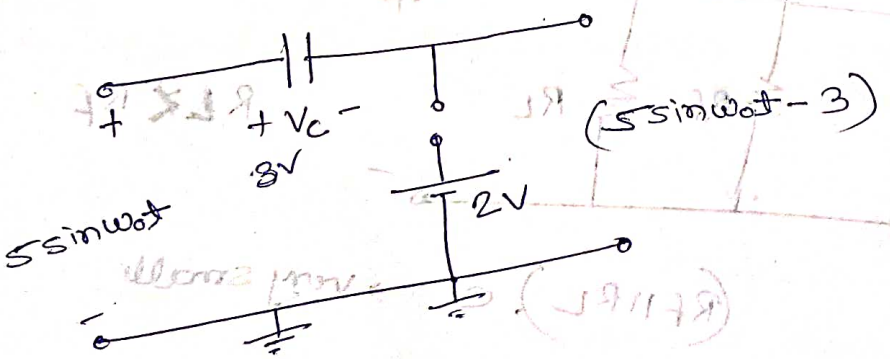


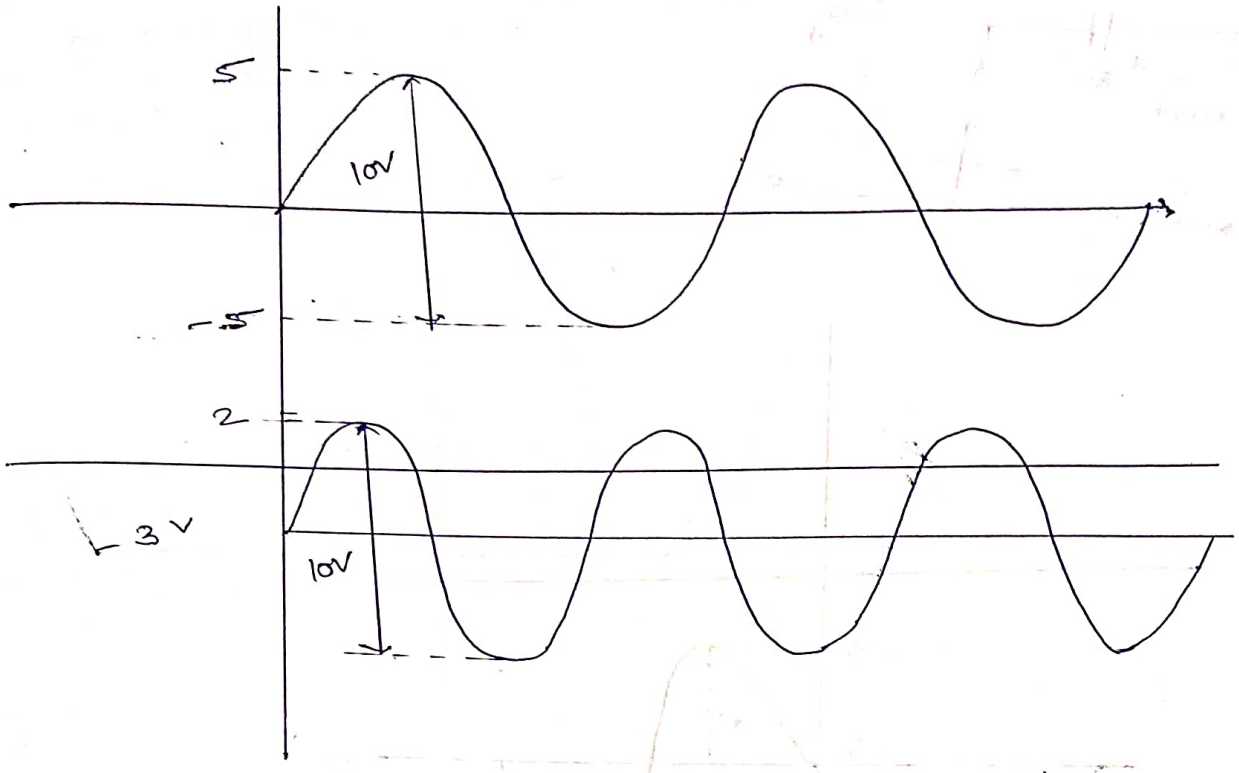
Q)



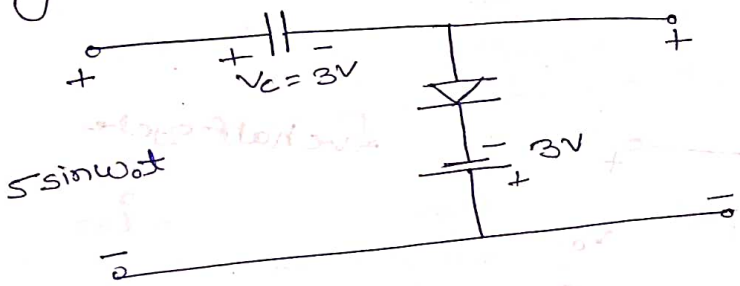
$5 - 2 = 3V$

$\therefore$ $V_p > V_n$ Diode off

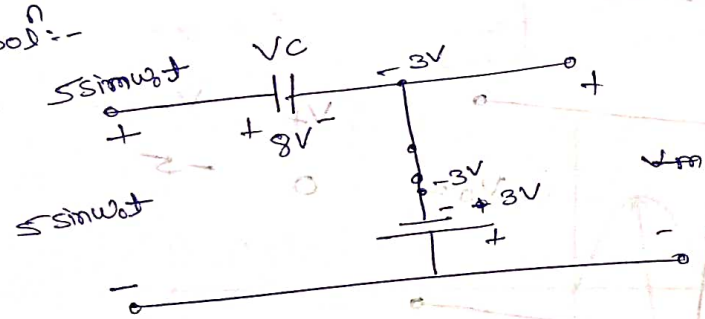




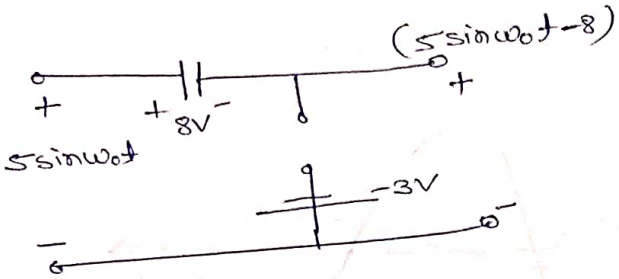
e.g:-

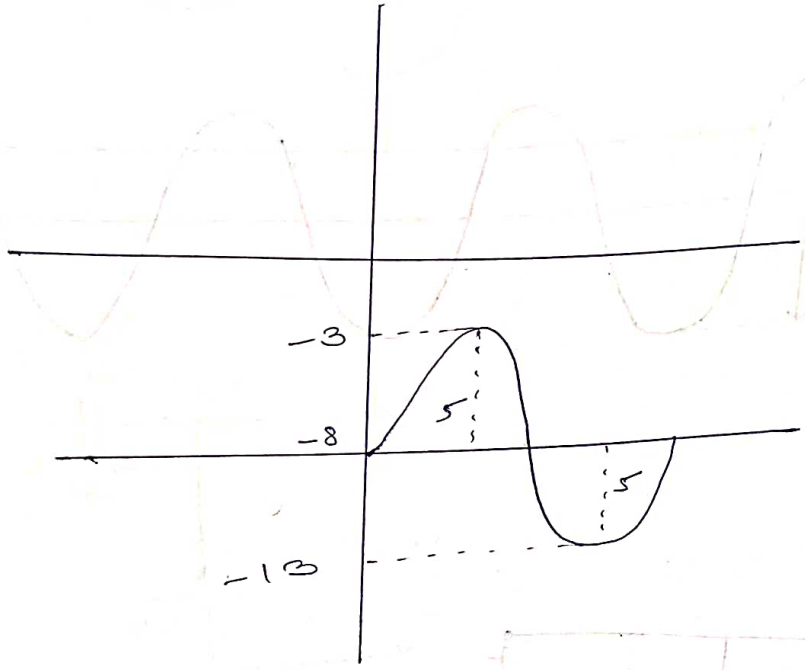


Soln:-

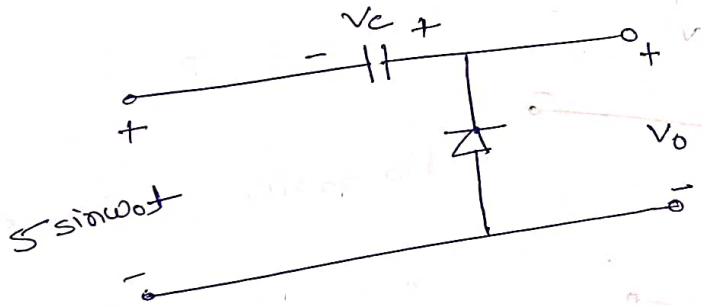


Vc	
V+	- V-
5	+ 3
= 8V	



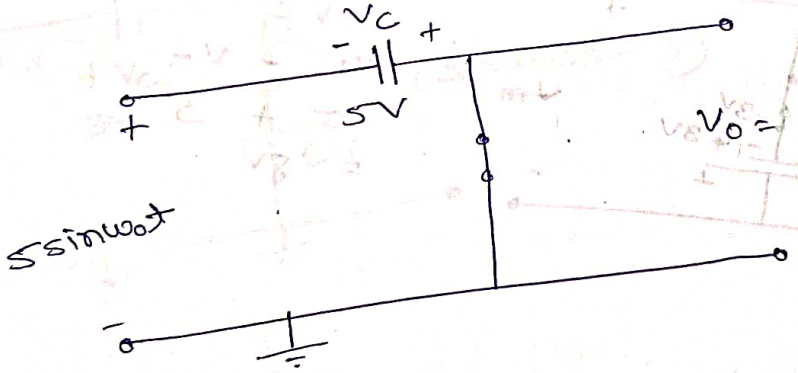


e.g:-

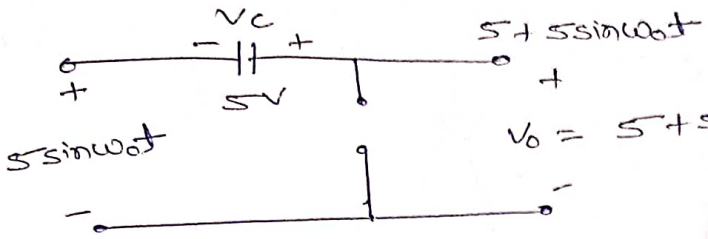


−ve half cycle

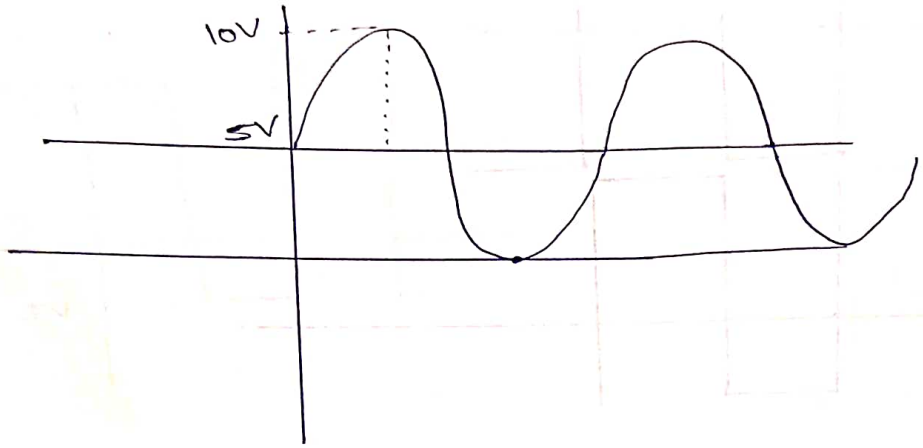
Sol:-



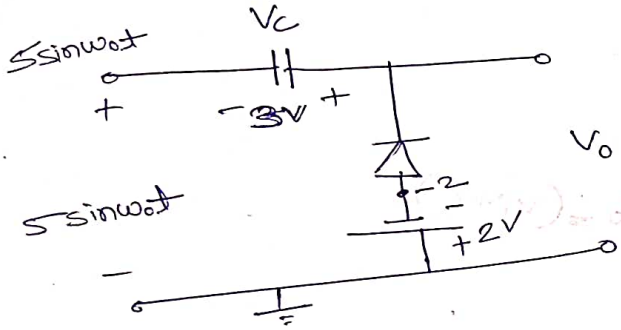
	V_+	V_-
$V_o =$	0	−5



$V_0 = 5 + 5\sin\omega_0 t$



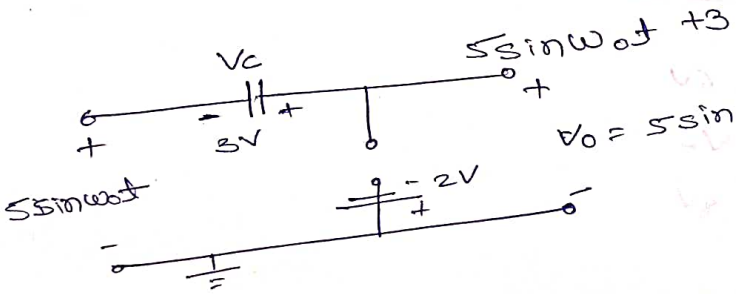
2)



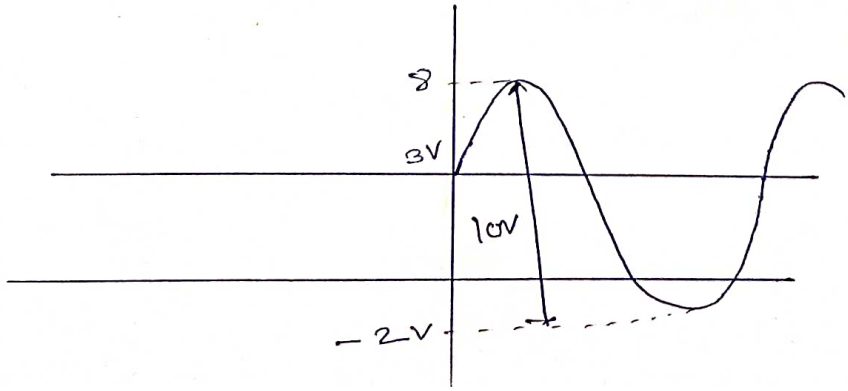
V_+ -2 V_- -5

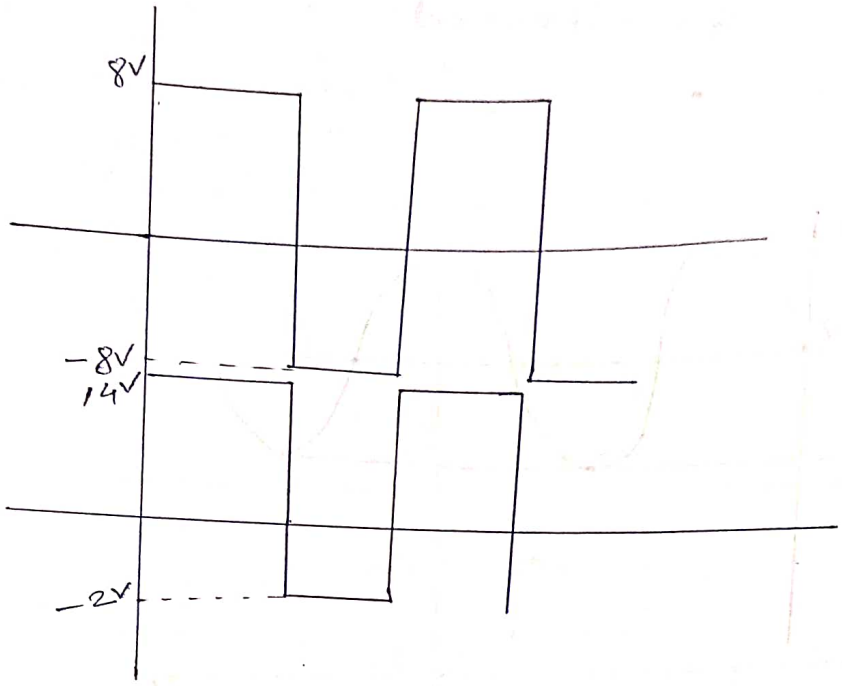
$V_c = +3V$

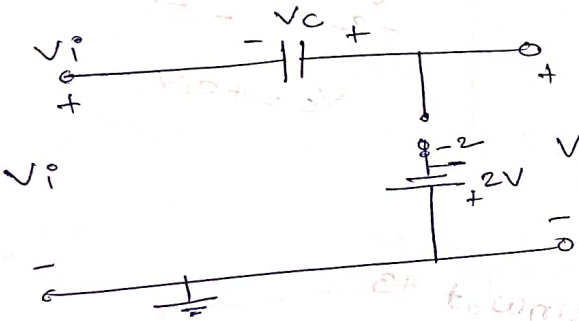
Sol:-



$V_0 = 5\sin\omega_0 t + 3$







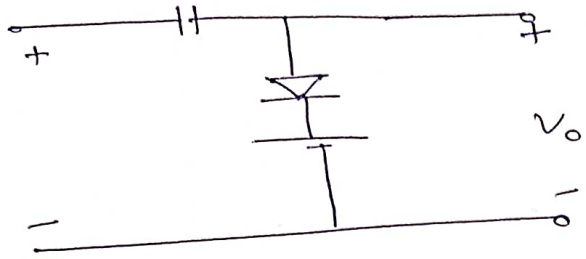
$V_o = (V_i + 6)$

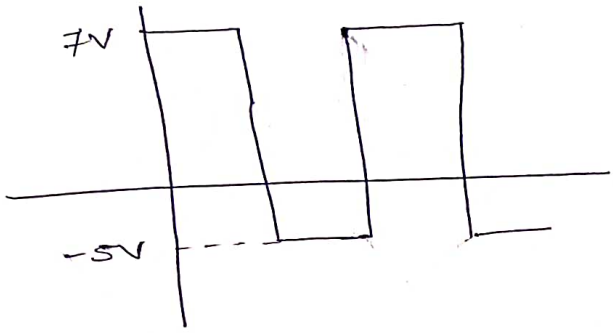
$V_c = 6V$

V_+ V_-

$-2V$ $-8V$

Q)



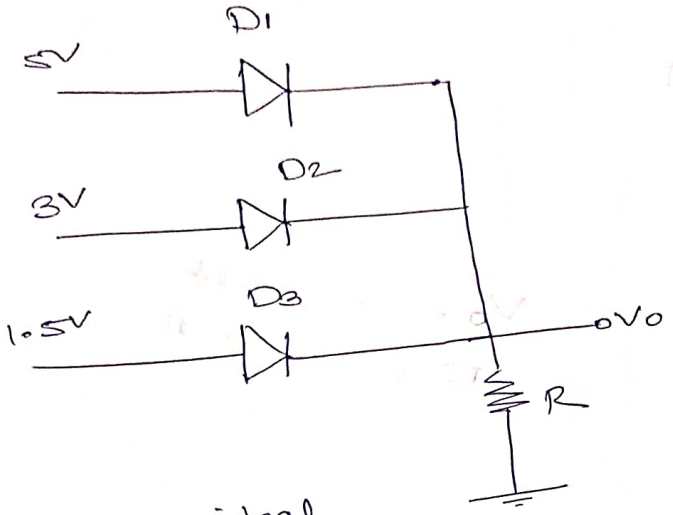


Soln:-

Mixed questions

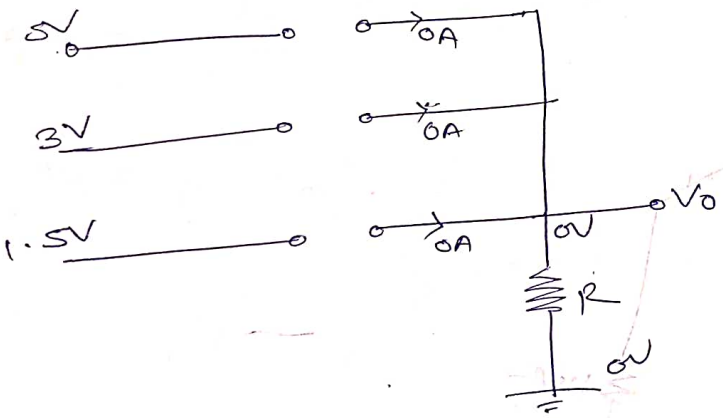
Lect - 4

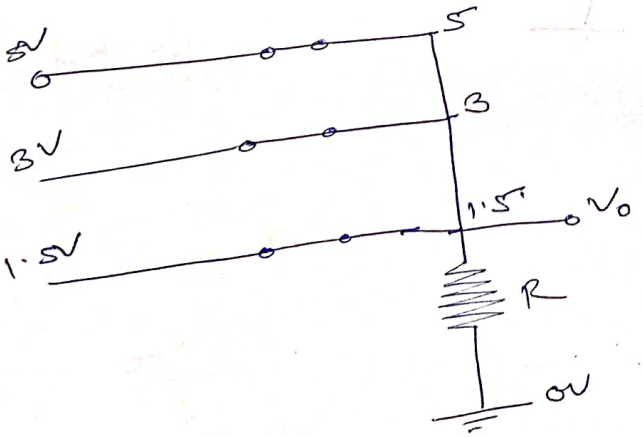
Q)



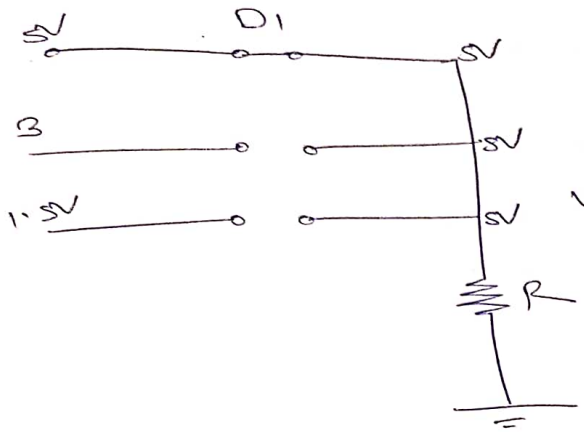
D_1, D_2, D_3 - ideal

Sol:-



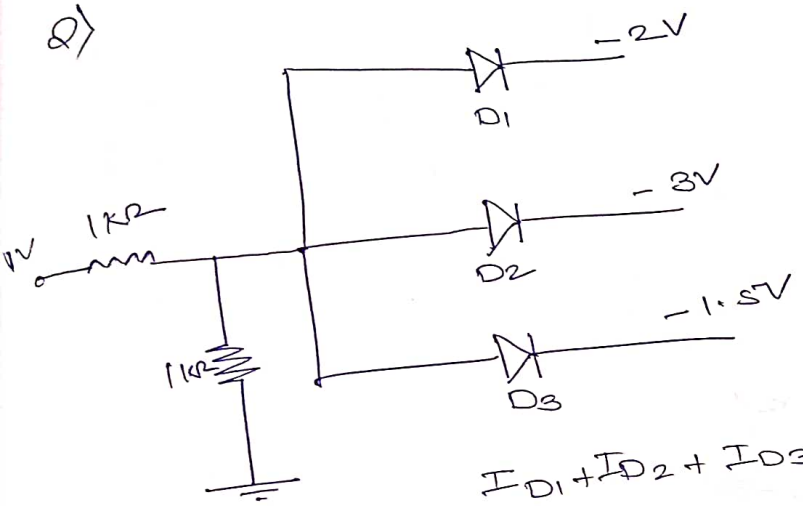


✗ not possible



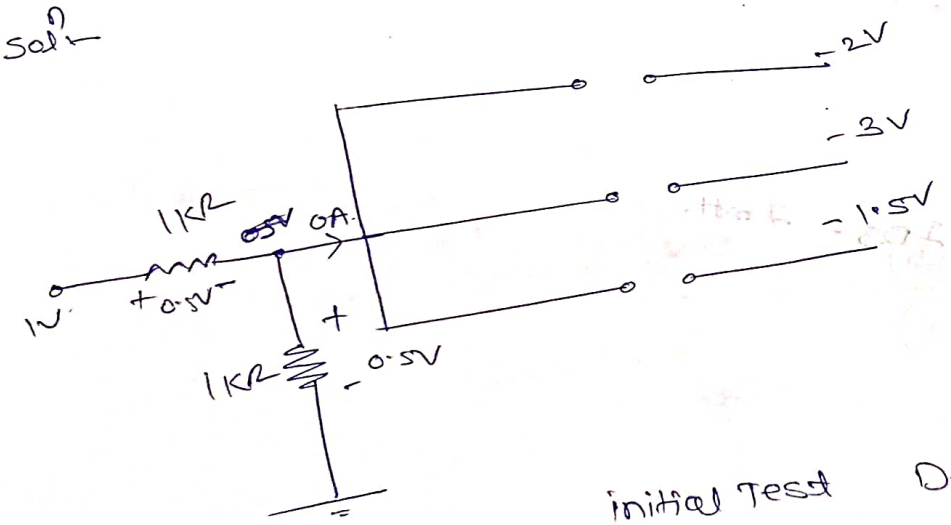
$V_0 = 5.$

Q)



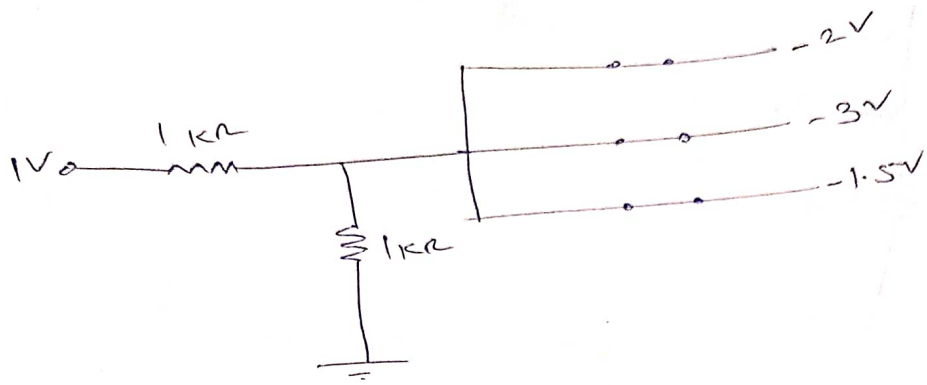
$I_{D1} + I_{D2} + I_{D3}$ - - - - mA

Sol^n



initial Test D_1 D_2 D_3 ON

$\frac{1}{2} = 0.5mA$

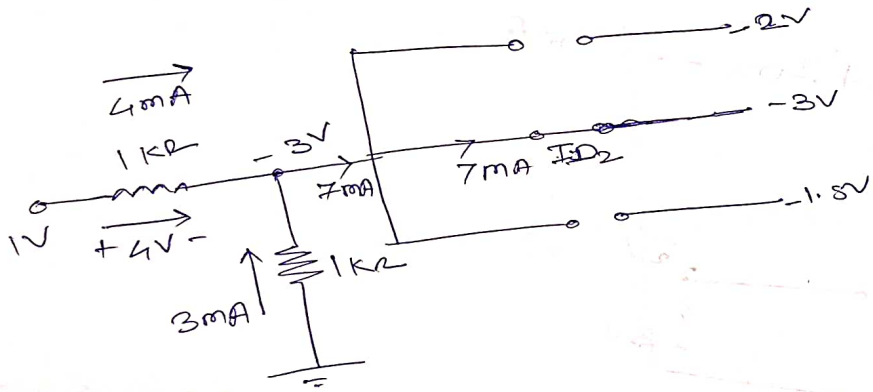


Now D1 only ON

$V_p > V_n$

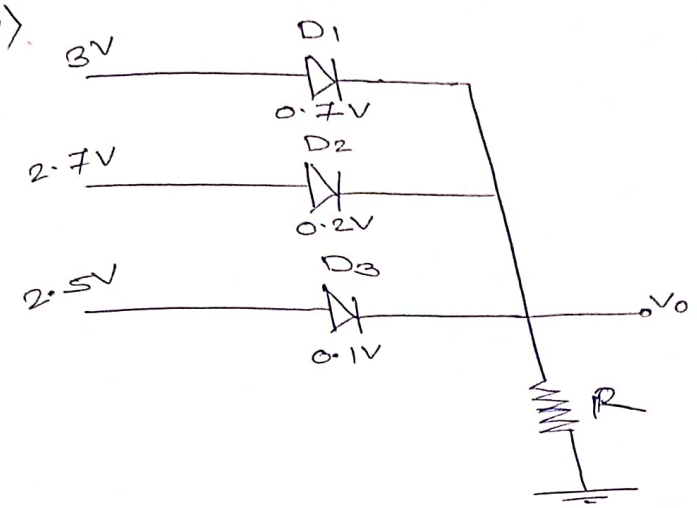
Now D2 only ON

∴

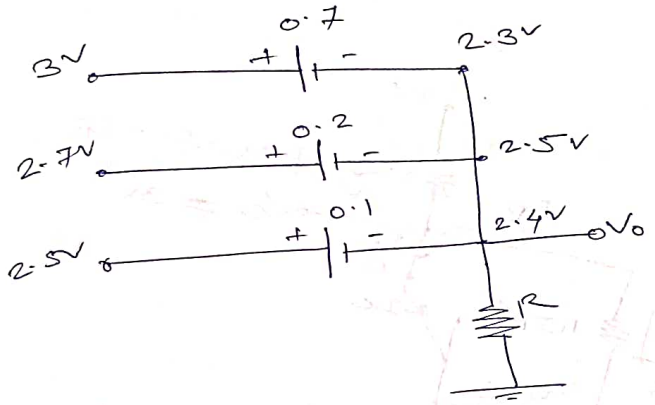


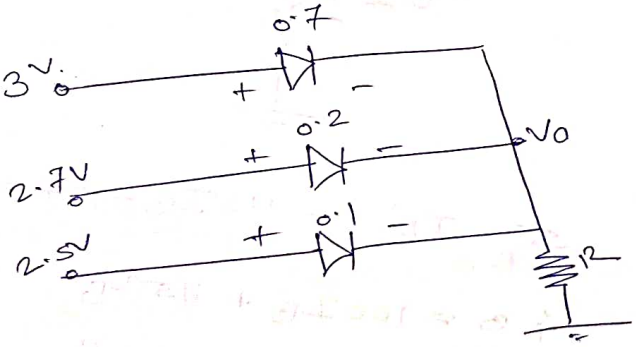
$I_{D1} + I_{D2} + I_{D3} = 7mA.$

Q)



Sol:-





$(3 - V_a) - 0.7 = 2.3 - V_a$

$(2.7 - V_a) - 0.2 = 2.5 - V_a$

$(2.5 - V_a) - 0.1 = 2.4 - V_a$.

D2 ON.