-: P-N Junction Diode :-

Pure Semiconductor	Impure Semiconductor
→ External atoms are not added.	→ External atoms are added.
→ Ex: Si (Pure), Ge	→ Conductivity changes ($e^{\ominus}s$)
→ $\boxed{\text{INTRINSIC}}$	→ $\boxed{\text{EXTRINSIC}}$
	→ $\boxed{\text{Quality changes}}$ → n-type, P-type

N-type	p-type
• Pentavalent ($5e^{\ominus}s$)	• Trivalent ($3e^{\ominus}s$)
• Phosphorous	• Al → 13 2, 8, 13
Si → $\boxed{\text{extra } e^{\ominus}}$	→ Acceptor Impurity
→ Donor Impurity	
→	

• Si needs 4 $e^{\ominus}s$ for forming covalent bond.

• Pentavalent → $5e^{\ominus}s$

• Trivalent → $3e^{\ominus}s$

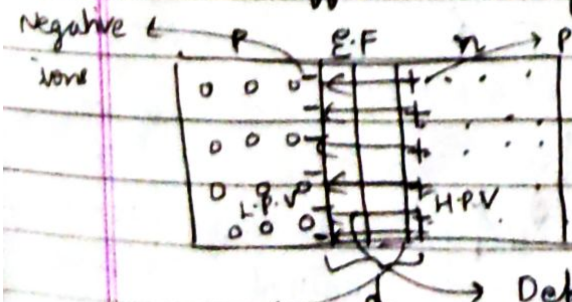
(maj. holes) P n (maj. $e^{\ominus}s$)

• → $e^{\ominus}s$	o → holes

$e^{\ominus}$ moves (current)

→ neutralizes by going to p-side region

→ diffusion → diffusion current.



→ Depletion layer [charge deficient]

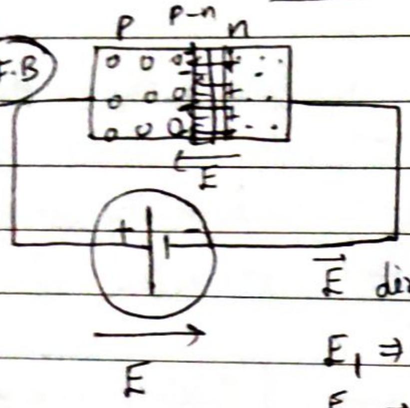
★ Impurity ↑ → Depletion layer ↓

$\boxed{V = E \cdot d}$

Potential barrier

FORWARD AND REVERSE BIAS :-

① F.B

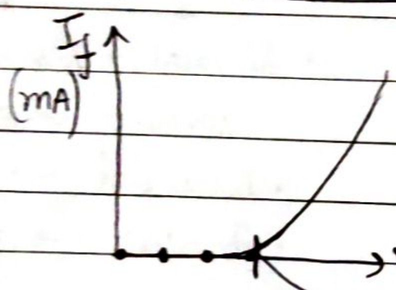


$\vec{E}$ directions are opposite in nature

$E_1 \Rightarrow 80$ overall

$E_2 \Rightarrow 60$ $E = 80 - 60 = 20$ $E\downarrow$

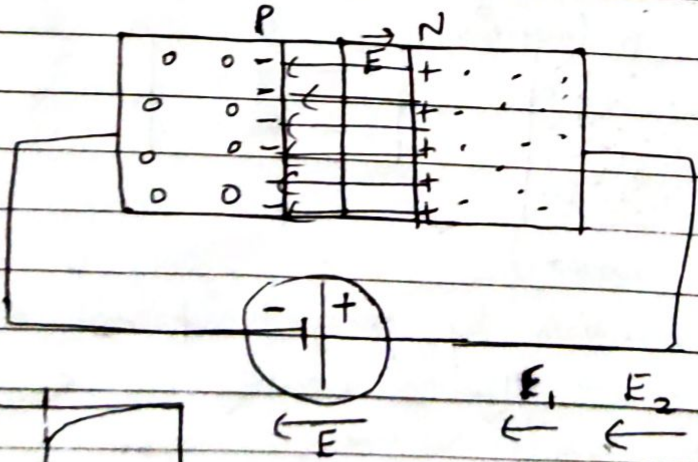
(current sufficient) Less energy required ⟵ $\boxed{\text{Potential barrier}}$ ↓ ↓ $V = E \cdot d$ ↓ ↓



→ Cut off voltage or knee voltage or Threshold voltage

V_f	I_f
0	0
1	0
2	0
3	0
4	1
5	2

② Reversed Biasing



→ Electric current is due to only minority charge carriers.

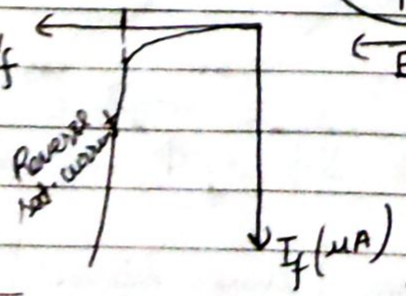
E_1 ⟵ E_2 ⟵ ($\vec{E}$ are in same direction)

$E = E_1 + E_2$

$\uparrow E = 80 + 60$

V_f	I_f (μA)
0	0
1	1
2	1
3	1
4	1
5	10
6	20
8	50

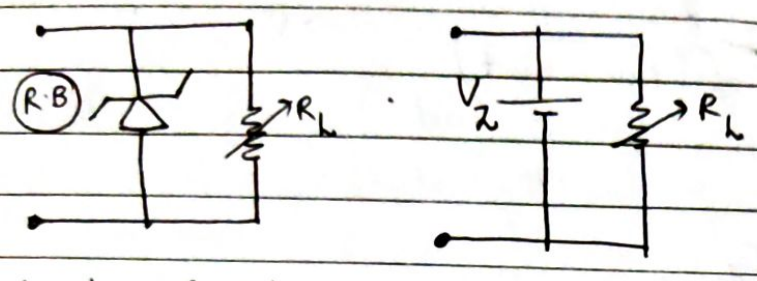
Current is suddenly increasing



$\boxed{\text{Pot. barrier} \leftarrow V\uparrow}$ → More energy required (Less current found ↑ almost equal to 0)

Zener Diode :-

→ Zener Diode is a Special Diode → Acts as Voltage Regulator.



→ **Avalanche Breakdown :-**

Lightly Doped Diodes [Normal Diode]

→ **Zener Breakdown :-**

→ Highly Doped Diode → Breakdown is acheived much earlier

→ "Rupture" → Tearing ↑ E·F

→ High Power Dissipation capability

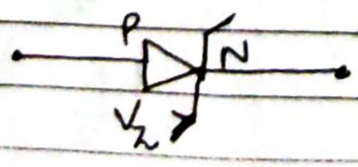
$\boxed{\text{Zener Diode} > \text{Normal Diode}}$

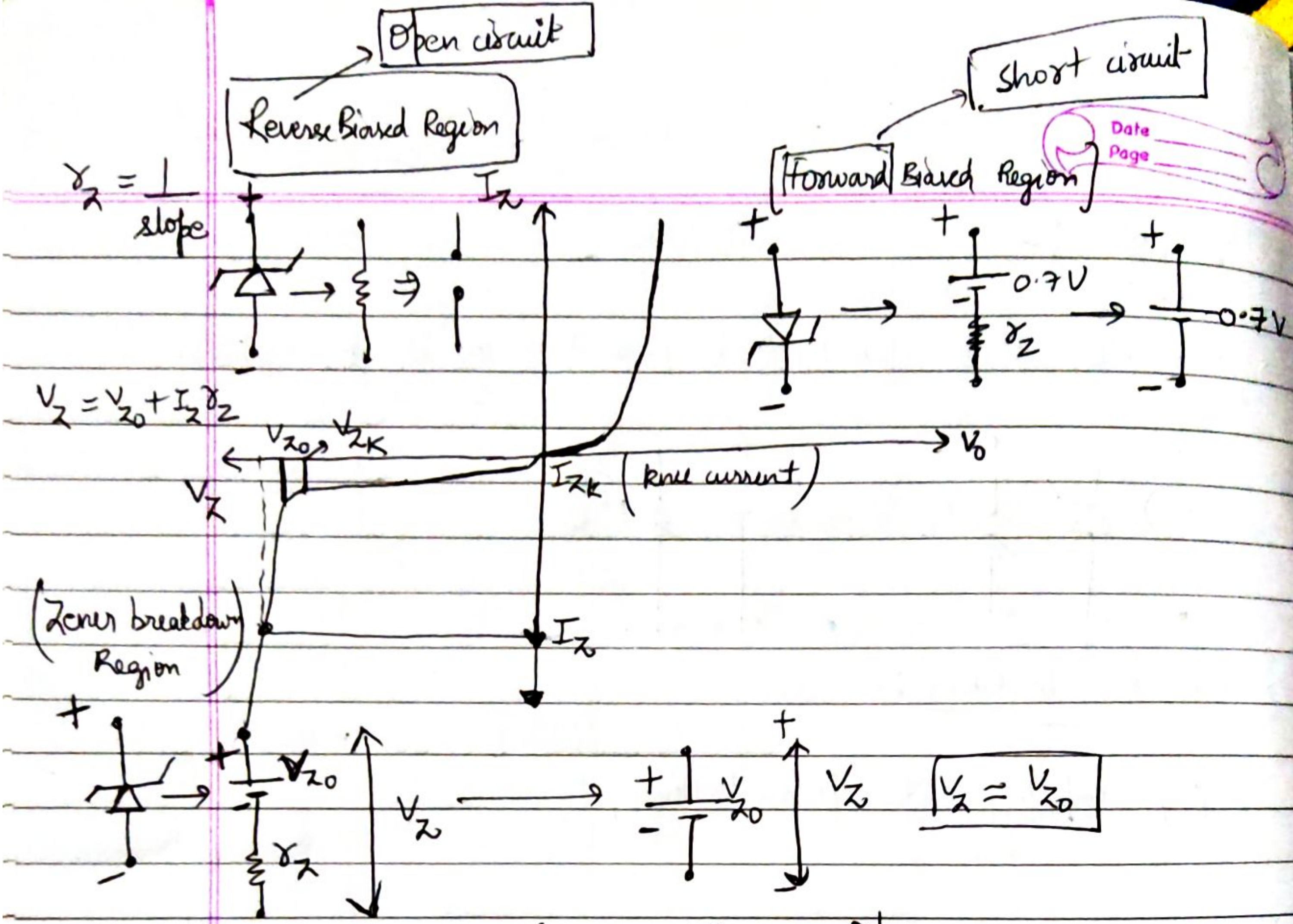
→ Properties will not degrade.

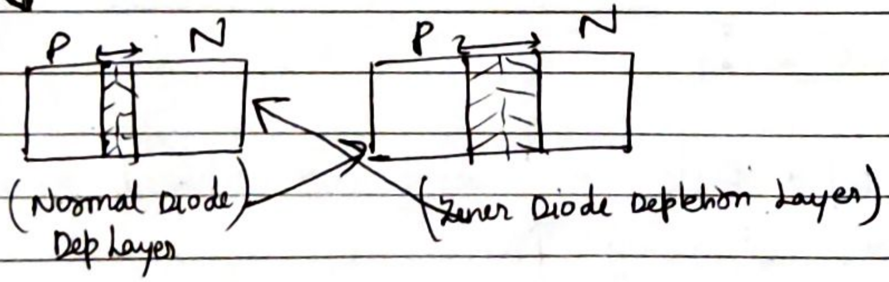
Imp → Zener Diode in F·B region is same as Normal Diode in F·B region.

Symbol :-

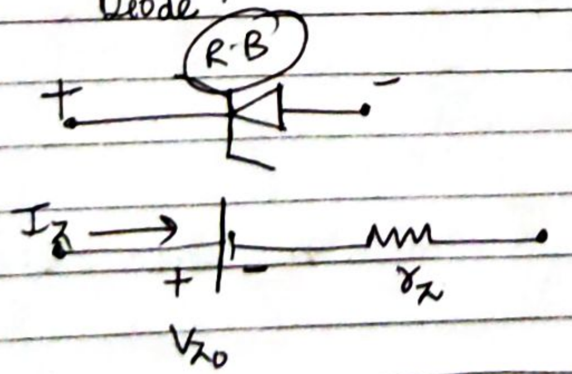
$\boxed{V_z \rightarrow \text{Zener Voltage}}$



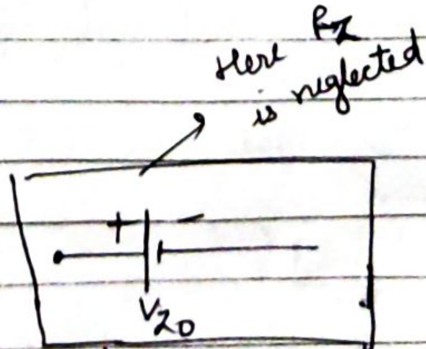




→ Depletion layer in case of Zener Diode is very thin as compared to Depletion layer in case of Normal Diode.



$$\boxed{V_z = V_{z0} + I_z r_z}$$



$$\boxed{V_z = V_{z0}}$$

Used in Numericals

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Temperature Effect on Zener Voltage :-

Temp. coefficient

$$\boxed{T_c = \frac{\Delta V_z / V_z}{T_1 - T_0} \times 100 \% / ^\circ C}$$

$\Delta V_z \rightarrow$ change in Zener Voltage
$V_z \rightarrow$ Zener Potential (Voltage) at $25^\circ C$.
$T_1 \rightarrow$ New temp.
$T_0 \rightarrow$ Room Temp. $(25^\circ C)$

Q. Calculate change in Zener Voltage if zener voltage is 10 V at $25^\circ C$, and new temp. is $100^\circ C$. Temp. coefficient (T_c) is $0.072 \% / ^\circ C$.

Sol^n $\Delta V_z = ?$ ~~$T_0 = 10$~~

$V_z = 10\,V$
$T_1 \Rightarrow 100^\circ C$
$T_c = 0.072 \% / ^\circ C$

$$T_c = \frac{\Delta V_z / V_z}{(T_1 - T_0)} \times 100\% / ^\circ C$$

$$\Delta V_z = \frac{T_c V_z}{100\%} (T_1 - T_0)$$

$$\Rightarrow \frac{(0.072 \% / ^\circ C)(10)(100 - 25)}{100}$$

$$\Delta V_z \Rightarrow 0.54 \text{ Volts}$$

New zener potential $= V_z + \Delta V_z$
$= 10\,V + 0.54\,V$
$\Rightarrow 10.54\,V$

$\uparrow T \quad V_z \uparrow$
$25^\circ C \rightarrow 10\,V$
$100^\circ C \rightarrow 10.54\,V$

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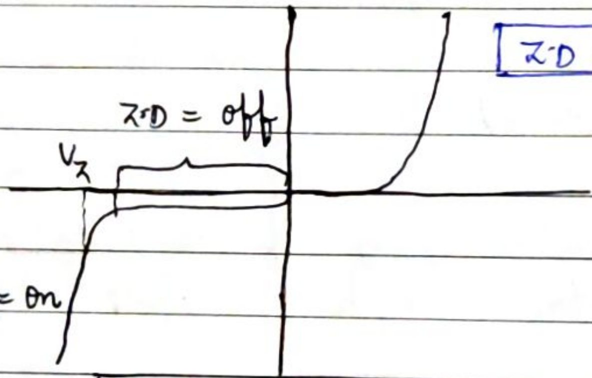
(1) Zener Diode as Voltage Regulator :- [V_i and R_L fixed]

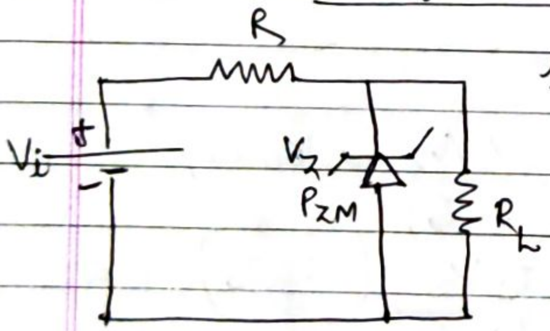
Q. What is Voltage Regulator ?

Ans. A voltage Regulator is a combination of elements designed to ensure that the output voltage of a supply remains constant.



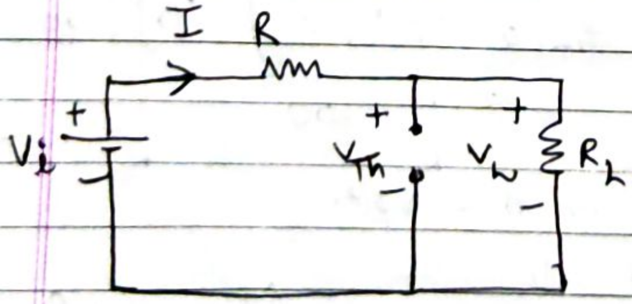
$\boxed{Z \cdot D = N \cdot D}$ → In forward biased

$\boxed{\text{Voltage accross the Z·D} \geq V_Z}$



Cases :-

i) V_i and R_L fixed
ii) V_i fixed and R_L is variable
iii) V_i variable and R_L is fixed
iv) V_i and R_L variable.



$$V_i - IR - IR_L = 0$$

$$I = \frac{V_i}{R + R_L}$$

$$V_{Th} = V_L = IR_L$$

$$= \frac{V_i R_L}{R + R_L}$$

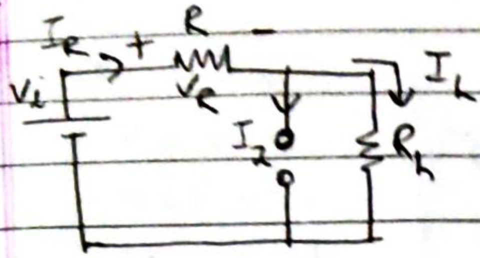
Case (I): $V_{Th} \geq V_Z$ → On Diode

Case (II): $V_{Th} < V_Z$ → Diode is off

Open circuit

Zener ↑

Case (II) $V_{Th} < V_Z$ [Diode is off]



$I_Z = 0$

$P_Z = I_Z \cdot V_Z = 0$

$I_R = I_L + \cancel{I_Z}^{\,0}$

$I_R = I_L$

$$I_R = \frac{V_i}{R+R_L} = I_L$$

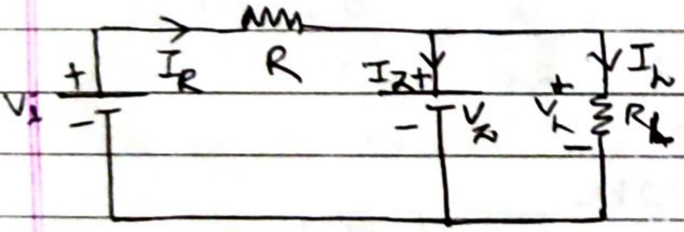
$V_R = I_R R$

$$V_R = \frac{V_i}{R+R_L} \cdot R$$

$V_L = I_L \cdot R_L$

$$V_L = \frac{V_i}{R+R_L} \cdot R_L$$

Case (I) $V_{Th} \geq V_Z$ [Zener Diode is on]



$I_R = I_L + I_Z$

$I_Z = I_R - I_L$

$$I_R = \frac{(V_i - V_Z)}{R}$$

$$I_L = \frac{V_L}{R_L} \qquad V_Z = V_L$$

$$I_L = \frac{V_Z}{R_L}$$

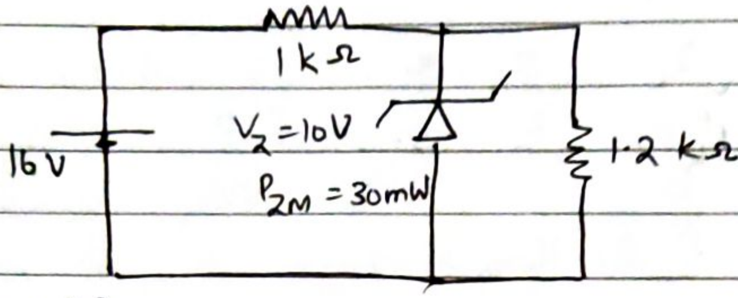
$$I_Z = \frac{(V_i - V_Z)}{R} - \frac{V_Z}{R_L}$$

$$P_Z = I_Z V_Z$$

$$= \left[\frac{(V_i - V_Z)}{R} - \frac{V_Z}{R_L}\right] \times V_Z$$

$$\boxed{P_Z < P_{ZM}}$$

Q. for the zener diode network, determine V_L, V_R, I_Z, P_Z



Given :-

$V_i = 16\ V$

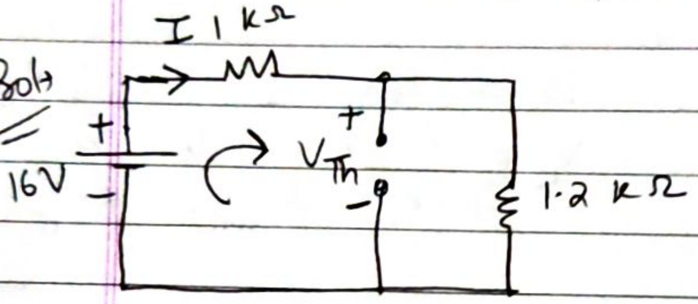
$R = 1\ k\Omega$

$R_L = 1.2\ k\Omega$

$V_Z = 10\ V$

$P_{ZM} = 30\ mW$

Sol^n



$$16 - I \times 1 - I \times 1.2 = 0$$

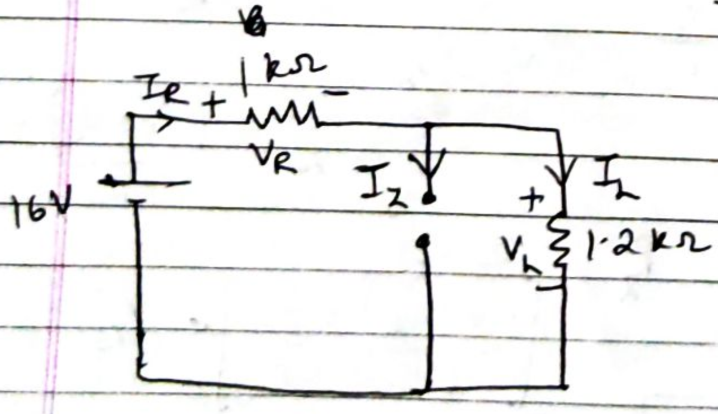
$$I = \frac{16}{1+1.2} = \frac{16}{2.2} = 7.27\ mA$$

$$V_{Th} = V_L = I \times 1.2\ k\Omega$$

$$= 7.27 \times 1.2\ k\Omega$$

$$V_{Th} = 8.27\ V$$

$\boxed{V_{Th} < V_Z}$ → So Zener Diode remains off.



$$I_R = \frac{16}{2.2} = 7.27\ mA$$

$$I_R = I_L$$

$$I_Z = 0 \quad P_Z = 0$$

$$V_R = I_R \cdot (1\ k\Omega)$$

$$V_R = 7.27 \times 1\ k\Omega$$

$$\boxed{V_R = 7.27\ V}$$

$$V_L = I_L \times 1.2\ k\Omega$$

$$V_L = 7.27 \times 1.2\ k\Omega$$

$$\boxed{V_L = 8.64\ V}$$

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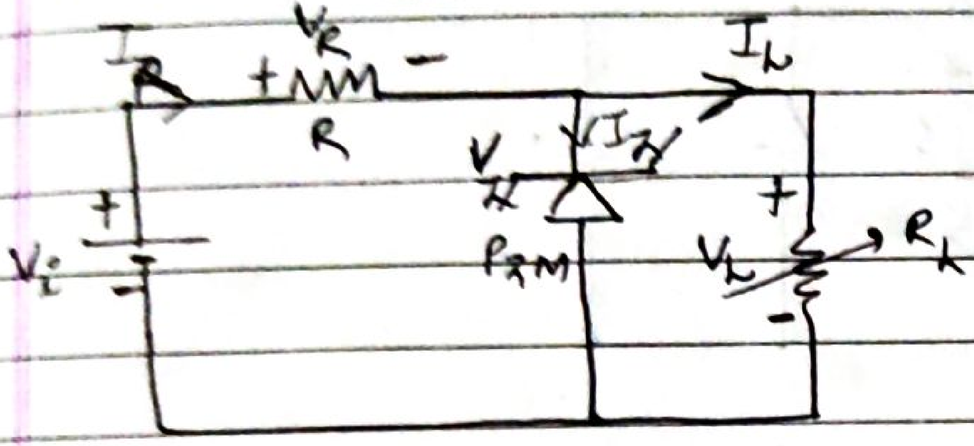
(2) Zener Diode as Voltage Regulator [V_i fixed & R_L variable]



$I_R = I_Z + I_L$

$\downarrow$ min $\quad \downarrow$ max

$I_{Z_{min}} = I_R - I_{L_{max}}$

Cond^n for $\boxed{\text{minimum}}$ Load Resistance [R_L] :-

Voltage across Z·D = V_Z

$V_L = V_L = V_{Th} = \dfrac{V_i R_L}{R + R_L} = V_Z$

$V_i - IR - IR_L = 0$

$I = V_i / R + R_L$

$V_Z (R + R_L) = V_i R_L$

$\boxed{R_{L_{min}} = \dfrac{V_Z R}{V_i - V_Z}}$

$I_{L_{max}} = \dfrac{V_L}{R_{L_{min}}} = \dfrac{V_Z}{R_{L_{min}}}$

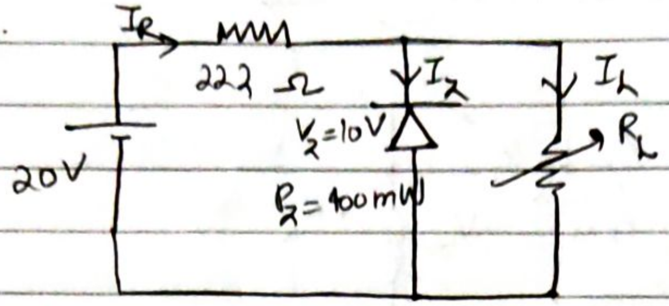
Cond^n for max R_L :-

$R_{L_{max}} = I_{L_{min}} = I_{Z_{max}}$

$P_{ZM} = I_{Z_{max}} \cdot V_Z$

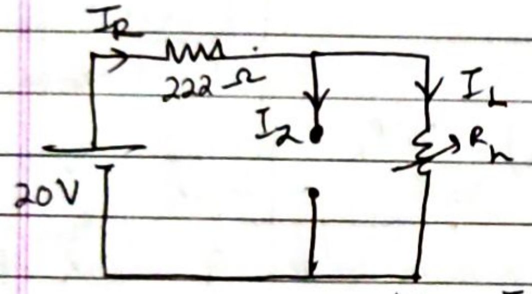
Q. Determine the minimum and maximum values of Load Resistance

Q. Determine the minimum and maximum values of Load Resistance R_L.



Sol: Case ① for R_L to be min:

$R_{L\,min} \rightarrow I_{L\,max} \rightarrow I_{Z\,min} \rightarrow 0$ (open circuit) ↳ when diode is off



$$I_R = \cancel{I_Z}^{\,0} + I_L$$

$$I_R = I_L$$

$$20 - 222 I_R - I_L \cdot R_L = 0 \qquad V_L = V_Z$$

$$20 - 222 I_R - I_R \cdot R_L = 0$$

$$20 = 222 I_R + I_R \cdot R_L$$

$$20 = I_R (222 + R_L) \qquad V_L = I_L \cdot R_L$$

$$I_L = I_R = \frac{20}{222 + R_L} \qquad 10 = \frac{20}{222+R_L} \cdot R_L$$

$$222 + R_L = 2 R_L$$

$$\boxed{R_{L\,min} = 222 \Omega}$$

Case (II) for R_L to be max:

$$I_R = I_{L\,min} + I_{Z\,max}$$

$R_{L\,max} \longrightarrow I_{L\,min} \longrightarrow I_{Z\,max}$

$$P_{Z\,max} = I_{Z\,max} V_Z \qquad I_R - I_{L\,min} = I_{Z\,max}$$

$$I_{zmax} = \frac{P_{zM}}{V_z} = \frac{40\cancel{0}}{1\cancel{0}}$$

$$R_{Lmax} = \frac{V_L}{I_{Lmin}} = \frac{V_z}{I_{Lmin}}$$

$$I_{Lmin} = I_R - I_{zmax}$$

$$I_{Lmin} = \frac{V_i - V_z}{R} - 40$$

$$I_{Lmin} = \frac{10}{222} - \frac{\cancel{40}}{\cancel{1000}}$$

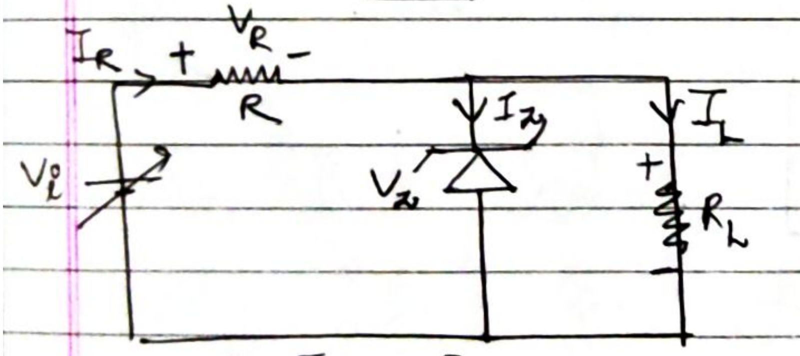
$$\Rightarrow \cancel{0.\,04 - 0.}$$

$$I_{Lmin} = 45\,mA - 40\,mA$$

$$\boxed{I_{Lmin} = 5\,mA}$$

$$\boxed{R_{Lmax} = \frac{1\cancel{0}}{\cancel{5}} = 2k\Omega}$$

③ Zener Diode as Voltage Regulator [Variable V_i & fixed R_L]



Cond^n for min V_i :-

$V_{Th} \geq V_z \longrightarrow$ ON

$V_{Th} < V_z \longrightarrow$ OFF

$$V_i - IR - IR_L = 0$$

$$I = \frac{V_i}{R+R_L}$$

$$V_{Th} = V_L = IR_L$$

$$V_{Th} = \frac{V_i R_L}{R+R_L}$$

$$V_{Th} = V_z$$

$$\frac{V_i R_L}{R+R_L} = V_z$$

$$\boxed{V_{imin} = \frac{V_z (R+R_L)}{R_L}}$$

Cond^n for V_{imax} :

V_{imax} is limited by I_{zmax}

$$I_L = \frac{V_L}{R_L} = \frac{V_z}{R_L}$$

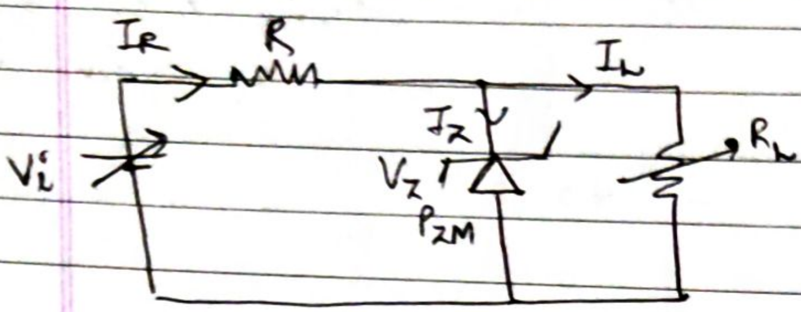
$$I_{R_{max}} = I_{z_{max}} + I_L$$

$$V_{i_{max}} - V_{R_{max}} - V_z = 0$$

$$V_{imax} = V_{Rmax} + V_z$$

$$\boxed{V_{imax} = I_{R_{max}} R + V_z}$$

④ Zener Diode as Voltage Regulator [V_i & R_L Variable]



$$R_{min} = \frac{V_{imax} - V_Z}{I_{Rmax}}$$

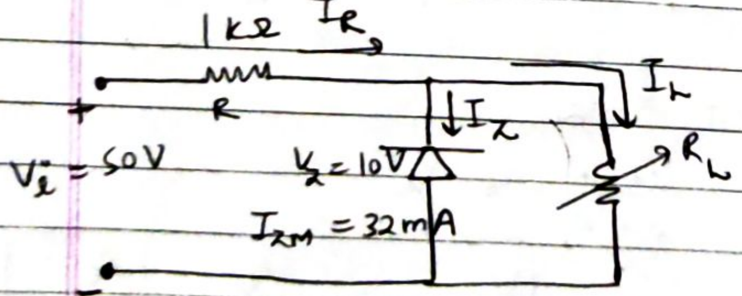
$$R_{max} = \frac{V_{imin} - V_Z}{I_{Rmin}}$$

Always True in Zener diode Problems

* $\boxed{I_R \geq I_Z + I_L}$

* $\boxed{\frac{V_i - V_Z}{R} \geq I_Z + I_L}$

Q.



find R_{Lmax}, R_{Lmin} & I_{Lmax}, I_{Lmin}

$V_L = V_Z = I_L \cdot R_L$

Sol:

$10 = 8 \cdot R_{Lmax}$

for R_{Lmax}: $\boxed{10/8 = R_{Lmax}}$

$R_{Lmax} \rightarrow I_{Lmin} \rightarrow I_{Zmax}$

$I_R = I_{Lmin} + I_{Zmax}$

$I_{Lmin} = I_R - I_{Zmax}$

$I_R = \frac{V_i - V_Z}{R}$

$I_{Lmin} = 40 - 32$

$I_R \Rightarrow \frac{40}{1}$

$(I_{Zmax} = 32\,mA)$
↓
Given

$\boxed{I_{Lmin} = 8\,mA}$

$\boxed{R_{Lmax} = 10/8}$

for $R_{L\,min}$:

$R_{L\,min} \rightarrow I_{L\,max} \rightarrow I_{z\,min}$

$P_{max} = V_z I_{zm}$

$\Rightarrow 10 \cdot 32$

$= 320\,mW$

$I_R = I_{z\,min} + I_{L\,max}$

$I_{L\,max} = I_R - \cancel{I_{z\,min}} \rightarrow 0$

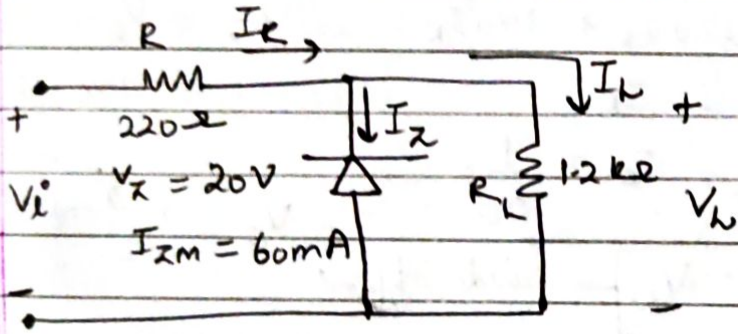
~~$I_{z\,min} = I_R -$~~

$I_{L\,max} = 40$

$V_L = R_{L\,min} \cdot 40$

$\dfrac{10\,k\Omega}{40} = R_{L\,min}$

$R_{L\,min} = \dfrac{10 \times 1000}{40} = 250\,\Omega$



find range of V_i that will maintain the zener diode in on state

sol for V_i to be min:

$V_i - IR - IR_L = 0$

$I = \dfrac{V_i}{R + R_L}$

$V_{Th} = V_z$

$V_{Th} = V_L = I R_L$

$V_{Th} = \dfrac{V_i}{R + R_L} \cdot R_L$

$\dfrac{1.2 \times 1000}{10}$

$V_{i\,min} = \dfrac{20(1200 + 220)}{1200} = 23.67\,V$

$I_{R\,max} = I_{z\,max} + I_L$

$= 60 + 16.67$

$V_{i\,max} = I_{R\,max} R + V_z$

$= (76.67)(0.22) + 20$

$\Rightarrow 36.87\,V$

$I_L = \dfrac{V_L}{R_L} = \dfrac{20}{1.2}$

$\Rightarrow 16.67$

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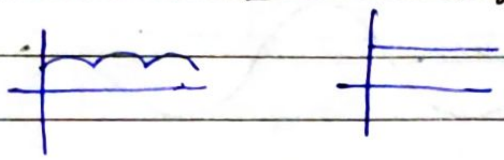
Introduction to Diode Rectifier Circuits :-

Rectification → correction of error/ mistakes.

→ AC power is supplied in our house. [Because it is convinient to transmit AC power over long distance]

→ But Most of appliances used D.C power, so rectified is used as to convert A-C power to DC power.

Transformer — Rectifier — Filter — Voltage Regulator [Imp. → Zener Diode] — Load



$f = 50\ Hz$ [In India]

$f = 60\ Hz$ [In USA]

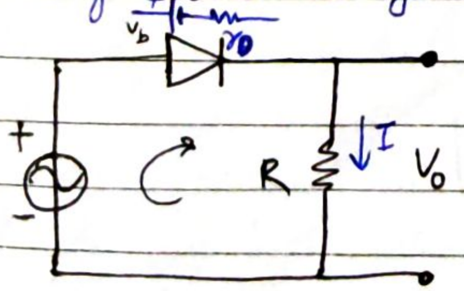
Types of Rectifier :- ① Half-wave Rectifier

② Full-Wave Rectifier :- a) Center Type

b) Bridge Type

→ HALF-WAVE RECTIFIER :-

• Only one half of the ac voltage is rectified, for the other half we get zero voltage.



Case of forward Biased :- [Short circuit]

$$+V_i - V_b - Ir_D - IR = 0$$

$$\boxed{I = \frac{V_i - V_b}{R + r_D}}$$

$$V_o = IR$$

$$V_o = \left(\frac{V_i - V_b}{R + r_D}\right)R$$

$$V_o = \left(\frac{R}{R + r_D}\right)V_i - \left(\frac{R}{R + r_D}\right)V_b$$

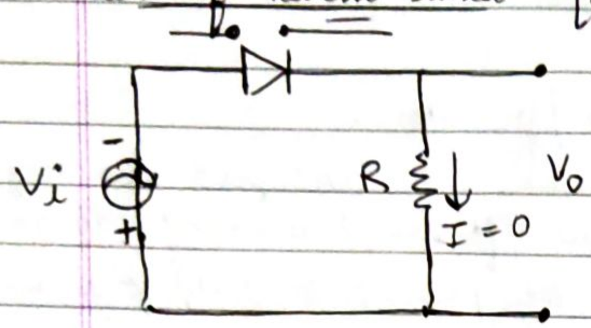
$$\boxed{r_D <<< R}$$

$$\boxed{V_o = V_i - V_b}$$

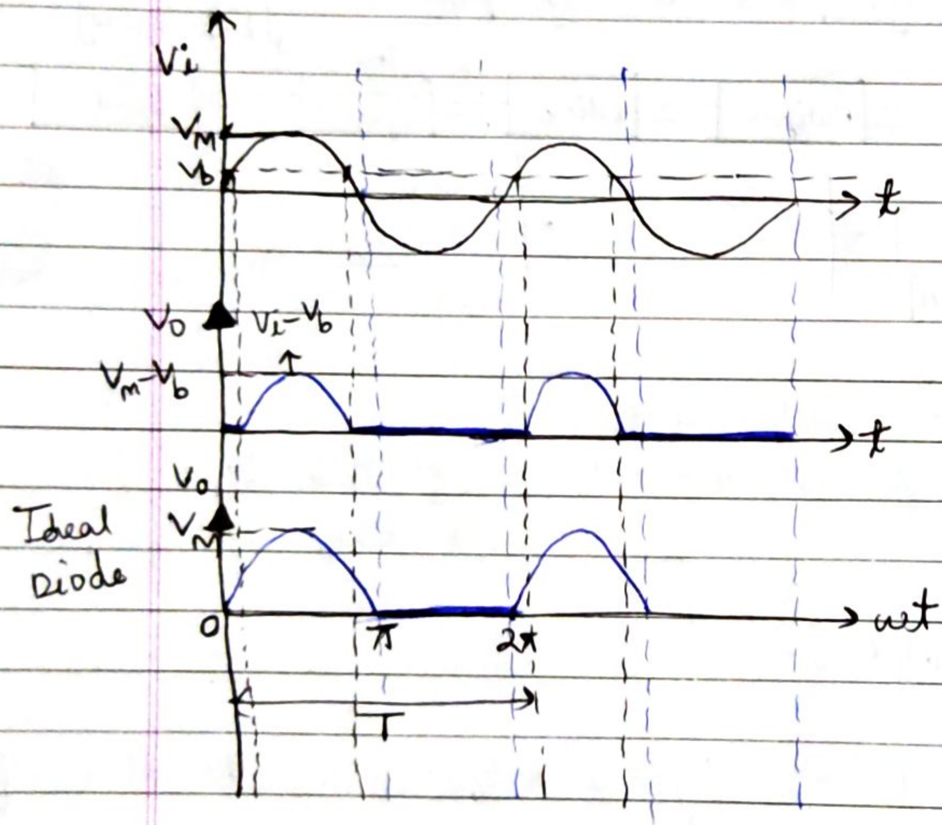
$\boxed{V_b = 0.7\ V}$ → Silicon

$\boxed{V_b = 0.3\ V}$ → Germanium

Case of Reverse Biased [open circuit]



$\boxed{V_o = 0}$



$\boxed{V_o = V_i - V_b}$

$\boxed{V_i < V_b} \rightarrow$ off Diode

$\boxed{V_i > V_b} \rightarrow$ On Diode

Ideal Model

$V_b = 0$

$V_o = V_i \rightarrow$ +ve

$V_o = 0 \rightarrow$ -ve

Average output voltage :-

$V_o = V_m \sin \omega t \quad [0 \le \omega t < \pi]$

$V_o = 0 \quad \pi \le \omega t \le 2\pi$

$$V_{avg} = \frac{\int_0^{2\pi} V_o \, d(\omega t)}{2\pi - 0} \Rightarrow \frac{1}{2\pi}\left[\int_0^{\pi} V_m \sin \omega t \, d(\omega t) + \cancel{\int_{\pi}^{2\pi} 0 \, d(\omega t)}^{0}\right]$$

On solving

$$\boxed{V_{avg} = \frac{V_M}{\pi} = 0.318 V_M}$$

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Avg load current :-

$$I_{avg} = \frac{V_{avg}}{R} \Rightarrow \frac{V_M/\pi}{R} \Rightarrow \frac{I_M}{\pi}$$

Half Wave Rectifier [RMS load current & RMS load voltage]

RMS load current :-

$\sqrt{mean[sq.(I)]}$

$$I_{rms} = \sqrt{\frac{\int_0^{2\pi} I^2 \, d(\omega t)}{2\pi - 0}}$$

$I = I_M \sin \omega t \qquad 0 \le \omega t \le \pi$

$I = 0 \qquad \pi \le \omega t \le 2\pi$

$$\Rightarrow \left[\frac{1}{2\pi}\int_0^{\pi} I_M^2 \sin^2 \omega t \, d(\omega t) + \cancel{\int_{\pi}^{2\pi} 0 \, d(\omega t)}\right]^{1/2}$$

$$\Rightarrow \left[\frac{I_M^2}{2\pi}\int_0^{\pi} \sin^2 \omega t \, d(\omega t)\right]^{1/2}$$

$\cos 2\theta = 1 - 2\sin^2\theta$

$\sin^2\theta = \frac{1}{2}(1 - \cos 2\theta)$

$$\Rightarrow \left[\frac{I_M^2}{2\pi}\int_0^{\pi} \frac{1}{2}(1 - \cos 2\omega t) \, d(\omega t)\right]^{1/2}$$

$$\Rightarrow \left[\frac{I_M^2}{4\pi}\left[\omega t - \frac{\sin 2\omega t}{2}\right]_0^{\pi}\right]^{1/2} \Rightarrow \left[\frac{I_M^2}{4\cancel{\pi}} \times \cancel{\pi}\right]^{1/2}$$

$$\Rightarrow \boxed{\frac{I_M}{2} \Rightarrow I_{rms}}$$

$V_{rms} = I_{rms} R$

$= \frac{V_M}{2\cancel{R}} \cdot \cancel{R}$

$$\boxed{V_{rms} = \frac{V_M}{2}}$$

HALF WAVE RECTIFIER [FORM FACTOR]

Form factor :- It is defined as the ratio of rms load voltage and average load voltage

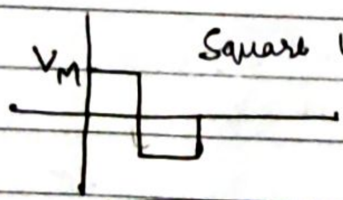
$$\boxed{\text{Form factor} = \frac{V_{rms}}{V_{avg}}}$$

rms value ;
5 V rms value = 5 V dc
rms value ≤ peak value

$\boxed{f.f \geq 1}$ $\boxed{rms \geq avg}$

$V_{rms} = \frac{V_m}{2}$ $V_{avg} = \frac{V_M}{\pi}$

$$f.f = \frac{V_M/2}{V_M/\pi} \Rightarrow \frac{\pi}{2} = \frac{3.14}{2} = 1.57 > 1$$



Square Wave

$V_{rms} = V_M$

$V_{avg} = V_M$

$$\boxed{f.f = \frac{V_m}{V_M} = 1}$$

$$\boxed{V_{rms} = 1.57\, V_{avg}}$$

HALF WAVE RECTIFIER [RIPPLE FACTOR]

Ripple factor :- The output current contains both ac and dc components. The ripple factor measures the percentage of ac component in the rectified output.

The ideal value of Ripple factor should be zero.
$\gamma = 0\%$
a.c comp $= 0 = \gamma = 0$

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Page

$$\gamma = \frac{\text{rms value of ac comp. of output}}{\text{avg. value of output}}$$

$$I = I_{ac} + I_{dc} \Rightarrow I_{ac} \Rightarrow I - I_{dc}$$

$$I_{ac_{rms}} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} I_{ac}^2 \, d(\omega t)}$$

$$\boxed{\text{Ripple factor} = \sqrt{\left((F.F)^2 - 1\right)}} \qquad \boxed{F.F = \frac{I_{rms}}{I_{dc}}}$$

γ

$$\boxed{\gamma\,\% = \sqrt{(F.F)^2 - 1} \times 100\%}$$

HALF WAVE RECTIFIER [P.I.V and Efficiency]

Efficiency :- It is defined as ratio of dc power available at the load to the input ac power.

$$\boxed{\eta\% = \frac{P_{Load}}{P_{in}} \times 100\%} \qquad P = VI \qquad P = I^2R$$

$$\Rightarrow \frac{I_{dc}^2 \cancel{R}}{I_{rms}^2 \cancel{R}} \times 100\% \qquad I_{dc} = \frac{I_M}{\pi} \qquad I_{rms} = \frac{I_M}{2}$$

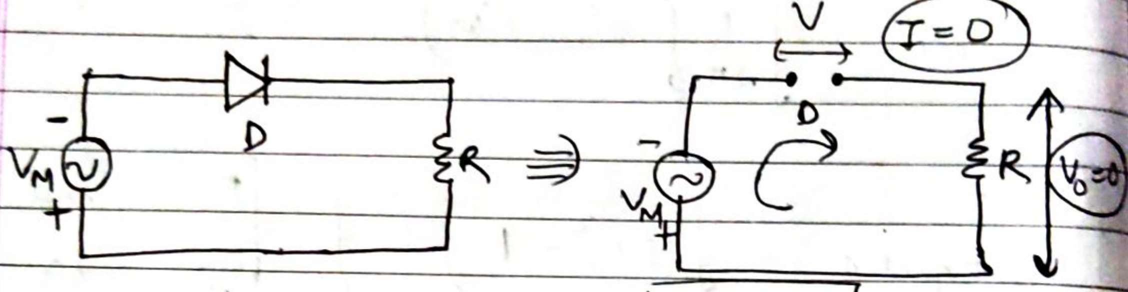
$$\Rightarrow \frac{\frac{I_M^2}{\pi^2}}{\frac{I_M^2}{4}} \times 100\% \Rightarrow \frac{4}{\pi^2} \times 100\%$$

$$\boxed{\eta\% = 40.56\%} \rightarrow \text{Low efficiency}$$

→ Disadvantage of Half wave Rectifier.

Peak Inverse Voltage [PIV] :

Max. reverse bias voltage that can be applied across the diode before ~~the~~ entering to the zener or breakdown region.



$\boxed{PIV = V}$

$$-V_M + V = 0$$
$$V = V_M$$
$$\boxed{PIV = V_M}$$

$\boxed{PIV \geq V_M}$

Full wave Bridge Rectifier :-

100 %

Disadvantages of H.W.R :-

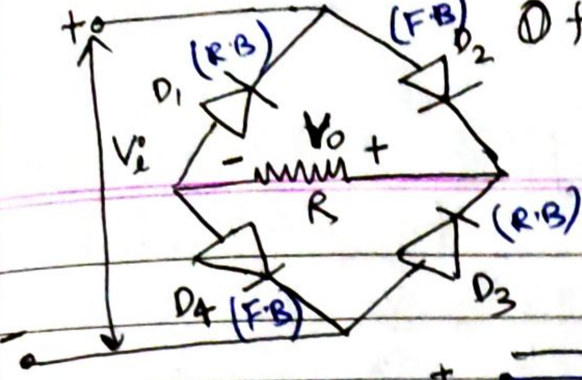
i) +ve half cycle $\longrightarrow V_0 = V_i = V_m \sin\omega t$
   -ve half cycle $\longrightarrow V_0 = 0$

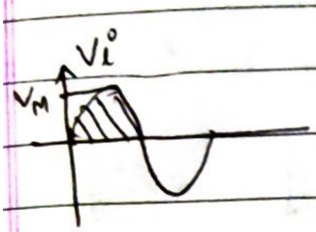
ii) ripple factor(%) = 121 %

iii) $\boxed{\eta\% = 40.56\%}$ $\rightarrow$ Low efficiency

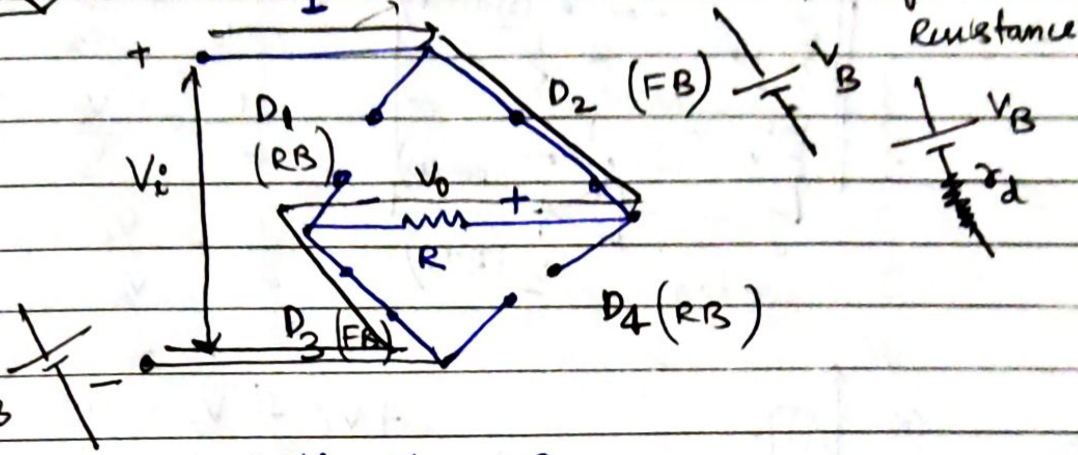
- That's why we use full wave rectifier.

① for +ve half cycle :





I → current will choose the path of min Resistance

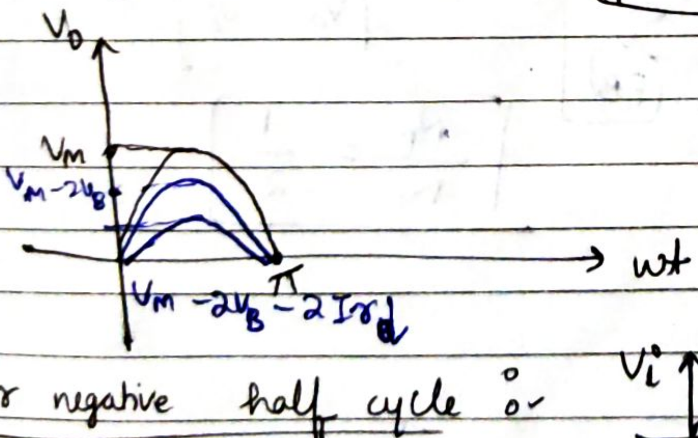


$$+V_i - V_o = 0$$

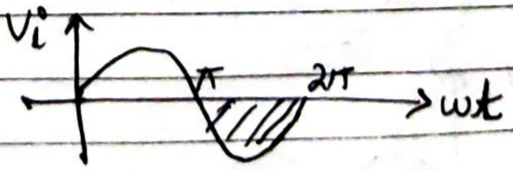
$$\boxed{V_o = V_i}$$ Ideal Model

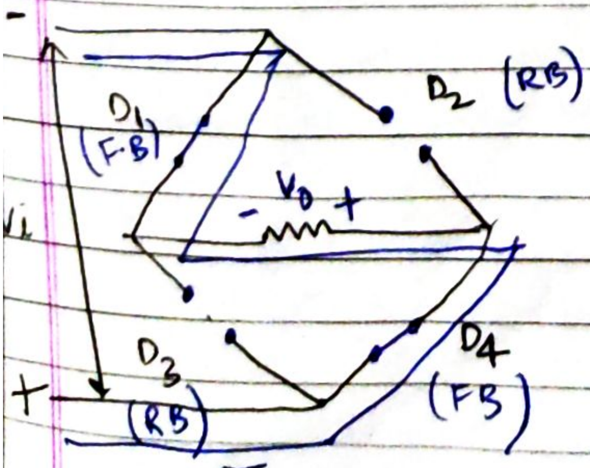
$$\boxed{V_o = V_i - 2V_B}$$ constant voltage drop model

$$\boxed{V_o = V_i - 2V_B - 2Ir_d}$$ → Peicewise linear model



② for negative half cycle :-

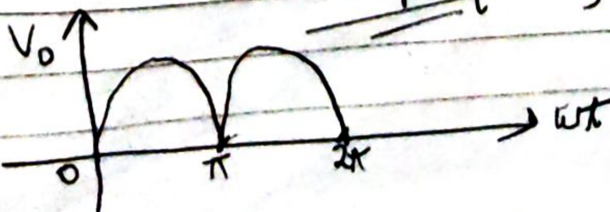




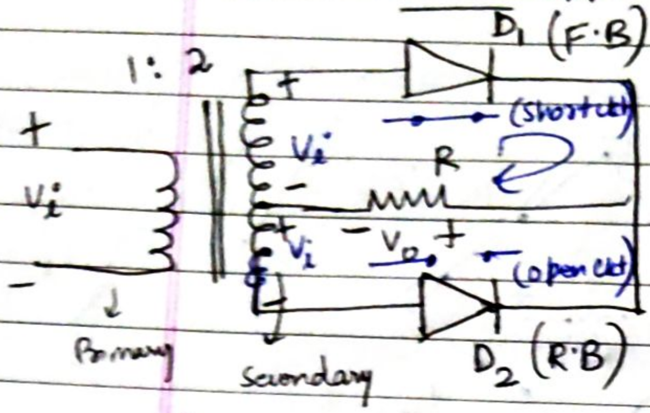
$$+V_i - V_o = 0$$

$$\boxed{V_o = V_i}$$

output [final]



Full wave Center Tapped Rectifier :-



for +ve half cycle :

$$\frac{N_p}{N_s} = \frac{V_p}{V_s}$$

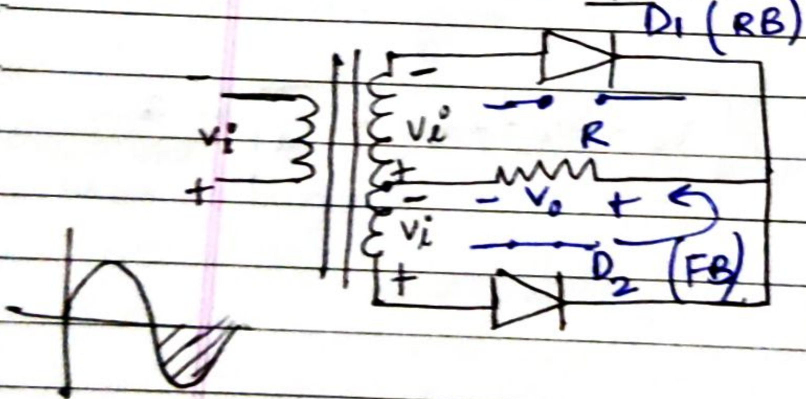
$$\frac{1}{2} = \frac{V_p}{V_s}$$

$$\frac{1}{2} = \frac{V_i}{V_s} \qquad \boxed{V_s = 2V_i}$$

$$+V_i - V_o = 0$$

$$\boxed{V_o = V_i}$$

for negative half cycle :

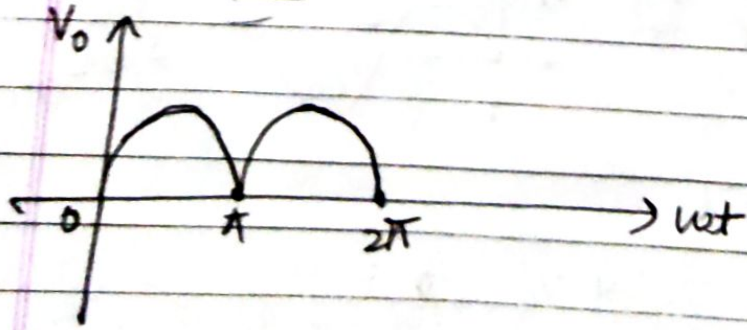


$$+V_i - V_o = 0$$

$$\boxed{V_o = V_i}$$

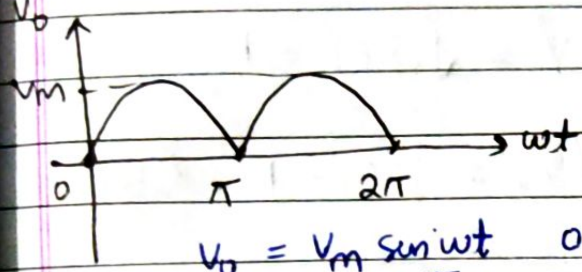
$$\boxed{\frac{N_p}{N_s} = \frac{1}{2}}$$

final waveform :



Full wave Rectifier [Avg. Load current & Avg load voltage]

Avg (dc) Load voltage :



$$V_0 = V_m \sin\omega t \quad 0 \le \omega t \le \pi$$

$$V_{av} = V_{dc} = \frac{1}{\pi}\int_0^{\pi} V_m \sin\omega t \, d(\omega t)$$

$$= \frac{V_M}{\pi}\Big[-\cos\omega t\Big]_0^{\pi}$$

$$= \frac{V_M}{\pi}\Big[-\cos\pi - (-\cos 0)\Big]$$

$$\boxed{V_{avg} = \frac{2V_M}{\pi}}$$

$$V_{avg} = \frac{V_M}{\pi}\Big[1+1\Big] \Rightarrow \frac{2V_m}{\pi}$$

Avg(dc) Load current :-

$$I_{avg} = \frac{V_{avg}}{R} = \frac{2V_M}{\pi R} \Rightarrow \boxed{\frac{2I_M}{\pi}}$$

$$\cos 2\theta = 1 - 2\sin^2\theta$$

RMS Load current & RMS Load Voltage :-

RMS Load current :

$I \Rightarrow$ Load current

$$I = I_M \sin\omega t \quad 0 \le \omega t \le \pi$$

$$I_{rms} = \left[\frac{1}{\pi}\int_0^{\pi} I^2 \, d(\omega t)\right]^{1/2}$$

$$I_{rms} = \left[\frac{1}{\pi}\int_0^{\pi} I_M^2 \sin^2\omega t \, d(\omega t)\right]^{1/2}$$

$$I_{rms} = \left[\frac{I_M^2}{\pi}\int_0^{\pi} \sin^2\omega t \, d(\omega t)\right]^{1/2}$$

$$I_{rms} = \left[\frac{I_M^2}{\pi}\int_0^{\pi} \frac{1}{2}(1-\cos 2\omega t)\, d\omega t\right]^{1/2}$$

On solving

$$\boxed{I_{rms} = \frac{I_M}{\sqrt{2}}}$$

$$V_{rms} = I_{rms} R = \frac{I_M R}{\sqrt{2}} = \frac{V_M}{\sqrt{2}}$$

$$\boxed{V_{rms} = \frac{V_M}{\sqrt{2}}}$$

Full wave Rectifier [Form factor & Ripple factor]

Form factor :

$$F.F = \frac{V_{rms}}{V_{avg}} \text{ or } \frac{I_{rms}}{I_{avg}}$$

$$F.F = \frac{V_m/\sqrt{2}}{2V_m/\pi}$$

$$F.F = \frac{\pi}{2\sqrt{2}}$$

$$\boxed{F.F = 1.11}$$

Ripple factor :

$$\gamma = \sqrt{(F.F)^2 - 1}$$

$$\gamma\% = \sqrt{(F.F)^2 - 1} \times 100$$

$$\gamma\% = \sqrt{(1.11)^2 - 1} \times 100$$

$$\boxed{\gamma\% = 48\%}$$

ac component

In H.W.R :

$$\boxed{\gamma\% = 121\%}$$

So γ is reduced by 73% by using F.W.R

Efficiency & PIV :-

Efficiency :

$$\eta\% = \frac{\text{output dc power}}{\text{input ac power}} \times 100\%$$

$$P = I^2 R$$

$$= \frac{I_{dc}^2 R}{I_{rms}^2 R} \times 100\%$$

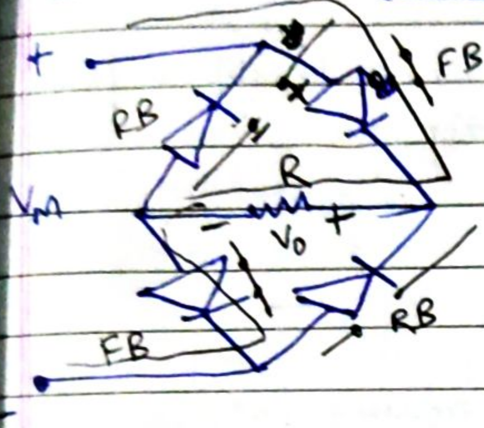
$$\Rightarrow \frac{4 I_m^2}{\pi^2 \cdot \cancel{I_m^2}} \cdot 2 \times 100\%$$

$$I_{dc} = \frac{2I_m}{\pi}$$

$$I_{rms} = \frac{I_m}{\sqrt{2}}$$

$$\boxed{\eta\% = 81.13\%}$$

PIV :- full wave Bridge Rectifier:



$+V_m - V_0 = 0$

$\boxed{V_0 = V_M}$

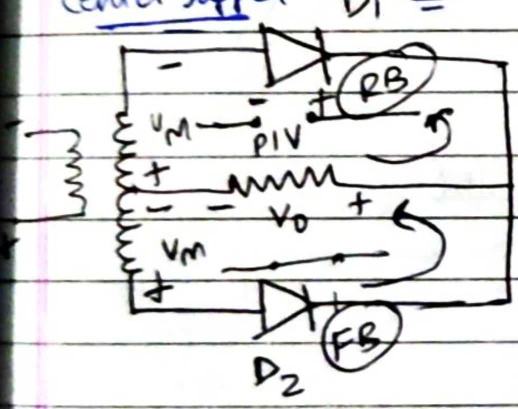
$-V_0 + PIV = 0$

$-V_M + PIV = 0$

$\boxed{PIV = V_M}$

$\boxed{PIV \geq V_M}$

Center Tapped Rectifier



$+V_M - V_0 = 0$

$V_0 = V_M$

$+V_0 - PIV + V_M = 0$

$PIV = 2V_M$

$\boxed{PIV \geq 2V_M}$

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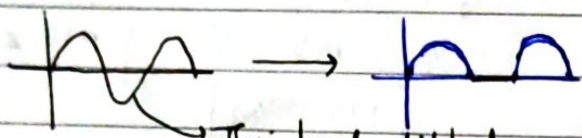
Introduction to Clippers :-

Clippers :- Clippers are the networks that use diodes to clip a portion of input signal without distorting the remaining part of the waveform.

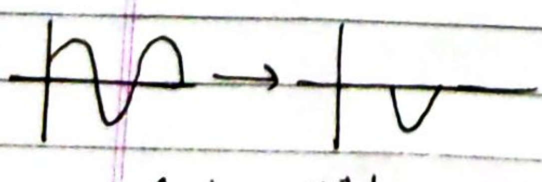


This part clipped and remaining part is same

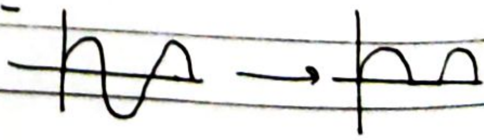
→ Clippers are also used to eliminate the noise effect in signal.

Clippers
- Series
  - Unbiased series [Basic]
    - +ve → Positive portion of waveform is clipped
    - −ve
  - Biased series [Additional DC source]
    - +ve
    - −ve
- Parallel
  - Unbiased Parallel [Basic]
    - +ve
    - −ve → −ve portion of waveform is clipped.
  - Biased Parallel [Additional DC Source]
    - +ve
    - −ve

Ex :-

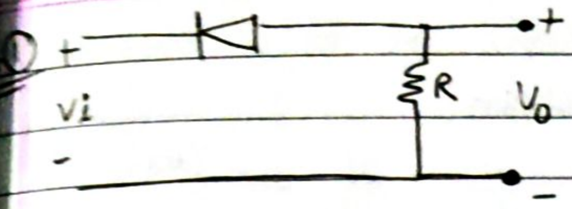


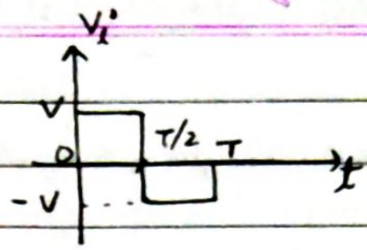
Ex :-



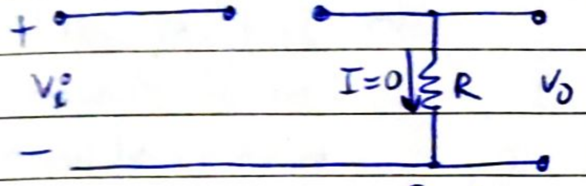
→ Series clipper ⟶ Diode is connected in series with Resistance
→ Parallel clipper ⟶ " " " " parallel " "
→ Biased clipper ⟶ Additional DC source applied.
→ Unbiased clipper ⟶ No Add^n DC source ".

①



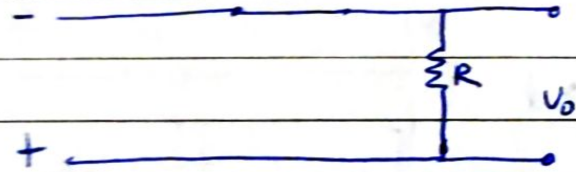


for +ve half cycle $[0 \rightarrow T/2]$
Diode is Reversed Biased [Open circuit] $\longrightarrow$ $\boxed{i = 0}$



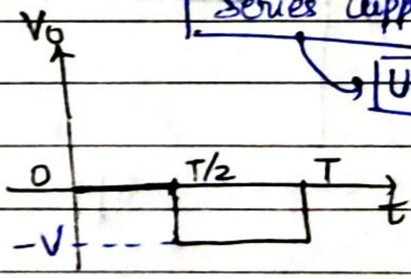
$\boxed{V_0 = 0}$

for -ve half cycle $[T/2 \longrightarrow T]$
Diod is forward Biased [Short circuit]



$V_0 - V_i = 0 \qquad V_0 = V_i$

$\boxed{V_0 = -V}$



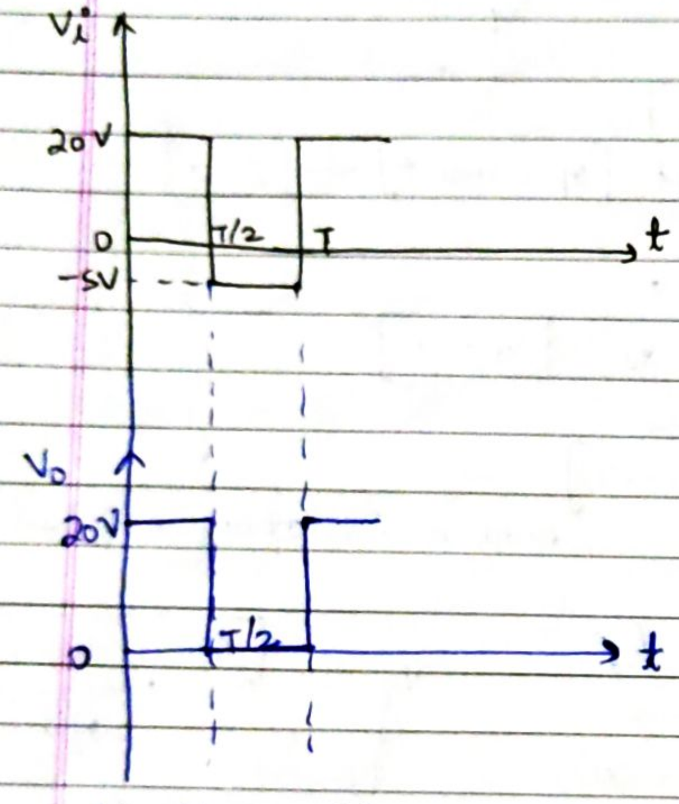
$\boxed{\text{Series clipper}}$ $\rightarrow$ $\boxed{\text{Unbiased}}$

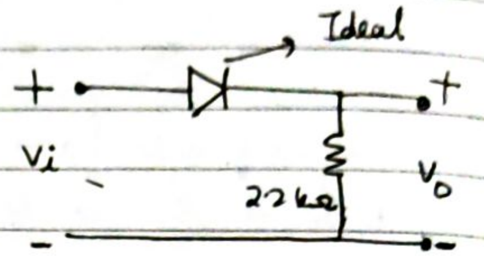
As we can see in output positive portion is clipped out, so it is positive clipper.

finally this circuit is Positive Unbiased Series Clipper.

UNBIASED SERIES CLIPPERS:

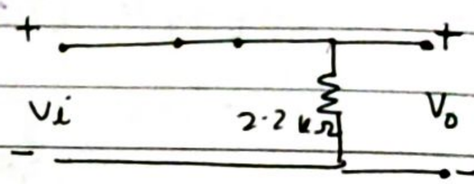
Q. Determine V_o for the input shown.





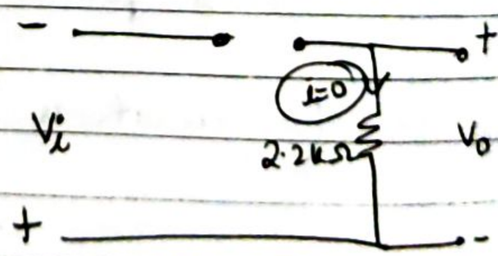
→ Negative clipper

for first half cycle $(0 \to T/2)$
Diode is Forward Biased (short circuit)



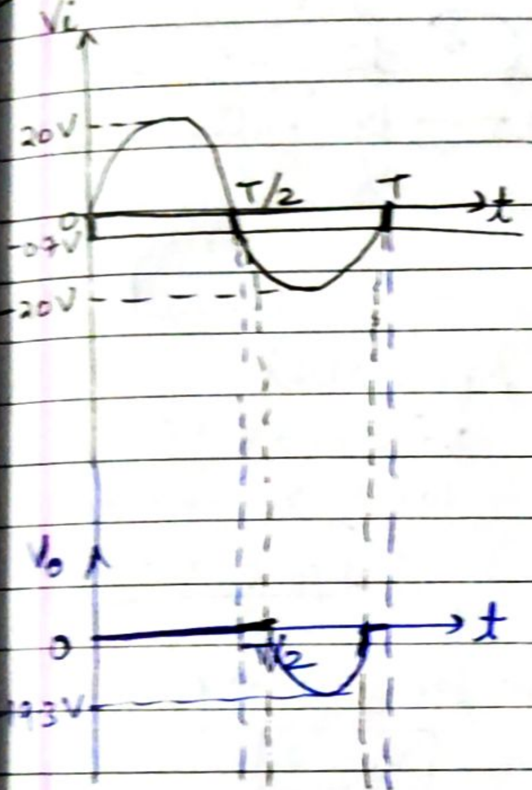
$\boxed{V_o = V_i}$

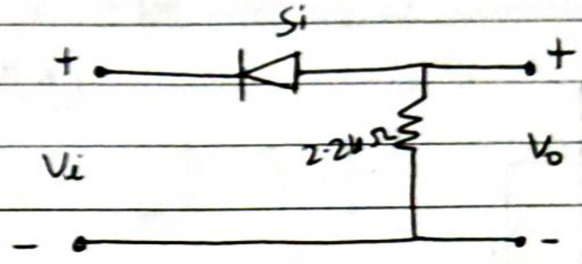
for next half cycle $(T/2 \to T)$
Diode is Reverse Biased
(open circuit)



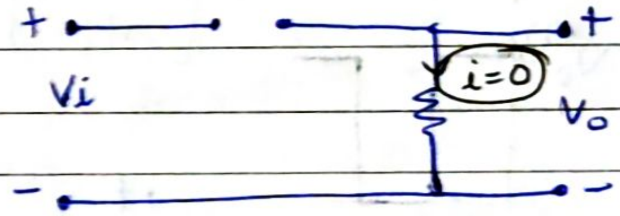
$\boxed{V_o = 0}$

Q. Determine V_o for the input shown :



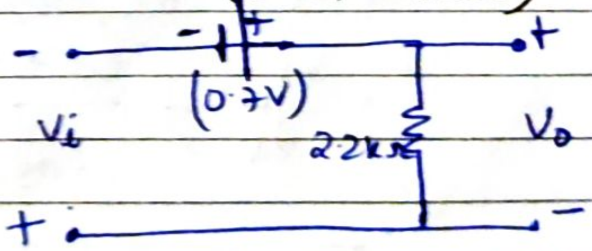


for first half cycle $(0 \rightarrow T/2)$
Si Diode is Reversed Biased
(open circuit)



$\boxed{V_o = 0}$

for next half cycle $(T/2 \rightarrow T)$
Si Diode is forward Biased
(short circuit)



Here we can see in output waveform that -ve portion is clipped so it is -ve clipper.

$$-V_i + 0.7 - V_o = 0$$

$$V_o = 0.7 - V_i$$

$$V_o = 0.7 - (20)$$

$$V_o \Rightarrow -19.3\ V$$

eq^n valid when

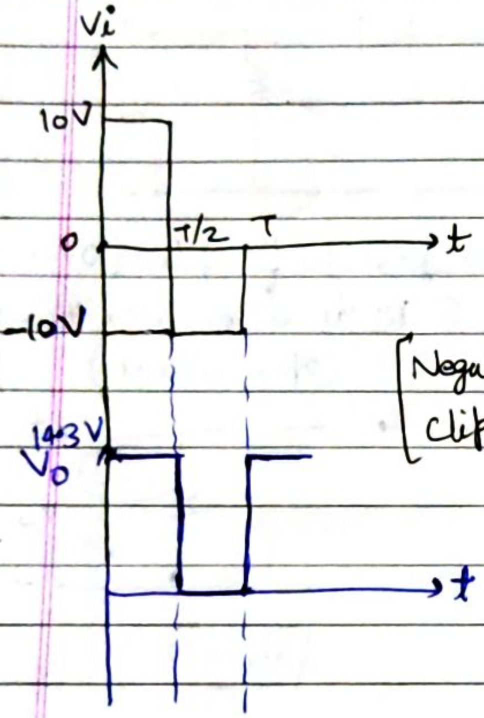
$$\boxed{V_i > V_b}$$

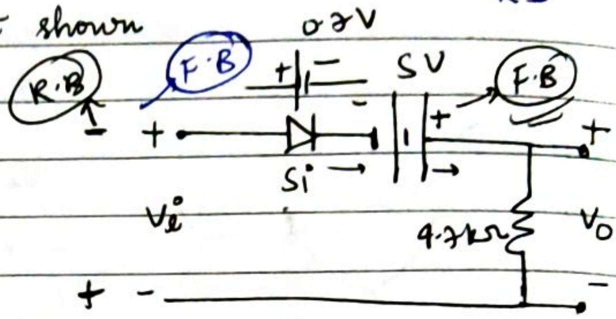
(0.7V)

★★ Only considered that DC source & forget Vi & find the state of diode → F.B / R.B

BIASED SERIES CLIPPERS: (Add^n DC Source)

① Determine V_o for the input shown





[Negative Clipper]

for $(0 \rightarrow T/2)$

$V_i - 0.7V + 5V = V_o$

$10 - 0.7V + 5V = V_o$

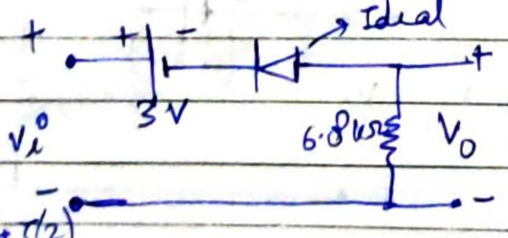
$\boxed{V_o = 14.3V}$

for $(T/2 \rightarrow T)$

$\boxed{V_o = 0}$

5V is not enough sufficient to make diode (F.B) because it is less than $V_i \exists 10V$

Q② Determine V_o for the input shown



$V_i = 0 \quad V_o = -3V$

$V_i = 3V \quad V_o = 0$

Sol^n for $(0 \rightarrow T/2)$

F.B $\rightarrow V_i < 3V \rightarrow V_o = V_i - 3V$

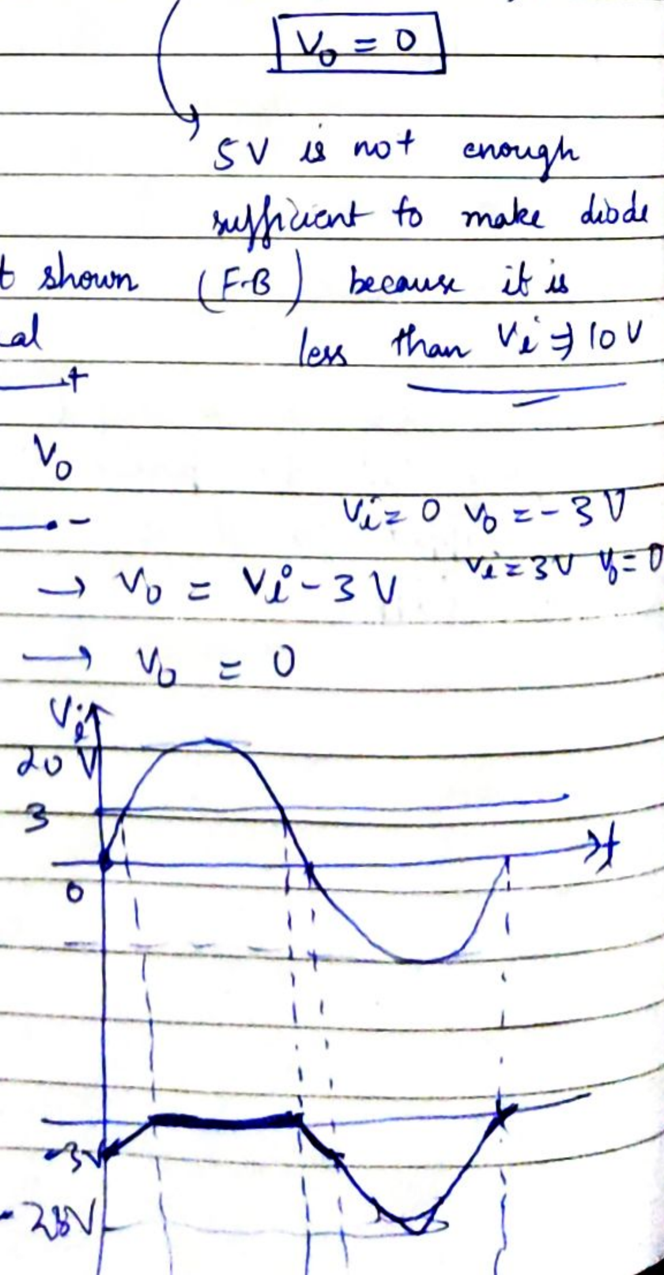
R.B $\rightarrow V_i > 3V \rightarrow V_o = 0$

for $(T/2 \rightarrow T)$

$\boxed{V_o = -V_i - 3V}$

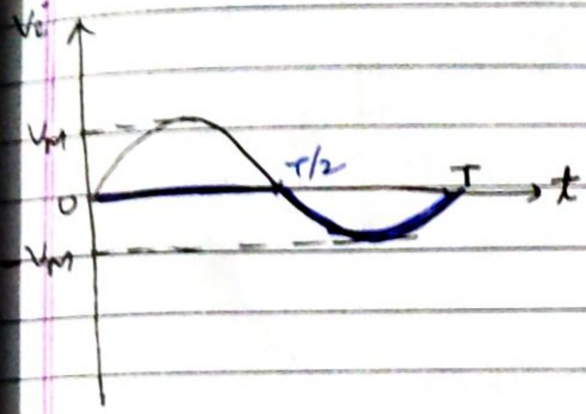
$V_o = -20 - 3$

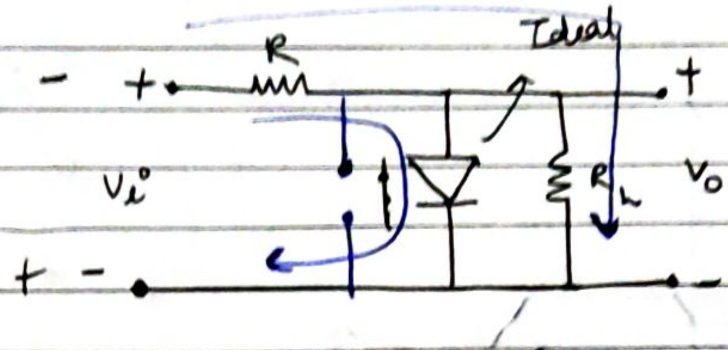
$= -23V$



(Diode is connected parallel with Load Resistance)

UNBIASED PARALLEL CLIPPERS :-





from 0 to T/2 (forward biased) → short circuit

$V_i \geq 0$

$\boxed{V_0 = 0}$

from T/2 to T

$+V_i + V_0 - V_R = 0$

$V_0 = V_R - V_i$

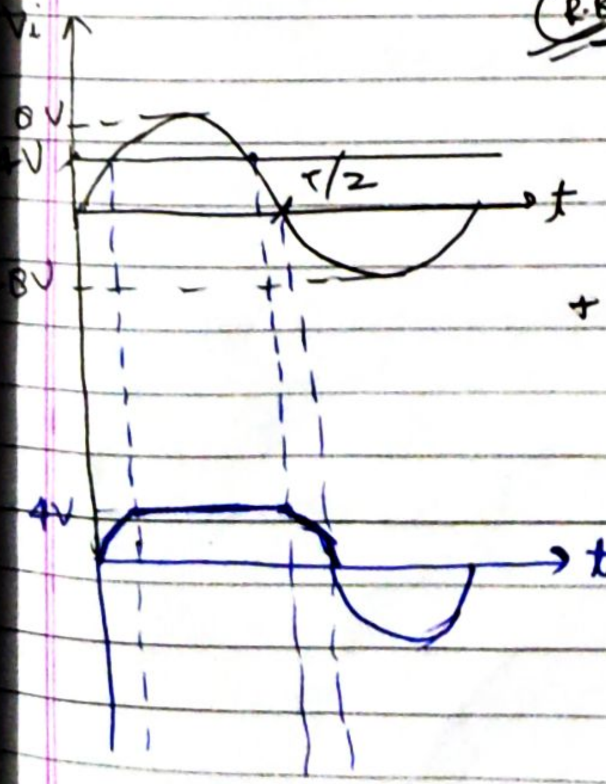
$\boxed{V_0 = -V_i}$

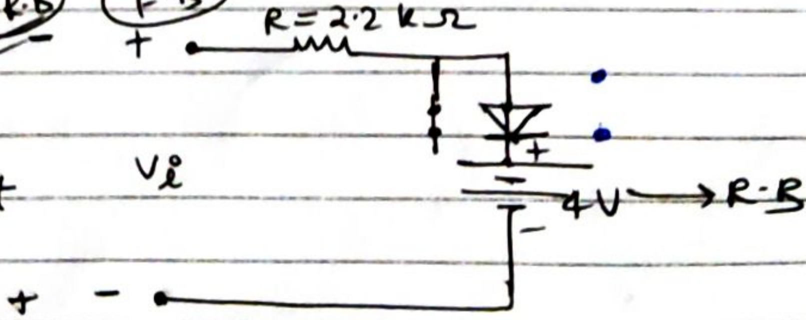
Resistance is very small

so $V_R = 0$

BIASED PARALLEL CLIPPERS :-

R·B F·B





for +ve half cycle F·B :- → $V_i > 4V$ $\boxed{V_0 = 4V}$

R·B → $V_i < 4V$, $\boxed{V_0 = V_i}$

$+V_0 - V_i = 0$

$V_0 = V_i$

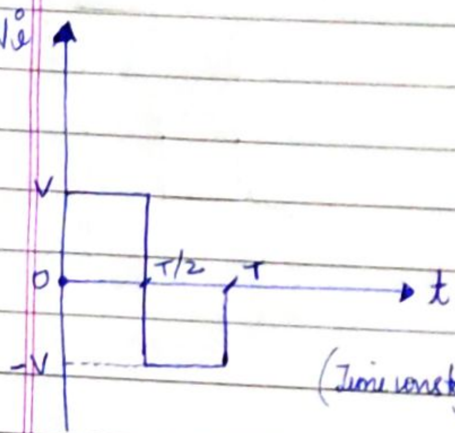
for -ve half cycle $\boxed{V_0 = V_i}$

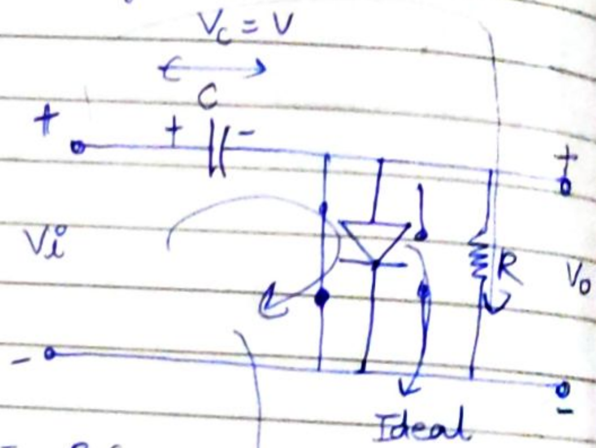
Positive clipper

★★ Assume discharging time of capacitor is very large ($\tau >>> 5\tau$) so capacitor give const voltage $= V$

Clampers :-

A clamper is a network constructed of a diode, a resistor, and a capacitor that shifts the waveform to a different dc level without changing the appearance of the applied signal.





(Time constant) $\tau = RC$ → 5τ

$T/2 \rightarrow T$ (Diode off)

for $T/2$ diode off

so $\boxed{\tau >> T/2}$

In this loop $R = 0$

So $\boxed{\tau = 0}$

for $(0 \rightarrow T/2)$

[Diode on] → F.B → Short ckt

$V_i = +V$

$\boxed{V_o = 0}$

$+V_i - V_c = 0$

$V_c = V_i$

$\boxed{V_c = +V}$

for $(T/2 \rightarrow T)$

$V_c = V$

Diode is R.B (open ckt)

$+V_i + V_o + V = 0$

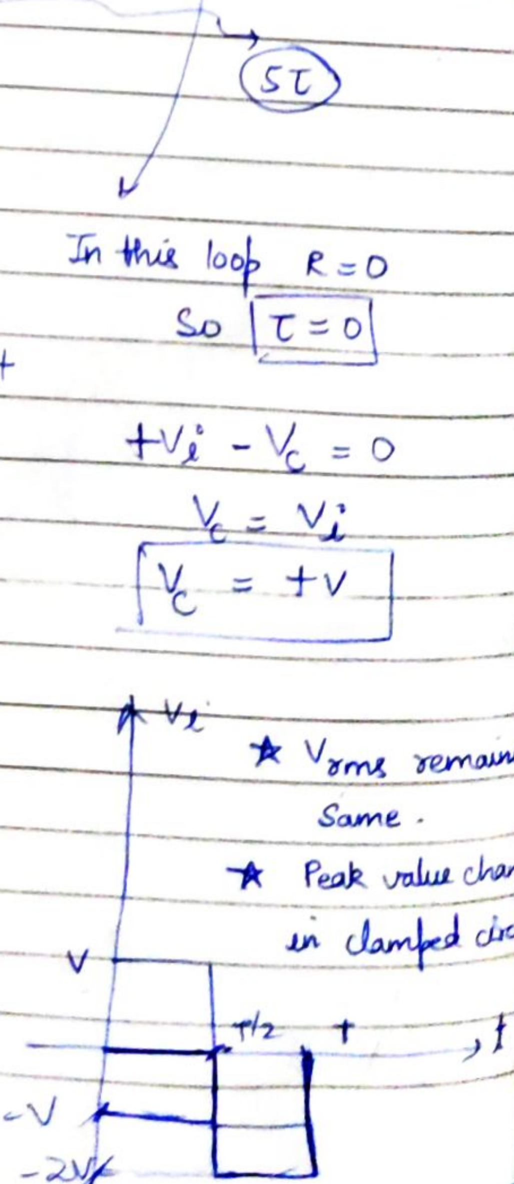
$V_o = -V - V_i$

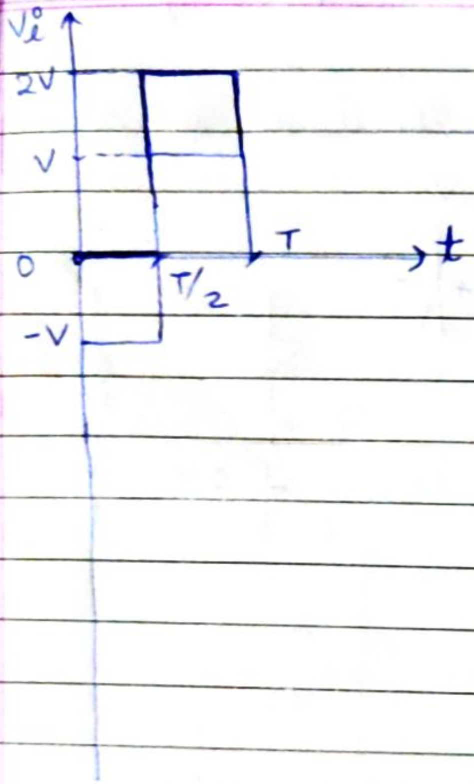
$V_o = -2V$

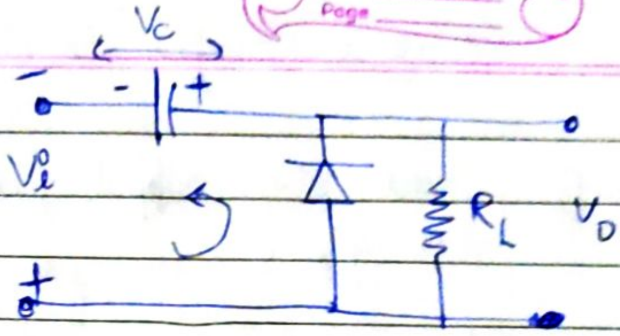
★ $\boxed{\tau >> T/2}$

★ V_{rms} remains Same.

★ Peak value changes in clamped circuit







0 to T/2 (Diode is F.B)

$V_i = -V$

$\boxed{V_o = 0}$

$-V_i = -V$

$V_i = V$

$+V_i - V_c = 0$

$V_c = V_i$

$V_c = -(-V_i)$

T/2 → T :-

$V_o = V_i + V_c$

$= V + V$

$\boxed{V_o = 2V}$