Diodes

Unit-1

Insulator

$\Delta E_g > 5ev$

conductor

$\Delta E_g \simeq 0$

(overlapping)

Semiconductor

$\Delta E_g \simeq 1ev$

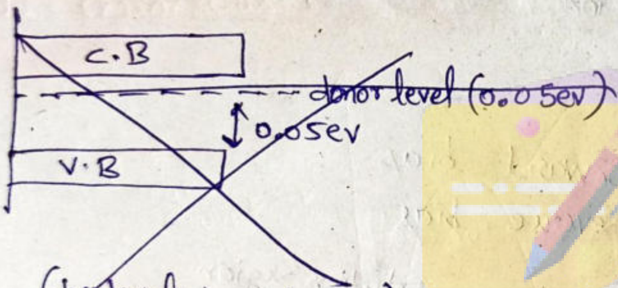
$Si = 1.12ev$

$Ge = 0.72ev$

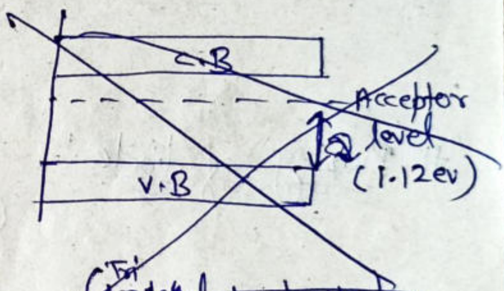
$GaAs = 1.43ev$

n type

p-type



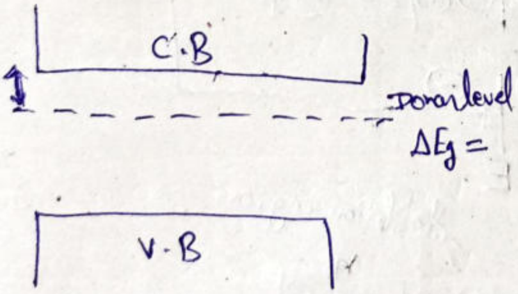
~~(pentavalent Impurity)~~

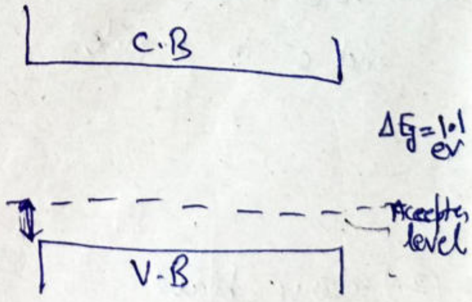


~~(Tri-valent impurity)~~

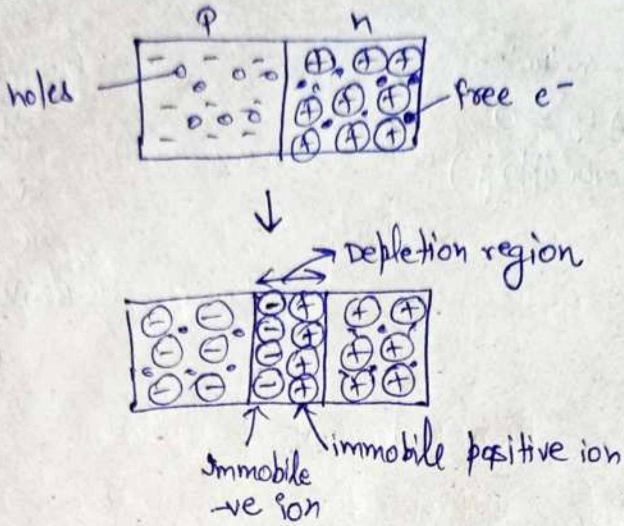
$\boxed{\text{pentavalent Impurity}}$

$\boxed{\text{Trivalent impurity}}$





Junction diode !

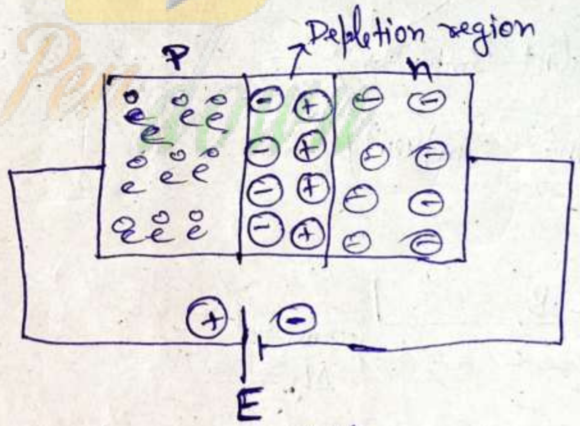


Biasing of diode !-

① forward bias
② Reverse bias

① forward bias !-

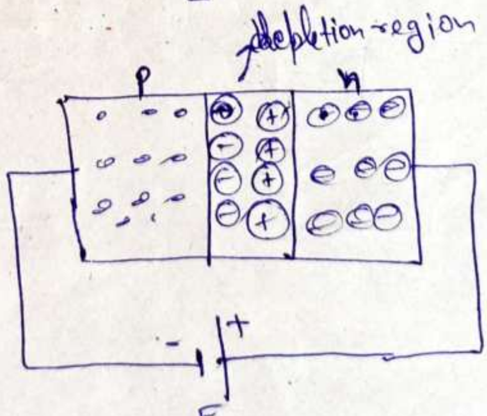
current is due to hole in p-side and e⁻ in n-side



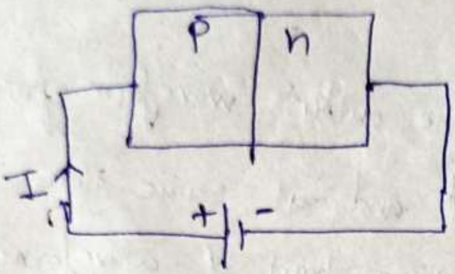
② Reverse bias !

current is due to hole in n side and

☆ current is due to minority charge carriers e⁻ which are thermally generated



V-I characteristics!



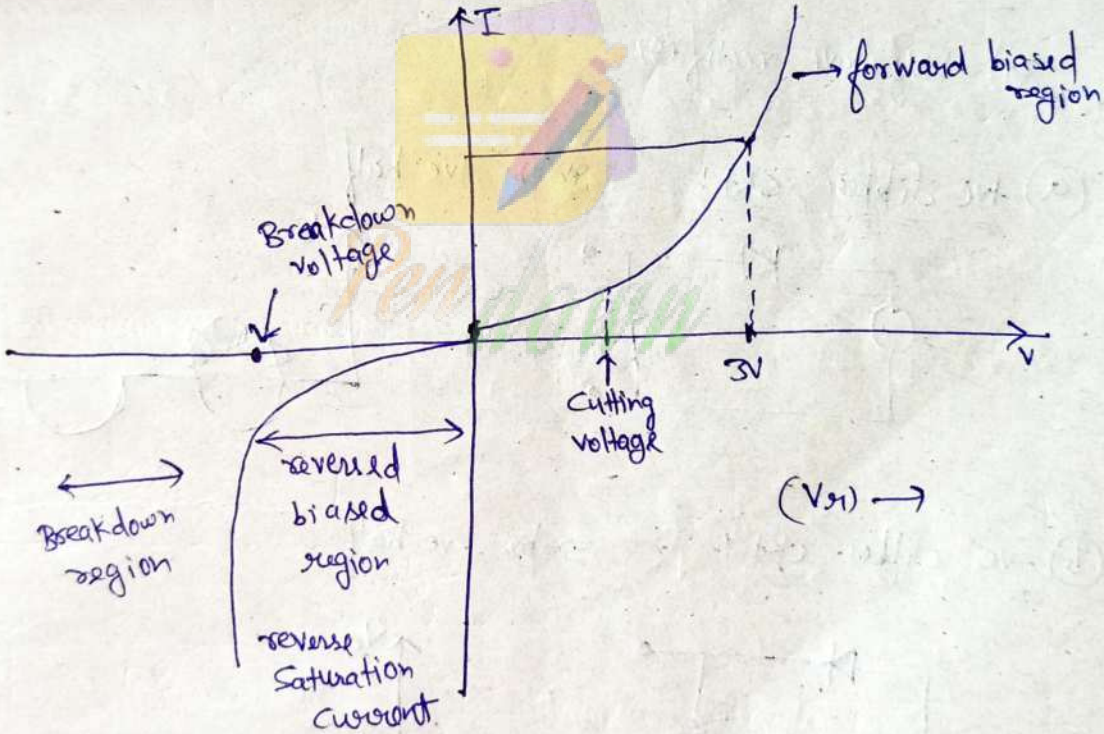
η = const.

$$I = I_0\left(e^{\frac{V}{\eta V_T}} - 1\right)$$

☆ $$\boxed{I = I_0\left(e^{\frac{V}{nV_T}} - 1\right)}$$

$$\boxed{V_T = \frac{T}{11600\,V}}$$

at room temp
$V_T = 26\,mev$



☆ value of I_0 for Ge is in micro ampere
for si is in nano ampere

for si!

$$\boxed{\cancel{I_0(T) = I_0 \cdot 2^{\left(\frac{T-T_1}{10}\right)}}} \rightarrow \boxed{I = I_0\, 2^{\left(\frac{T-T_1}{10}\right)}}$$

for 10°C ↑ in T ⇒ I_0 will double//.

Application of Diode :- (depending upon location of diode)

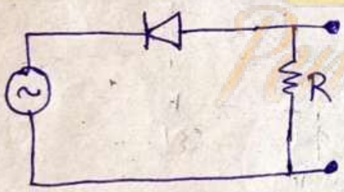
① clipper Circuit :-

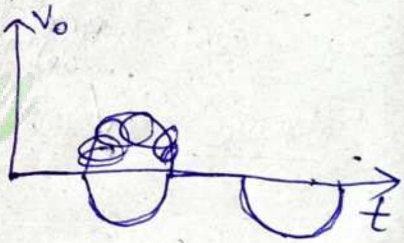
A clipper circuit prevents the output waveform from exceeding the certain level and at same time it doesnot distort the remaining part of waveform

★ used in overvoltage protection circuit to prevent the circuits from high voltage spikes

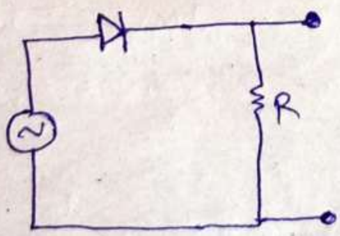
Eg) half wave rectifier

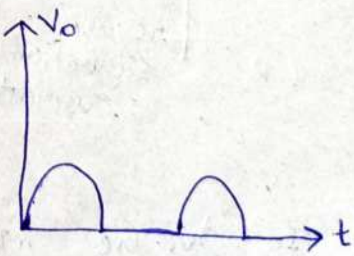
ⓐ +ve clipper ckt! stops +ve half



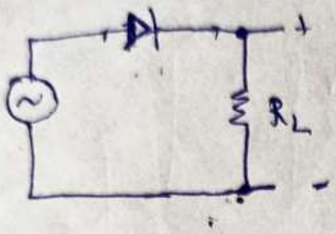


ⓑ -ve clipper ckt :- stops -ve half



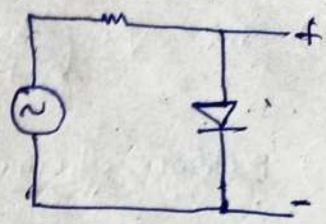


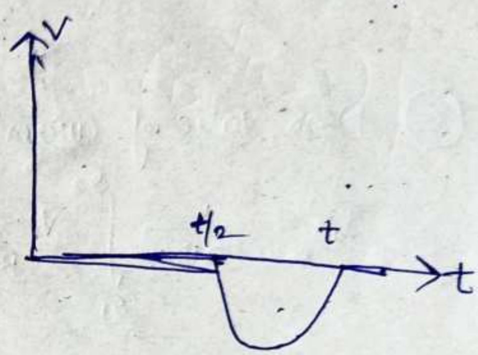
(a) series clipper ckt



-ve clipper

(b) parallel clipper ckt



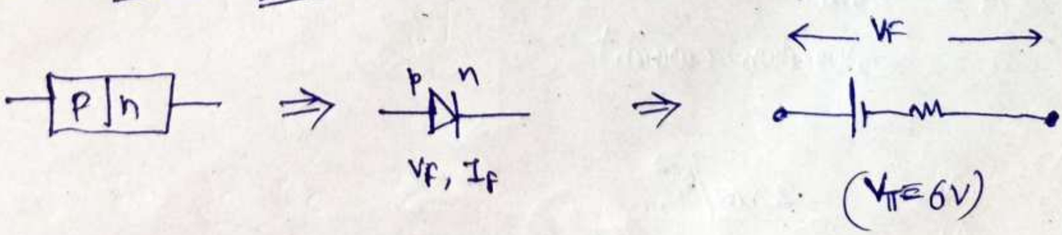


+ve clipper

Reverse Resistance !. Resistance offered by diode during reverse biased is called reverse Resistance

Ideally $\boxed{R=\infty}$. but practically very high

diode equivalent ckt!



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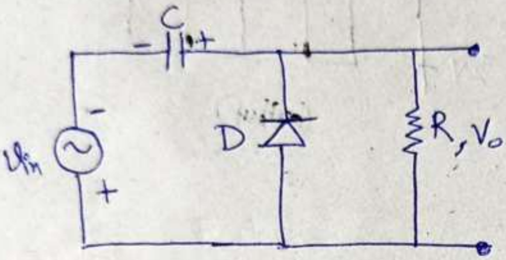
$\boxed{\text{AOE}}$

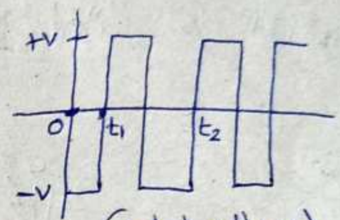
Clamper:- A single tool

It will introduce some DC level into AC signals. ~~class~~ (convert AC → DC)

①



(vin = square wave)



(Input voltage)

from 0 to t_1 (−ve half cycle)

D = Short ckt (ON)

$V_C = V_0$

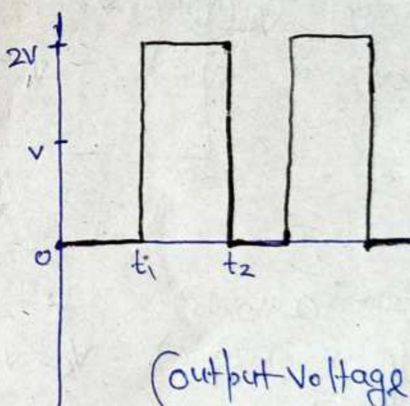
for t_1 to t_2 (+ve half cycle)

D = open ~~source~~ (OFF)

$V_R = 2V_0$

$(V_0 + V_0)$

V, from capacitor

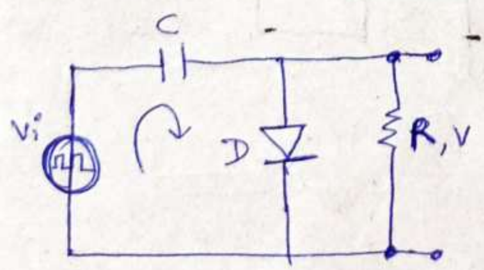


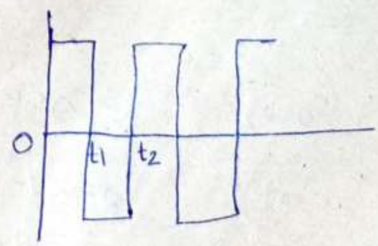
(output voltage)

This type of member called as +ve Member, because input voltage are clamped in the +ve side.

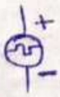
This ckt is called <u>+ve clamper</u>.

②





from 0 to t_1 (+ve half cycle)



D = Short ckt (ON)

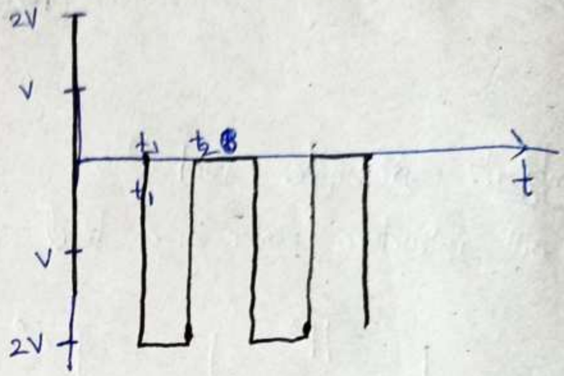
capacitor charged to V_0

& $V_R = 0$

from t_1 to t_2
(-ve half cycle)

$D =$ open (OFF)

$\boxed{V_R = 2V_0}$

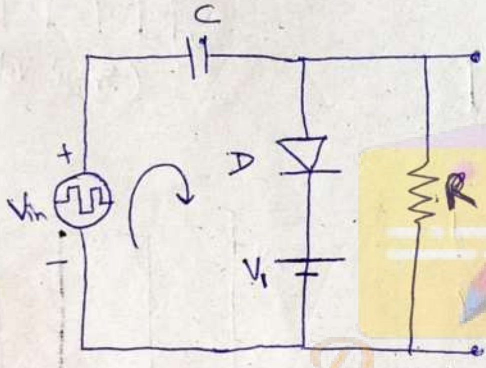


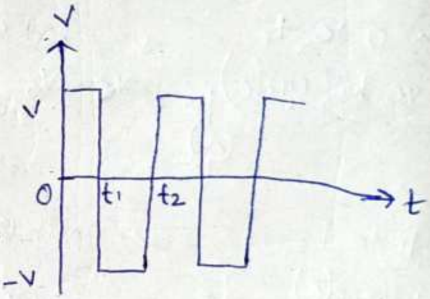
(output)

This ckt is called <u>Negative clamper</u>.

③

Condition:
($V_1 < V$)



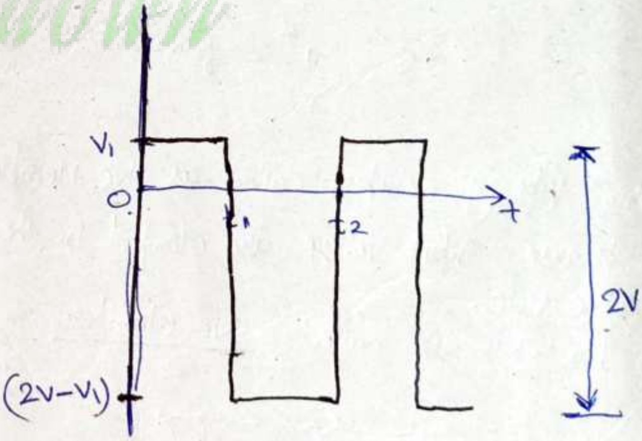


from 0 to t_1
(+ve half cycle)

$D =$ ON

$V_C = V - V_1$

$V_R = V_1$

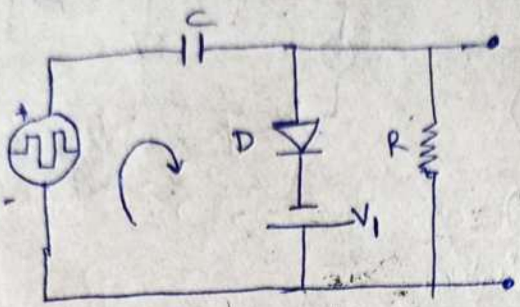


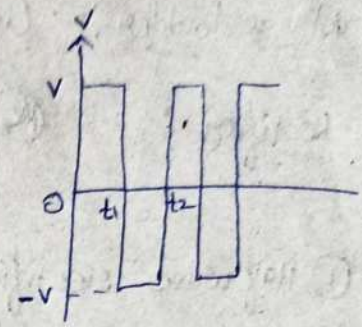
from t_1 to t_2
(-ve half)

$D =$ OFF

$V_R = V - V_1 + V$
$= 2V - V_1$

(4)



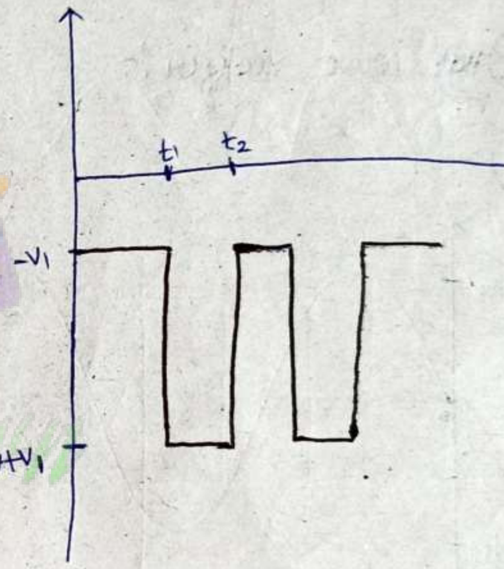


from 0 to t_1

D=ON

$\boxed{V_R = V + V_1}$

$V_R = -V_1$



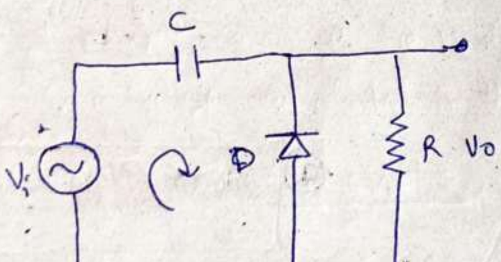
from t_1 to t_2

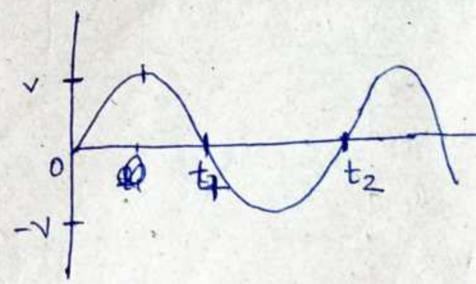
D = OFF

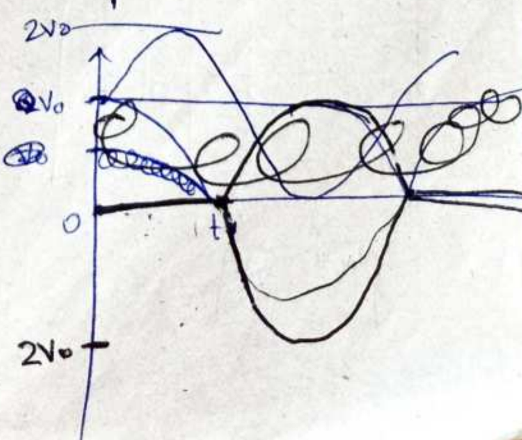
$V_R = V + V_1 + V$

$\boxed{V_R = 2V + V_1}$

(5)







from 0 to t_1

D = open (OFF)

$V_C = V_0$

$V_R = 0$

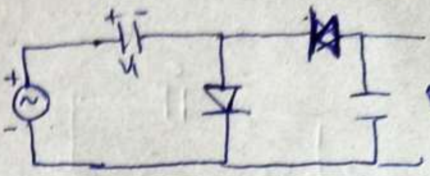
from t_1 to t_2

D = ON

$V_R = 2V_0$

21/09/22

Voltage doubler :- (in Tutorial)



first half $V_1 = V_M$

Second half $\cdot V_M + V_M - V = 0$

$$\boxed{V = 2V_M}$$

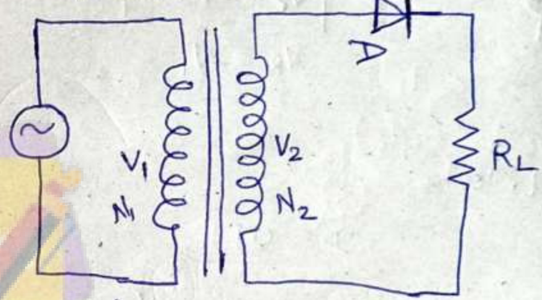
Rectifier :- AC $\xrightarrow{\text{to}}$ DC

DC → Pulsative

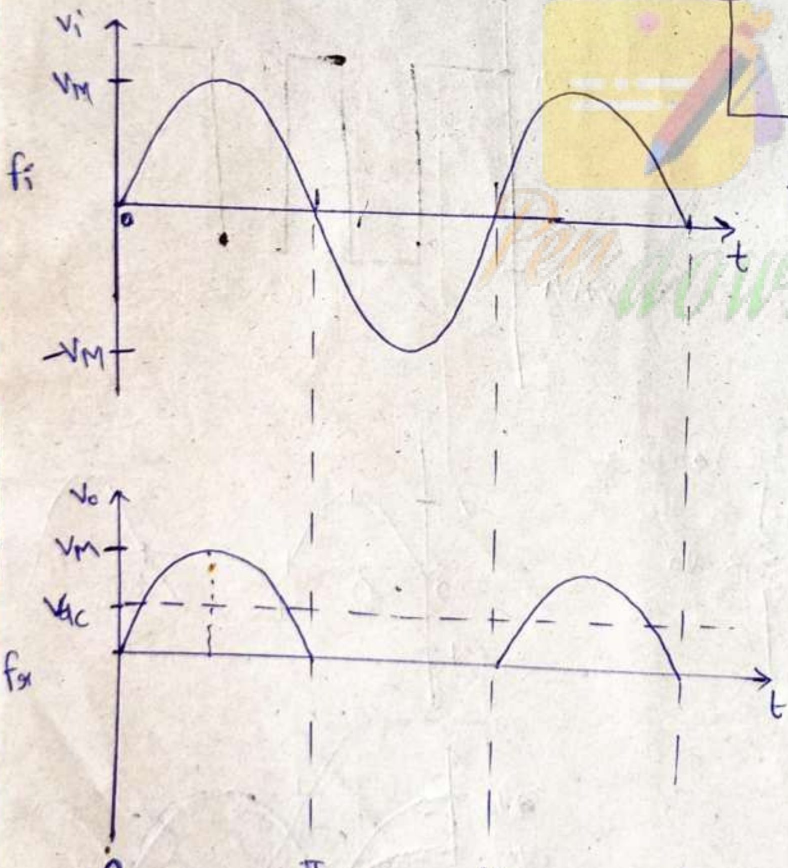
① Half wave rectifier

② full wave rectifier

① Half wave rectifier :-



$$\frac{N_1}{N_2} = \frac{V_1}{V_2}$$



$$\boxed{V_{dc} = \frac{V_M}{\pi}}$$

$$\boxed{I_m = \frac{I_o}{\pi}}$$

$$\boxed{\begin{aligned} V_{rms} &= \frac{V_m}{2} \\ I_{rms} &= \frac{I_m}{2} \\ TUF &= 0.287 \end{aligned}}$$

ⓐ $\boxed{V_{dc} \text{ or } V_{avg} = \frac{V_M}{\pi}}$

ⓑ $\boxed{r = 1.21}$

ⓔ $\boxed{f_r = f_i}$

ⓒ $\boxed{\eta_{max} = 40.6}$ %

ⓕ $\boxed{V_{rms} = \frac{V_M}{2}}$

ⓓ $\boxed{PIV = V_M}$

★ **Ripple factor** (r) :- The Ratio of output DC and AC remaining in output.

★ **Rectification efficiency** (η) :- It is represented as how much ac power converted to dc power.

Ratio of DC Power and AC Power

$$\boxed{\eta = \frac{P_{dc}}{P_{ac}}}$$

$$\boxed{\eta = \frac{40.6\ R_L}{r_d + R_L}}$$ for Half wave rectifier

R_L = load R
r_d = diode resist^n
$r_d << R_L$

hence

$$\boxed{\eta_{max} = 40.6}$$

★ **PIV (Peak Inverse voltage)** :- It is defined as max^m reverse voltage for which diode must be able to withstand without breakdown of diode

★ It is property of diode to design/select it.

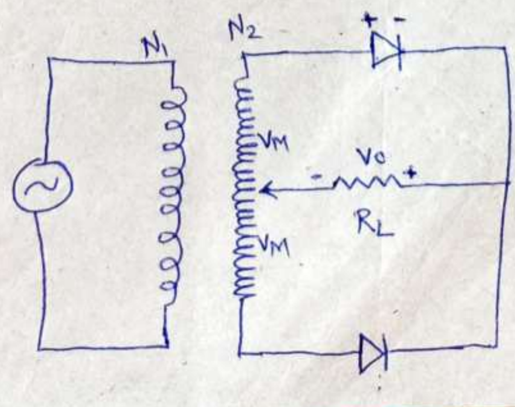
★ **Ripple frequence** :- freq. of output signal [F_r]

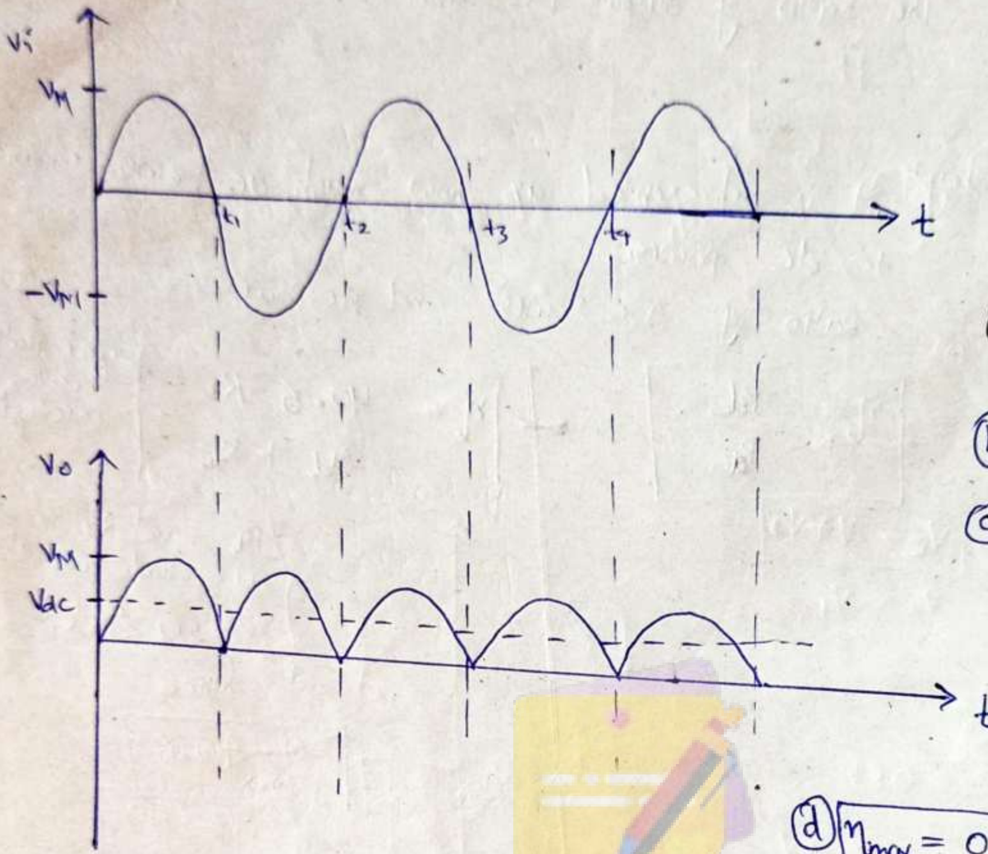
---

② **Full wave rectifier** :- (2 types)
→ ⓐ Centretap full wave rectifier
→ ⓑ Bridge " " "

ⓐ **Centre tap FWR** :-

$$\boxed{N_2 = 2N_1}$$





(a) $\boxed{V_{dc} = \frac{2V_M}{\pi}}$

(b) $\boxed{r = 0.482}$

(c) $\boxed{\eta = \frac{0.812 R_L}{r_d + R_L}}$

(d) $\boxed{\eta_{max} = 0.812} = 81.2\%$

(e) $\boxed{f_r = 2f_i}$

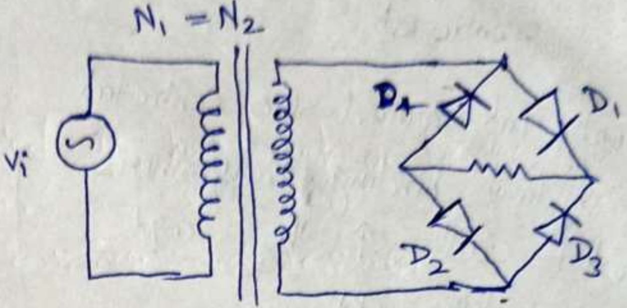
(f) $\boxed{PIV = 2V_m}$

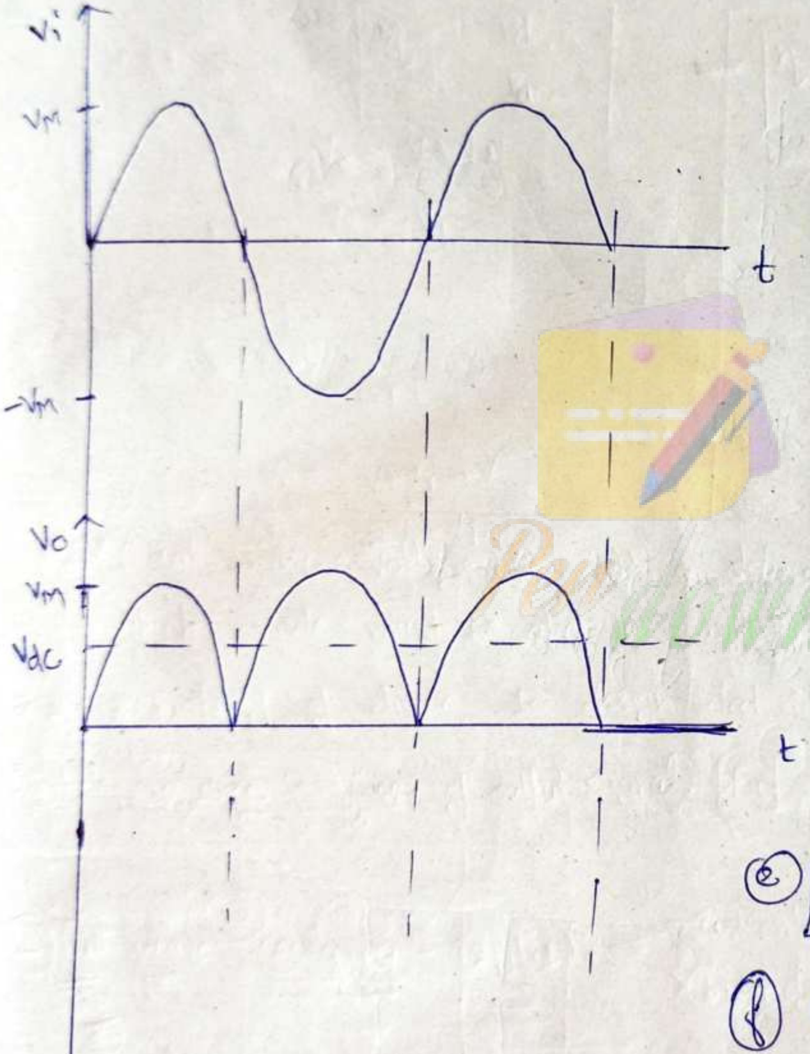
(g) $\boxed{V_{rms} = \frac{V_M}{\sqrt{2}}}$

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

23/09/22

(b) Bridge Rectifier:-





0 to t_1 D_1 & D_2 = ON

t_1 to t_2 D_3 & D_4 = ON

(a) $\boxed{V_{dc} = \frac{2V_m}{\pi}}$

(b) $\boxed{V_{rms} = \frac{V_m}{\sqrt{2}}}$

(c) $\boxed{r = 0.482}$

(d) $\boxed{\eta = \frac{0.812\, R_L}{r_d + R_L}}$

(e) $\boxed{\eta_{max} = 0.812}$

(f) $\boxed{f_r = 2f_i}$

(g) $\boxed{PIV = V_m}$

Centre Tap	Bridge
① Centre Tap required the centre tap secondary binding transformer. which will ↑ the cost of rectifier ckt.	① No secondary binding required
② diode used in centre tap should be PIV rating of 2VM., which increase the cost of diode.	② $PIV = V_M$
③ centre tap ~~Bridge~~ rectifier req 2 diode.	③ Bridge rectifier requires 4 diode.
④ more efficient as 2 diode	④ less efficient as 4 diode

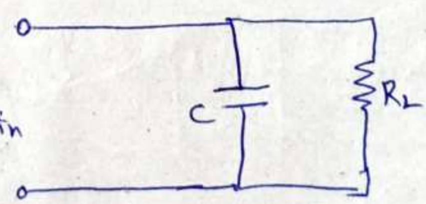
* Circuit that removes ripples from the rectified output dc

Filter:- There are diff. types of filters-

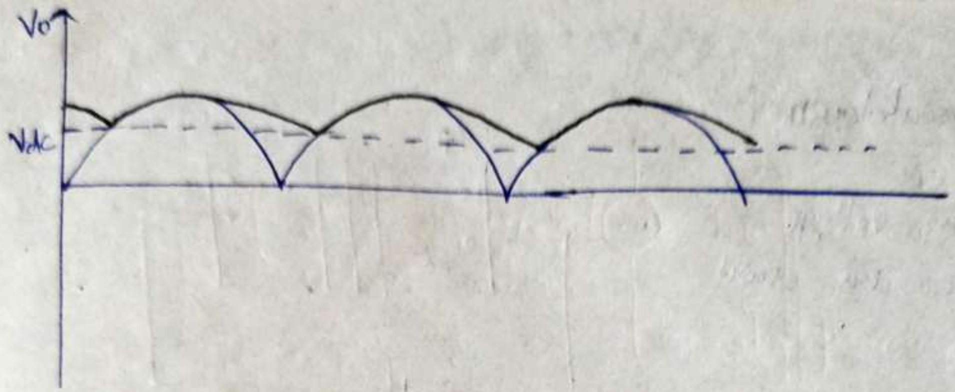
① Inductor filter
② Capacitor filter

depend on ckt combo
① series
② Sun/parallel

② **Capacitor filter:**

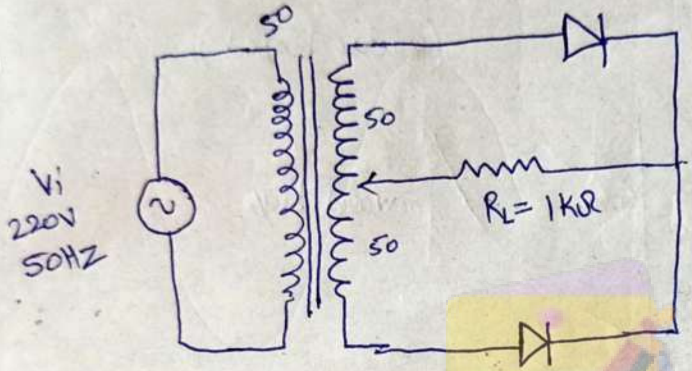


* It allows ac & blocks DC
* always connected in parallel to load resistor.



by using filter quality of rectifier output ↑ses

Ques)



$V_{rms} = ?$

$V_{dc} = ?$

$r = ?$

$f_r = ?$

$PIV = ?$

$$V_{rms} = \frac{V_0}{\sqrt{2}} = \frac{220}{\sqrt{2}}$$

$$V_{dc} = \frac{2V_M}{\pi} = \frac{2 \times 220}{\pi}$$

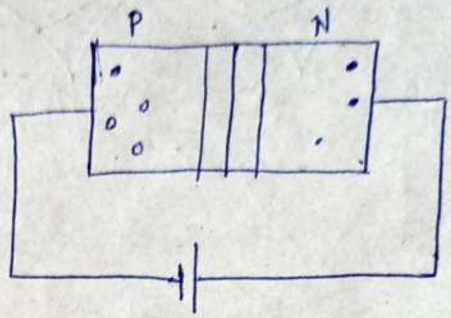
$r = 0.482$

$f_r = 2 \times 50Hz = 100Hz$

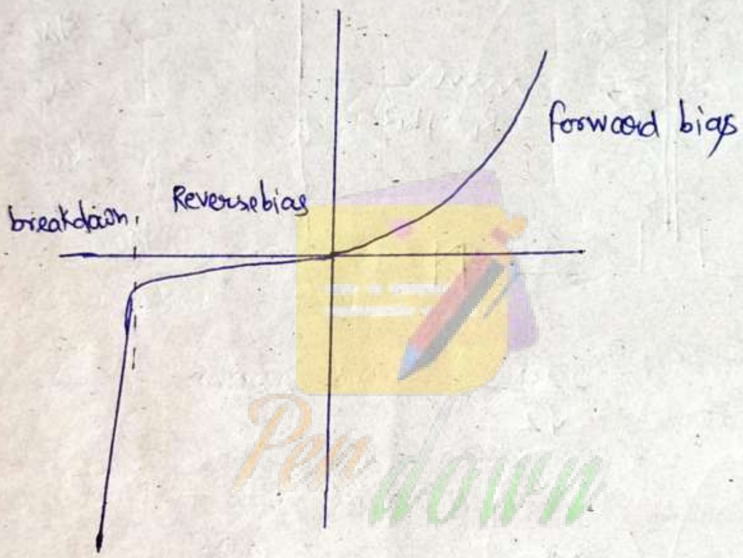
$PIV = 2V_M = \underline{\underline{440V}}$

Junction breakdown :-

At high ext voltage minority carriers start moving



(Reverse biased)



It is of 2types → ① Avalanche breakdown
② zener "

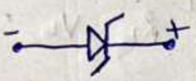
① AB :- If reverse voltage is 5V or higher, then KE of minority carriers becomes very large then electrons becomes free from covalent bond and collide with other carrier which will free more ~~other~~ electrons.

ⓐ It is due to KE
ⓑ It occurs in lightly doped diode ~~depletion width~~
ⓒ large depletion region
ⓓ breakdown V = 6V (generally)
ⓔ breakdown vol. ↑ with temp i.e positive temp coefficient.

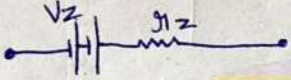
② ZB :- electric field applied across the junction break the covalent bond, large number of free minority carriers are generated which will ↑ the reverse current.

ⓐ due to electric field
ⓑ occurs in highly doped diode
ⓒ small depletion width as doping conc is high
ⓓ breakdown $\boxed{V < 6V}$
ⓔ breakdown voltage is -ve temp coefficient i.e Breakdown V ↓ with temp.

Symbol:

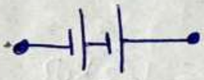


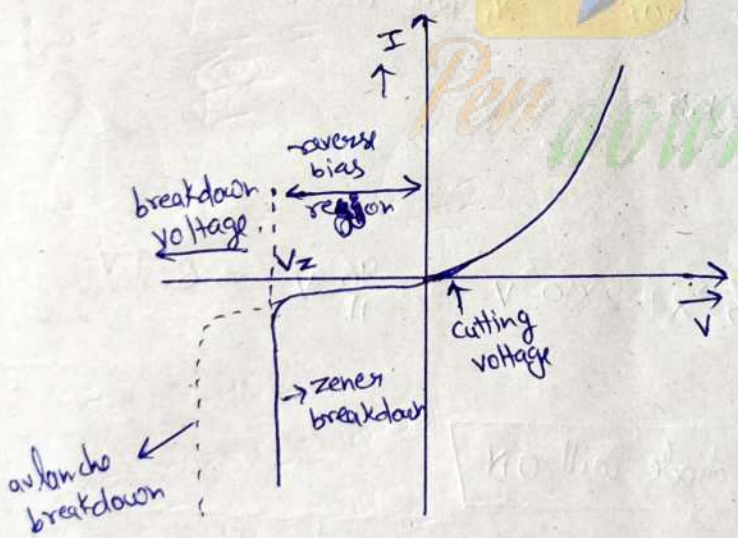
(In reverse will work)



(non-ideal)

Ideal equivalent ckt of ZD :-





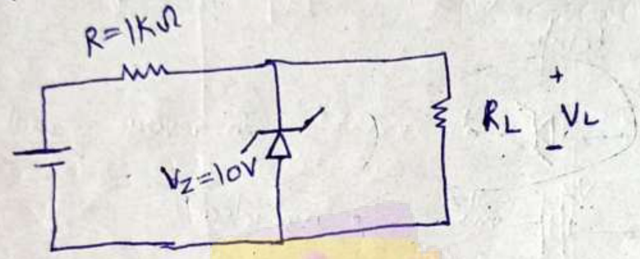
① breakdown is not a destructive process provided that diodes are placed in given maximum ~~forward special region~~ power discipiation region.

② max^m power rating of general diode depends on max^m reverse current and is represented as I_{ZM}.

③. zener diode are available with $V_z = 1.8V$ to $200V$ and power ~~station~~ discipiation upto 50W

Advantages:-

ⓐ Smaller in size
ⓑ cost is less
ⓒ longer life



Case (i) $R_L = 1.2 K\Omega$ $V_L = ?$

Since ZD in reverse bias, V_i will distributed in R & R_L

$$R_{eq} = 1 + 1.2 = 2.2 K\Omega$$

$$i = \frac{16}{2.2} \times 10^{-3} A$$

$$V_L = iR_L = \frac{16}{2.2} \times 10^{-3} \times 1.2 \times 10^{3} V = \frac{96}{11} V = 8.7 V$$

$\boxed{\text{when } V_z > V_L \text{ zener diode will ON}}$

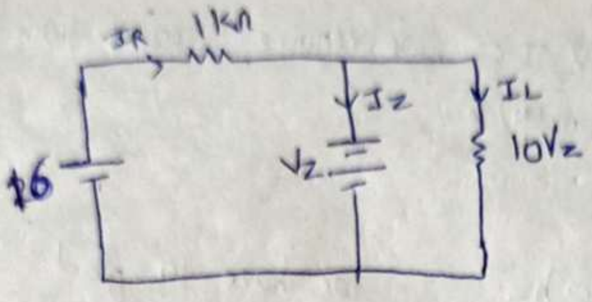
Case (ii): $R_L = 3 K\Omega$

we have to use zener diode to fix voltage

$$R_{eq} = 4 K\Omega$$

$$i_L = \frac{16}{4} = 4 mA$$

$$V_L = 4 \times 3 = \underline{12 V} \quad (\text{as } V_L > V_Z)$$



$I_L = \frac{10}{3k\Omega} = 3.33mA$

$I_R = 6mA$

$I_Z = I_R - I_L$

$= 6 - 3.33$

$= \underline{2.67}\ mA$

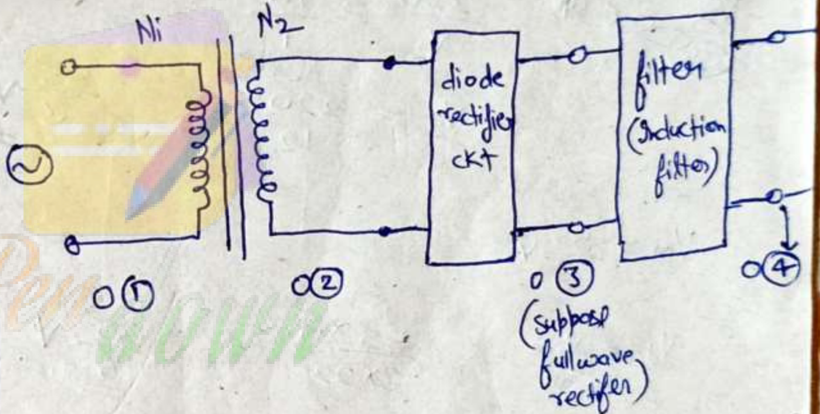
Power discipiation on zener diode :-

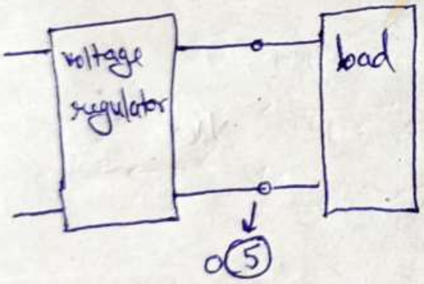
$P_Z = V_Z I_Z$

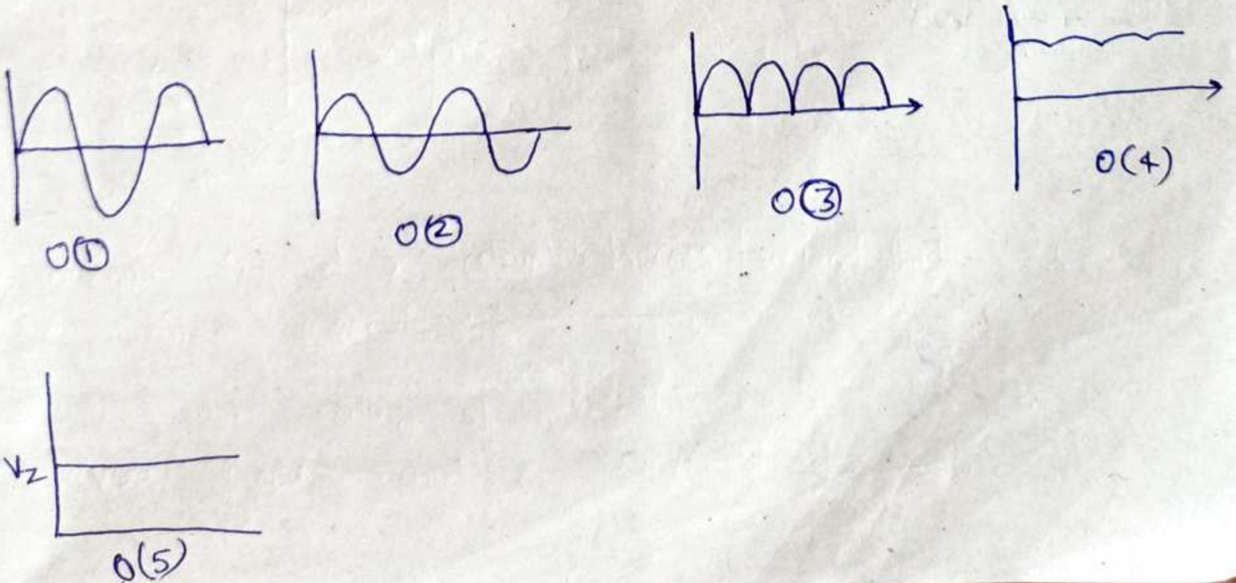
$= 10 \times 2.67mA$

$\boxed{P_Z = 26.7\ mwatt}$

DC Power supply :-







Generally to generate the 5V DC, we require ~~12:1~~ turn ratio of 12:1 (i.e step down transformer).

Q) suppose

AC input = 220V, 50 hz

from $N_1 : N_2 = 12:1$

we have to find output voltage of rectifier for half wave rectifier.

Also Calculate (i) PIV (ii) ripple factor

$$\frac{V_1}{V_2} = \frac{N_1}{N_2}$$

$$\frac{220}{V_2} = \frac{12}{1}$$

$$V_2 = \frac{\cancel{220}^{\cancel{110}\,55}}{\cancel{12}_{\cancel{6}\,3}} = \frac{55}{3}\,V$$

$$V_M = \frac{55}{3}\,V$$

$$V_{dc} = \frac{V_M}{\pi} = \frac{\cancel{55}^{5} \times 7}{3 \times \cancel{22}_{2}} = \frac{35}{6}\,V$$

$$V_{dc} = \frac{55}{3\pi}$$

(i) $PIV = V_M = \frac{55}{3}\,V$

(ii) $r = 1.21$

30/09/22. POE

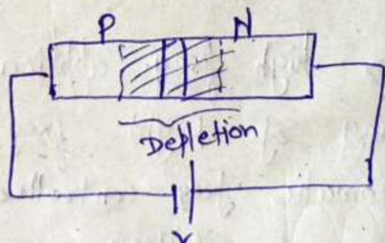
Diode Capacitance :-

① Diffusion or storage capacitance (C_d)
② Depletion or Transition capacitance

① **Diffusion capacitance :-** Diffusion capacitance is forward biased diode, during the forward biasing, no. of majority carriers (i.e holes in P side & e^- in N-side) increases, diffusion region reduce if we change the forward biasing to reverse biasing, the direction of current is changes, but lot of majority carriers stores in the diffusion region, This stored charged is represented as diffusion capacitance.

$$\boxed{C_d \propto I \propto V} \qquad \boxed{C_d = \frac{dq}{dV}}$$

② **Transition capacitance :-** This capacitance is in the reverse biasing condition. as you know that



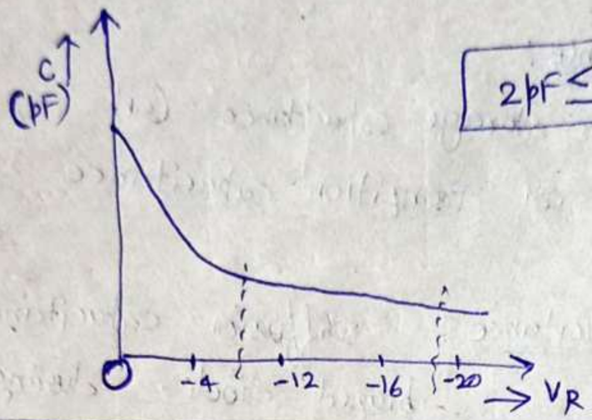
In reverse biasing depletion region ↑ses because in depletion region, large number of p & n types charge carriers

Capacitance of this diode

$$\boxed{C = \frac{\epsilon A}{W_d}}$$

where ϵ = permittivity of material
A = area of depletion region
W_d = width of depletion region

$$\boxed{\text{on } \uparrow V \Rightarrow \text{region} \uparrow \Rightarrow W_d \uparrow \Rightarrow C \downarrow}$$



range of C

$$\boxed{2pF \leq C \leq 100pF}$$

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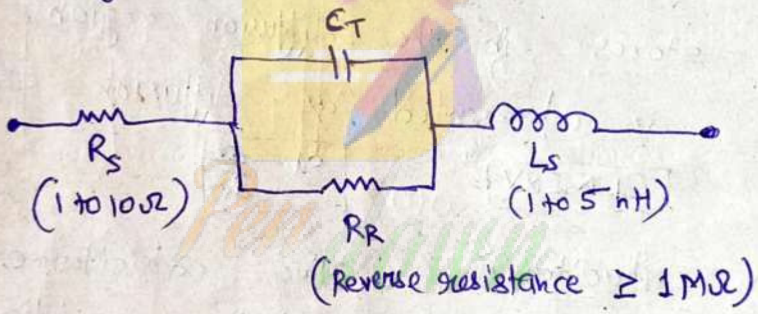
① **Varactor diode :-** Voltage variable diode.

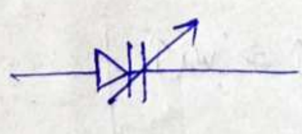
Equivalent ckt of varactor diode :-



★ It is generally used for high freq. application (>10MHz).

★ It is used in designing of hight freq FM ~~moderators~~ modulators, automatic freq controlled device, parametric amplifiers and designing of filters.

Symbolic rep of varactor diode -

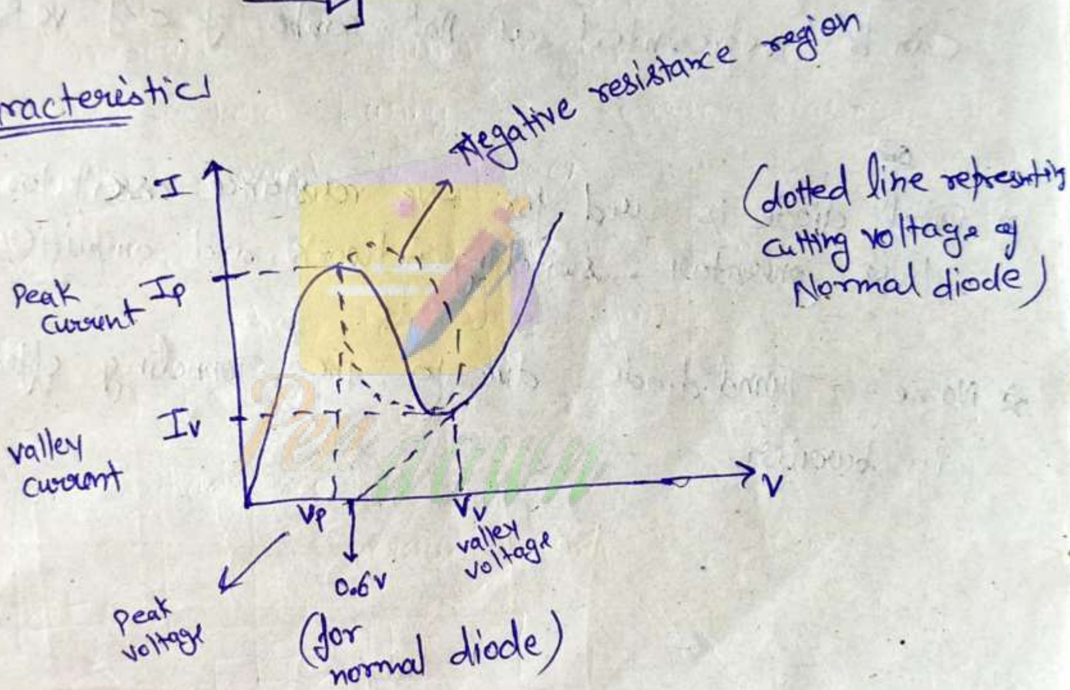


② Tunnel diode :- (~~generally show two~~ stores -ve resistance).

Tunnel diode is very heavy doped diode. ~~(nearly 100 times~~ doping conc. is nearly 100 times of normal diode so depletion layer ↓ (very narrow) And it is generally made of ~~Boron~~ Gallium Arsenide.

Symbolic representation of Tunnel diode is

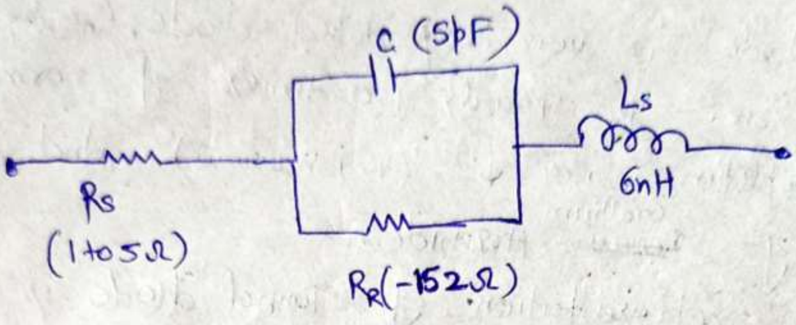
VI - characteristic



ON upto 0.1 to 0.2 mV (if V range in millivolts)
OFF in above 1V (may damage Tunnel diode)

★ Tunnel diode is used for application of low voltage and high switching devices (ON & OFF at high speed) like computer & mobile.

☆ Equivalent ckt of Tunnel diode-



At high freq. Rs & Ls can be ignored & ideally it can be represented as ||al combo of C & -ve RR

☆ Tunnel diode is used for -ve resistance oscillator, pulse generator, switching network and amplifier.

☆ Name = Tunnel diode due to the Tunneling effect in barrier.

formulae

① $I_m = \sqrt{2}\left(\frac{V_{rms}}{R}\right)$

② Rectifier efficiency

$$\boxed{\eta = \frac{I_{dc}^2}{I_{rms}^2}}$$

③ Mean value of current:

$$I_M = \frac{1}{2\pi}\int_{\theta_1}^{\theta_2} \frac{V_i - V_o}{R}\, d(\omega t)$$

④ Power discipated in load in half wave rectifier

$$\boxed{P = (I_{rms})^2 R}$$

⑤

$$\boxed{I_D = I_s\left(e^{\frac{V}{\eta V_T}} - 1\right)}$$

for Si $\rightarrow$ $\eta = 2$

for Ge $\rightarrow$ $\eta = 1$

$V_T = 26mV$

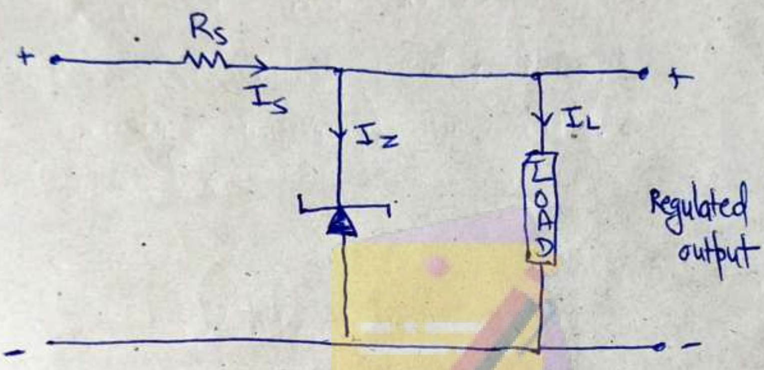
I_s = saturation current

⑥ $\frac{\Delta V}{\Delta T} = -2 mv/^{o}c$

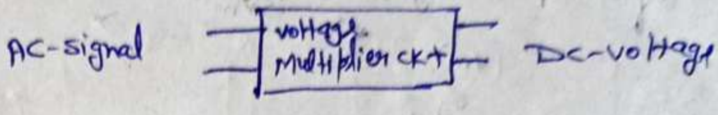
zener diode as voltage regulator

Regulation:- The process of keeping constant voltage across load is called regulation

as shunt voltage regulator-



voltage Multiplier :-



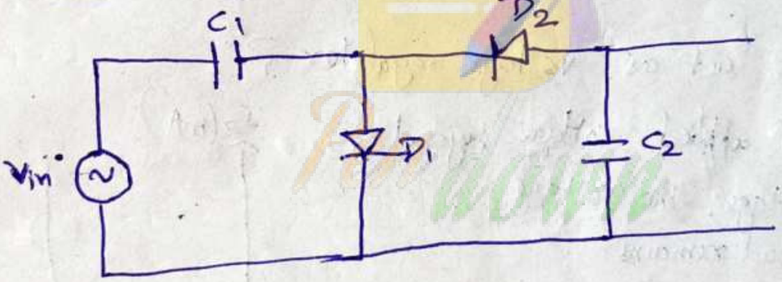
Need ?

ans) we can increase voltage by step up transformer but we have to use step-up transformer as well as rectifier circuit, then cost as well as size of circuit will increase hence in many application it is used.

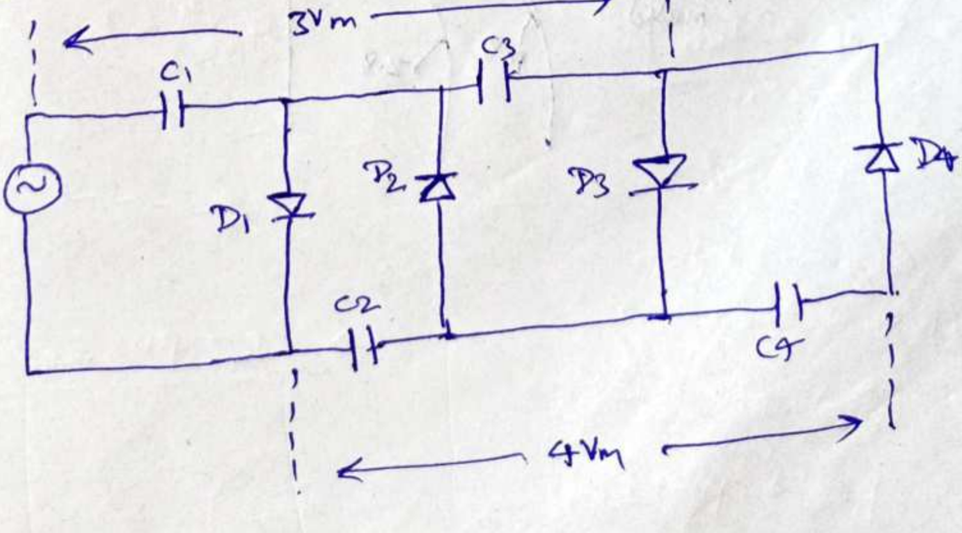
eg) in fax, in photo-copy machines etc

They are of 3 types :- (of apply Vm as input)

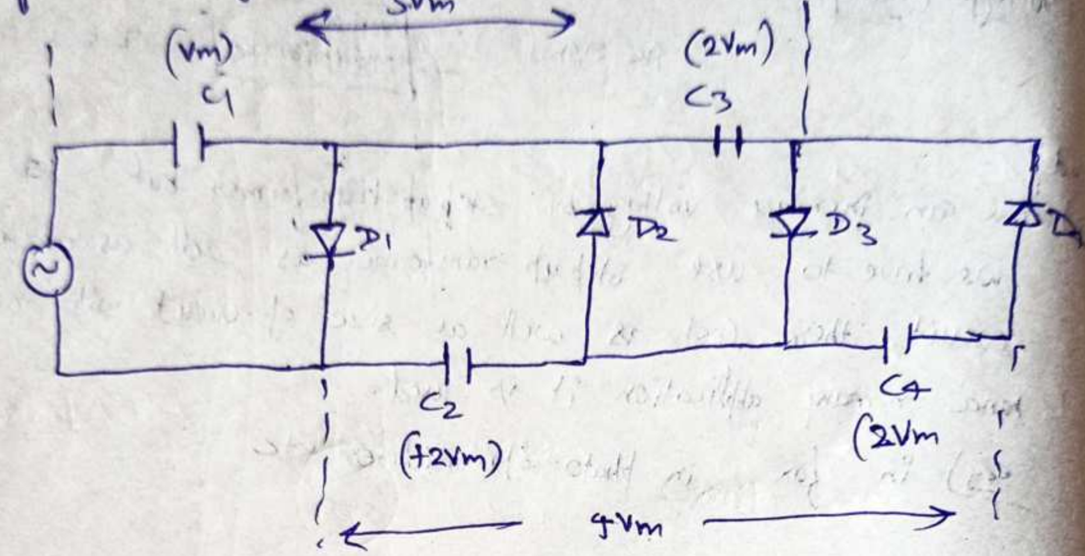
(1) voltage Doubler :- (output = 2Vm)



(2) voltage tripler (output = 3Vm). & voltage Quadrupler - (4Vm)



After some cycles



zener diode act as voltage regulator ?

ans) If we ↑ applied voltage beyond zener voltage, the voltage across load remains constant