Unit - 1

* Introduction to Semiconductors :

- **Semiconductor :-**

⇒ It is a material that has conductivity between Insulator and conductor. Eg - Silicon and Germanium.

⇒ **Conductor** : Conductor is a material which have very high conductivity because of presence of large no. of free electrons. Eg - Metal

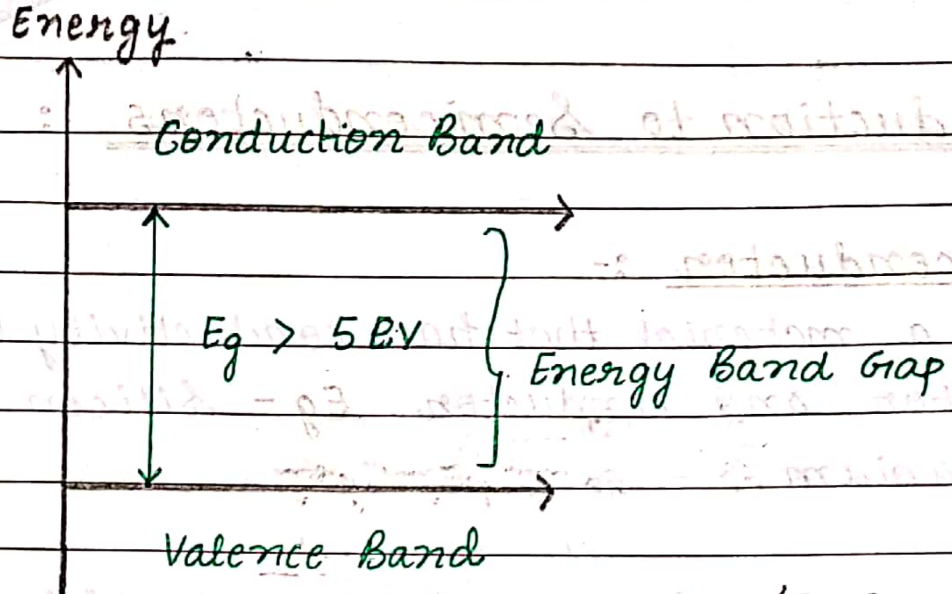
⇒ **Insulator** : It is a material which have almost no conductivity because of absence of free electrons. Eg - wood, plastic, paper, etc.

⇒ The semiconductors have negative temperature coefficients of resistance. That means with the increase of temperature, the resistivity of semiconductors decreases.

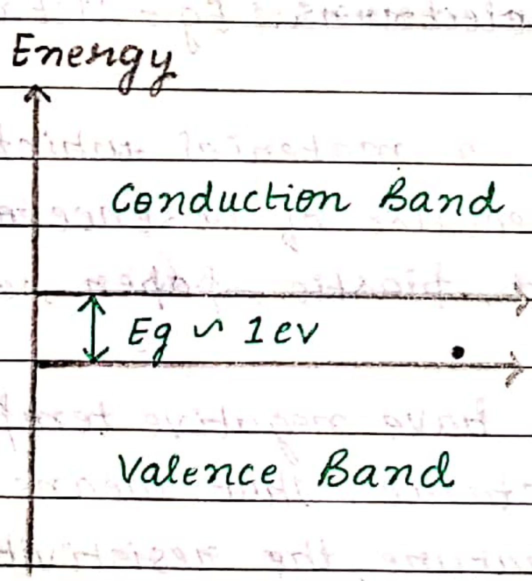
⇒ At absolute zero temperature (i.e. 0K (zero Kelvin)), the semiconductors behaves like insulator and it becomes a good conductor at high temperature.

- At high temperature, the semiconductors behaves like conductors because the valence electrons absorbs sufficient thermal energy to break the covalent bond and produces free carriers. This increases the no. of carries with increase in conductivity and lowers the resistance.

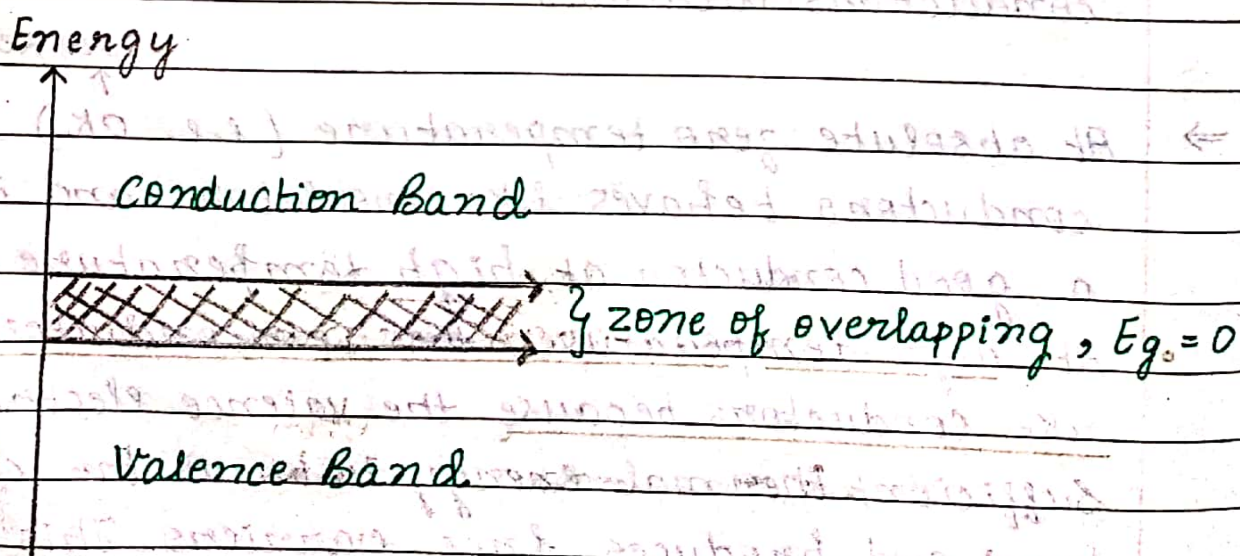
* Energy Band Diagram :



⇐ Insulators



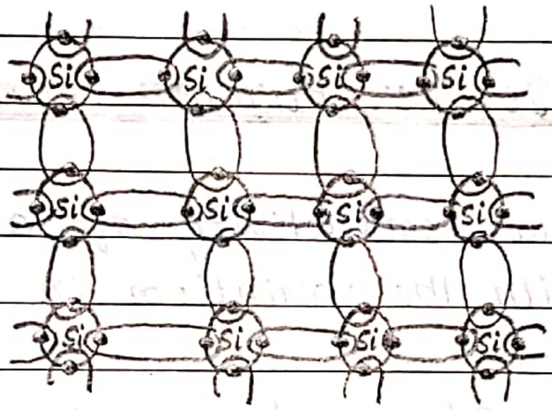
⇐ Semi Conductors



⇐ Conductors

* ## Types of Semiconductor :

1] **Intrinsic semiconductor** : It is the purest form of semiconductor without any impurities is called Intrinsic Semiconductor.
Eg - Silicon, Germanium

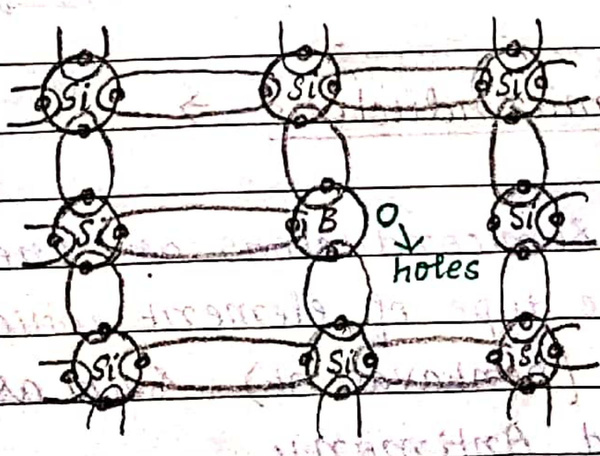


⇐ Intrinsic Semiconductor

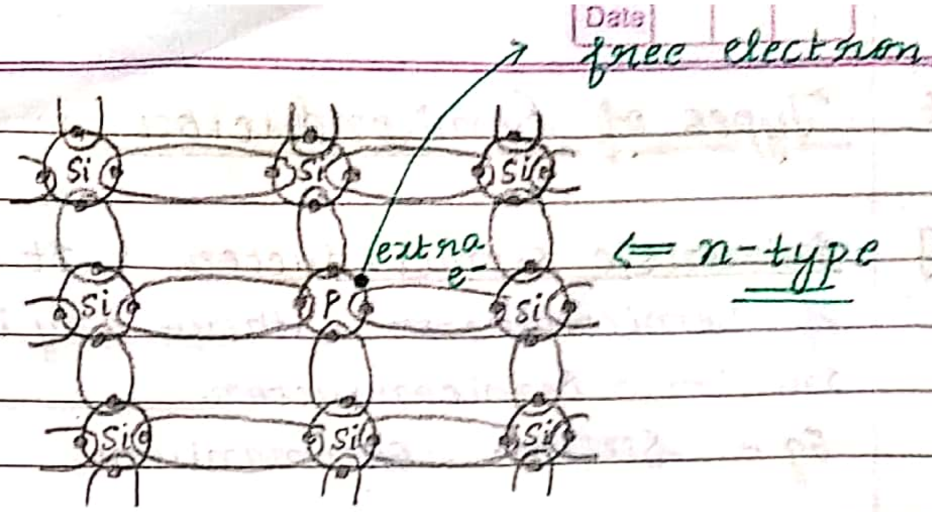
2] **Extrinsic Semiconductor** : In this, adding small amount of impurities in a semiconductor is called Extrinsic semiconductor.

⇒ The process of adding impurities into a semiconductor is called Doping.

• There are two types of Extrinsic material based on the impurities added to it, these are -
→ p-type (Trivalent Impurities)
→ n-type (Pentavalent Impurities)



⇐ p-type



(2 Marks Ques)

* Effect of Temperature on Semiconductor :

⇒ The electrical conductivity of a semiconductor changes with the variation in temperature.

⇒ At absolute 0 (zero) temperature, all the electrons are tightly held by the semiconductor atoms. At this temperature, the covalent bonds are very strong and there are no free electrons. Therefore, the semiconductor behaves like a perfect insulator at 0 (zero) Kelvin.

⇒ When the temperature is applied across the semiconductor, due to negative (-ve) temp. coefficient, resistivity across the semiconductor decreases and conductivity increases. Hence, at high temp. semiconductor behaves like a perfect conductor.

* N-type Semiconductors ⇒

⇒ The n-type semiconductors are created by introducing those type of element which have 5 valence electrons (pentavalent) such as Phosphorous, Arsenic and Antimony.

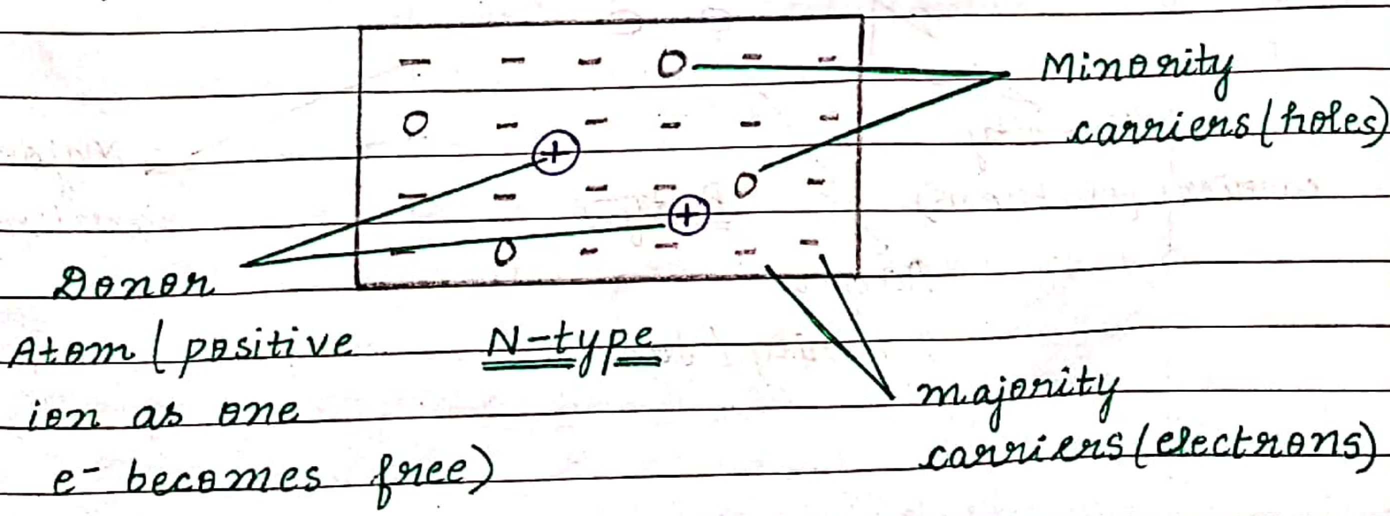
⇒ N-type contains electrons as majority carriers and few thermally generated minority holes.

⇒ The process of adding impurity is known as <u>Doping</u> and the material used as impurity in doping process is known as <u>Dopant</u>.

⇒ When pentavalent impurities is added to make n-type semiconductors, an additional fifth electron due to the impurity atom remains free. This remaining electrons or free e⁻s loosely bound to its parent atom and is ∴ relatively free to move within the newly formed n-type material.

⇒ Since, the inserted impurity atom has donated a relatively free electron to the structure, this diffused impurities with 5 valence electrons are called <u>Donor atoms</u>.

⇒ In a n-type material, the <u>e⁻</u> is called <u>majority carriers</u> and <u>holes are minority carriers</u>.



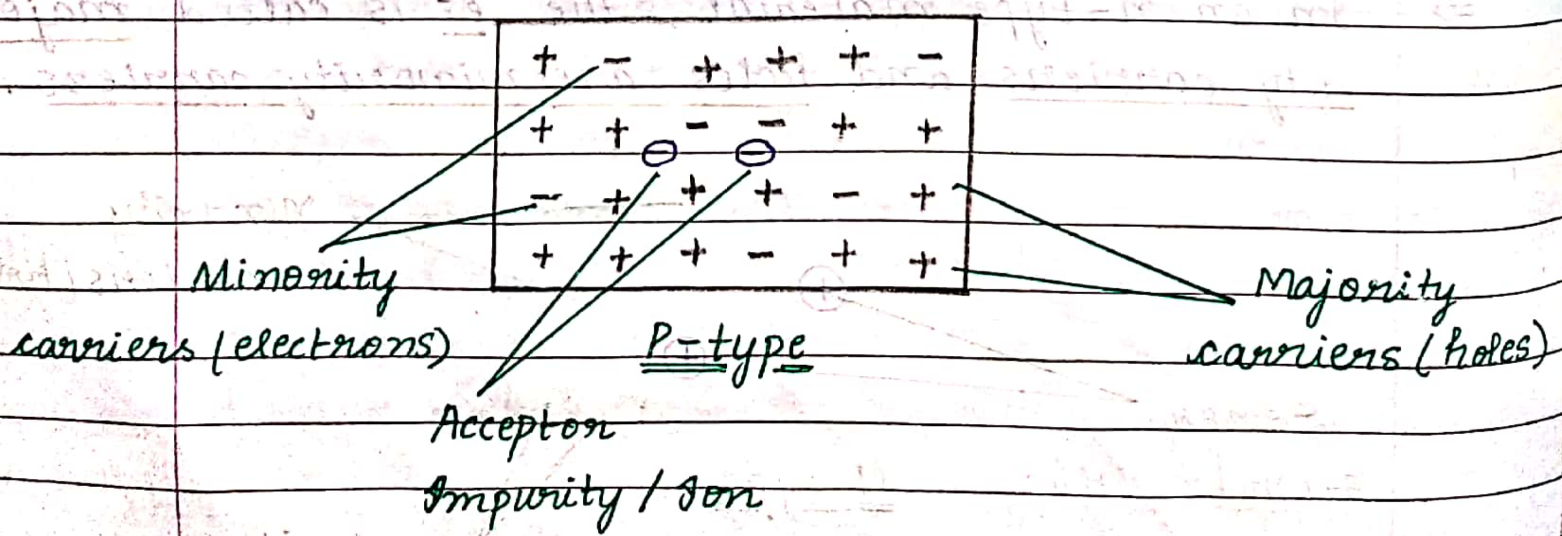
* P-type Semiconductors ⇒

→ The p-type material is formed by doping those types of impurities having 3 valence e⁻s such as Boron, Gallium and Indium (Trivalent).

⇒ The trivalent impurities, consists three (3) e⁻s in the outermost orbit and it is always ready to accept one e⁻. Hence, it is called Acceptor Impurity / ion.

⇒ Due to three (3) valence e⁻s in Boron, there is an insufficient number of e⁻s to complete the covalent bonds with Silicon and Germanium. And, this results deficiency of e⁻ called holes represented by small circle or +ve sign.

⇒ In a p-type material, the holes are majority carriers and e⁻s are minority carriers.

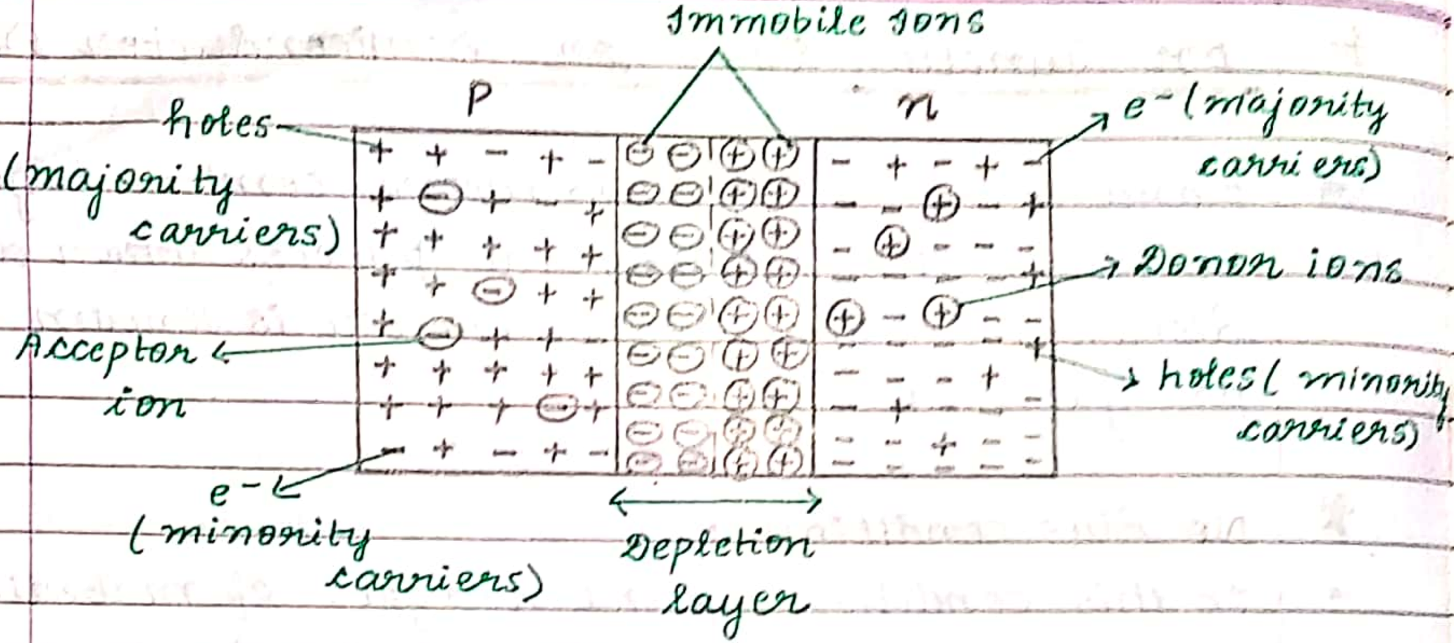


* pn-Junction Diode or Semiconductor Diode :-

⇒ p and n-type of Semiconductors combine together by means of some physical process which do not disturb the crystalline structure is known as pn-junction Diode.

No Bias condition :

- In this condition, p and n-types of materials are combined and no external supply is given (DC).
- p-type materials contains holes as majority carriers and n-type materials have electrons as majority carriers. Hence, there is a concentration difference of charges.
- Due to the concentration difference, holes from 'p' side to 'n' side and electrons from 'n' side to 'p' side starts flowing (from high conc. area to low conc. area). This process is called Diffusion.
- As holes crosses the junction from 'p' to 'n' and electrons crossess the junction from 'n' to 'p', so there will be recombination of charges because of which holes will be recombine with free electrons and electrons with holes.
- Because of recombination the acceptor ion on 'p' side and donor ion on 'n' side will be collected accross the junction or near the junction.
- These -ve charges on 'p' side and +ve charges on 'n' side across the junction will form a layer which is called Depletion layer.



P-N Junction

→ The region where there is no mobile charges, only Immobile or fixed charges are available is known as Depletion region, due to fixed ions which are electrically charged it is also known as Space charge region and depletion layer is when the pn-junction is created there is no movement of electrons and holes stops because it electrons and holes will be repelled due to the layer of -ve immobile ions and +ve immobile ions.

Forward Biasing :

- When p-type material is connected with +ve terminal of the battery and n-type is connected with the -ve terminal of the battery is called forward bias.

- The process of applying external DC supply is known as Biasing.

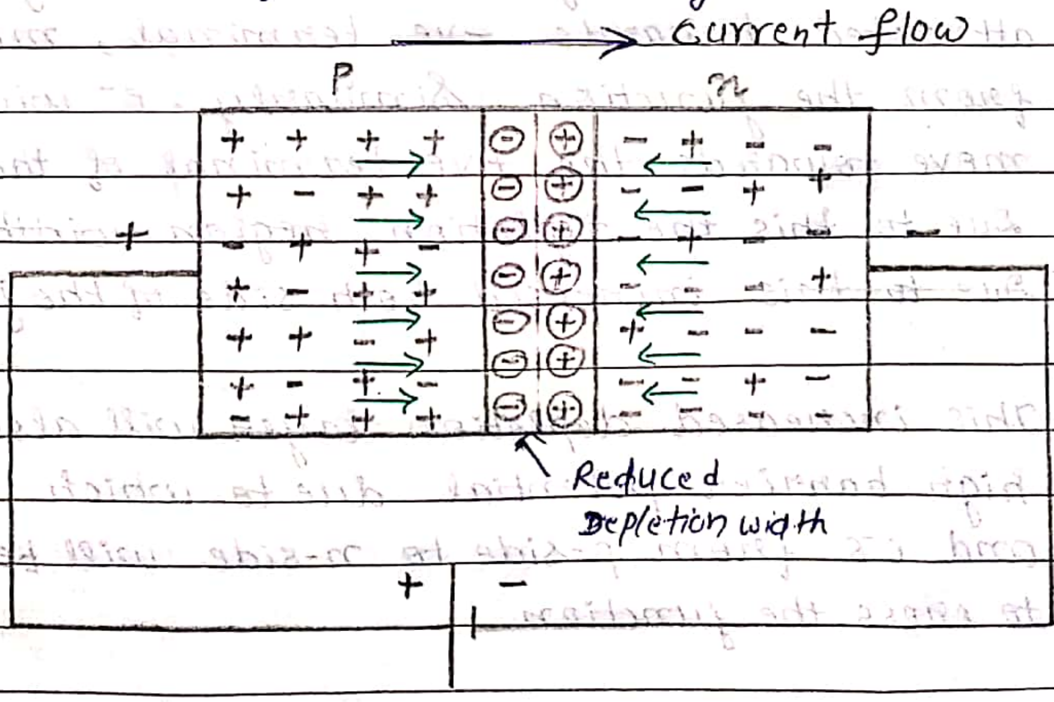
- Due to the presence of +ve and -ve ions across the junction, an electric field is created which is called Barrier potential or Junction Potential or Cut-in voltage.

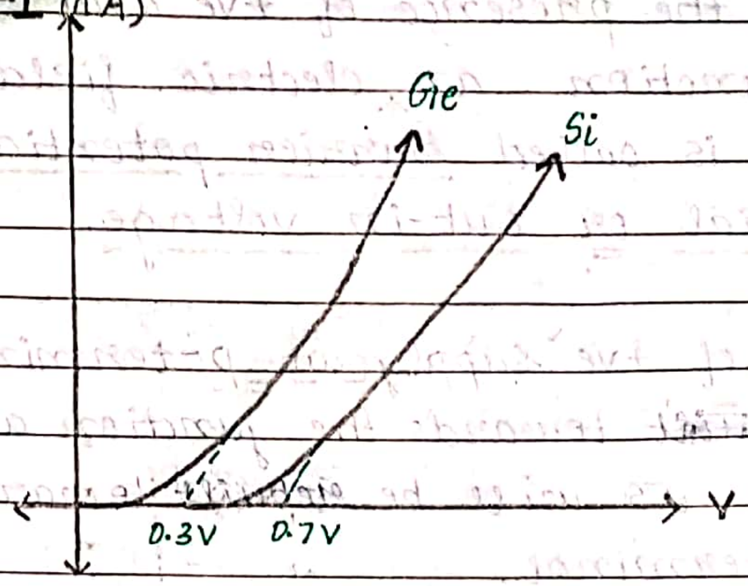
- Because of +ve supply at p-terminal, holes will be Repelled towards the junction and due to -ve Supply, e^-s will be Repelled towards the junction of n-terminal.

- The holes start neutrilizing the -ve ion of p-side and e^-s of n-side. As a result, the depletion layer's width gets reduced.

- When the applied forward bias voltage is further increased, the depletion layer width will continue to decrease until the flow of e^- can pass through the junction resulting in exponential rise in current in forward bias region.

formed





Knee voltage

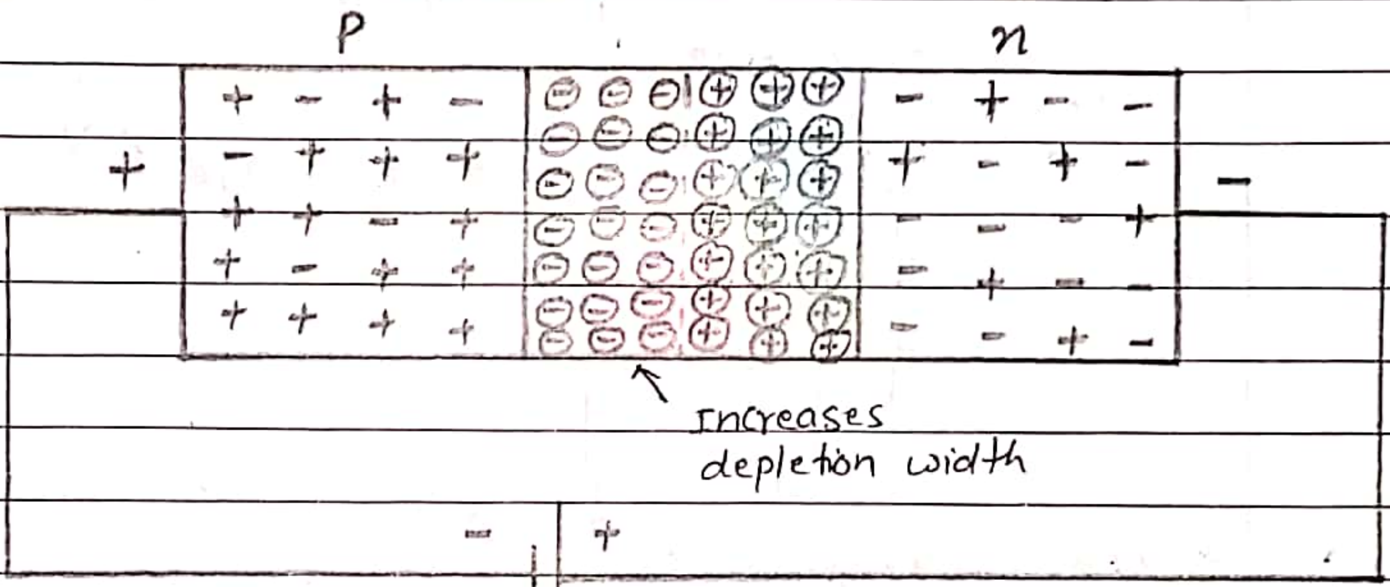
Reverse Biasing :

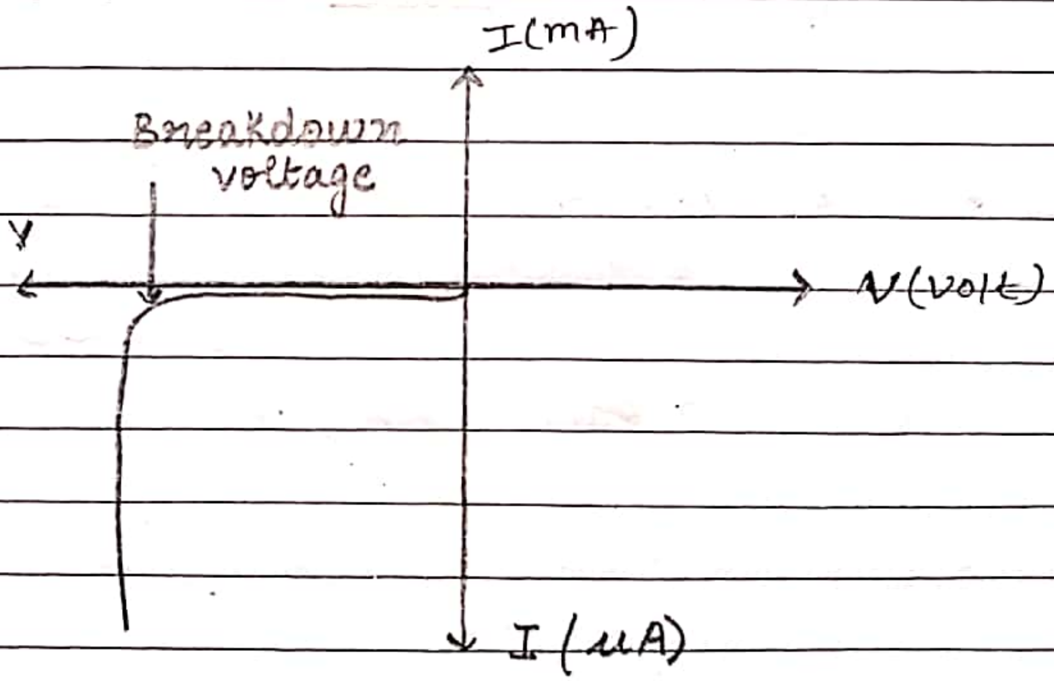
- Positive terminal of the battery is connected with 'n' side and negative terminal of the battery is connected with 'p' side is called Reverse Biasing.

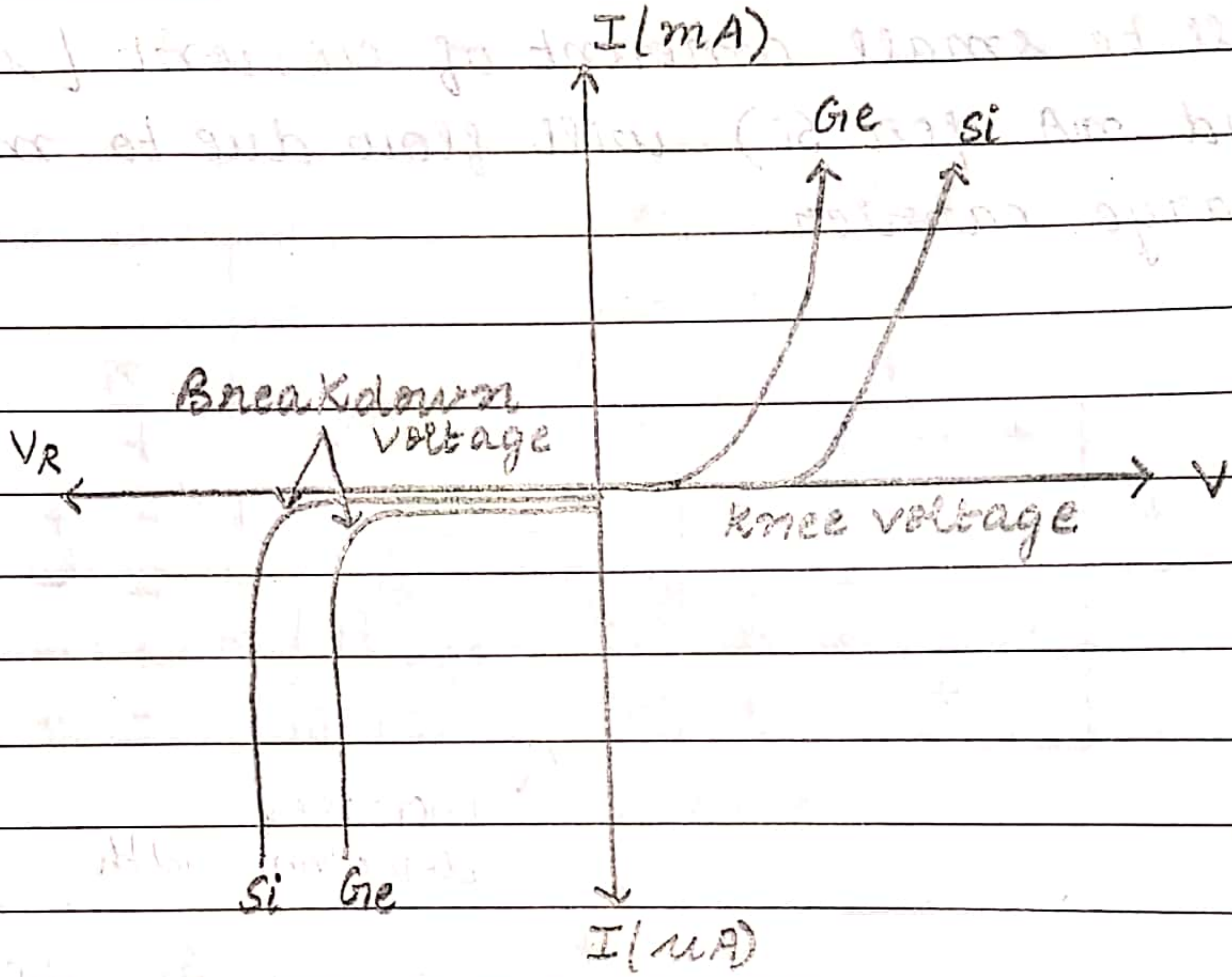
- In Reverse Biasing, holes of the p-region attracted towards −ve terminal, means away from the junction. Similarly, e⁻ will also move towards the +ve terminal of the junction. Due to this the depletion region width gets ~~Due to this~~ increased both side of the junction.

- This increased depletion layer will also give high barrier potential due to which holes and e⁻s from p-side to n-side will be enable to cross the junction.

- The current flow due to majority charge carriers in reverse bias condition is zero (0) but there will be small amount of current (μA for Ge and mA for Si) will flow due to minority charge carrier.







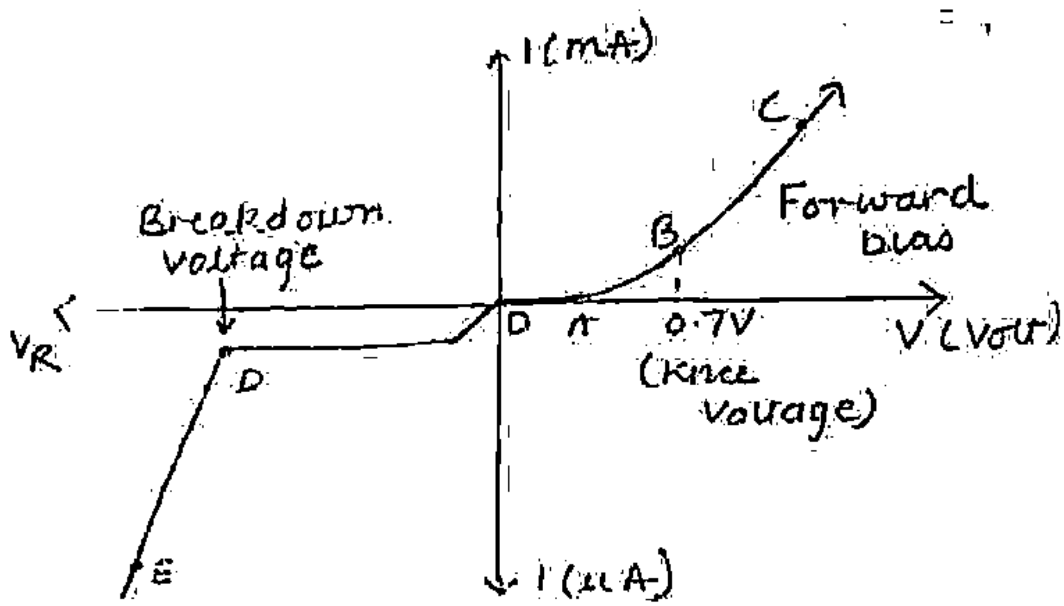
V-I Characteristics of pn-Junction Diode

VI characteristics of PN Junction Diode

- Voltage Ampere (V-I) characteristics of PN junction or semiconductor diode is the curve between voltage across the junction and the current through the circuit
- The characteristics can be explained under three cases such as
  - Zero bias
  - Forward bias
  - Reverse bias

(i) zero bias -

- In this condition, no external voltage is applied to the p-n junction i.e the circuit is open. Hence the potential barriers does not permit current flow
- Therefore, the circuit current is zero at V=0V, as indicated by point O



(2) Forward bias

- In forward bias condition, p type of pn junction is connected to the positive terminal and n type is connected to negative terminal of external voltage This results in reduced potential barrier
- From forward characteristics, it can be noted that at first i.e region OA, the current increases very slowly and curve is non linear. It is because in this region the external voltage applied to the pn junction is used in overcoming potential barrier
- At some forward voltage i.e 0.7 V for Si & 0.3V for Ge, the potential barrier is almost eliminated and the current starts flowing in the circuit
- From this instant, the current increases with the increase in forward voltage. Hence a curve AB is obtained $\bar{c}$ forward bias
- However, once the external voltage exceeds the potential barrier voltage. The potential barrier is eliminated and the pn junction behaves as an ordinary conductor. Hence, the curve BC rises very sharply with the increase in external voltage and the curve is almost linear.

(3.) Reverse Bias

- In reverse bias condition, the p type of the pn junction is connected to the negative terminal and n type of pn junction diode is connected to the positive terminal of the external ~~a~~ voltage. This results in increased potential barrier at the junction.
- Hence the junction resistance becomes very high and as a result ideally no current flows through the circuit
- However, a very small current of the order of uA (micro Ampere) flows through the circuit. This is known as reverse saturation current (I_s) and it is due to minority carriers in the junction shown by OD curve
- The reverse bias applied to the p-n junction act as forward bias to their minority carriers and hence small current flows in reverse direction
- If reverse voltage is increased beyond particular value, large reverse current can flow damaging the diode. This is called reverse breakdown of a diode represented by DE region in V-I graph.

* Diode Current Equations :-

$$\boxed{I = I_D = I_F = I_S\left[e^{V/\eta V_T} - 1\right]}$$

⇒ I = diode forward current = $I_D = I_F$

$I_S = I_0 = I_R$ = Reverse Saturation current / Diode Reverse current

$V_D = V_F = V$ = Diode Forward voltage

η = coefficient $\begin{cases} = 1 \text{ for Germanium (Ge)} \\ = 2 \text{ for Silicon (Si)} \end{cases}$

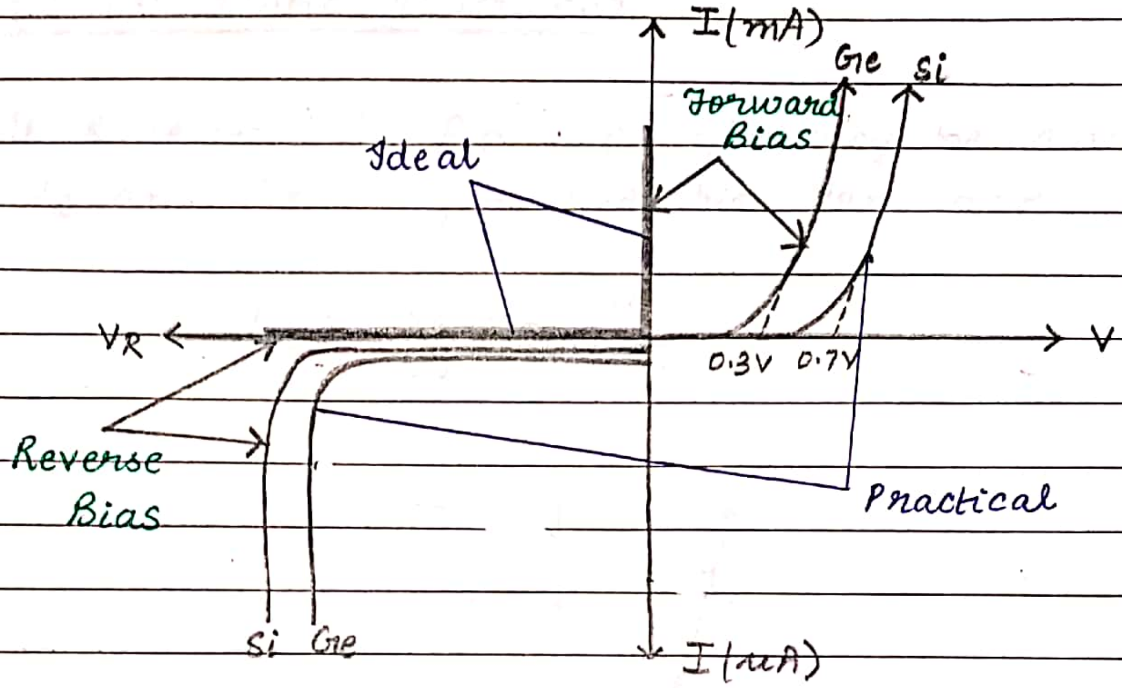
$$\boxed{V_T = \frac{KT}{q}}$$

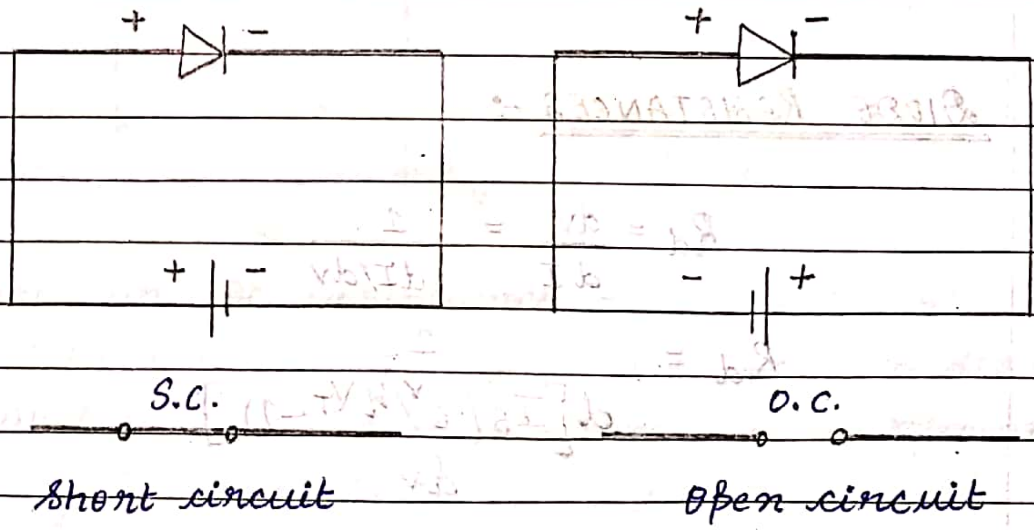
→ K = Boltzman's constant = 1.38×10^{-23} J/K

T = Temperature in Kelvin

q = 1.6×10^{-19} coulomb

* IDEAL Vs PRACTICAL DIODE :





★ If resistance is not given than voltage is 0(zero) when circuit is short, voltage is 0 when circuit is open then voltage is maximum.

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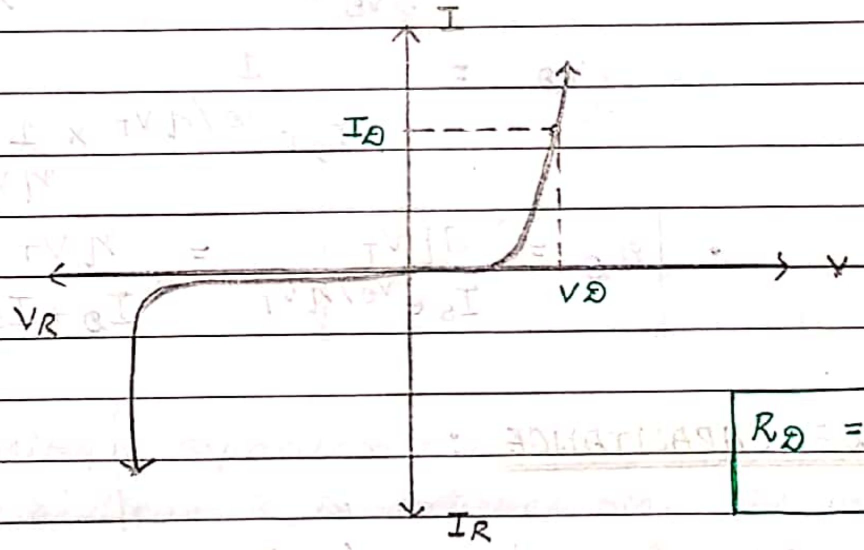
Date

(a) • The resistance offered by a pn-junction diode when applied voltage is DC then it is known as DC or Static resistance.

• It is denoted by R_D and given by the ratio of V_D and I_D in forward bias condition.

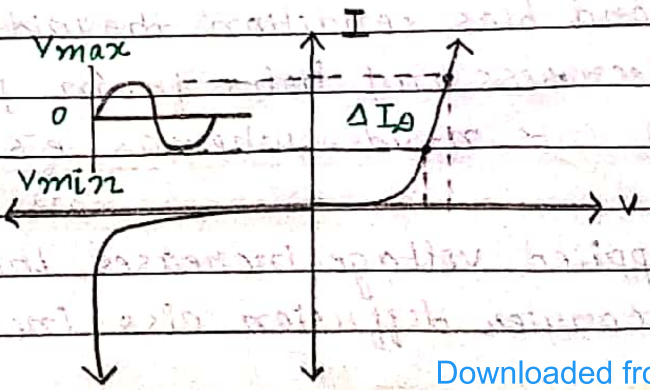
$$R_D = \frac{V_D}{I_D} = \frac{V_F}{I_F}$$



$$\boxed{R_D = \frac{V_D}{I_D}}$$

(b) • Dynamic or AC resistance –
The resistance offered by a pn-junction diode when applied voltage is AC then it is known as AC or Dynamic resistance.

• It is denoted by r_D and is given by the ratio of ΔV_d and ΔI_D.



$$\boxed{r_D = \frac{\Delta V_D}{\Delta I_D}}$$

Mathematically it is given as –

$$r_D = \frac{\partial V_D}{\partial I_D}$$

$$r_D = \frac{1}{\frac{\partial I_D}{\partial V_D}}$$

$$r_D = \frac{1}{\frac{\partial}{\partial V_D}\left(I_S e^{V_D/\eta V_T} - 1\right)}$$

$$r_D = \frac{1}{I_S e^{V_D/\eta V_T} \times \frac{1}{\eta V_T}}$$

$$\therefore \boxed{r_D = \frac{\eta V_T}{I_S e^{V_D/\eta V_T}} = \frac{\eta V_T}{I_D + I_S}}$$

* DIODE CAPACITANCE :

(a) Diffusion Capacitance (C_D)
(b) Transmission Capacitance (C_T)

(a) • Diffusion Capacitance –
The capacitance exist in forward bias condition is called Diffusion capacitance or Storage capacitance.

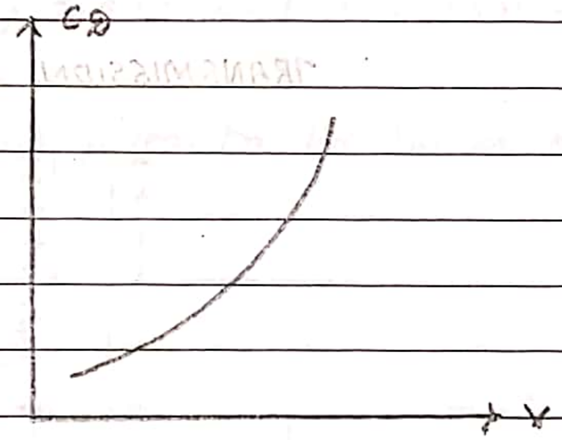
- In forward bias condition the width of depletion region decreases and holes from p-side gets diffused into n-side whereas e^-s from n-p side.

- As the applied voltage increases, the conc. of charge carrier diffusion also increases. This rate of change of injected charge with applied voltage is defined as capacitance called Diffusion Capacitance.

$$C_D = \frac{dQ}{dV}$$

$$\boxed{C_D = \frac{\tau I}{\eta V_T}}$$

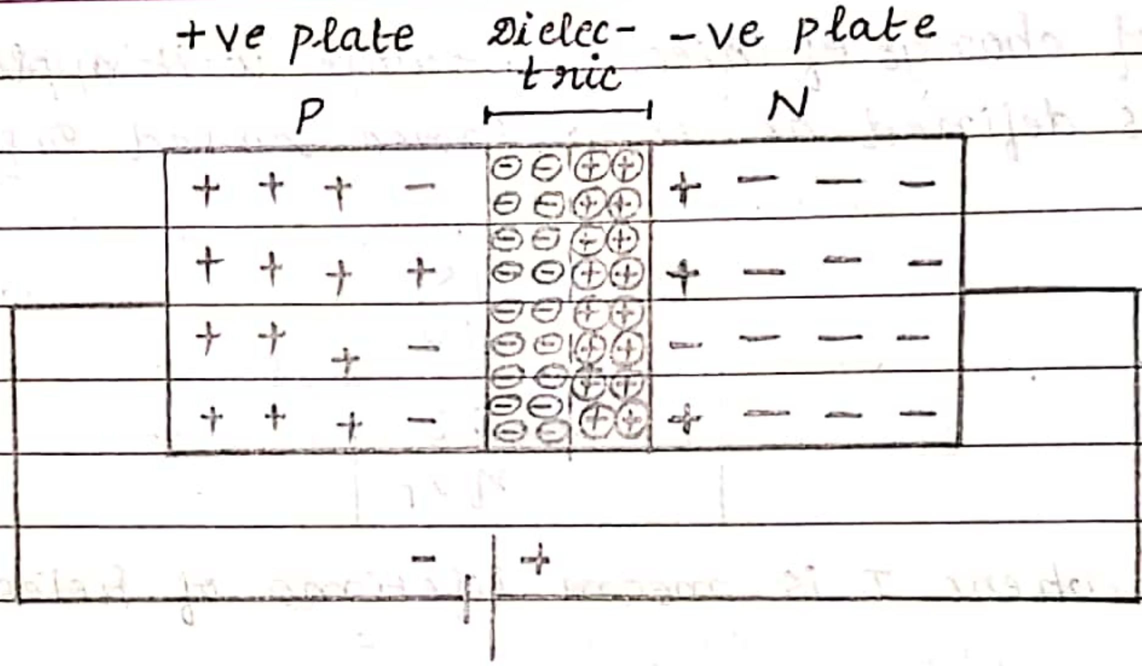
where τ is mean lifetime of holes.



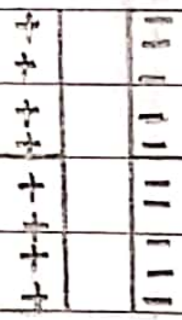
(b) • Transition Capacitance –
When a diode is in reverse bias, the width of depletion region increases and there are more no. of +ve and –ve charges present in it.

• Due to this, the p-region and n-region acts like the plates of capacitance and the widened depletion region acts like dielectric.

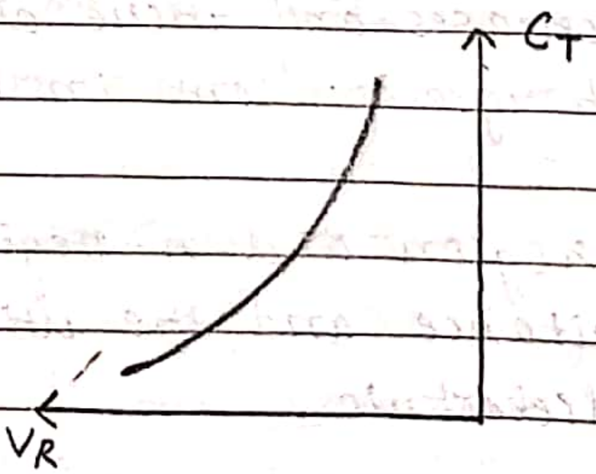
• Hence, the existance of capacitance in reverse bias of pn-junction is known as Transition Capacition or Junction Capacitance or Space charge capacitance or Barrier capacitance or Depletion capacitance.



TRANSMISSION CAPACITANCE



$$\boxed{C_T = \frac{\varepsilon A}{d}}$$



* DIODE CLIPPERS : (Application of Diode)

- An electronic circuit which used to shape up the waveform or clip off or remove the portion of waveform without distorting the remaining part or portion of the system is known as Diode Clipper / Diode clipper circuit.

- It consists of only diode and resistance.

- The input is always given in the form of alternating cycle.

→ Types of Clippers

- Clippers
  - Unbiased
    - Series
      - +ve
      - −ve
    - Parallel/Shunt
      - +ve
      - −ve
  - Biased
    - Series
      - +ve
      - −ve
    - Parallel/Shunt
      - +ve
      - −ve
  - Combinational

(1)• Unbiased Series Clipper : (Positive)

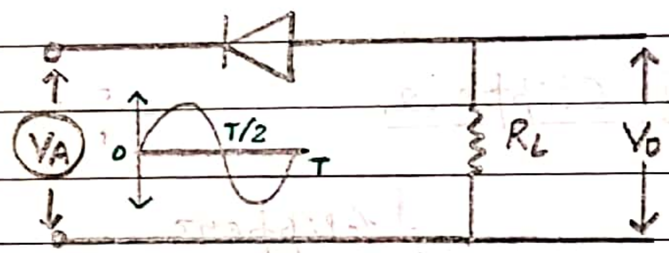
Unbiased ⇒ There is no external DC supply given to the circuit.

⇒ It will clip off or remove the complete half cycle of the input waveform.

Series ⇒ The diode is connected in series with the load.

+ve ⇒ Unbiased Series Clipper (positive):

If the +ve half cycle of the input waveform is removed in the output is known as positive clipper.

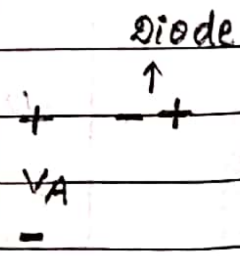


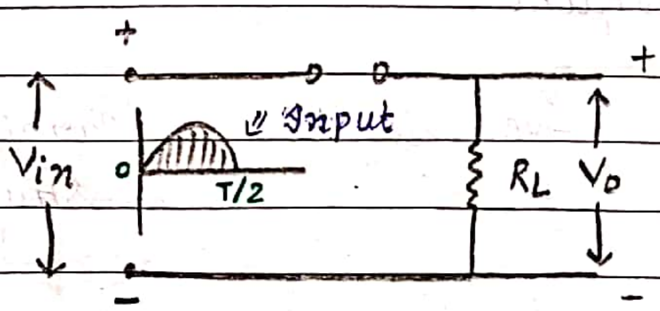
Case 1 : (i) $V_{in} > 0$ (positive half cycle)

(ii) Diode will be reversed bias.

(iii) it acts as an open circuit.

(iv) output across R_L , $\boxed{V_o = 0}$



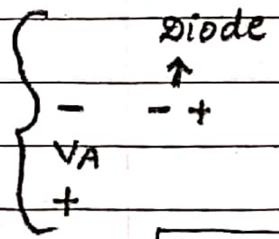


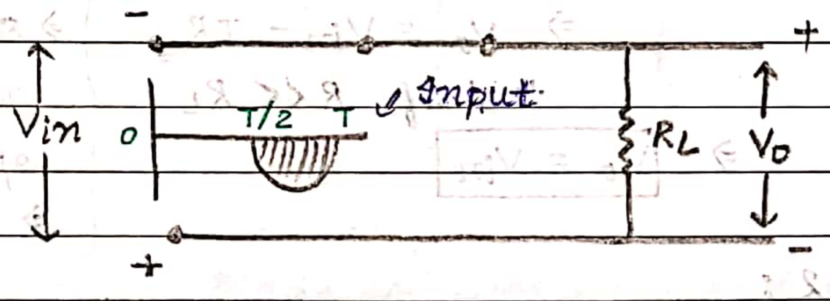
Case 2 : (i) $V_{in} < 0$ (negative half cycle)

(ii) Diode will be forward biased.

(iii) It acts as short circuit.

(iv) Output across load resistance, $\boxed{V_o = V_{in}}$



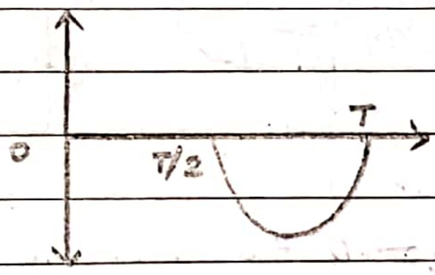


$\Rightarrow -V_{in} - IR = 0$

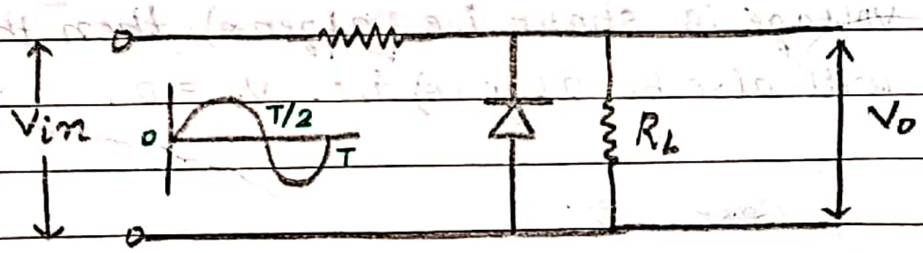
$\Rightarrow -V_{in} - (-V_o) = 0$

$\Rightarrow \boxed{V_{in} = V_o}$

Output $\Rightarrow$



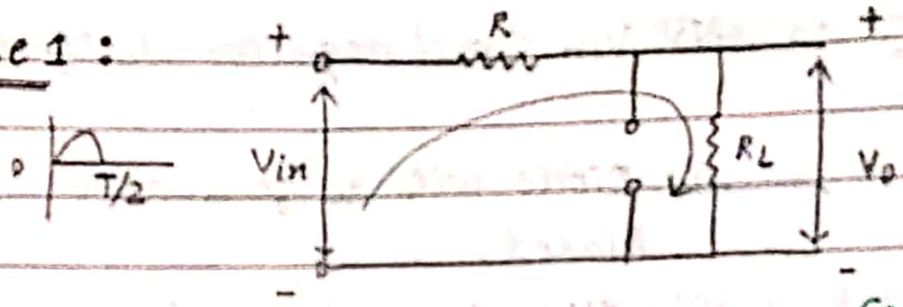
(2) • Unbiased Shunt Negative clipper :



parallel $\Rightarrow$ The diode is connected in parallel with the load resistance.

−ve $\Rightarrow$ The −ve half cycle of the input waveform is removed in the output is known as negative clipper.

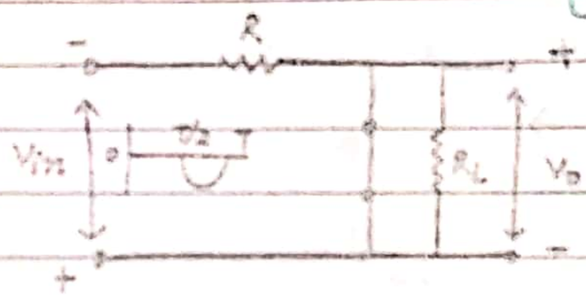
Case 1 :



Case 1 ⇒
⇒ $V_{in} > 0$
⇒ Diode becomes reversed bias and open circuit.
⇒ $V_o = V_{in}$

$$V_{in} - IR - V_o = 0$$
$$\Rightarrow V_o = V_{in} - IR$$
$$\text{if } R << R_L$$
$$\Rightarrow \boxed{V_o = V_{in}}$$

Case 2 :

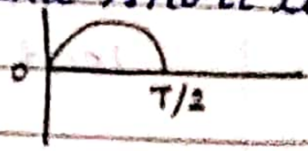


$$V_o - 0 = 0$$
$$\Rightarrow \boxed{V_o = 0}$$

∵ In ||el, the voltage remains same, if one voltage is short i.e. 0(zero) then the other will also be 0(zero) i.e. $V_o = 0$.

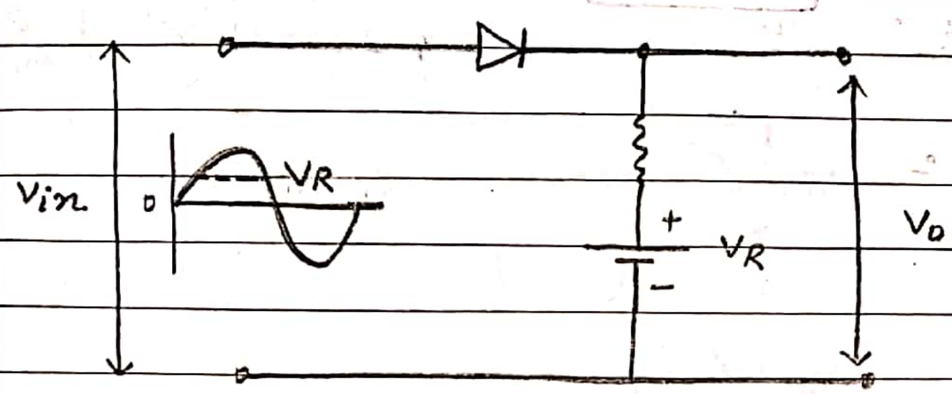
Case 2 ⇒
⇒ $V_{in} < 0$
⇒ Diode becomes forward bias and short circuit
⇒ $V_o = 0$.

Output :-



(3) • Unbiased series negative clipper
(4) • Unbiased shunt positive clipper

(5) BIASED CLIPPER :

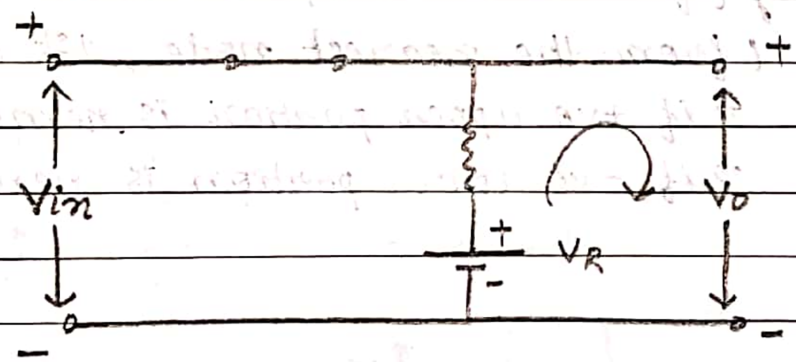


Case 1 : (i) $V_{in} > V_R$

(ii) Diode becomes forward bias.

(iii) It behaves like a short circuit

(iv) Apply KVL to get output.



$$V_{in} - V_o = 0$$

$$\Rightarrow \boxed{V_{in} = V_o}.$$

$\{\because V_{in} - \underbrace{IR - V_R}_{= V_o} = 0\}$

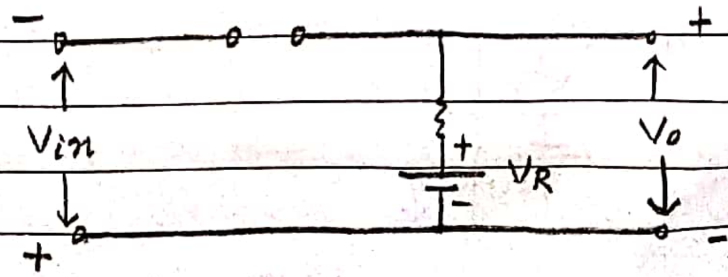
$\because$ In ||el voltage remains the same.

Case 2 : (i) $V_{in} < V_R$

(ii) Diode becomes reversed bias

(iii) It behaves like an open circuit

(iv) Apply KVL to get output

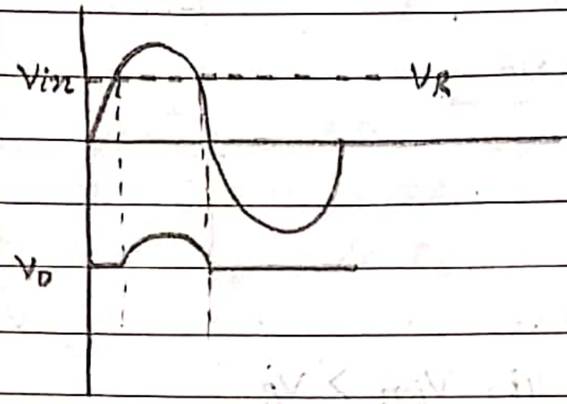


$$V_R - IR = V_0$$

$$\Rightarrow \boxed{V_R = V_0}$$

$\left\{ \begin{array}{l} IR = 0 \\ \because I = 0 \\ \because \text{open circuit} \end{array} \right.$

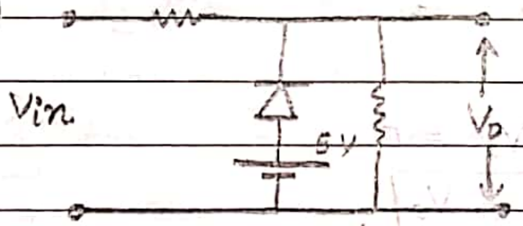
Output :-



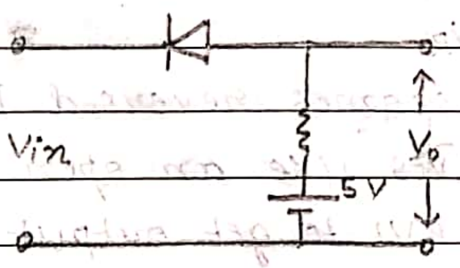
* Direct Method :

(1) Battery (from down to up or anticlockwise)
(2) Diode (from the nearest node, 1st sign
⇒ if +ve upper portion is removed
⇒ if -ve lower portion is removed)

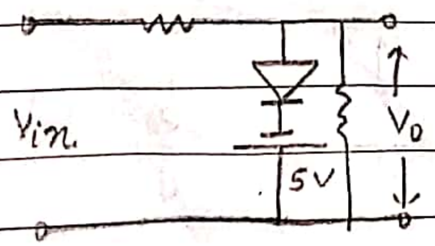
Ques (i)



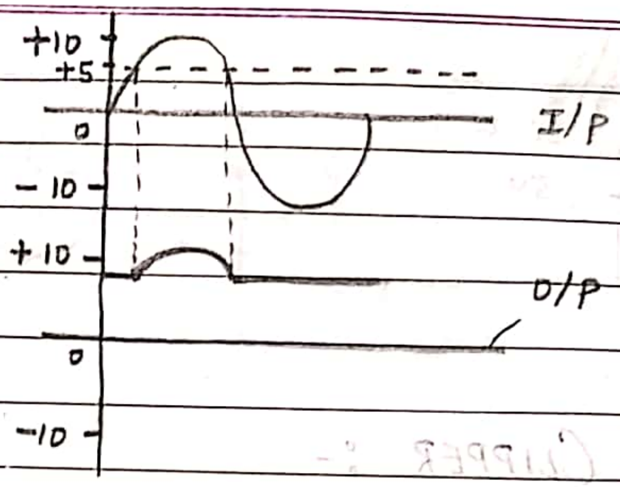
(ii)



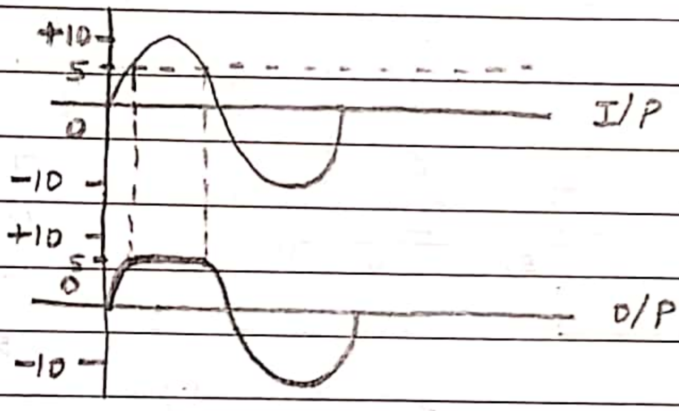
(iii)



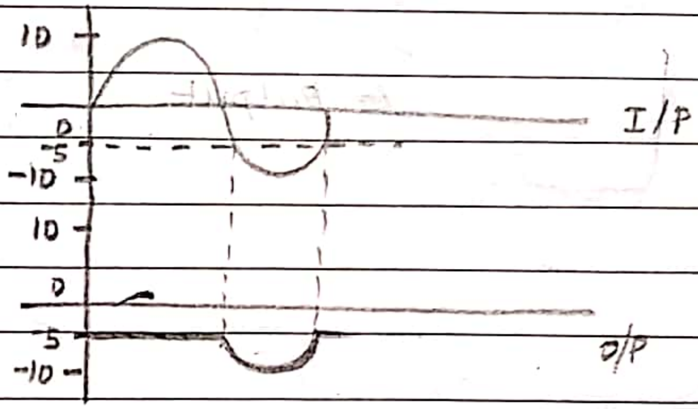
Ans (i)



(ii)

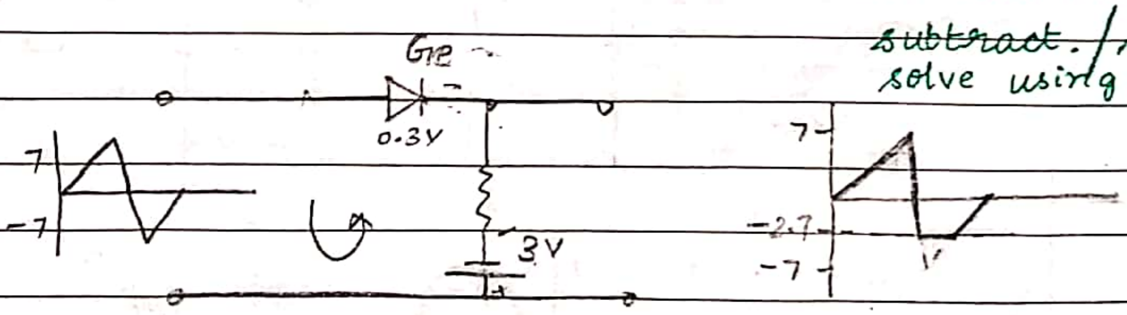


(iii)

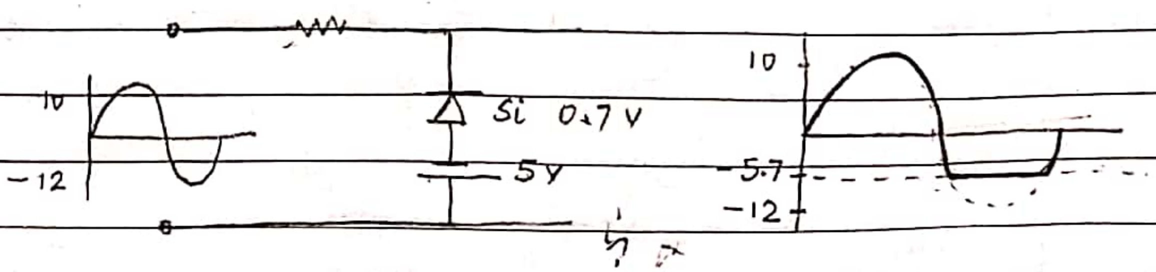


* In same polarity of diode & battery ~~then add otherwise subtract.~~ / Simply solve using KVL.

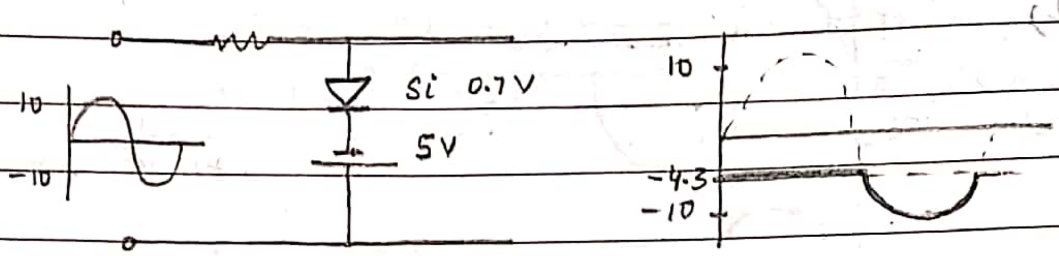
Ques (i)



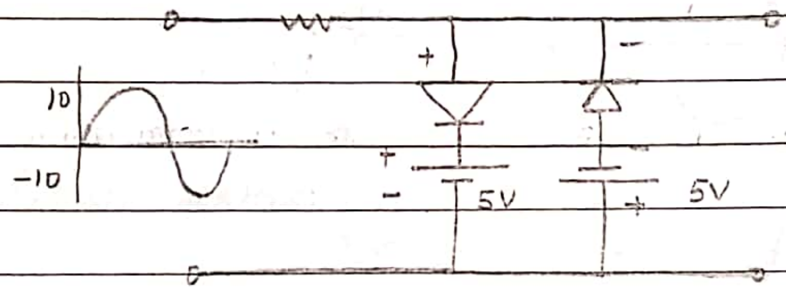
(ii)



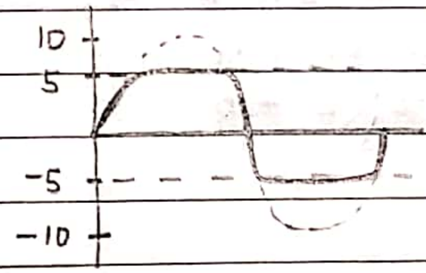
(iii)



* COMBINATIONAL CLIPPER :-

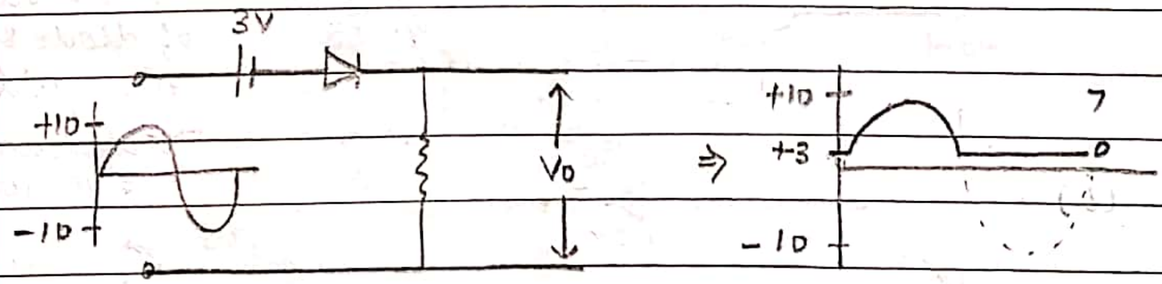


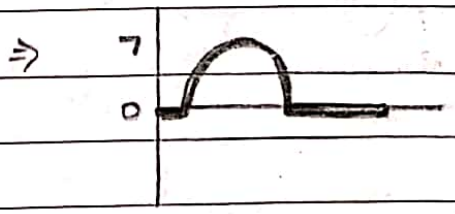
* Solve both of them seperately and then give the final output.



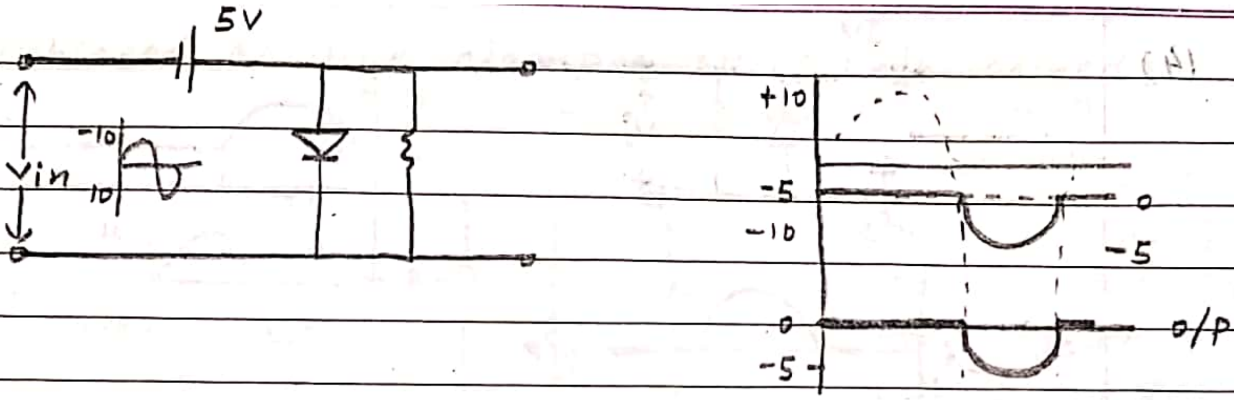
← Output

Ques

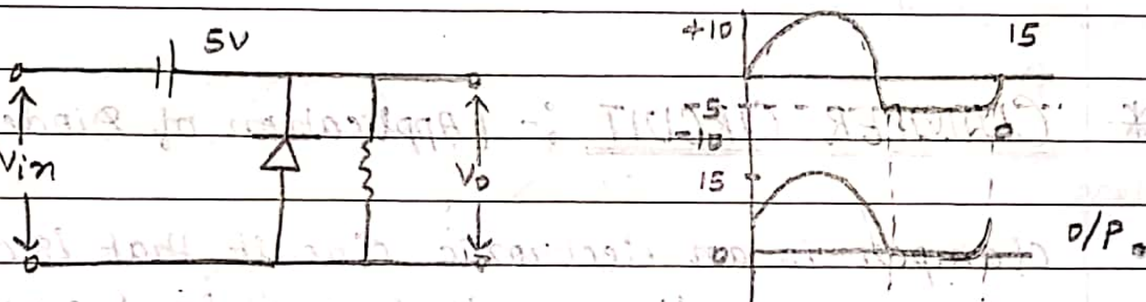




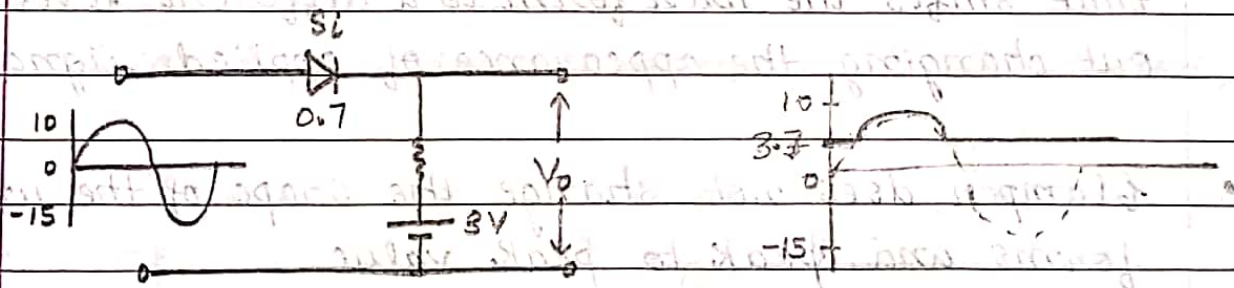
Ques (i)


5V
Vin
-10
10
+10
-5
-10
0
-5
0
-5
o/P

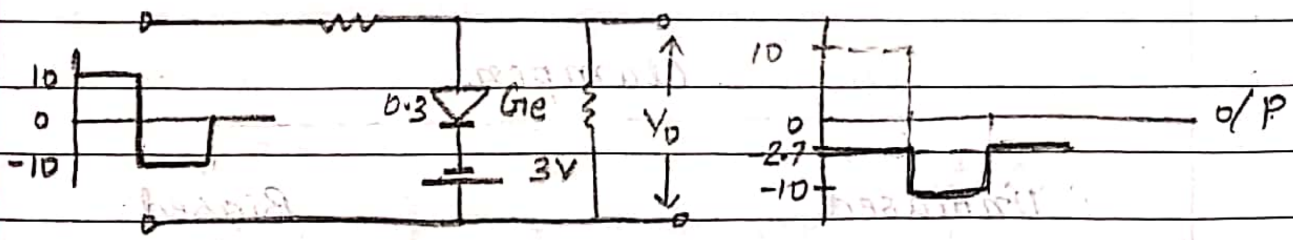
(ii)


5V
Vin
Vo
+10
15
-5
-10
15
0
O/P

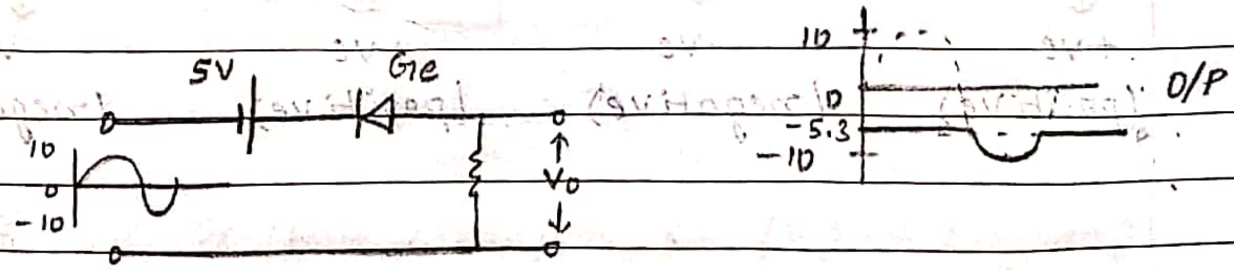
(1)

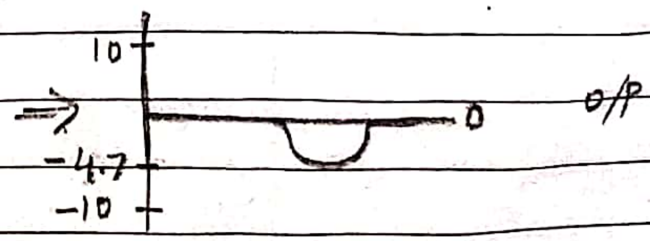

Si
0.7
10
0
-15
3V
Vo
10
3.7
0
-15
O/P

(2)

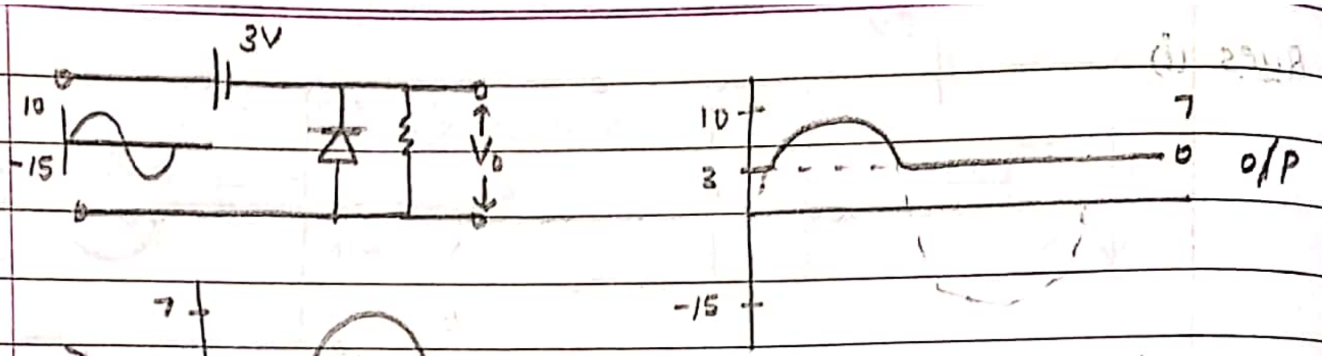

10
0
-10
0.3
Ge
3V
Vo
10
0
-2.7
-10
O/ P

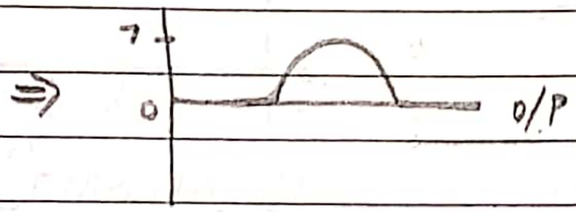
(3)


5V
Ge
10
0
-10
Vo
10
0
-5.3
-10
O/P


10
0
-4.7
-10
O/P

(4)



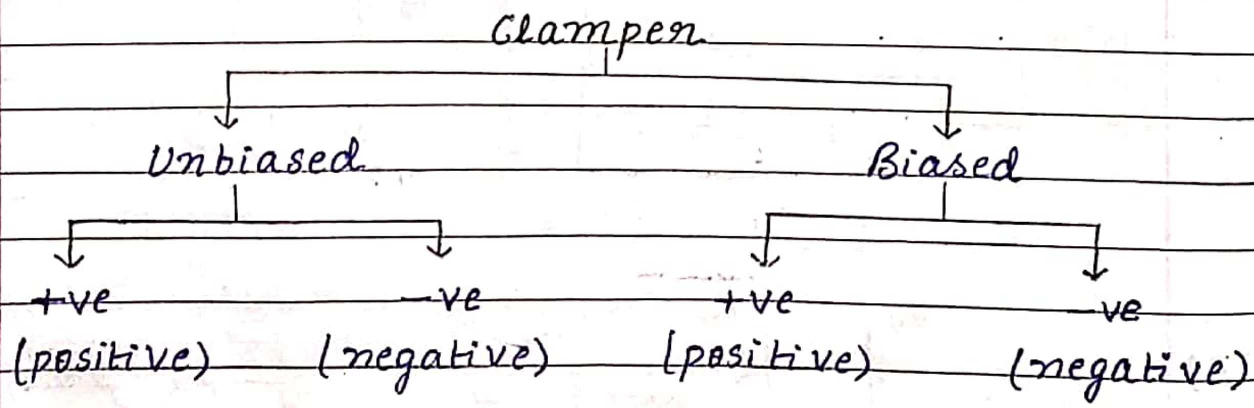


* CLAMPER CIRCUIT :- (Application of Diode)

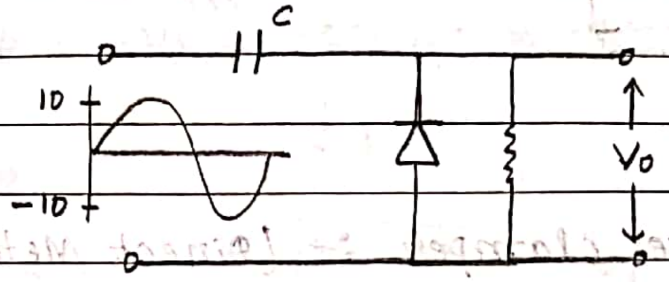
- Clamper is an electronic circuit that is constructed using a capacitor, a diode and load resistor that shifts the waveform to a different level without changing the appearance of applied Signal.

- Clamper does not change the shape of the waveforms and peak to peak value.

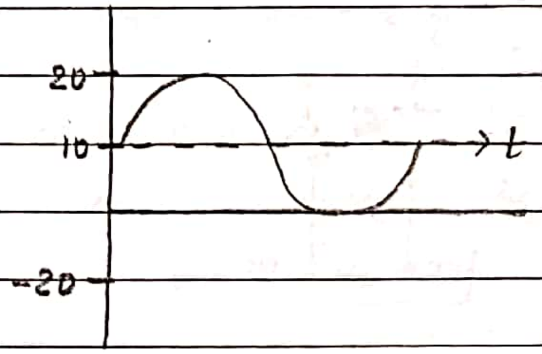
- TYPES OF CLAMPER :-



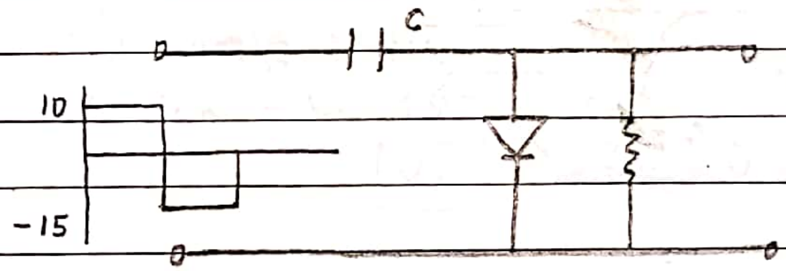
1) Unbiased Positive clamper :- (Direct Method)

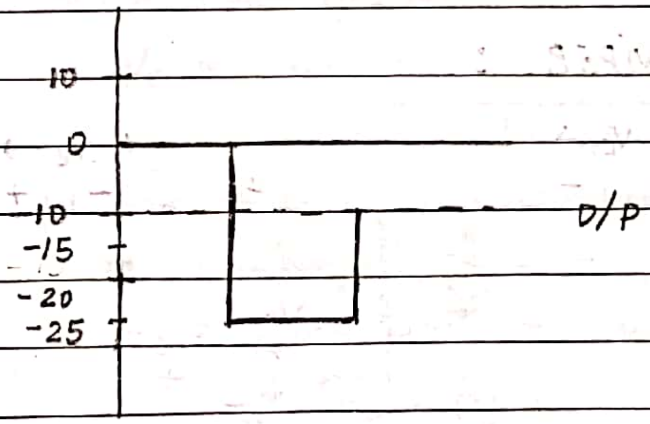


* See where the sharpness side of the arrow is that side only the whole output will shift.
⇒ Here, upwards
⇑
Direct Method

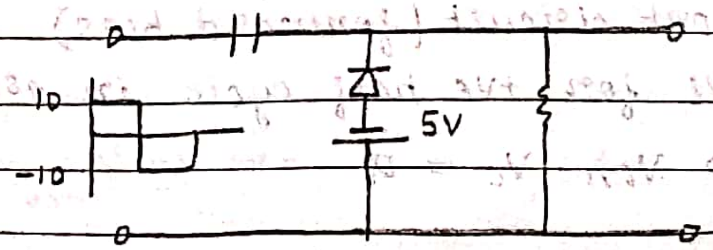


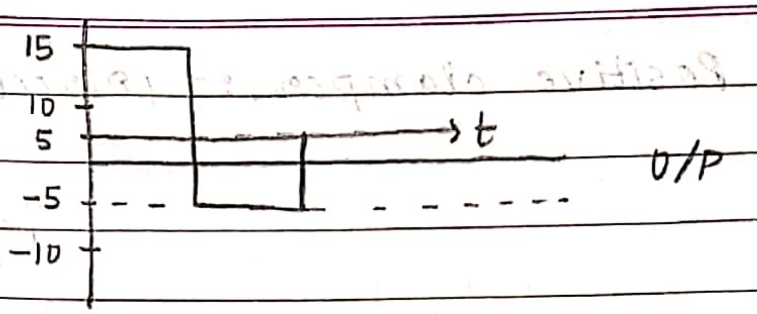
2) Unbiased Negative clamper :- (Direct Method)



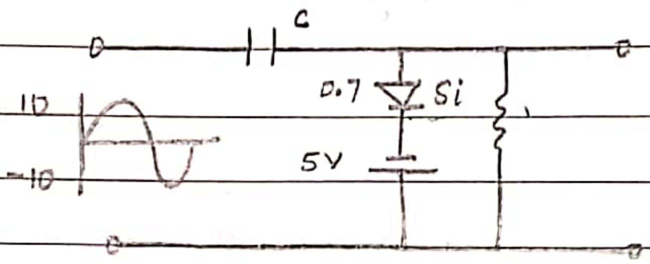


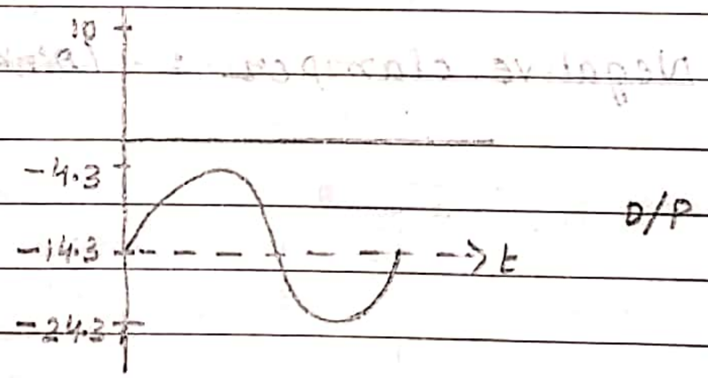
3) Biased Positive clamper :- (Direct Method)



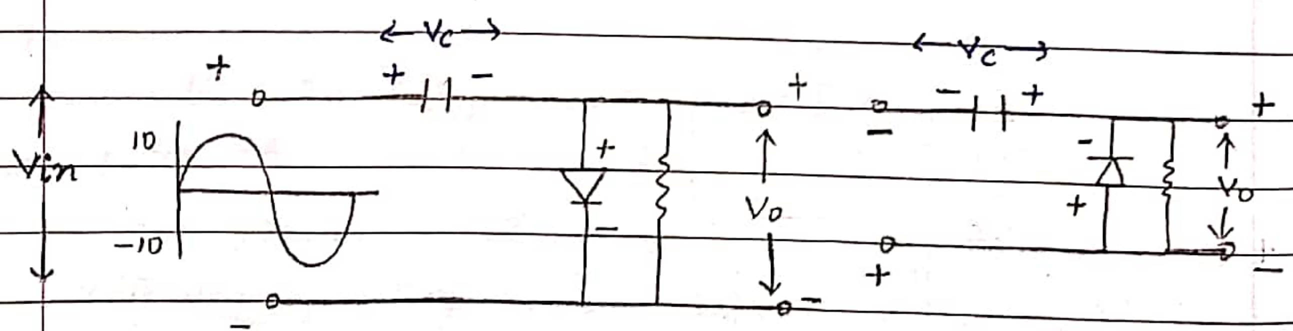


4] Biased Negative clamper :- (Direct Method)





* UNBIASED CLAMPER :



Note : (1) Start with cycle which makes diode short circuit (forward bias)

(2) Apply KVL for +ve half cycle in 1st loop.

consider sign of V_{in} $\Rightarrow$ $V_{in} - V_C = 0$ (+ve cycle inner loop)

$$\Rightarrow \boxed{V_C = V_{in}}$$

Consider ~~sign of Vin~~ • $\Rightarrow -V_{in} + V_C = 0 \Rightarrow \boxed{V_C = V_{in}}$ (-ve cycle inner loop)

don't consider the ~~sign of Vin then afterwards take the sign seperately.~~

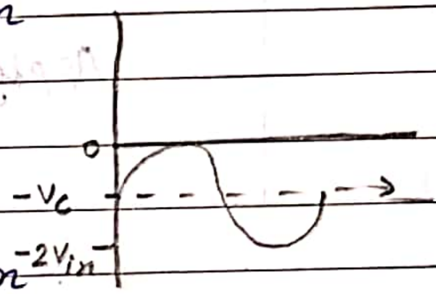
• $\Rightarrow V_{in} - V_C - V_o = 0$ (+ve cycle outer loop)

$$\Rightarrow \boxed{V_o = V_{in} - V_C} \quad \text{— (1)}$$

For +ve cycle –

$$V_o = V_{in} - V_C = V_{in} - V_{in}$$

$$\Rightarrow \boxed{V_o = 0}$$



For -ve cycle –

$$V_o = -V_{in} - V_C = -V_{in} - V_{in}$$

$$\Rightarrow \boxed{V_o = -2V_{in}}$$

~~At axis~~ $\Rightarrow \boxed{\cancel{V_o = -V_C}}$

• $\Rightarrow V_{in} + V_C - V_o = 0$

$$\Rightarrow \boxed{V_o = +V_{in} + V_C} \quad \text{— (2)}$$

For +ve cycle –

$$V_o = V_{in} + V_C = V_{in} + V_{in}$$

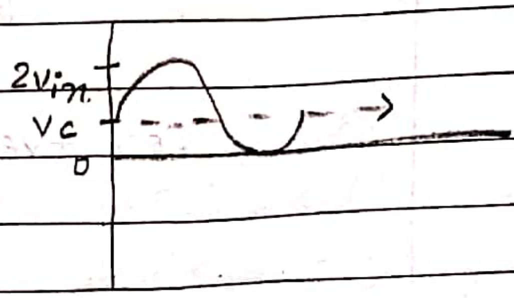
$$\Rightarrow \boxed{V_o = 2V_{in}}$$

For -ve cycle –

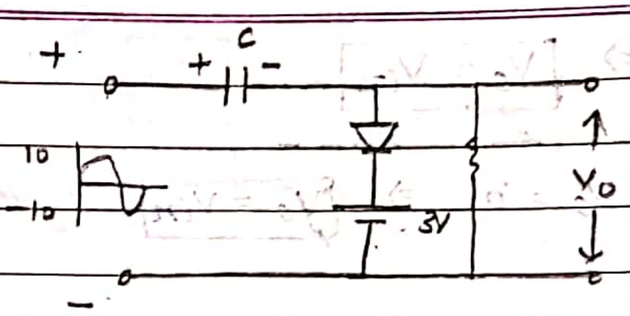
$$V_o = -V_{in} + V_C = -V_{in} + V_{in}$$

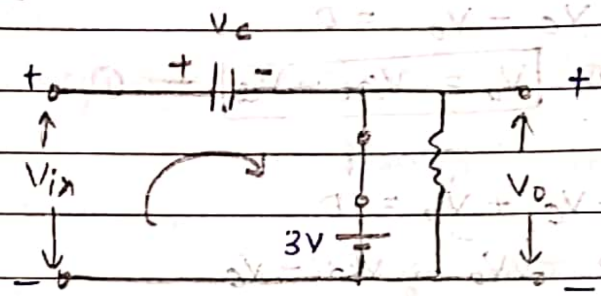
$$\Rightarrow \boxed{V_o = 0}$$

At axis $\Rightarrow \boxed{V_o = V_C}$



Ques





Applying KVL, (inner loop)

$$V_{in} - V_c - 3 = 0$$

$$\boxed{V_{in} - V_c = 3}$$

$$V_{in(max)} = 10$$

$$\Rightarrow \quad 10 - V_c = 3 \Rightarrow \boxed{V_c = 7V}$$

Applying KVL, (outer loop)

$$V_{in} - V_c - V_o = 0$$

$$\boxed{V_o = V_{in} - V_c} \text{ — (1)}$$

For +ve half cycle →

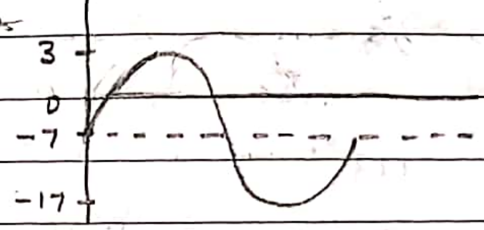
$$V_o = V_{in} - V_c$$
$$= 10 - 7 = 3$$
$$\Rightarrow \boxed{V_o = 3V}$$

For -ve half cycle →

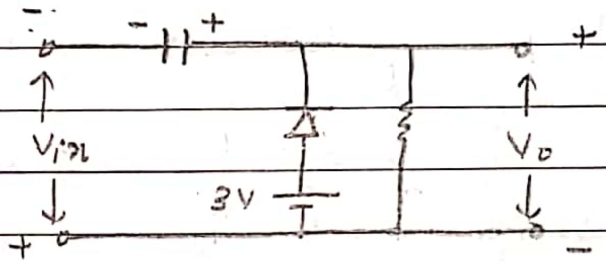
$$V_o = -V_{in} - V_c$$
$$= -10 - 7 = -17$$
$$\boxed{V_o = -17V}$$

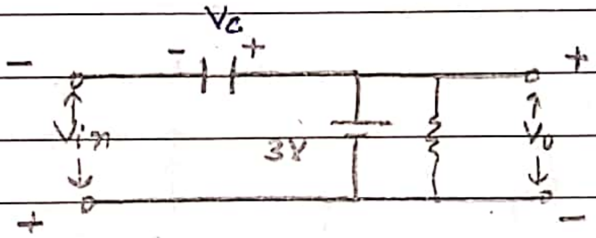
For axis, $V_o = 0 - 7 = \underline{-7V}$.

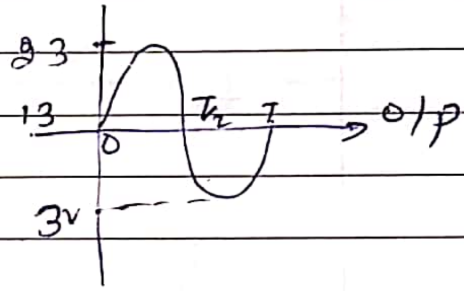
Output –



Ques







Applying KVL (inner),

$$-V_{in} + V_C - 3 = 0$$

$$-V_{in} + V_C = 3$$

$$V_C = V_{in} + 3 = +10 + 3 = \underline{\underline{13\,V}}$$

Applying KVL (outer),

$$+V_{in} + V_C - V_o = 0$$

$$\boxed{V_o = +V_{in} + V_C} \quad \text{— (1)}$$

For +ve half cycle →

$$V_o = V_{in} + V_C = 10 + 13 = 23\,V$$

$$\Rightarrow \boxed{V_o = 23\,V}$$

For –ve half cycle →

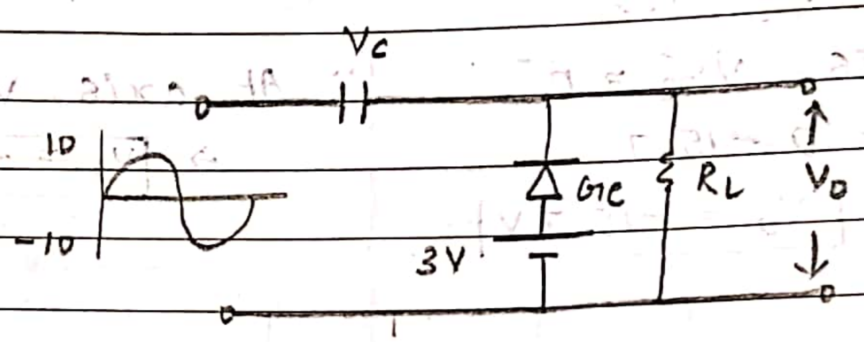
$$V_o = -V_{in} + V_C = -10 + 13 = +3\,V$$

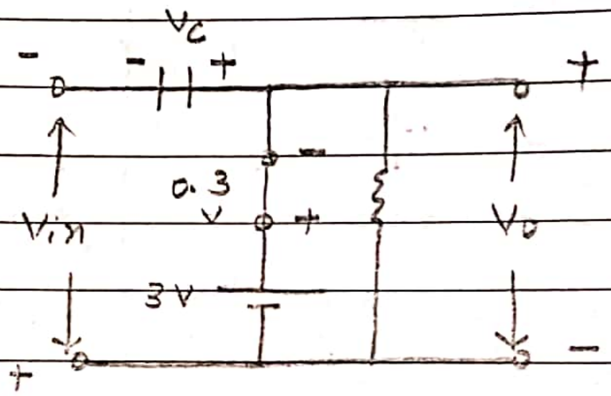
$$\boxed{V_o = +03\,V}$$

At axis, $V_{in} = 0$

$$V_o = V_{in} + V_C = 0 + 13 = \underline{\underline{+13\,V}}$$

Ques





Applying KVL (inner),

$$-V_{in} + V_C + 0.3 - 3 = 0$$

$$-10 + V_C - 2.7 = 0$$

$$\boxed{V_C = 12.7\ V}$$

Applying KVL (outer),

$$V_{in} + V_C - V_0 = 0$$

$$\boxed{V_0 = V_{in} + V_C} \quad \text{— ①}$$

For +ve half cycle,

$$V_0 = 10 + 12.7$$

$$\boxed{V_0 = 22.7\ V}$$

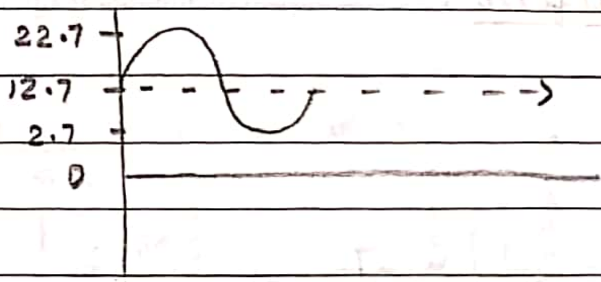
For -ve half cycle,

$$V_0 = -10 + 12.7$$

$$\boxed{V_0 = 2.7\ V}$$

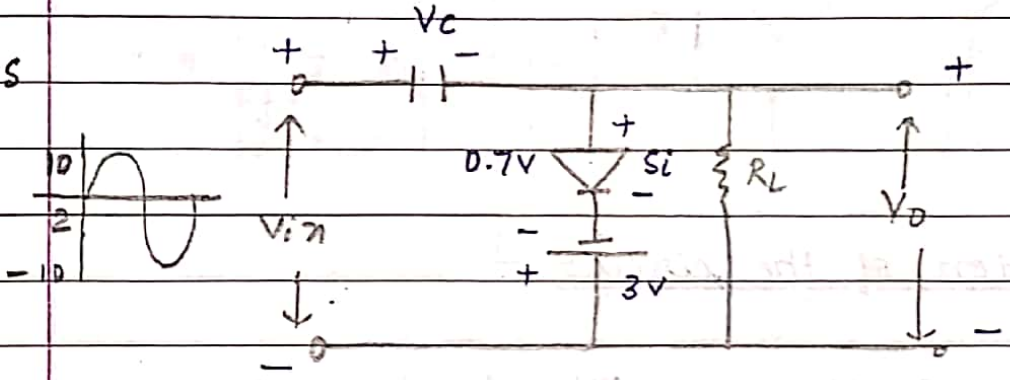
At axis, $V_{in} = 0$

$$\Rightarrow \boxed{V_o = V_C = 12.7\ V}$$



$\Leftarrow$ output

Ques



Applying KVL (inner),

$$V_{in} - V_C - 0.7 + 3 = 0$$

$$10 - V_C - 0.7 + 3 = 0$$

$$\boxed{V_C = 12.3\ V}$$

Applying KVL (outer),

$$V_{in} - V_C - V_o = 0$$

$$\Rightarrow \boxed{V_o = V_{in} - V_C} \quad \text{—} (1)$$

For +ve cycle,

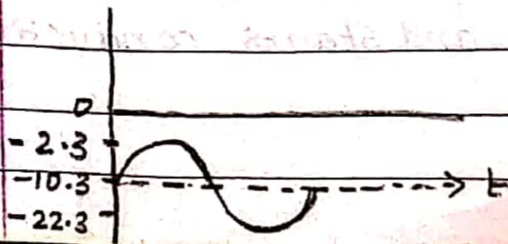
$$\Rightarrow V_o = 10 - 12.3 \Rightarrow V_o = -2.3\ V$$

For -ve cycle,

$$\Rightarrow V_o = -10 - 12.3 \Rightarrow V_o = -22.3\ V$$

At axis, $V_{in} = 2$

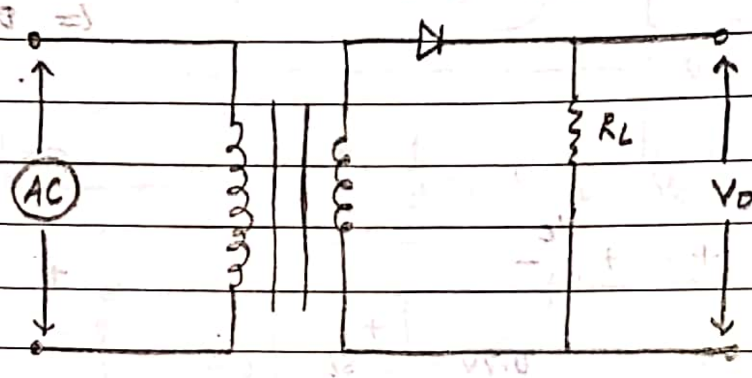
$$\Rightarrow V_o = 2 - 12.3 \Rightarrow V_o = -10.3\ V$$



$\Leftarrow$ output

* Rectifiers :- (Application of Diode)

* 1) Half wave Rectifier :

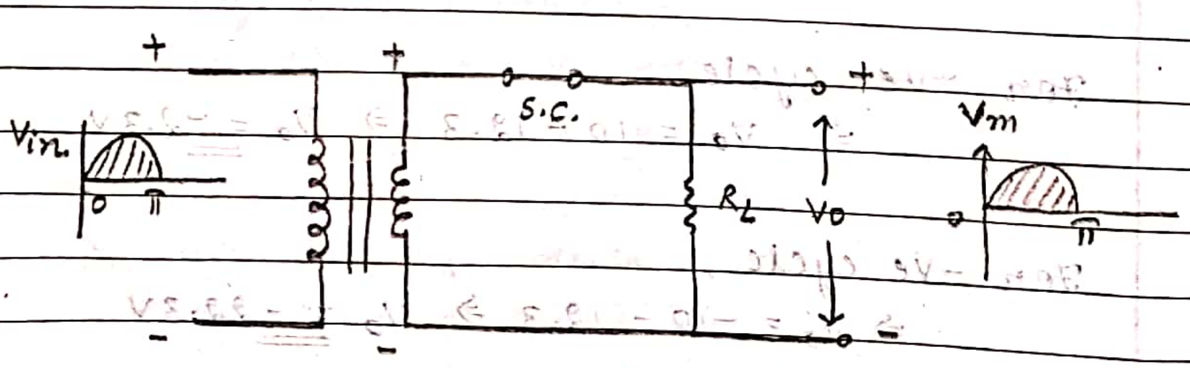


⇒ **Description of the circuit** –

- Half wave Rectifier consists of a transformer, a diode and resistive load.
- It provides the output for only half cycle of the input waveform.

⇒ **Working** –

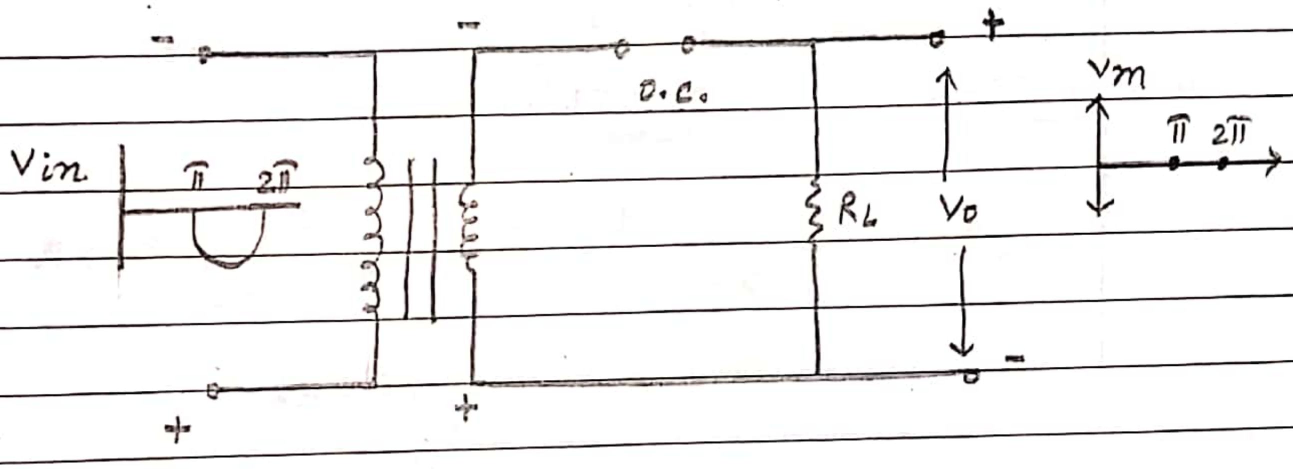
(a) **Positive Half Cycle** :



- In +ve half cycle of A.C. input, the diode will operate in forward bias and starts conducting.

- In this interval, the diode gives the output in the same phase applied as input A.C. voltage as shown in the figure.

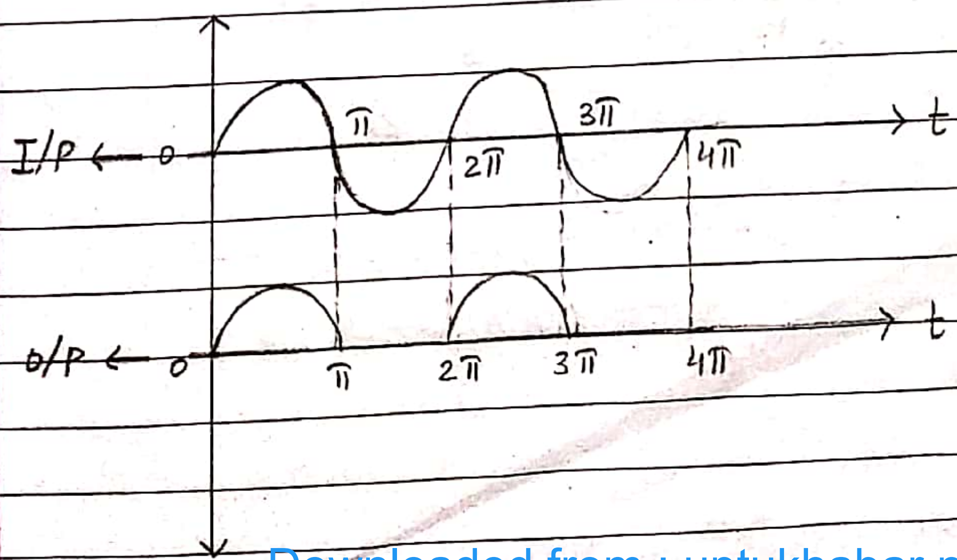
(b) Negative Half Cycle :



- In -ve half cycle the polarity of the applied voltage is reversed and due to this the diode will become reversed biased and do not conduct i.e. open circuit.

- The output across the load resistance R_L will be 0(zero) because of reverse biasing of the diode.

⇒ Input, output waveform -



1) * DC or Average Load Current (I_{DC} or I_{Avg}) :

$$I_{DC} \text{ or } I_{avg} = \frac{1}{2\pi}\int_0^{2\pi} i_L \, d(\omega t)$$

$$i_L = I_m \sin\omega t$$

$$\Rightarrow I_{avg} = \frac{1}{2\pi}\left[\int_0^{\pi} I_m \sin\omega t \, d(\omega t) + \int_{\pi}^{2\pi} 0 \, d(\omega t)\right]$$

$$= \frac{I_m}{2\pi}\left[-\cos\omega t\right]_0^{\pi}$$

$$= \frac{I_m}{2\pi}\left[-(-1) - (-1)\right]$$

$$= \frac{I_m}{\cancel{2}\pi} \times \cancel{2}$$

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

$$\therefore \boxed{I_{DC} \text{ or } I_{avg} = \frac{I_m}{\pi}}$$

2) * RMS load current (I_{rms}) :

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

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

$$= \left[\frac{I_m^2}{4\pi}\int_0^{\pi} (1 - \cos 2\omega t) \, d(\omega t)\right]^{1/2}$$

$$= \left[\frac{I_m^2}{4\pi} \left[\omega t - \frac{\sin 2\omega t}{2} \right]_0^{\pi} \right]^{1/2}$$

$$= \left[\frac{I_m^2}{4\pi} \left[\pi - \frac{\sin \pi}{2} - 0 - 0 \right] \right]^{1/2}$$

$$= \left[\frac{I_m^2}{4\cancel{\pi}} \times \cancel{\pi} \right]^{1/2}$$

$$= \frac{I_m}{2}$$

$$\therefore \boxed{I_{rms} = \frac{I_m}{2}}$$

3) * <u>Ripple factor</u> : (r)

- It is defined as the percentage of AC content present in the output, its ideal value should be 0(zero) and the practical should be as low as possible.

- Mathematically, it is expressed as –

$$I_{rms}^2 = I_{AC}^2 + I_{DC}^2$$

$$I_{rms}^2 - I_{DC}^2 = I_{AC}^2$$

$$I_{AC} \text{ or } (I_{AC})_{rms} = \sqrt{I_{rms}^2 - I_{DC}^2}$$

$$r = \frac{\text{R.M.S value of A.C component of o/p}}{\text{DC component of o/p}}$$

$$\boxed{r = \frac{(I_{AC})_{rms}}{I_{DC}}}$$

$$\Rightarrow r = \sqrt{\frac{I_{rms}^2 - I_{DC}^2}{I_{DC}^2}}$$

$$r = \sqrt{\left(\frac{I_{rms}}{I_{DC}}\right)^2 - 1} = \sqrt{\frac{\frac{I_m^2}{2\times 2}}{\frac{I_m^2}{\pi \times \pi}} - 1}$$

$$\Rightarrow \boxed{r = 1.21}$$

4) * Rectification Efficiency :

- It is defined as the ratio of output DC power to the AC input power.

- Mathematically, it can be expressed as –

$$\boxed{\% \eta = \frac{P_{oDC}}{P_{iAC}} \times 100}$$

$$\Rightarrow \% \eta = \frac{I_{dc}^2 \times R_L}{I_{AC}^2 \times R_L} = \left(\frac{\frac{I_m}{\pi}}{\frac{I_m}{2}} \right)^2 \times 100$$

$$= \frac{4}{\pi^2} \times 100$$

$$= 40.53\ \%$$

$$\Rightarrow \boxed{\% \eta = 40.53\%}$$

5) * Average or DC voltage :

$$\boxed{V_{DC} = I_{DC} \times R_L}$$

$R_S \rightarrow$ winding resistance

$R_f \rightarrow$ forward resistance of diode

$$V_{DC} = \frac{I_m}{\pi} \times R_L$$

$$= \frac{V_m}{(R_L + R_S + R_F)\pi} \times R_L \qquad \{R_L + R_S + R_f \cong R_L\}$$

$$= \frac{V_m}{\pi} \Rightarrow \boxed{V_{DC} = \frac{V_m}{\pi}}$$

6. Peak Inverse Voltage (PIV):

→ The peak Inverse voltage is the peak voltage across the diode in the reverse direction, i.e. when diode is reverse bias condition, called PIV rating of a diode.

→ In half wave rectifier, the load current is ideally zero when the diode is reverse biased and hence the maximum value of the voltage that can exist across the diode is V_m.

$$\boxed{PIV = V_m}$$

PIV = V_m for Half wave rectifier

7. Transformer Utilization Factor (T.U.F.)

→ The T.U.F. is defined as the ratio of D.C. power delivered to the load to the A.C. power rating of the transformer.

$$T.U.F. = \frac{\text{D.C. power delivered to the load}}{\text{A.C. power rating of the Transformer}}$$

→ for half wave rectifier: $T.U.F. = \frac{P_{DC}}{P_{RMS}}$

→ $P_{DC} = I_{DC}^2 \times R_L = \left(\frac{I_m}{\pi}\right)^2 \times R_L$

→ AC power Rating of transformer $= V_{rms} \cdot I_{rms}$

$$= \frac{V_m}{\sqrt{2}} \times \frac{I_m}{2}$$

$$= \frac{I_m R_L \times I_m}{2\sqrt{2}}$$

$$T.U.F = \frac{\frac{I_m^2 \times R_L}{\pi^2}}{\frac{I_m^2 \times R_L}{2\sqrt{2}}} = \frac{2\sqrt{2}}{\pi^2} = 0.287$$

$$T.U.F. = 0.287$$

(8.) Voltage Regulation

→ The voltage regulation is the factor which tells us about the change in the d.c. output voltage as load changes from no load to full load condition.

→ if $(V_{dc})_{NL}$ = D.C. voltage on NO Load

$(V_{dc})_{FL}$ = D.C. voltage on full load

then Voltage regulation is defined as

$$\% \text{ voltage Regulation}(R) = \frac{(V_{dc})_{NL} - (V_{dc})_{FL}}{(V_{dc})_{FL}} \times 100$$

→ for half wave $(V_{dc})_{NL} = \frac{V_m}{\pi}$

$$(V_{dc})_{FL} = I_{DC} \times R_L$$
$$= \frac{I_m}{\pi} \times R_L$$
$$= \frac{V_m}{\pi(R_L + R_f + R_s)} \times R_L$$

$$\therefore \% R = \frac{\frac{\cancel{V_m}}{\cancel{\pi}} - \frac{\cancel{V_m}}{\cancel{\pi}(R_L+R_f+R_s)} \times R_L}{\frac{\cancel{V_m}}{\cancel{\pi}(R_L+R_f+R_s)} \times R_L}$$

$$= \frac{1 - \frac{R_L}{(R_L+R_f+R_s)}}{\frac{R_L}{(R_L+R_f+R_s)}} = \frac{\frac{R_L+R_f+R_s-R_L}{\cancel{(R_L+R_f+R_s)}}}{\frac{R_L}{\cancel{(R_L+R_f+R_s)}}}$$

$$\therefore \% R = \left(\frac{R_f + R_s}{R_L}\right) \times 100$$

neglating secondary winding

$$\boxed{\% R = \frac{R_f}{R_L} \times 100}$$

(g) * AC or RMS load voltage :

$$\boxed{V_{rms} = I_{rms} \times R_L}$$

$$V_{rms} = \frac{I_m}{2} \times R_L$$

$$= \frac{V_m}{2(R_L + R_S + R_f)} \times R_L \quad \{R_L \cong R_S + R_f + R_L\}$$

$$= \frac{V_m}{2}$$

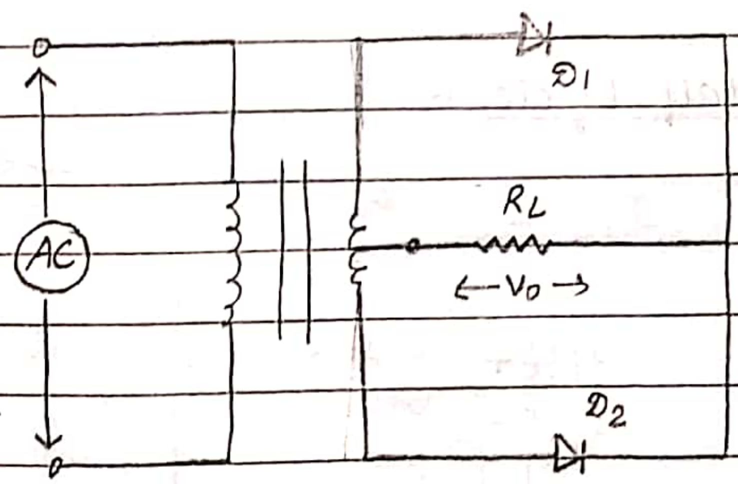
$$\Rightarrow \boxed{V_{rms} = \frac{V_m}{2}}$$

★★★★★

2) Full wave Rectifier :

V.V.V.V. imp

(i) CENTRE TAPPED RECTIFIER –



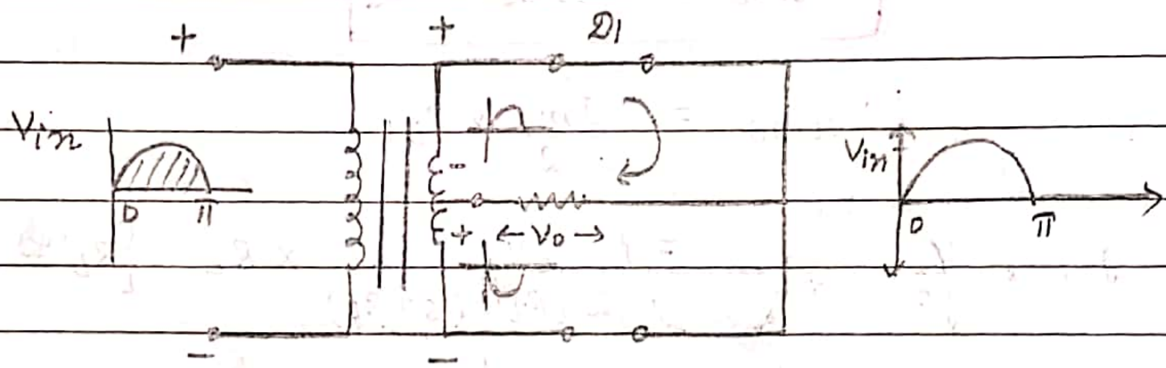
⇒ Description of the circuit –

- Centre tapped rectifier consists of a centre-tapped transformer, two diodes and resistive load.

It gives output for both cycle.

⇒ Working -

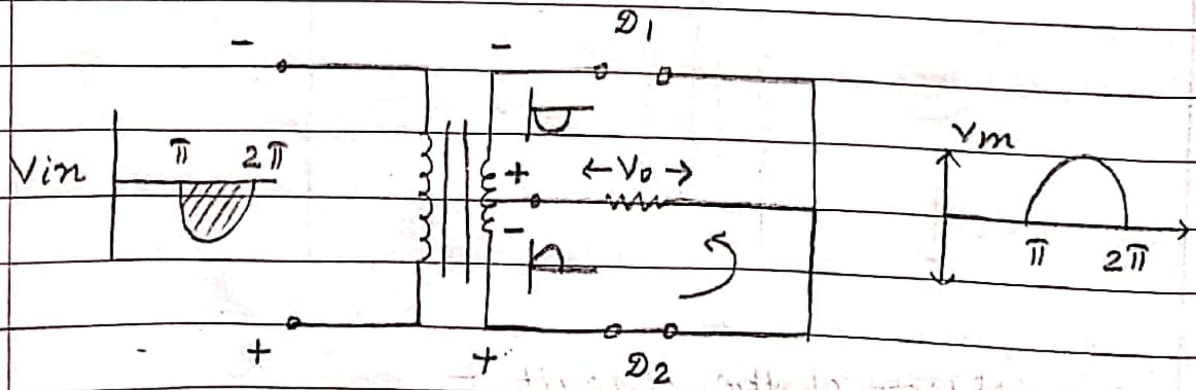
(a) Positive Half Cycle :



- During +ve half cycle, the applied voltage is passed through the step-down transformer (centre tapped) and diode D_1 operates in forward bias and D_2 operates in reversed bias.

- The output across the load resistance R_L will be in the same phase with input due to diode D_1 as shown in figure.

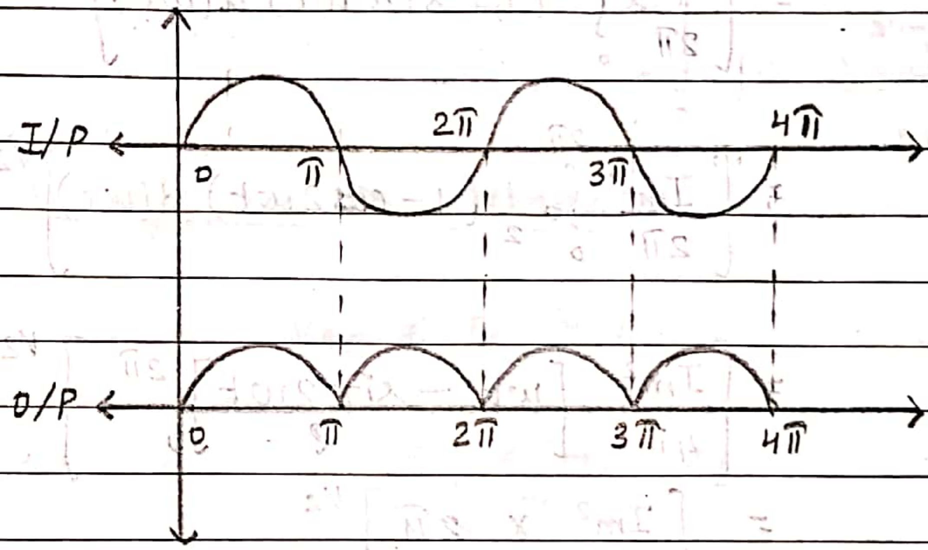
(b) Negative Half Cycle :



- In negative half cycle, the polarity will be reversed, Diode D_1 operates in reversed bias and diode D_2 in forward bias.

- The output across the load resistance will be 180° outer phase with the input due to Diode D_2 and properties of centre tapper transformer.

→ Input, output waveform -



1) * DC or Average load current (I_{DC} or I_{avg}) :

$$I_{DC} = \frac{1}{2\pi} \int_0^{2\pi} i_L \, d(\omega t)$$

∵ out of phase

$$= \frac{1}{2\pi} \left[\int_0^{\pi} I_m \sin\omega t \, d(\omega t) + \int_{\pi}^{2\pi} -I_m \sin\omega t \, d(\omega t) \right]$$

$$= \frac{I_m}{2\pi} \left[[-\cos\omega t]_0^{\pi} + [\cos\omega t]_{\pi}^{2\pi} \right]$$

$$= \frac{I_m}{2\pi} \left[[-(-1)+1] - [-1+(-1)] \right]$$

$$= \frac{I_m}{\cancel{2}\pi} \times \cancel{4}^{\,2}$$

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

$$\therefore \boxed{I_{DC} \text{ or } I_{av} = \frac{2I_m}{\pi}}$$

2) * AC or RMS root mean square (I_{AC} or I_{rms}) :

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

taken in one cycle only $\because$ -ve ~~sign is consumed~~ in the square.

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

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

$$= \left[\frac{I_m^2}{4\pi}\left[\omega t - \frac{\sin 2\omega t}{2}\right]_0^{2\pi}\right]^{1/2}$$

$$= \left[\frac{I_m^2}{\cancel{4\pi}_{2}} \times \cancel{2\pi}^{1}\right]^{1/2}$$

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

$$\therefore \boxed{I_{AC} \text{ or } I_{rms} = \frac{I_m}{\sqrt{2}}}$$

3)* Ripple factor :

$$r = \sqrt{\left(\frac{I_{rms}}{I_{DC}}\right)^2 - 1} = \sqrt{\frac{\frac{I_m^2}{2}}{\frac{4I_m^2}{\pi^2}} - 1}$$

$$= 0.48$$

$$\Rightarrow \boxed{\eta = 0.48}$$

4) * Rectification Efficiency :

$$\% \eta = \frac{I_{DC}^2}{I_{AC}^2} \times 100 = \frac{4 Im^2}{\pi^2} \times \frac{2}{Im^2} \times 100 =$$

$$= 0.81 \times 100 = 81\%$$

$$\Rightarrow \boxed{\therefore \eta = 0.81} \text{ or } \boxed{\% \eta = 81\%}$$

5) * Average or DC voltage :

$$V_{DC} = I_{DC} \times R_L$$

$$= \frac{2 Im}{\pi} \times R_L$$

$$= \frac{2 Vm}{(R_L + R_S + R_F)\pi} \times R_L$$

$$= \frac{2 Vm}{\pi}$$

$$\Rightarrow \boxed{V_{DC} = \frac{2 Vm}{\pi}}$$

6) * AC or RMS load voltage :

$$V_{rms} = I_{rms} \times R_L = \frac{Im}{\sqrt{2}} \times R_L$$

$$= \frac{Vm}{(R_L + R_S + R_F)\sqrt{2}} \times R_L = \frac{Vm}{\sqrt{2}}$$

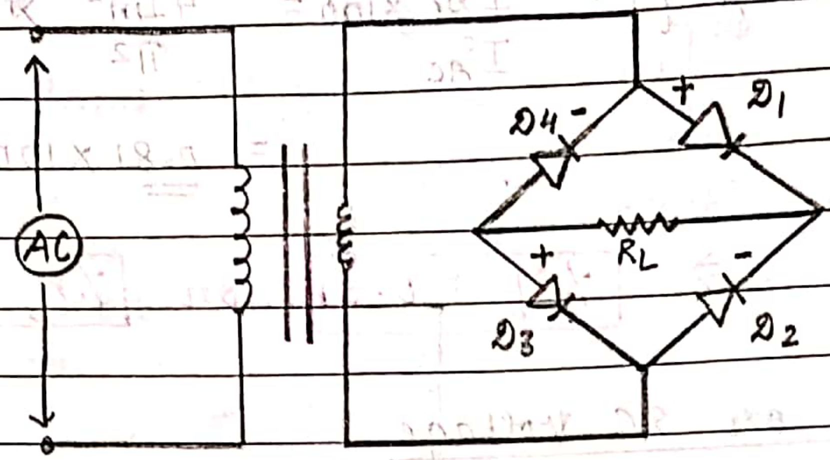
$$\Rightarrow \boxed{V_{rms} = \frac{Vm}{\sqrt{2}}}$$

*****

* 2) Full wave Rectifier :

V.V.V.V.V. Imp

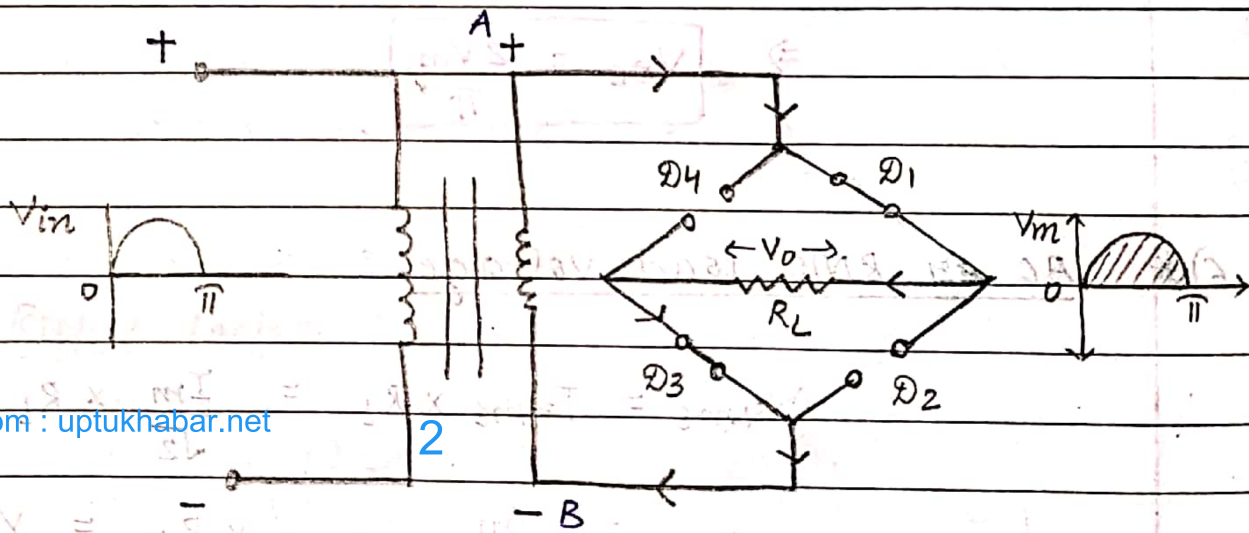
(ii) BRIDGE RECTIFIER :-



⇒ Circuit Description -

- It consists of a transformer and four diodes with load resistance.
- It gives output for both cycles.

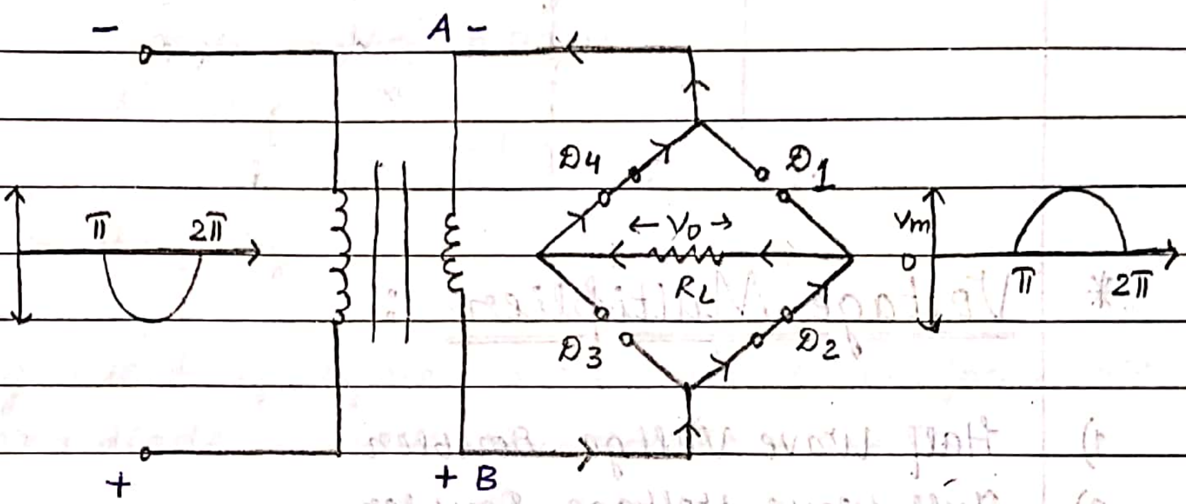
⇒ Working -



- In +ve half cycle, the +ve polarity will appear across the terminal A and -ve polarity will appear across the terminal B.

- In this cycle, the diode D_1 and D_3 will become forward bias and D_2 and D_4 will become reverse bias.

- The output across the load resistance 'R_L' will be in same phase with the input due to the diode D_1 and D_3 as shown in figure.



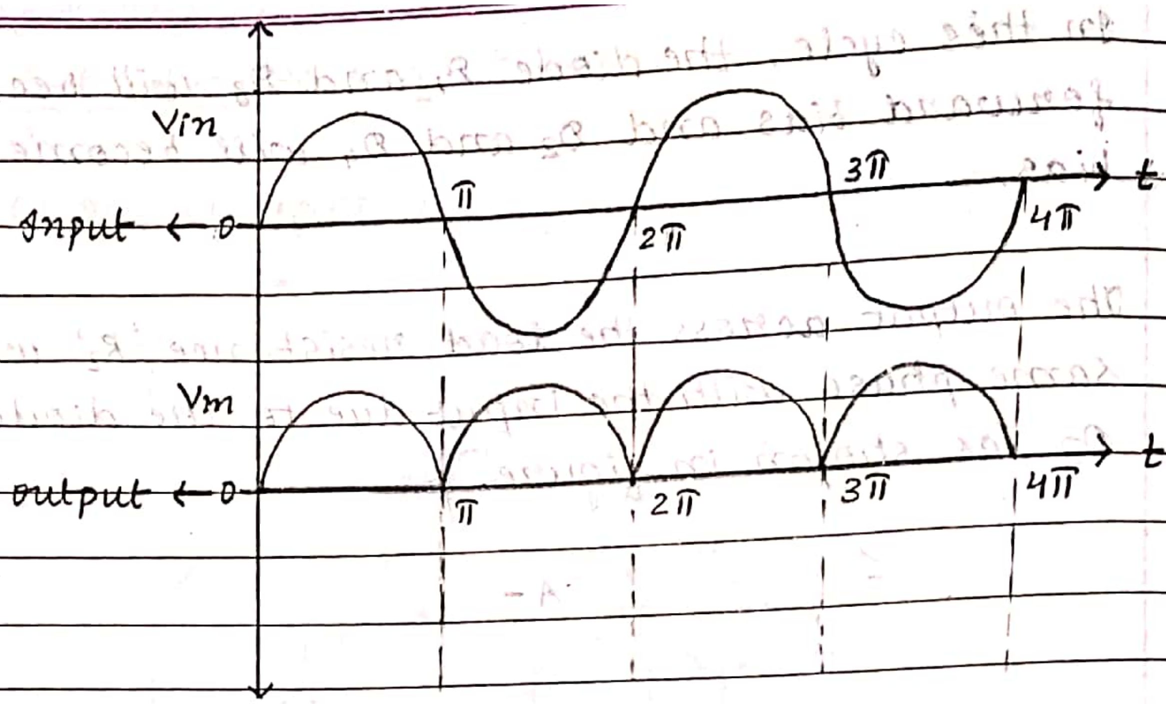
- In the −ve half cycle, the polarity gets reversed. Terminal A becomes −ve and B becomes +ve.

- In this cycle, D_2 and D_4 will be become forward bias and D_1 and D_3 will be in reverse bias.

- The output across the load resistance 'R_L' will be 180° outer phase with the input due to diode D_2 and D_4, or with the same phase as the +ve half cycle.

⇒ Input / output waveform −

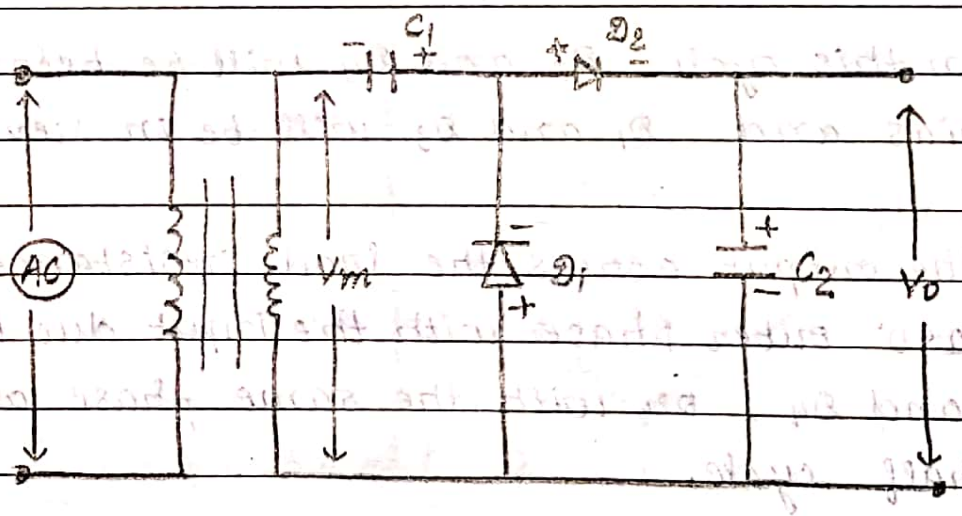
⟹



* Voltage Multiplier :

1) Half Wave Voltge Doubler
2) Full Wave Voltage Doubler
3) Voltage Tripler or quadrapler

* II) ⇒ HALF WAVE VOLTAGE DOUBLER :



⇒ Circuit Description –

- Half wave voltage doubler consists of two diodes and two capacitors along with the transformer as shown in the figure.

⇒ Negative Half cycle –

- During –ve half cycle, diode D_1 will be forward bias and D_2 will be reversed bias.

- In this cycle, capacitor C_1 will be charged through diode D_1 and it is given as,

$$-V_m + V_{C1} = 0$$

$$\boxed{V_{C1} = V_m}$$

⇒ Positive Half cycle –

- During +ve half cycle, diode D_2 will be forward bias and diode D_1 will be reverse biased.

- The capacitor C_2 will be charged through diode D_2, with the polarity of applied cycle.

$$V_m + V_{C1} - V_{C2} = 0$$

$$V_{C2} = V_m + V_{C1}$$

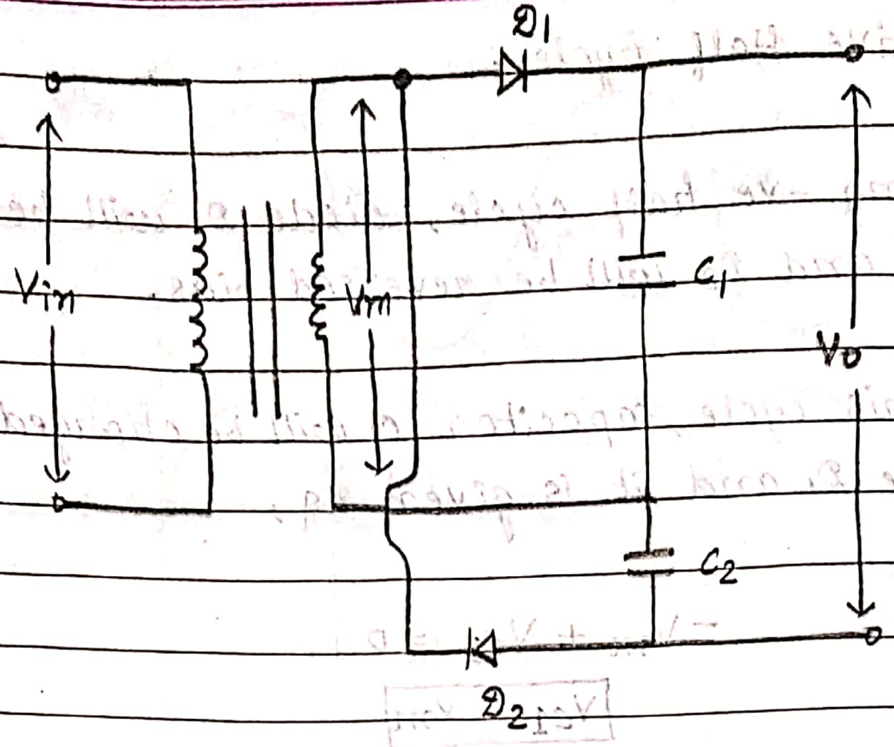
$$V_{C2} = V_m + V_m$$

$$\boxed{V_{C2} = 2V_m}$$

- The output will be equal to V_{C2}.

* (2) ⇒ FULL WAVE VOLTAGE DOUBLER :

⟹



⇒ Circuit Description –

- It consists of two diodes and two capacitors with a transformer.

⇒ Positive Half Cycle –

- During +ve half cycle, Diode d_1 will be forward bias and diode D_2 will be reversed bias.

+ C_1 −

- Capacitor C_1 will be charged through diode D_1 with the polarity of +ve cycle.

$$V_m - V_{C1} = 0$$

$$\boxed{V_{C1} = V_m}$$

⇒ Negative Half cycle –

- During −ve half cycle, Diode D_1 will be reversed bias and D_2 will be forward bias.

- Capacitor C_2 will be charged through diode D_2

* For full wave voltage doubler view the circuit carefully and then understand. In -ve cycle hidden signs are there.

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$\overset{+}{\underset{-}{=}} C_2$ with the polarity of -ve cycle.

$$V_m - V_{C2} = 0$$

$$\boxed{V_{C2} = V_m}$$

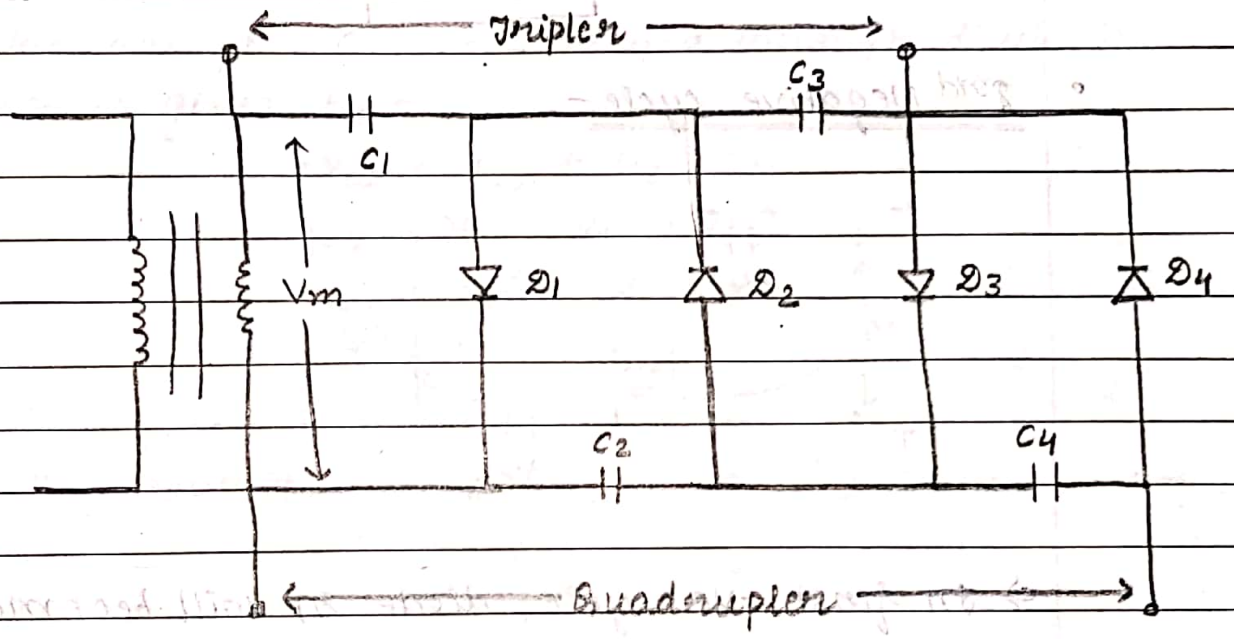
- Output will be equal to -

$$V_o = V_{C1} + V_{C2}$$

$$V_o = V_m + V_m$$

$$\boxed{V_o = 2V_m}$$

* (3) ⇒ <u>VOLTAGE TRIPLER OR QUADRUPLER</u> :

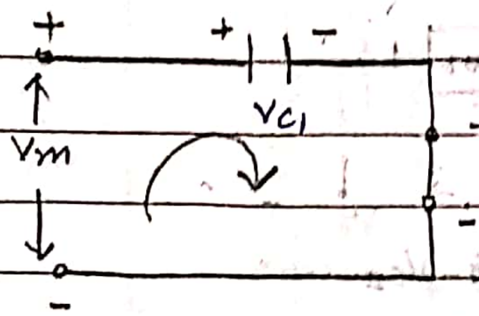


⇒ Circuit Description -

It consits of three diodes and three capacitors for Tripler along with a transformer and if for quadrupler then four diodes and four capacitors alongwith a transformer.

⇒ Working -

- ## 1^{st} Positive cycle -



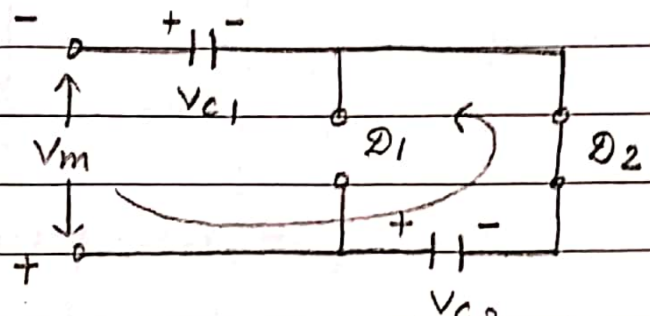
⇒ In first +ve cycle, Diode D_1 becomes forward bias.

⇒ The capacitor C_1 gets charged through diode D_1 and is given by -

$$V_m - V_{C1} = 0$$

$$\boxed{V_{C1} = V_m}$$

- ## 1^{st} Negative cycle -



⇒ In first -ve cycle, diode D_1 will become reverse bias (open circuit) and D_2 becomes forward bias (short circuit).

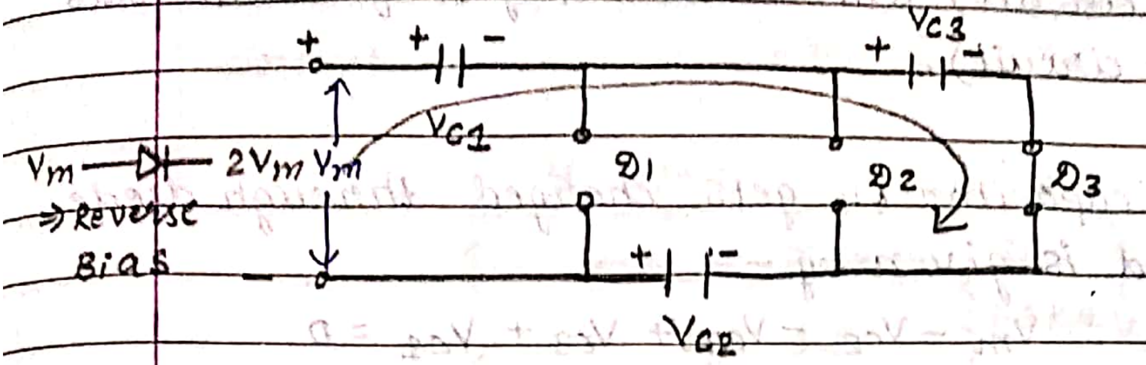
⇒ The capacitor C_2 gets charged through diode D_2 and is given by -

$$V_m - V_{C2} + V_{C1} = 0$$

$$V_m - V_{C2} + V_m = 0$$

$$\Rightarrow \boxed{V_{C2} = 2V_m}$$

- ## 2^{nd} Positive cycle –



(open circuit)

⇒ In this cycle, D_1 and D_2 are in reverse bias and diode D_3 becomes forward bias (short circuit).

⇒ The capacitor C_3 gets charged through diode D_3 and is given by –

$$V_m - V_{C1} - V_{C3} + V_{C2} = 0$$

$$V_{C3} = V_m - V_{C1} + V_{C2}$$

$$V_{C3} = \cancel{V_m} - \cancel{V_m} + 2V_m$$

$$\Rightarrow \boxed{V_{C3} = 2V_m}$$

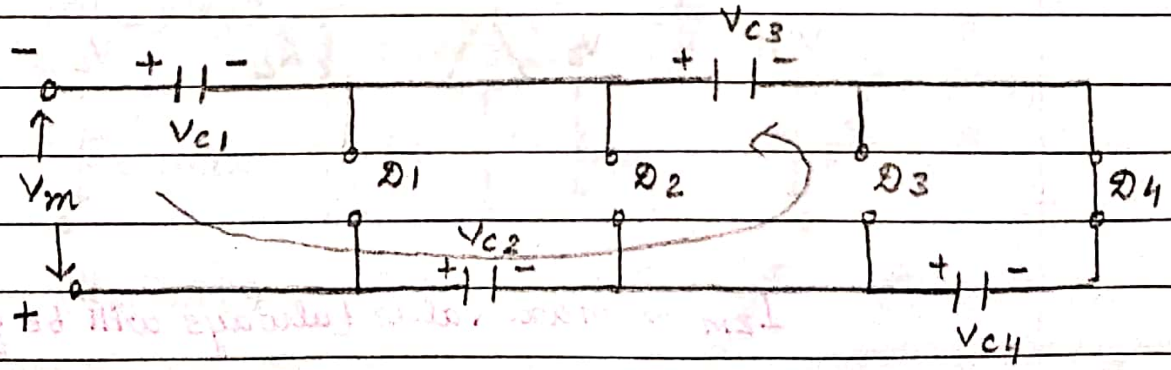
The output of the tripler is given by –

$$V_o = V_{C1} + V_{C3}$$

$$V_o = V_m + 2V_m$$

$$\boxed{V_o = 3V_m}$$

- ## 2^{nd} Negative cycle –



⇒ In this cycle, D_1, D_2, D_3 gets reversed bias (open circuit) and diode D_4 gets forward bias (short circuit).

⇒ The capacitor C_4 gets charged through diode D_4 and is given by -

$$V_m - V_{C2} - V_{C4} + V_{C3} + V_{C1} = 0$$

$$V_{C4} = V_m + V_{C1} - V_{C2} + V_{C3}$$

$$V_{C4} = \cancel{V_m} + \cancel{V_m} - 2\cancel{V_m} + 2V_m$$

$$\boxed{V_{C4} = 2V_m}$$

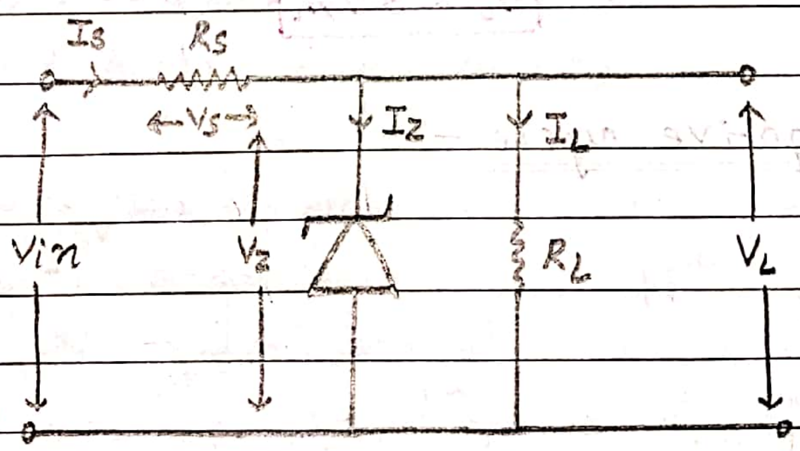
The output of the quadrupler is given by -

$$V_o = V_{C2} + V_{C4}$$

$$V_o = 2V_m + 2V_m$$

$$\boxed{V_o = 4V_m}$$

* ZENER DIODE AS A SHUNT OR VOLTAGE REGULATOR :-



I_{ZM} → max. value (always will be given)

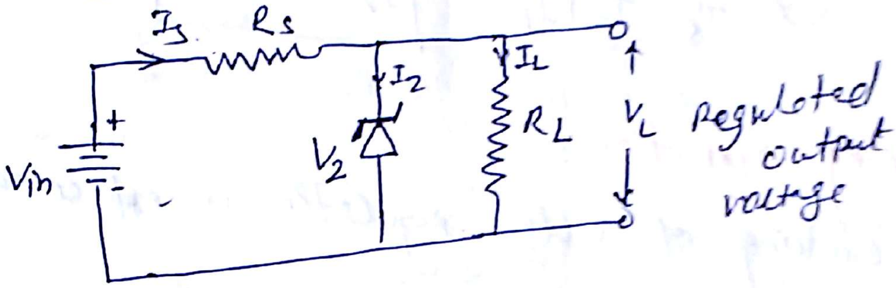
$I_{Z(min)}$ → 0 (always)

ZENER DIODE AS A VOLTAGE REGULATOR

⇒ Voltage Regulator is a circuit whose function is to maintain a constant output D.C. voltage inspite of the A.C. input variations or change in load resistance values.

Circuit Diagram

⇒ A zener diode as a shunt regulator circuit is shown in the figure



⇒ This is also known as shunt regulator because the zener diode is connected in shunt or parallel with the load.

⇒ The Resistance R_s is also known as current limiter resistor which is used to limit the current across the zener diode

⇒ The output or regulated voltage is obtained across the load resistor R_L

⇒ For the operation of the circuit, the input voltage V_{in} should be greater than zener diode voltage V_z. Then only zener diode operates in breakdown region.

⇒ To find the input current, Apply KVL in the 1st loop.

$\Rightarrow V_{in} = I_s R_s + V_z$ $\quad$ V_s = Input d.c. unregulated voltage

$\Rightarrow \boxed{I_s = \frac{V_{in} - V_z}{R_s}}$ $\quad$ V_z = voltage across zener diode.

⇒ The ideal zener diode may be assumed as a constant voltage source of voltage V_z.

⇒ The load voltage is then given by

$$\boxed{V_L = V_Z}$$

⇒ The current through the load resistance is given by

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

⇒ Applying KCL, the input current will be given by

$$I_S = I_Z + I_L \Rightarrow \boxed{I_Z = I_S - I_L}$$

Working operation

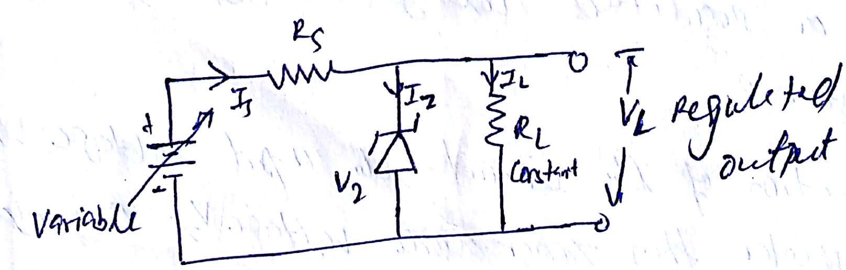
The working of voltage regulator is explained in two parts.

Case I: For variable input supply

⇒ In this case, the load resistance R_L is kept constant (fixed) and the input voltage (V_i) is varied.

⇒ When the input voltage increases, the input current I_s also increases.

Since $I_s = I_z + I_L$



⇒ This increased current I_s, increases the current through the zener diode without affected the load current.

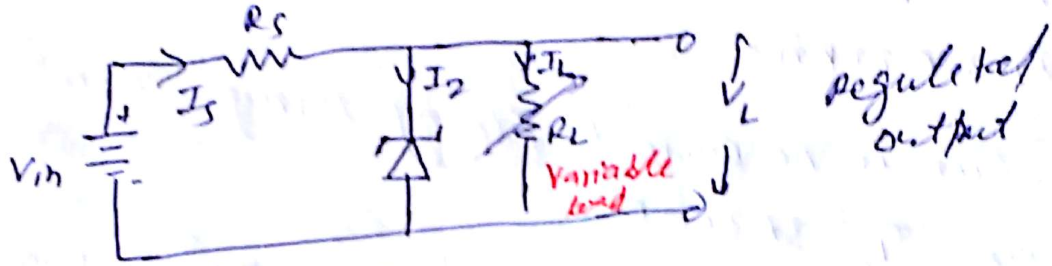
⇒ Due to increase in input current I_s, the voltage drop across resistence R_s also increases and keeping load voltage V_L constant.

=> Now, the voltage decreases, the input current also decreases. Due to this, the current through zener diode also decreases.

=> voltage drop across series resistance is reduced, hence the load voltage V_L and load current I_L remain constant.

Case II: For load resistance is variable input is fixed

=> In this case, the input voltage V_{in} is kept constant and the load resistance R_L is varied.



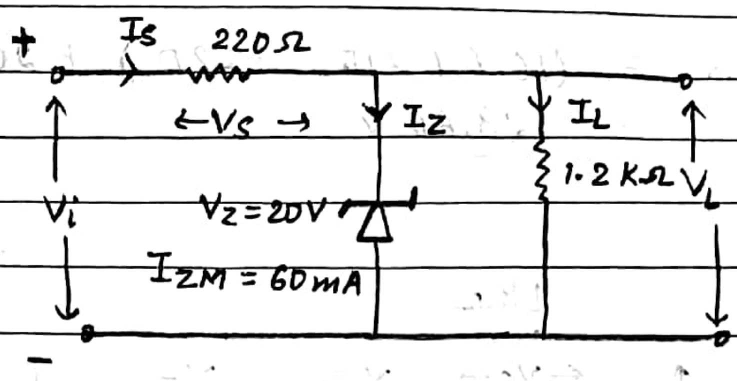
=> The load resistance R_L decreases, the load current increases. This cause zener diode current to decrease, due to this input current I_s & drop across the input resistance remains constant. Therefore the load voltage V_L is also constant.

=> Now the load resistance R_L, increases, the load current decreases. Due to this zener current increases.

=> This again keeps the values of input current & voltage drop across series resistance as constant.

=> Therefore, the load voltage remains constant.

Ques Determine the range of values of V_i that will maintain the zener diode in the ON state for the given circuit.



Sol^n Given − $V_Z = V_L = 20V$, $R_L = 1.2\,K\Omega$

$$I_L = \frac{20}{1.2 \times 10^{+3}} = 16.66 \times 10^{-3}\ A$$

$$I_L = 16.66\ mA$$

$$V_i = V_S + V_L \quad \text{or} \quad V_i = V_S + V_Z$$

$$\Rightarrow V_i = V_S + 20 \quad \text{—} ①$$

$$V_{i(max)} = V_{S(max)} + 20 \quad \text{—} ②$$

$$V_{i(min)} = V_{S(min)} + 20 \quad \text{—} ③$$

$$I_S = I_Z + I_L \quad \text{—} ④$$

$$\Rightarrow I_S = I_Z + 16.67 \quad \text{—} ⑤$$

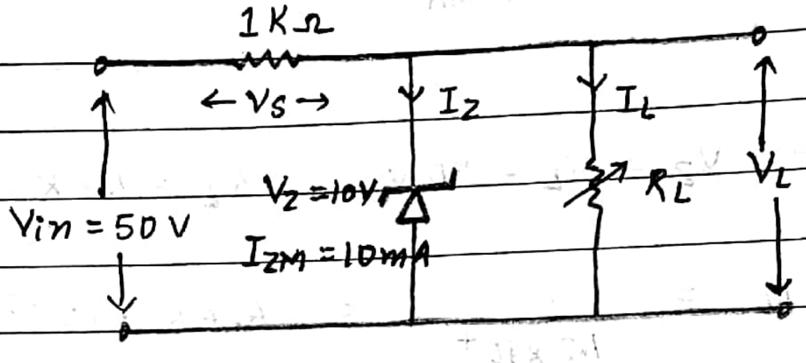
$$I_{S(max)} = 60 + 16.67 = 76.67\ mA$$

$$I_{S(min)} = 0 + 16.67 = 16.67\ mA$$

$$V_{i(max)} = I_{s(max)} \times 10^{-3} \times 220 + 20$$
$$= 76.67 \times 10^{-3} \times 220 + 20$$
$$= \underline{\underline{36.86\,V}}$$

$$V_{i(min)} = (16.67 \times 10^{-3} \times 220) + 20$$
$$= \underline{\underline{23.66\,V}}$$

Ques



Determine the range of R_L and I_L that will result in V_L being maintained at 10 V.

Soln Given – $I_{Z(max)} = 10\,mA$

$V_Z = V_L = 10\,V$

$$V_{in} = V_S + V_Z$$
$$50 = V_S + 10 \Rightarrow V_S = \underline{\underline{40\,V}}.$$

$$I_S = \frac{V_S}{R} = \frac{40}{1 \times 10^{+3}} = 40 \times 10^{-3}\,A = \underline{\underline{40\,mA}}.$$

$$I_S = I_Z + I_L$$
$$I_L = I_S - I_Z$$
$$\boxed{I_L = 40\,mA - I_Z} \quad \text{—— ①}$$

For the minimum value of $I_L \Rightarrow I_Z$ should be maximum

Maximum I_L then I_Z should be minimum

$$I_{L(max)} = 40 - 0 = 40 \text{ mA}$$

$$I_{L(min)} = 40 - 10 = 30 \text{ mA}$$

$$V_L = I_L \times R_L$$

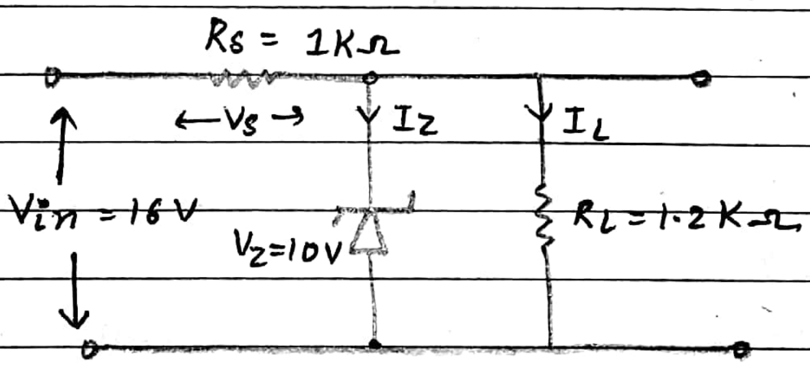
$$\Rightarrow R_L = \frac{V_L}{I_L}$$

R_L max. when I_L is minimum
R_L min. when I_L is max.

$$R_{L(max)} = \frac{10}{30 \times 10^{-3}} = 0.333 \text{ K}\Omega$$

$$R_{L(min)} = \frac{10}{40 \times 10^{-3}} = 0.250 \text{ K}\Omega$$

Ques.



Find out V_L, V_S, I_Z and P_Z (power across zener diode).

Sol^n

$$V_{in} = V_S + V_Z$$

$$16 = V_S + 10$$

$$\Rightarrow V_S = 6 \text{ V}$$

$$V_L = \frac{R_L \times V_{in}}{R_L + R_S} = \frac{1.2 \times 10^3 \times 16}{1.2 \times 10^3 + 1 \times 10^3} = 8.72 \text{ V}$$

$$I_L = \frac{V_L}{R_L} = \frac{8.72}{1.2 \times 10^3} = \underline{\underline{7.27\,mA}}.$$

$$I_S = I_Z + I_L$$

$$I_S = \frac{V_S}{R_S} = \frac{6}{1 \times 10^3} = \underline{\underline{6\,mA}}.$$

$$\Rightarrow \quad I_S = I_Z + I_L$$

$$I_Z = I_S - I_L = 6 - 7.27$$

$$=$$

* Special Purpose Diode :

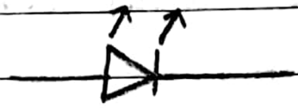
1) LED
2) LCD
3) Tunnel Diode
4) Varactor Diode
5) Photo Diode

1) •→ LED (Light Emitting Diode) :

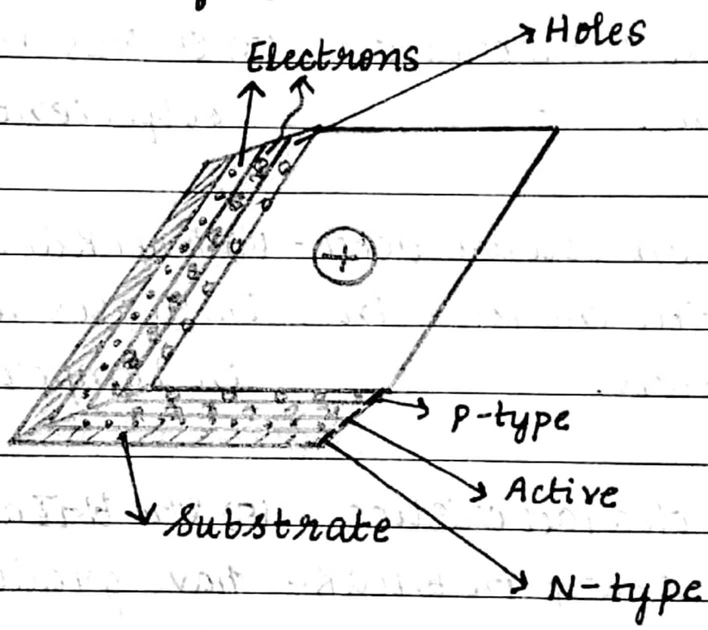
⇒ It is an optoelectronic device (which emits light).

⇒ It is an optical diode which emits light when it is in forward biased.

⇒ Symbol of LED ⇒



⇒ Construction of LED -



• The construction of LED is made up of depositing semiconductor layer on the substrate.

• The active region is between p-type and n-type semiconductors.

- Electrons and holes recombine in active region and emits light.

⇒ Basic operation –

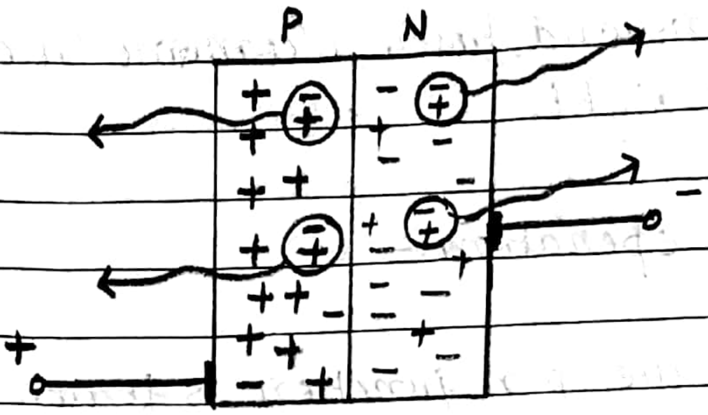
- When the p-n junction is forward bias, e^-s cross the junction from n-type to p-type and recombine with holes. The similar operation is being taken place in LED diode.

- In LED diode, GaAs (Gallium Arsenide) is used as a semiconductor material, in case of forward bias, the electrons and holes moves at active region where they recombine. According to the property of GaAs, it emits light (invisible) while recombination.

- The free e^-s releases energy in the form of photons which emits light energy also called Electroluminescece

- In silicon and germanium diode, the greater percentage of energy is converted in the form of heat during recombination, that's why, they are not used under construction of LED devices.

- Various impurities are added during doping process to control the wavelength of different colour of emitted light.
  [GaN → Blue, GaP → Green, GaAsP → Red or orange]

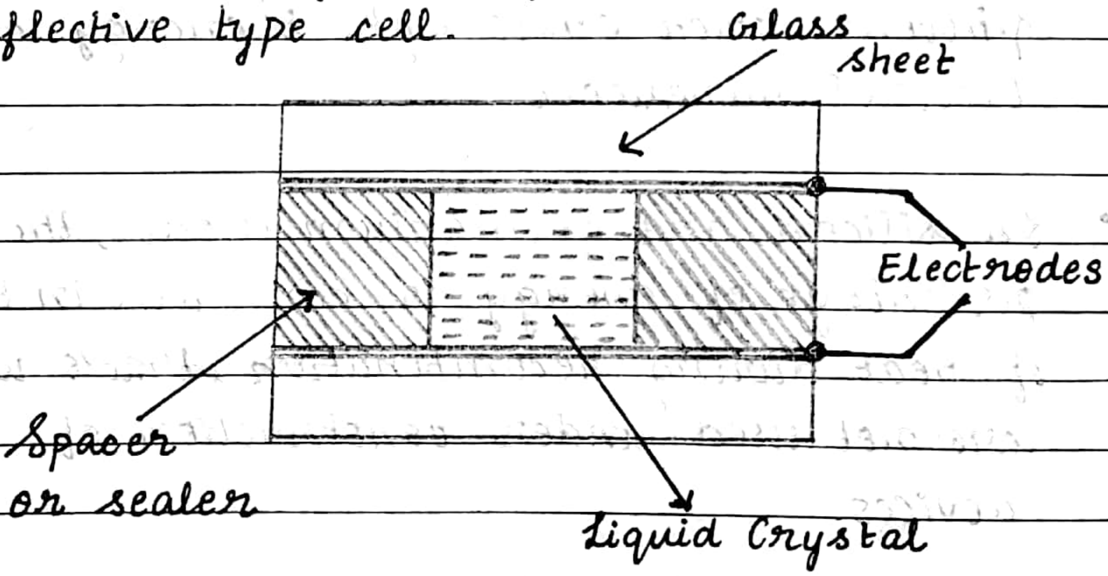


2)• → **LCD (Liquid Crystal Display):**

⇒ It consists of thin layer of liquid crystal sandwiched between two glass sheets with transparent electrodes.

⇒ If both the glass sheets are transparent then it is called transmittive type cell.

⇒ If only one glass sheet is transparent and other have refectling coating, the cell is called Reflective type cell.



⇒ Types of Displays of LCD :-

(a) Field Effect LCD

(b) Dynamic Scattering Display LCD

(a) → Field Effect LCD :

- It consists of front and back polariser at right angles to each other.
- Without electrical excitation, the light coming through the front polariser is rotated by 90° in the fluid and reflected back by the mirror.
- When electrostatic field is applied, liquid crystal molecules rotate 90° so that light is not reflected and absorbed by the real polariser. And, this results in dark digits on light background.

(b) → Dynamic Scattering Display LCD :

- When this display is energised, the molecules of energised area become turbulant and scatters light in all the directions. And, this activated area results in silver display.

⇒ Appications of LCD :

- Seven segment Display watches, portable instruments, television display.

V.Imp

3). → Tunnel Diode :
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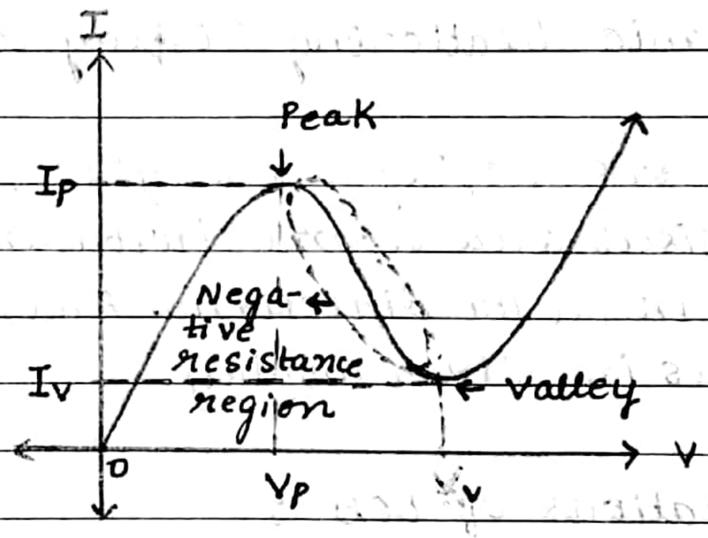
→ The tunnel diode is a two terminal pn-junction heavily doped about thousand times higher than a conventional diode & it has very high conductivity.

⇒ Due to heaving doping, the depletion layer width is reduced and because of ~~de~~ reduced depletion layer carriers penetrate through the junction even when they don't possess enough energy to overcome the barrier.

⇒ In mechanism of conduction in which charge carriers having very little energy penetrates a barrier instead of climbing over it is called Tunneling. And, the diode constructed using this phenomenon is called Tunnel Diode.

⇒ VI - characteristics of Tunnel Diode :



1. For small value of voltage, resistance remains small and current attains a peak value 'I_p' corresponding to 'V_p'.

2. At peak, $\frac{dI}{dV} = 0$ where $\frac{dI}{dV}$ represents a slope.

3. Furthur, voltage increases current will decrease and $\frac{dI}{dV}$ becomes -ve and this -ve resistance

4. Furthur increasing the voltage, there will be exponential rise in current as in normal pn-junction diode.

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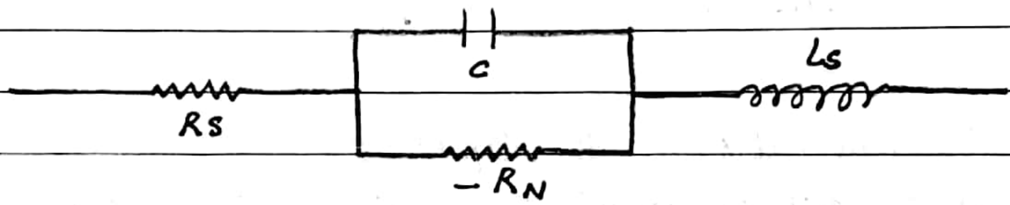
continue upto the value voltage 'V_V' corresponding to current 'I_V' and $\frac{dI}{dV}$ becomes 0 (zero) again.

⇒ Symbol of Tunnel Diode :

⇒ Equivalent Circuit :



4). ⇒ Varactor Diode :-

- In practice, a special type of diode is manufactured which shows the transistor capacitance property more predominantly as compared to conventional diode, is called Varactor Diode.

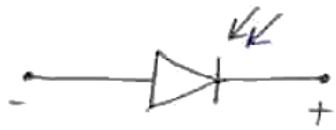
$$C_T = \frac{K}{(V_J + V_R)^n}$$

⇒ Applications of Varactor Diode:

- Tuned circuit
- FM modulator
- Automatic Frequency controlled device

5. Photo Diode

- It is a special type of PN junction device that generates current when exposed to light is known as photo diode. It is also known as photodetector or photosensor. It operates in reverse biased mode and converts light energy into electrical energy
- Symbol



Working

- In the photodiode, a very small reverse current flow through device, that is termed as dark current. It is when the device is not exposed to radiation.
- When device exposed to light, temperature of diode increases so the minority charge carriers increases. This generates high reverse current
- This current shows that there is radiation or light. or we can say that energy of light is directly proportional to current through the device.