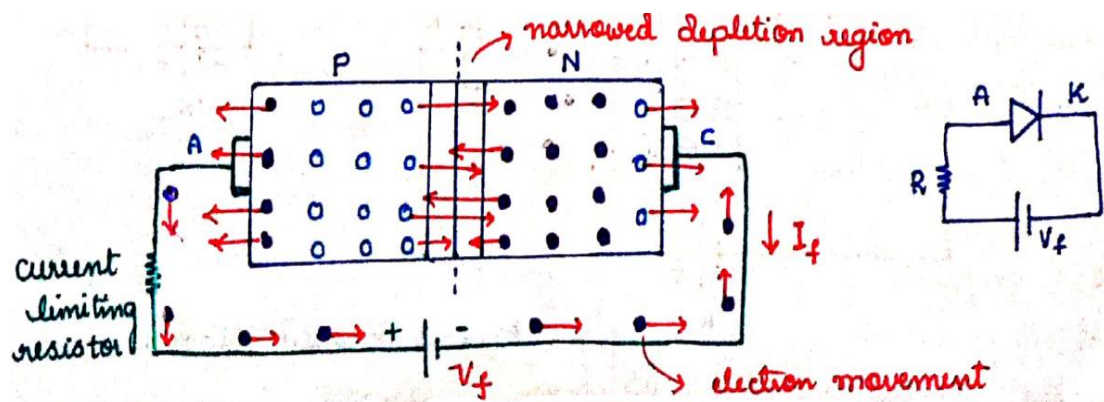


PN junction Diode:

- When P-type and N-type semiconductors are placed in contact with one another, it forms a PN junction.
- PN junction forms a popular semiconductor device called diode
- A diode is a two terminal semiconductor device which conducts only in one direction offering a low resistance when forward biased and high resistance when reverse biased.

Forward Biasing PN-Junction:

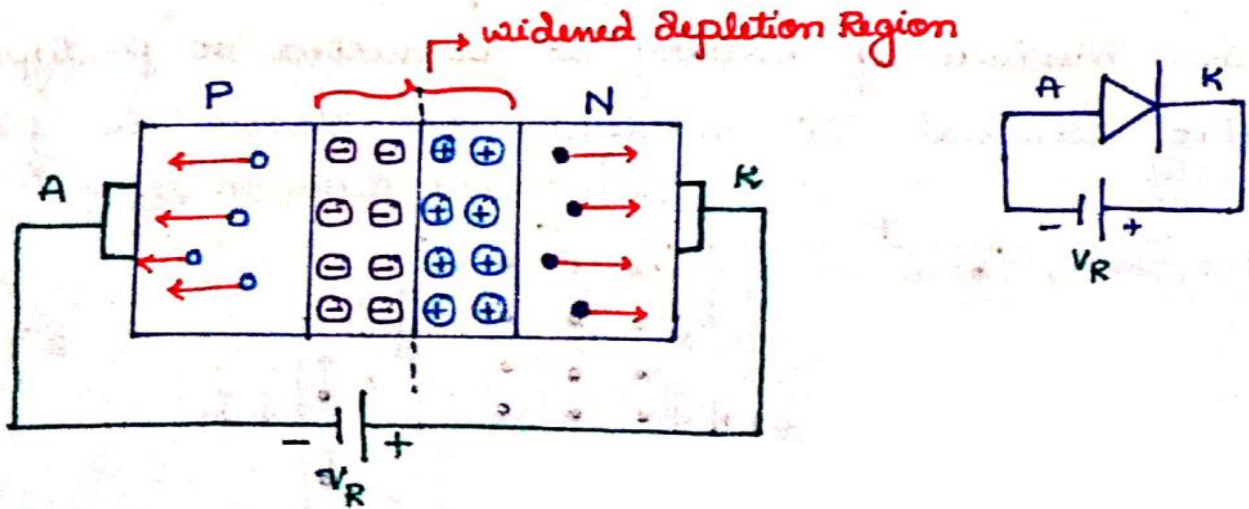
- PN Junction is said to be forward biased when the positive terminal of battery is connected to p-type and negative terminal of battery is connected to n-type as shown in fig.



- If the applied voltage is less than the barrier potential, there will be no conduction
- When the applied voltage is more than the barrier potential, then the holes on p-side which are positively charged gets repelled from positive terminal and driven towards junction.
- Similarly the electrons on n-side which are negatively charged gets repelled from negative terminal and move towards the junction.
- This result in the reduction of barrier potential, hence resulting large current known as forward current starts flowing as shown in fig.

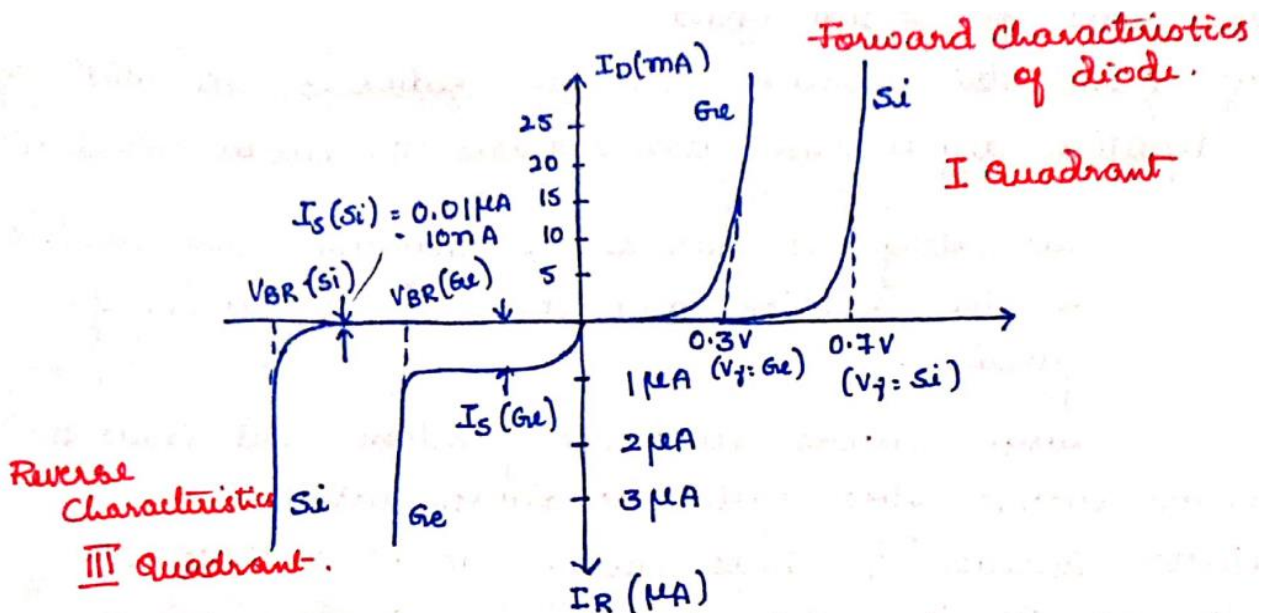
Reverse Biasing PN-Junction:

- PN Junction is said to be reverse biased when the positive terminal of battery is connected to n-type and negative terminal of battery is connected to p-type as shown in fig.



- When PN junction is reverse biased, then the holes on p-side of junction are attracted towards negative terminal and the electrons on n-side of junction are attracted towards positive terminal of battery.
- Thus holes on p-side and electrons on n-side move away from the junction thereby increase the barrier potential.
- If the barrier voltage is increased, majority charged carriers cannot cross the junction and there is no current flow across the junction.
- Minority charge carriers cross the junction and leads to a small current flow called reverse current as shown in fig.

V-I characteristics of diode:



Forward characteristics of diode:

- The positive terminal of battery is connected to p-type and negative terminal of battery is connected to n-type.
- If supply voltage is less than the cut in voltage (0.7V for Si and 0.3V for Ge) of diode, then forward current very low.
- If supply voltage is greater than the cut in voltage, then forward current increases linearly.

Reverse characteristics of diode:

- The positive terminal of battery is connected to n-type and negative terminal of battery is connected to p-type.
- Due to motion of minority carriers, a small reverse saturation current exists.
- At point A, reverse breakdown of diode occurs and current increases sharply.

Diode parameters:

Cut-in voltage/Knee voltage: it is the forward voltage at which the diode starts conducting.

Breakdown voltage (V_{br}): It is the reverse voltage at which the diode breaks down with sudden rise in reverse current.

Peak inverse voltage (PIV): It is the maximum reverse voltage that can be applied to a p-n junction diode without causing any damage to the junction.

Reverse saturation current (I_r): It is the maximum reverse current produced due to the flow of majority carriers across the pn junction at a given temperature.

Maximum forward current (I_{fmax}): It is the maximum current a diode can allow under forward biased condition without any damage to it.

Maximum Power rating (Power dissipation P_d): It is the maximum power that can be dissipated at the junction without damaging it.

Equivalent circuit of diode (Diode approximation):

- There are three Equivalent circuit model of diode

1) **Ideal diode model:**

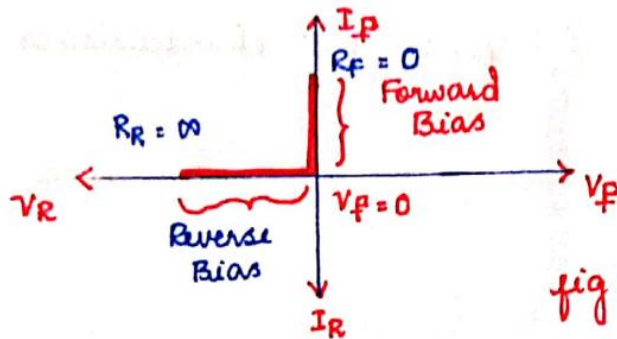
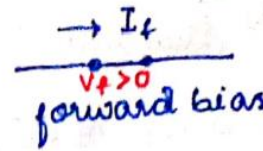
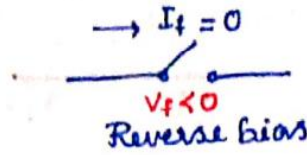
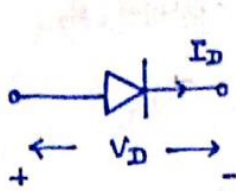


fig : Ideal diode characteristics

- An ideal diode offers zero forward resistance and infinite reverse resistance.
- The forward voltage drop is zero and reverse current is also zero.

2) **Approximate model/Practical model:**

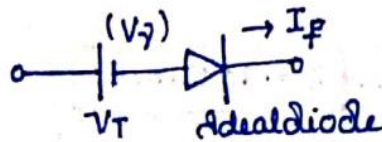


fig : Approximate Model

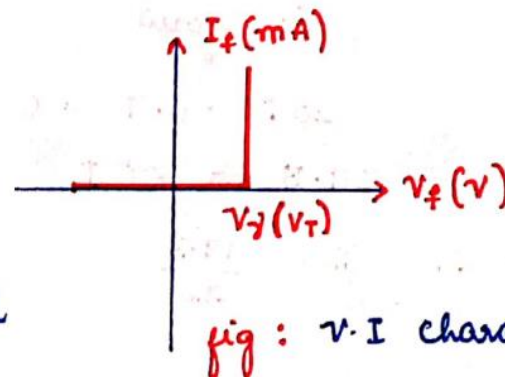
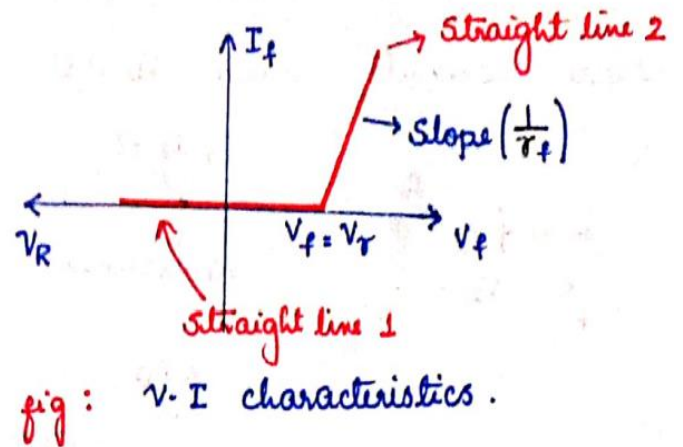
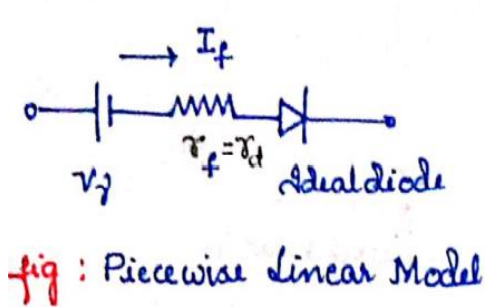


fig : v-I characteristics

- A practical diode offers zero forward resistance and infinite reverse resistance.
- The forward voltage drop is not zero.

3) Piecewise linear model:



- When the forward characteristics of a diode is straight-line approximation then it is called piecewise linear characteristics.

Rectifier:

- An electrical device used to convert ac voltage into pulsating dc voltage.
- Rectifiers are classified into 2 categories depending on period of condition
 1. Half wave rectifier
 2. Full wave rectifier –which is further classified into
 - a) Center tapped full wave rectifier
 - b) Bridge rectifier

Half-wave rectifier:

- Rectifiers which conducts current or voltage only during one half cycle of ac input is called half wave rectifier.
- Fig shows half wave rectifier, which single diode acts as half wave rectifier.
- AC input supply to be rectified is applied through transformer to diode D and series load resistor RL

Circuit Diagram

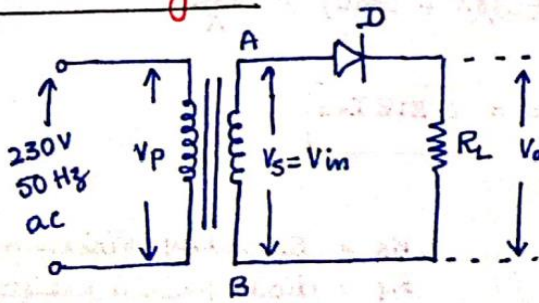


fig : circuit diagram

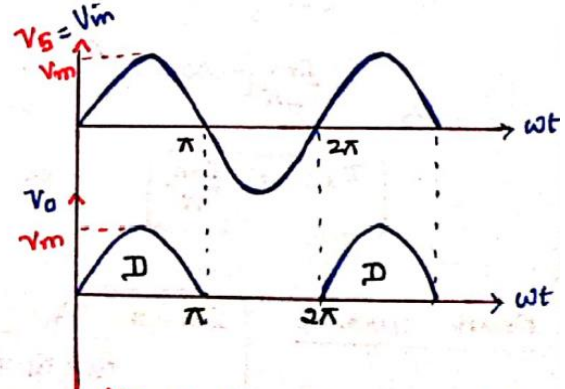


fig : d/p - o/p waveforms

Operation:

- During positive half cycle of supply voltage, diode is said to be forward biased and acts as a short circuit and current flows through R_L . Therefore $V_0 = +V_{in}$
- During negative half cycle of supply voltage, diode is said to be reverse biased and acts as an open circuit, no current flows through R_L . Therefore $V_0 = 0$.

Full wave rectifier:

- Full wave rectifier converts both the half cycles of input ac signal to pulsating dc.
- It consists of two diodes as shown in figure.
- Center tapping in the secondary of the transformer is done to obtain two equal voltages but of opposite phase.

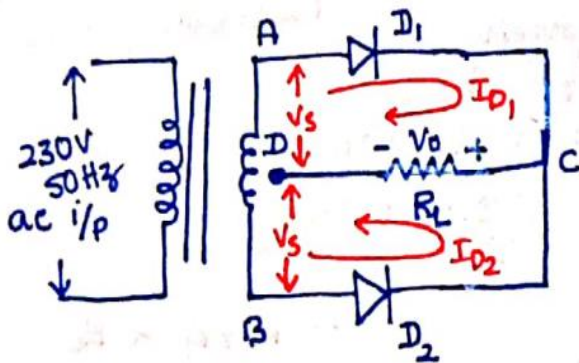


fig: circuit diagram

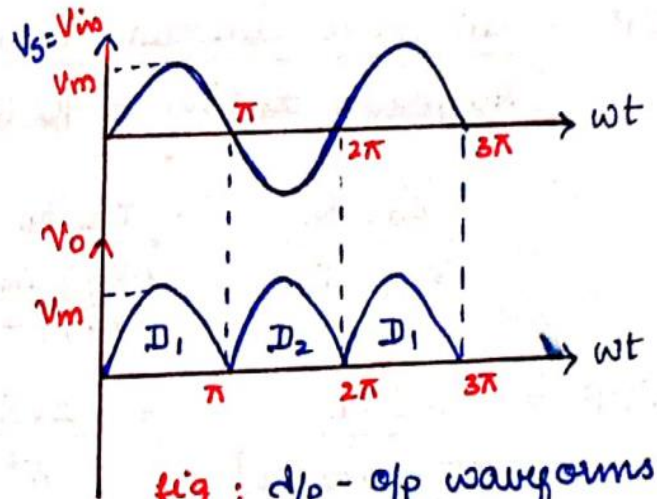


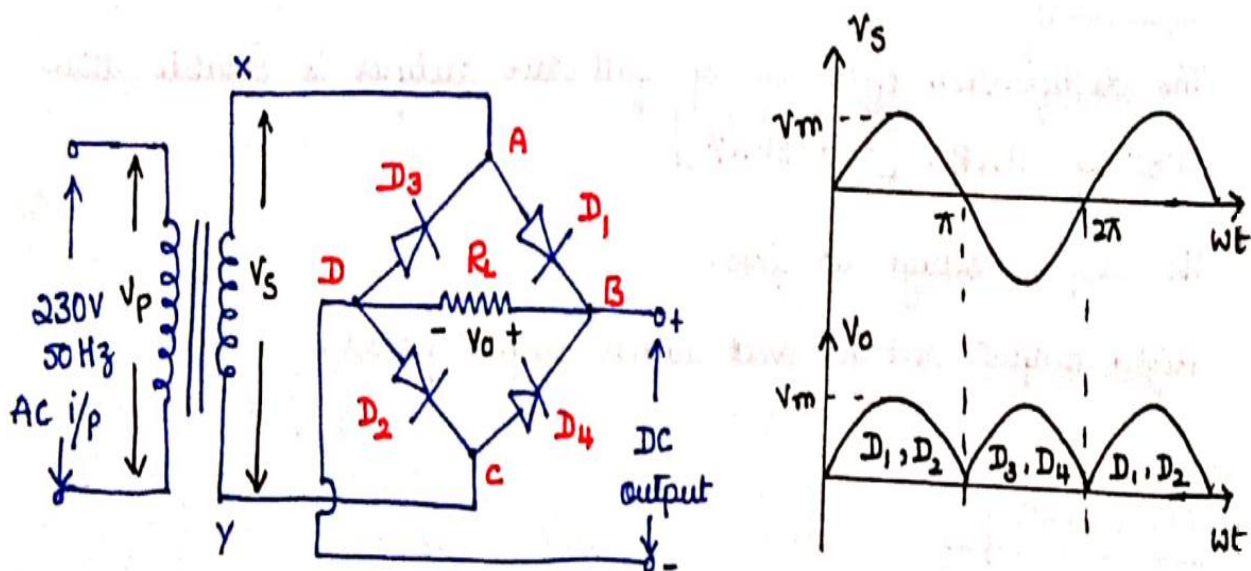
fig : d/p - o/p waveforms

Operation:

- During positive half cycle of supply voltage, terminal A is positive and terminal B is negative due to center tap transformer. Diode D1 will be forward biased and hence conduct, while D2 will be reverse biased and will not conduct. As D1 conducts, current flows through the path A-D1-C- R_L -D. Therefore $V_o = +V_{in}$.
- During negative half cycle of supply voltage, terminal A is negative and terminal B is positive due to center tap transformer. Diode D1 will be reverse biased, while D2 will be forward biased and hence conduct. As D2 conducts, current flows through the path B-D2-C- R_L -D. Thus current keeps on flowing through R_L .

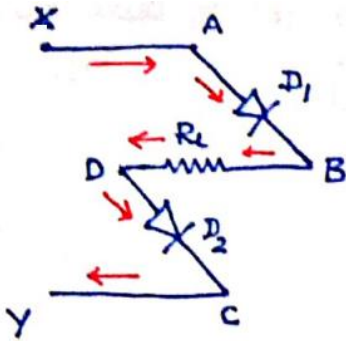
Full wave bridge rectifier:

- It is most popular rectifier.
- It requires four identical diodes to form a bridge network. The circuit consists of four diodes D1, D2, D3 and D4 connected across secondary of transformer and load R_L .
- The secondary of transformer is connected to node points A and C and the load resistor (R_L) is connected to other node points B and D.

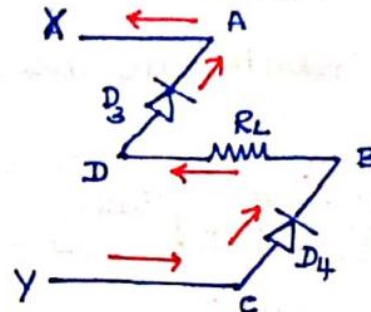


Operation:

- During the positive half cycle, the point X is positive and Y is negative. Diodes D1,D2 are forward biased acts like closed switch and D3,D4 are reverse biased and acts like a open switch and current flows through R_L through the path X-A-B- R_L -D-C-Y as shown below.



During +ve half cycle



During -ve half cycle

- During the negative half cycle, the point X is negative and Y is positive. Diodes D1, D2 are reverse biased and D3,D4 are forward biased and current flows through R_L through the path Y-C-D4-B- R_L -D-D3-A-X as shown above.

Filter circuit:

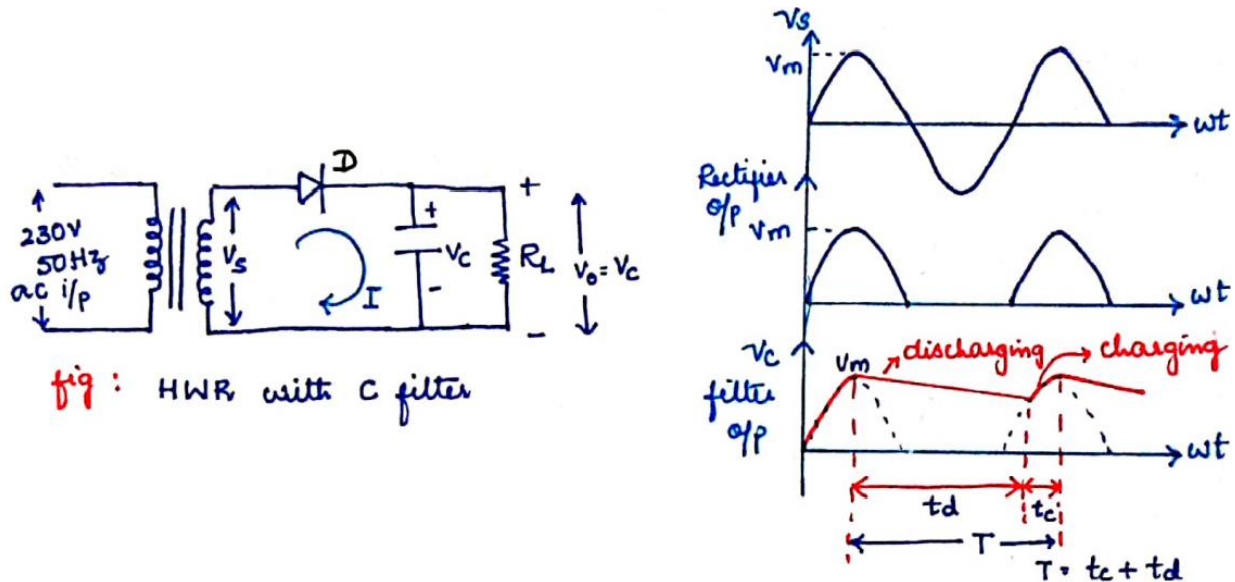
- Filter circuit are used to remove the ac component present in the output obtained from rectifier.
- Filters are the circuits which converts pulsating dc to pure dc.
- Capacitor and inductor are used in filter circuits.
- Filter circuit are connected between rectifier and load.
- Most popular used filters are capacitor and RC filter.

Capacitor Filter circuit:

- In capacitor filter circuit, capacitor is connected parallel with the output of the rectifier in a linear power supply.
- Capacitor increases the dc voltage and decreases the ripple voltage components of the output.

Half wave rectifier with capacitor filter:

- Half wave rectifier with capacitor filter is as shown in figure.

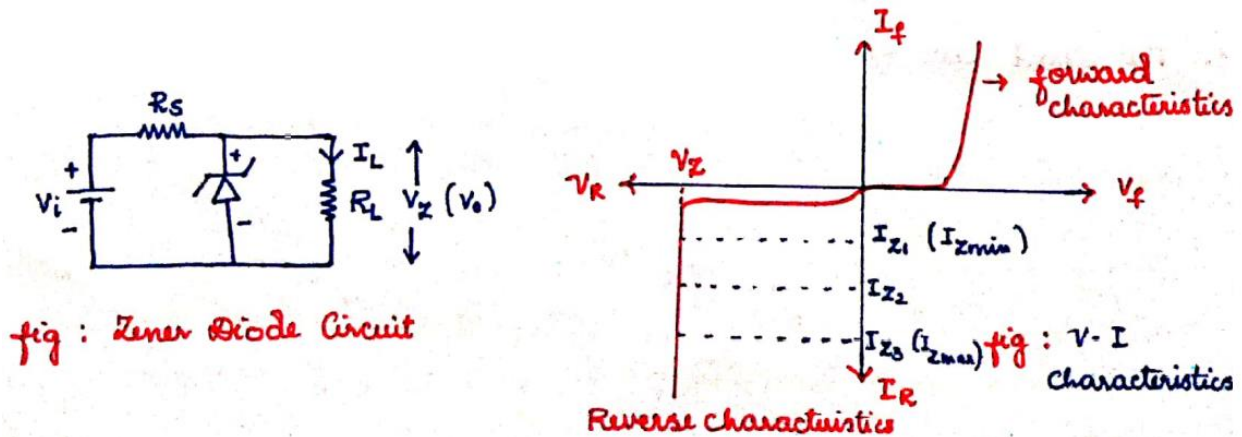


- During positive half cycle of input, diode is forward biased and capacitor charges to a peak value V_m as shown in fig.
- When input starts decreasing below its peak value, capacitor will be fully charged and holds the charge until the input ac supply to the rectifier reaches the negative half cycle.
- During negative half cycle of input, diode gets reverse biased and blocks the current through it. During this non-conduction period, V_s is less than V_c so the capacitor discharges through R_L until V_c is less than V_s . this cycle repeats producing a very smooth dc voltage.
- Time required by the capacitor is very small to charge while its discharging time is very large, ripple in the output gets reduced.

Zener diode characteristics:

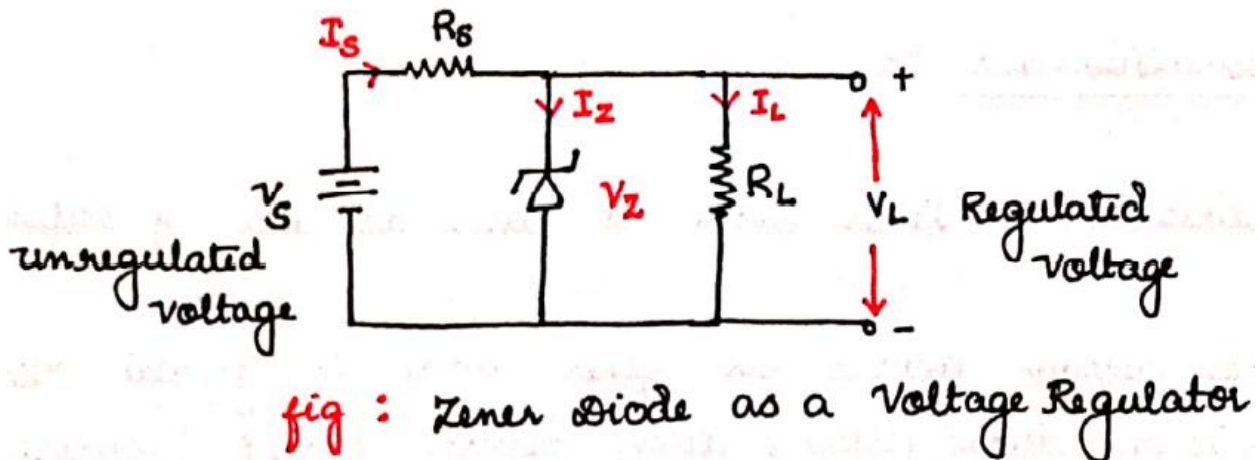
- Forward characteristics of zener diode is same as that of ordinary diode.
- When the reverse voltage across the zener diode is greater than V_z , the breakdown takes place, then reverse current increases rapidly.

- Under reverse biased condition there is a small leakage current of order of nA flowing through the diode initially but after certain voltage, breakdown occurs and the current increases at a constant voltage.



Zener diode as Voltage Regulator:

- A zener diode can be used as a voltage regulator, since it maintains a constant output voltage even though the current through zener changes.

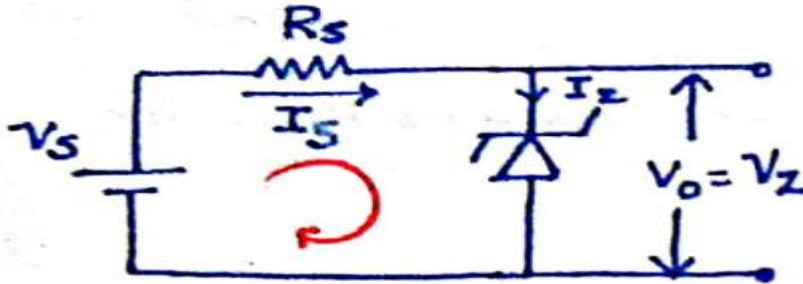


- Fig shows the zener diode as voltage regulator, zener is connected in parallel with the load, therefore the circuit is also known as shunt regulator.
- A resistance R_s is connected in series with zener to limit current in the circuit. Through R_s is also known as series current limiting resistor.
- Zener to work as voltage regulator, the following conditions must be satisfied.
 - a) Zener diode must be reverse biased.

- b) Input voltage must be greater than zener breakdown voltage.
- c) The load current should be less than $I_{z(max)}$.

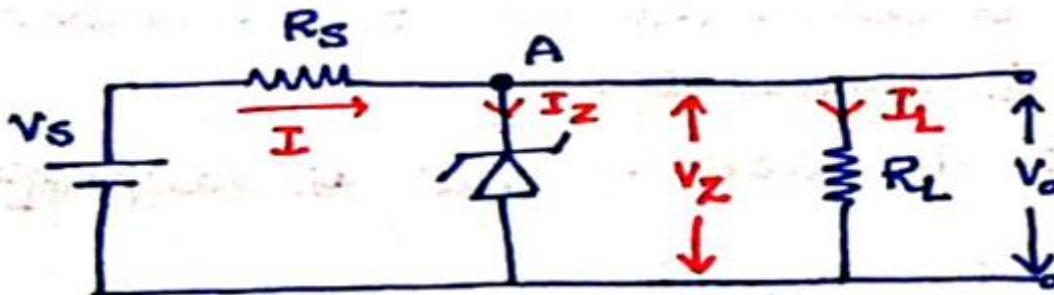
Regulator with no load:

- The resistor R_s is used to limit the zener diode current to desired value.



Regulator with load:

- Consider the circuit as shown in fig, the current through R_s is sum of load current and zener current, but care must be taken to ensure that $I_{z(min)}$ is greater to keep zener under breakdown region. 11



Problems:

- 1) Determine the peak output voltage and current for a bridge rectifier circuit when the secondary RMS voltage is 30V and the diode forward drop is 0.7V.
- 2) A diode with $V_F=0.7V$ is connected as a half wave rectifier. The load resistance is 500Ω and the secondary RMS voltage is 22V. Determine the peak output voltage and the peak load current.