Semi-Conductor - 2

Intrinsic ~~Co~~ Semiconductor

The extrimely pure form of a semi-conductor is called intrinsic semi-conductor. For example Silicon (Si), Germanium (Ge).

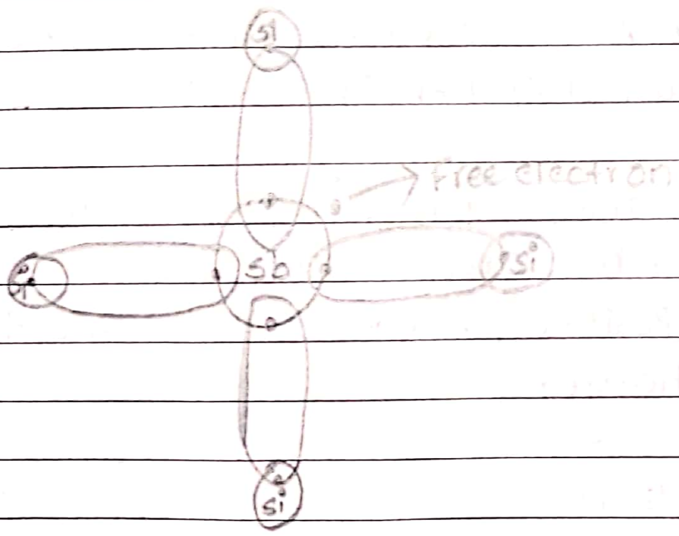
Their conductivity is small. The number of electrons and holes are equal.

Extrinsic Semiconductor

It is formed by doping impurities in pure semiconductor. It is of two type:

1. N-Type Semiconductor

It is formed by adding pentcovalent impurity [P, antimony (Sb) etc]

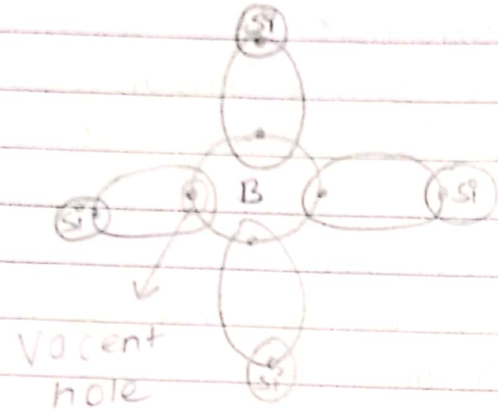


- Number of electrons in conduction bond is greater than number of holes in valance bond.

- This semiconductor, electrons are majority charge carriers & holes are minority charge carriers.

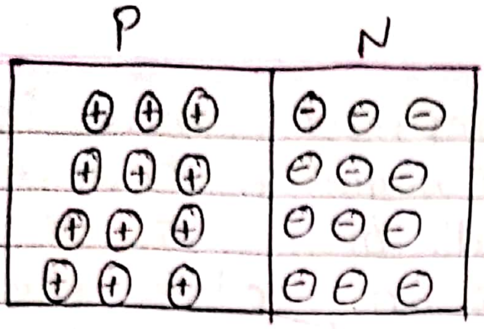
- N-type (Negative) because electrons are -vely charge particles.

2. P-type Semiconductor
It is formed by adding trivalent impurity (B, Al) in pure Semi-conductor.



- Here, Number of holes in valance bond is greater than number of electrons in conduction bond.
- Majority charge carrier are holes & minority charge carrier are electrons.
- P-type (Positive) because holes are treated as positive charge.

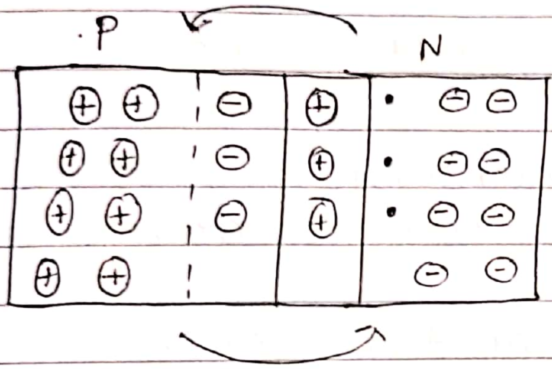
P-N Junction
When p-type Semiconductor is suitabley connected with N-type semi-conductor, a Junction formed is called p-N Junction. And the material formed by combining N-type & p-type semi-conductor is called p-N Junction diode.



$\ominus \rightarrow$ electrons

$\oplus \rightarrow$ Hole

Depletion layer & Barrier potential



$-ve \rightarrow$ electrons

$+ve \rightarrow$ Holes

As soon as, a PN Junction is formed electrons from N-region diffuse by P-region and get neutralized by combining with hole. Some electrons become immobile & remain near the Junction.

Similarly, holes from p-region diffuse into N-region & neutralized by combining with electrons. But some holes becomes ~~N-regi~~ immobile near the Junction in N-region.

So, a layer of positive & negative charge is formed near the Junction called depletion layer.

V_B for Ge = 0.3 V

V_B for Si = 0.7 V

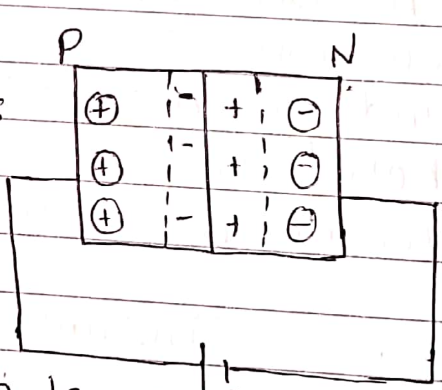
In the depletion layer is the group of positive & negative charges seperated by a distance. These charges produces an electric field called barrier field & the potential ~~barrier~~ developed at the junction is called barrier potential. Barrier potential prevents further diffusion of charge carriers across the junction.

Biasing of P-N Junction diode

Connecting an external battery to a PN junction diode is called biasing of PN junction diode.

It is of two types:

i) Forward Biasing



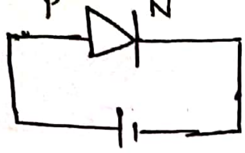
→ In this biasing p-side is connected to +ve terminal & N-side is connected to -ve terminal of a battery.

→ The thickness of depletion layer is small

→ Barrier potential is reduced.

→ The flow of current is due to majority charge carriers.

ii) Reverse Biasing



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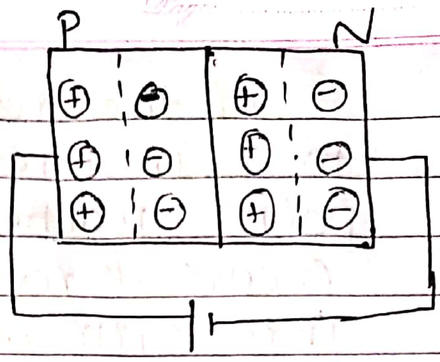


→ In this biasing p-side is connected to -ve terminal & N-side to +ve terminal of battery

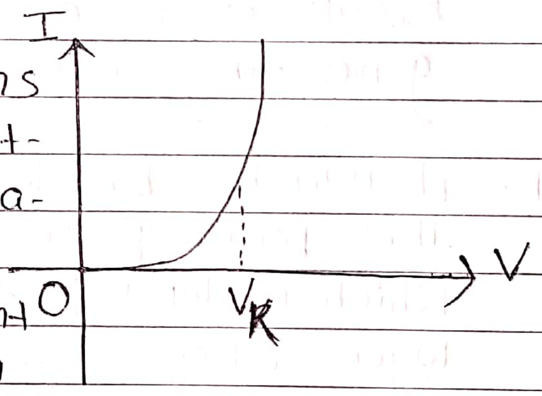
→ The thickness of depletion layer is large.
→ Barrier potential increases
→ The flow of current is due to minority charge carriers.

Characteristics of a PN Junction diode

A graph plotted between current & voltage of a p-N junction diode is called characteristics of a diode.

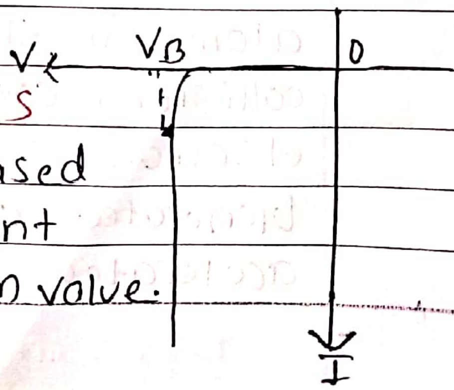
1) Forward bias characteristics

When the voltage is increased current remains zero upto barrier potential. As the applied voltage goes beyond barrier potential initially current rises gradually & after a certain voltage current increases rapidly. A voltage at which current increases steppily (suddenly) is called knee voltage (V_K).



2) Reverse bias characteristics

As the reverse voltage increased from zero, the reverse current rises quickly to it's maximum value.



If the reverse bias voltage applied to P-N junction diode is increased, a point reached when junction breakdown occurs & reverse current rises sharply. This critical value of voltage is known as breakdown voltage.

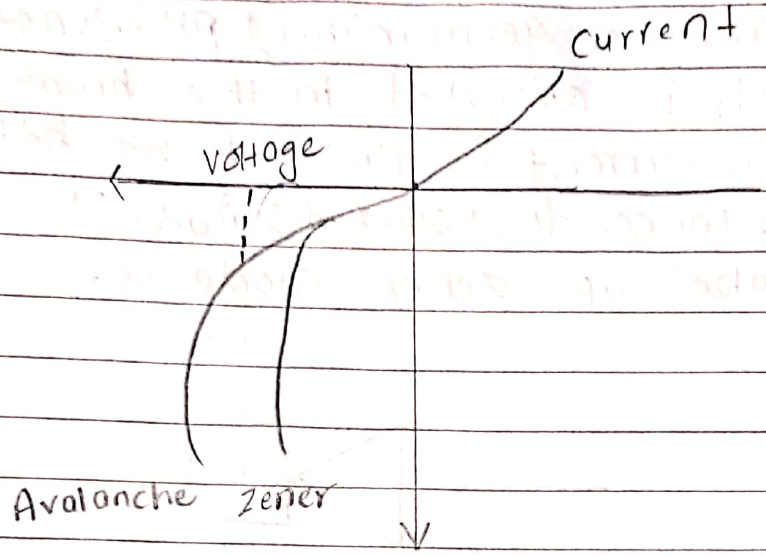
Junction breakdown occurs by two mechanism:-

a Zener breakdown

It occurs near a junction in which diodes are heavily doped having narrow depletion layer. This breakdown voltage sets up a strong electric field (10^8 V m^{-1}). This field is strong ~~in off~~ enough to break a covalent bond there by generating electron holes pairs.

b. Avalanche breakdow

This form of breakdown occurs in junctions which is lightly doped, have wide depletion layer where the electric field not so strong as like zener breakdown. In this case minority carriers are accelerated by electric field & colide with the semiconductor atoms in the depletion region. Due to collision, covalent bonds are broken and electron whole pair are generated. Newly generated charge carriers are further acclerated by electric field resulting in more collisions and hence produced large numbers of carriers.



Different between Zener breakdown & Avalanche breakdown.

	Zener breakdown	Avalanche breakdown
1.	In semiconductor, occurs from the collision of carriers with crystal ion of p-n Junction	In semiconductor, occurs because of direct rupture of covalent bonds due to high electric field across junction.
2.	It occurs for lightly doped diode	It occurs for heavily doped diode
3.	Depletion region is wide	Depletion region is narrow
4.	It occurs for higher than 6v	It occurs for lower than 6V

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Zener diode

It is a reverse biased heavily doped silicion (or germanium) PH junction diode which is operated in the breakdown where current is limited by both external resistance & power dissipation of the diode

Symbol of zener diode is.

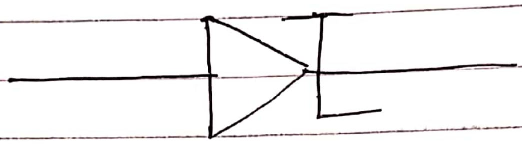

Fig: Symbol of zener diode

Zener diode as voltage Regulator

The voltage regulation is a ~~maj~~ measure of a circuits ability so, maintain a constant output voltage even when either input voltage or load current carriers.

A zener diode when working in a breakdown region can served as voltage regulator.

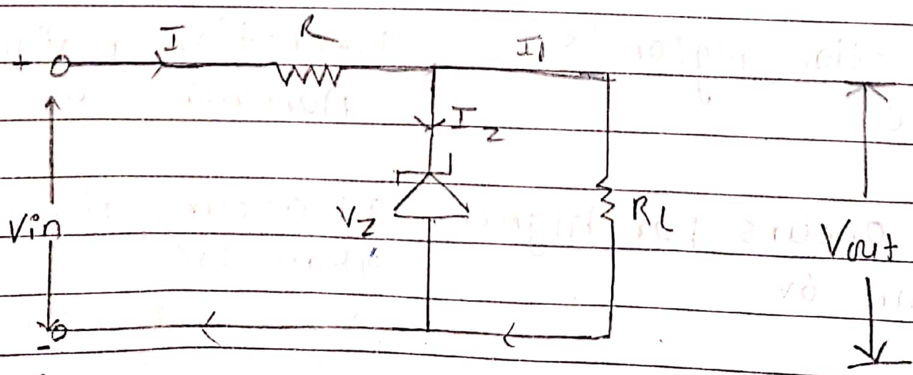

Fig: zener diode as a voltage regulator

In the above circuit diagram. Vin is the input DC voltage whose variation can be regulated. The load resistance (R_L) is connected in parallel with zener diode. The (PD) potential difference across (R_L) is Vout.

From the above circuit diagram.

$$I = I_Z + I_L$$

$$V_{out} = V_Z$$

$$V_{in} = IR + V_{out}$$

Case 1:

Let, R_L is kept fixed & ~~Vin~~ V_{in} variers.

Let, inputvoltage (V_{in}) increased slightly. It will increase the current (I), this increase in I will be absorbed by ~~the~~ zener diode without affecting I_L. The increase in V_{in} will be droped across R there by keeping V_{out} constant.

Conversely, let input voltage (V_{in}) decreased by which current I will decreases, i.e voltage drop $I \times R$ decreases. Thus, V_{out} again remain same.

Case 2:

In this case V_{in} is fixed but I_L changed.

When I_L increases, diode current I_Z decreases

There by keeping I constant and hence voltage drop IR constant. By which V_{out} is constant. $\left(V_{out} = V_{in} - IR\right)$

When I_L decreases, I_Z will increase in order to keep I constant. Hence, voltage drop IR also constant. By which V_{out} remain unchanged. In this way the output voltage remain constant even if input voltage (V_{in}) and load current I_L ~~Vary~~ varies.

Note
For proper biasing of a zener diode
→ Reverse biased
→ $V_{in} > V_Z$

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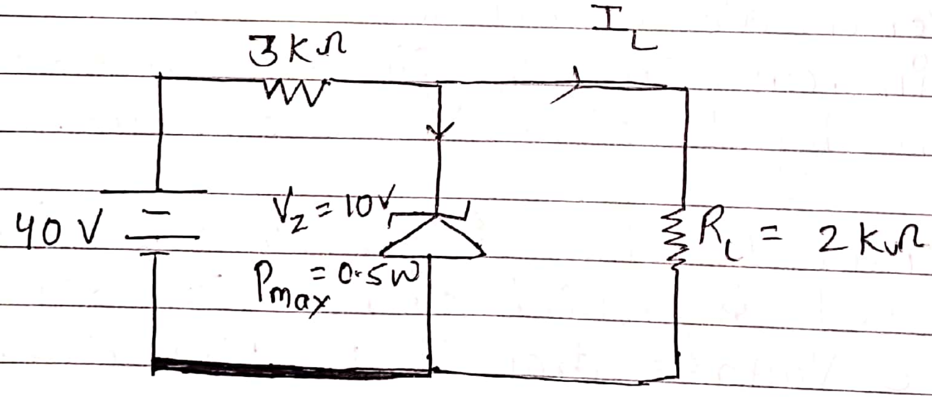

Calculate I, I_Z & I_L. Also, find I_Z(max)

Soln:

Voltage across 3 kΩ is
$40 - 10 = 30V$

$P = I^2 R$

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Current Across $3k\Omega$ is,

$$I = \frac{\text{Voltage Across } 3k\Omega}{3k\Omega}$$

$$I = \frac{30}{3\times10^3} A$$

$$I = 10\times10^{-3} A$$

$$I = 10mA$$

Voltage Across $R_L = 10$

current through R_L

$$(I_L) = \frac{\text{Voltage across } R_L}{R_L}$$

$$I_L = \frac{10V}{2\times10^3}$$

$$I_L = 5\times10^{-3} A$$

$$I_L = 5mA$$

$$I = I_Z + I_L$$

$$I_Z = I - I_L$$

$$= 10 - 5$$

$$= 5mA$$

Now,

$$P_{max} = I_{max} V$$

$$I_{max} = \frac{P_{max}}{V}$$

$$= \frac{0.5}{10}$$

$$I_{max} = 0.05A$$

I_Z I_L

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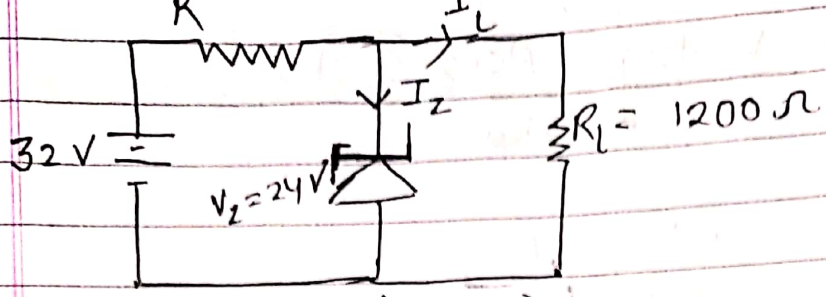


$P_{max} = 600mW$

Find R

Soln:

Voltage Across R is

$32 - 24 = \cancel{10V}\ 8V$

Voltage Across $R_L = 24V$

current through R_L

$$(I_L) = \frac{\text{Voltage across } R_L}{R_L}$$

$$= \frac{24}{1200}$$

$$= 0.02\ A$$

$$P_{max} = I_{max} \cdot V$$

$$600 \times 10^{-3} = I_{max} \cdot 24$$

$$I_{max} = \frac{600 \times 10^{-3}}{24}$$

$$= \cancel{25}\ 0.025\ A$$

$$I = I_L + I_Z$$

$$= 0.02 + 0.025$$

$$= 0.045A$$

$$V = IR$$

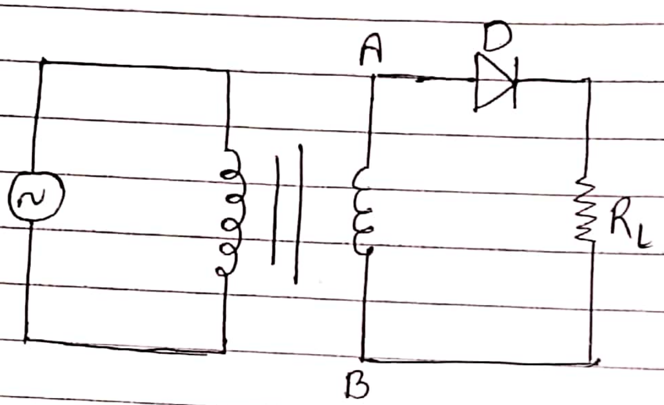
$$R = \frac{8}{0.045}$$

$$R = 177.7\ \Omega$$

Rectifier

It is an electrical device used to convert AC into DC. They are of two types.

1. Half Wave Rectifier



It converts only half cycle of AC int DC. from fig it is clear that an AC is connected to primary coil of a transformer. The input AC is induced to secondary coil.

During positive half cycle of AC ~~that~~ Let point A is positive & B is -ve. Due to this, diode D is forward biased and current flows through diode is the direction ADR_LBA.

During negative cycle of AC input, point A becomes negative & B becomes positive. By this, diode (D) is reverse biased and no current flows through it.

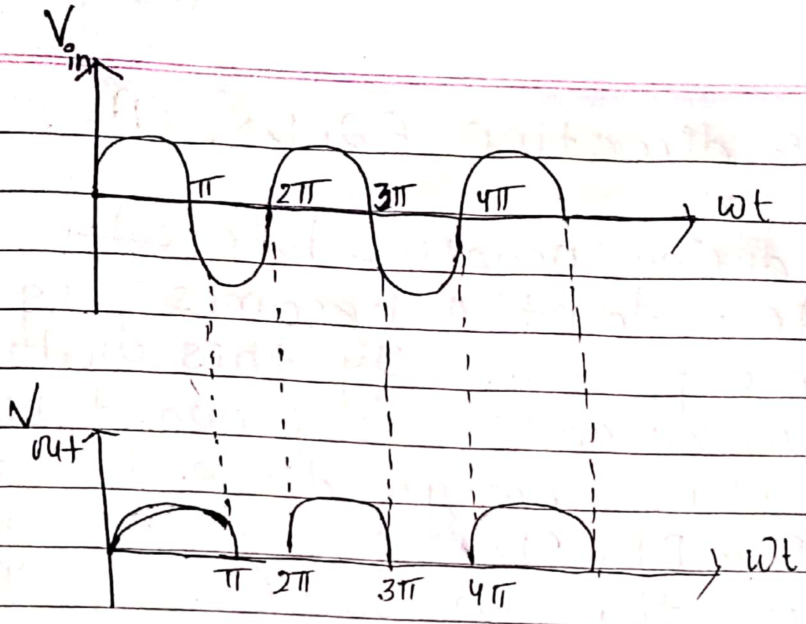
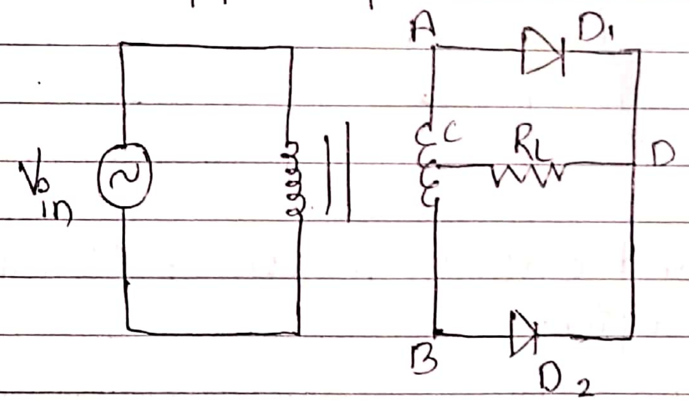


Fig: Input & output wave form

2) Full wave Rectifier

It converts full cycle of AC into DC. It is again of two types.

A) Centertapped full wave Rectifier



The input AC is applied to primary coil of a transformer. The input voltage is induced to secondary coil.

During positive half cycle of AC, let point A is positive & B is negative. By this diode D_1 is forward biased & diode D_2 is reverse biased so current flows through

D_1 in the direction AD_1DR_LCA.

Similarly during negative half ~~cyle~~ cycle of AC, point A becomes negative & B becomes positive. By this diode D_1 is reverse biased and D_2 is forward biased. So, current flows through diode D_2 is the direction BD_2DR_LCD. So, in both cycle current flows through load (R_L) in the same direction from D to C.

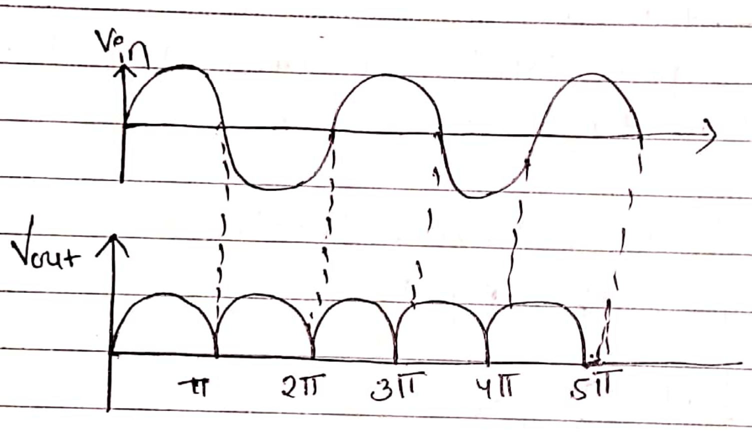
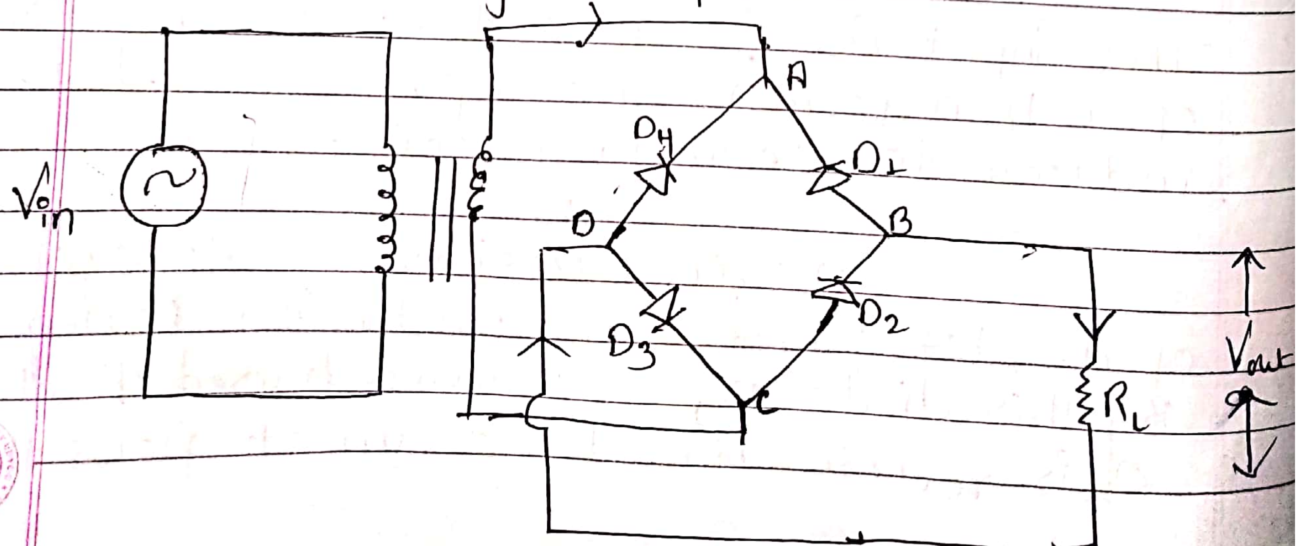


Fig: Input and output waveform of full wave rectifier.

B) Full wave bridge rectifier



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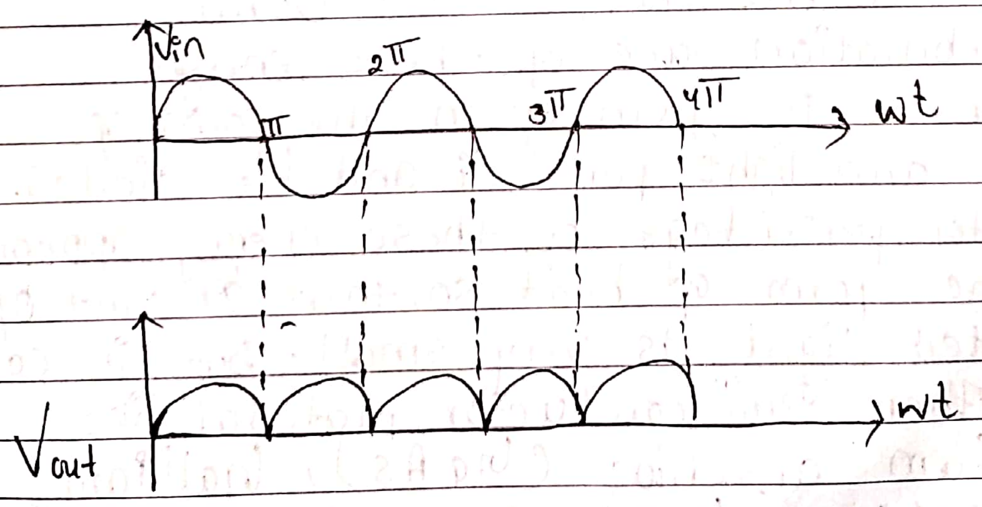
The circuit diagram for full wave bridge rectifier is as shown in fig above.

During positive half cycle of AC, point A becomes positive and C becomes negative. In this case diode D_1 & D_3 are forward biasedand D_2 and D_4 are reversed biased. Hence the current flows through D_1 and D_3 in the direction $AD_1BR_LD D_3CA$.

In the next half cycle, A becomes negative B becomes positive by which diodes D_2 D_4 are forword biased where as D_1 and D_2 are reverse biased.

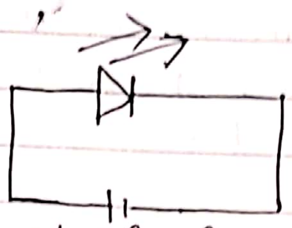
In this case current flows in the direction $CD_2BR_LD D_4AC$.

In both cases current flows through load resistance along same direction.

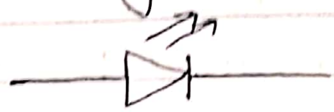


Light Emitting Diode (LED)

It is a forward biased P-N Junction Diode which Emits visible light when ~~Energy~~ energised (by applying potential).



fordword biasing of LED



symbol of LED

We know that, charge carrier recombination takes place when electrons from N-sides cross the junction and recombined with holes on p-sides.

The electrons are in the higher conduction bond on N-side where as holes are in the lower valance bond on P-side. During recombination some of these energy difference is given of in the form of heat and light for (Si and Ge) diodes. Greater percentage of these energy appears in the form of heat so, that amount of emitted light is very small. But in case of other semi-conductor material like Galliam arsenide (GaAs), Galliam phosphide (Gap), A greater percantage

Of energy is released in the form of light. This diodes can work as a light source (LED).

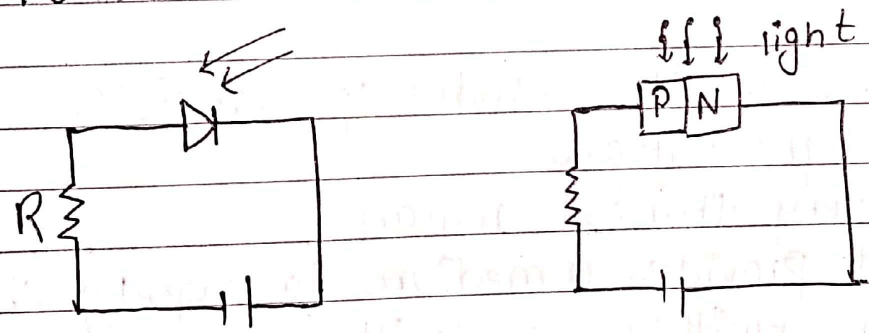
Application of LED

i) Used in cathode ray tube
ii) In 'picture phone'
iii) To supply input power to lasers
iv) Used in optical computer memories.

Photo Diode

1) P-N Junction photo diode

It is a two terminal Junction diodes When operated by first reverse biasing the Junction and that light is illuminating on it. The number of majority carriers depends on intensity of light incident on it.



Symbol of Photodiode