PN JUNCTION DIODE

PN Junction diode is a two terminal semiconductor device consisting of a PN junction, formed either in germanium or silicon crystal.

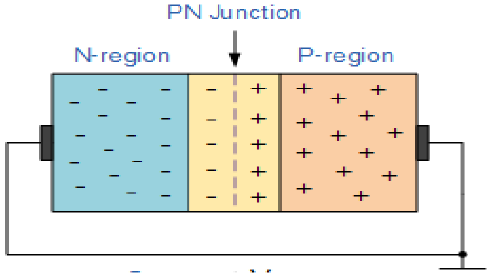
It allows the electric current in only one direction.

WORKING OF DIODE

As diode is a two terminal device, the application of a voltage across its terminal leaves three possibilities

i) No Bias ($V_D = 0v$)
ii) Forward Bias ($V_D > 0v$)
iii) Reverse Bias ($V_D < 0v$)

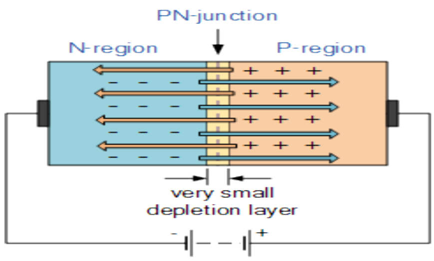
NO BIAS ($V_D = 0v$)



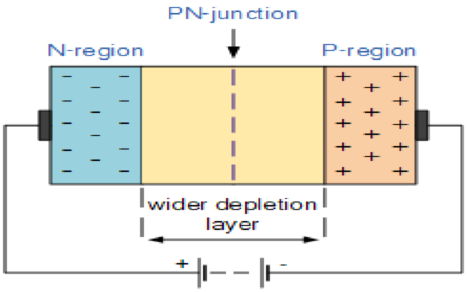
- In this case, no external voltage is applied to the PN junction diode.
- Due to concentration gradient, the holes from P region diffuse to the N region where they combine with the free electrons and the free electrons from the N region diffuse to the P region where they combine with the holes.
- The negative immobile acceptor ions in P region and positive donor ions in N region are left uncovered in the vicinity of junction.
- Now no further diffusion of holes and free electrons takes place across the junction because the holes trying to diffuse to N region are repelled by immobile positive ions and the electrons trying to diffuse in P region are repelled by immobile negative ions.
- The region contains immobile ions near the junction where charge carriers are depleted is called Depletion layer.

FORWARD BIAS ($V_D > 0v$)

- When diode is connected in forward bias condition, the negative terminal of the battery is connected to the N type material and positive terminal of the battery is connected to the P type material.



- If the external voltage becomes greater than the value of the potential; barrier approx. 0.7 volts for silicon and 0.3 volts for germanium, the potential barrier opposition will overcome and current will start to flow.
- This is because the negative voltage repels electronics towards the junction giving them the energy to cross over and combine with the holes being pushed in opposite direction towards the junction by the positive voltage.
- **REVERSE BIAS ($V_D < 0v$)**
- In reverse bias condition, the negative terminal of the battery is connected to the P type material and positive terminal of the battery is connected to N type material.



- The electrons of N type material attract towards the positive electrodes and move away from the junction, while the holes in the P type material are also attracted away from the junctions towards the negative electrodes.
- Due to which the depletion layer grows wider due to lack of electrons and holes. The result is that a high potential barrier is created thus preventing current flowing through the semiconductor material.

APPLICATION:

- ✓ Rectifier circuit
- ✓ Clipping and clamping circuit
- ✓ Voltage multiplier
- ✓ AM detector

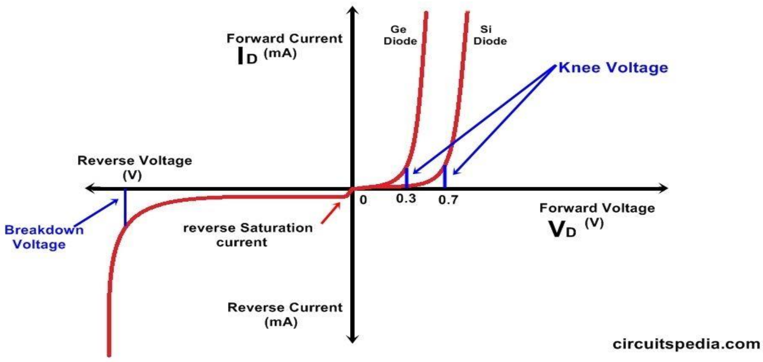
V-I CHARACTERISTIC OF PN JUNCTION DIODE

The V-I characteristic of a diode is simply a curve or graph between the voltage applied across is terminal and the current that flows through it.

The entire graph can be divided into two parts namely

i) Forward characteristic

ii) Reverse characteristic



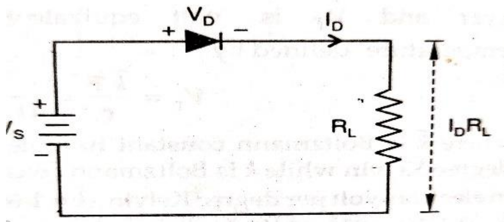
P-N Junction Diode V-I Characteristics

- **In forward characteristic**, the positive terminal of the battery is connected to the P type semiconductor and negative terminal of the battery is connected to the n type semiconductor.
- The diode said to be in forward bias. In this graph V_F represent the forward voltage where as I_F represents the forward current.
- If the external voltage is less than barrier potential, diode allows only small amount of current which is considered as negligible.
- Once the applied voltage is slightly greater than the barrier potential, the diode current increases rapidly and diode conducts heavily.
- The voltage at which current start increasing is called Knee voltage. Its value is 0.7v for silicon and 0.3v for germanium.
- **In reverse characteristic**, the negative terminal of the battery is connected to the P type semiconductor and the positive terminal of the battery is connected to the N type semiconductor.

- The diode is said to be in reverse bias. Here V_R represents the reverse voltage whereas I_R represents the reverse current.
- When the applied reverse voltage is below the breakdown voltage, the diode current is small and remains constant.
- As the reverse voltage is increased to a sufficiently large value, the diode reverse current increases rapidly. The applied reverse voltage at which this occurs is called as Breakdown voltage of a diode.

DC LOAD LINE

- DC load line is a graphical analysis which give precise relationship between forward voltage and forward current.
- Consider a simple diode connected in series with a load resistance R_L across a supply voltage V_S. Here the diode is forward biased.



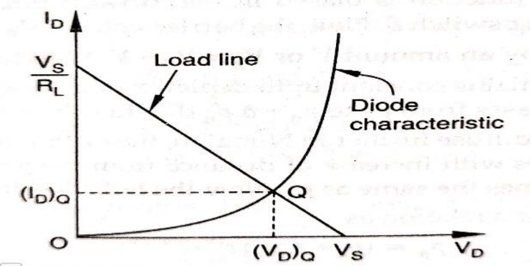
- Applying Kirchhoff's voltage law to the circuit, we have

$$V_S - V_D - I_D R_L = 0$$

- Where I_D is forward diode current and V_D forward diode voltage

$$I_D = \frac{Vs}{RL} - \frac{VD}{RL}$$

- This represent a straight line. So DC load line is a straight line.



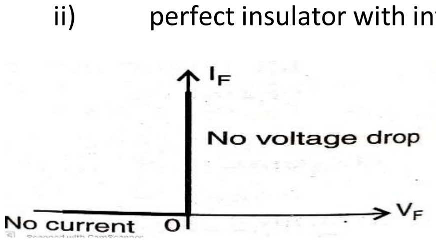
- From the above equation, when $V_D = 0$ then $I_D = \frac{Vs}{RL}$ and when $I_D = 0$ then $V_S = V_D$.
- A line passing through the points $\frac{Vs}{RL}$ and V_S is called a load line.
- The intersection of forward characteristic and DC load line of the diode is called Operating point or Quiescent point or Q point of the device.

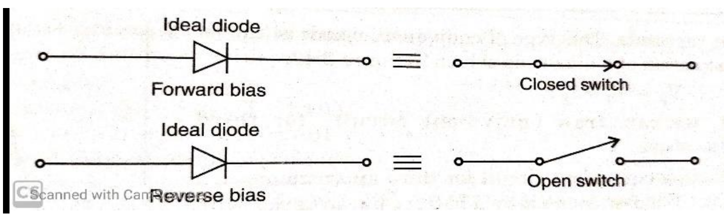
IDEAL DIODE

- An ideal diode is a two terminal device which has

i) perfect conductor with zero resistance when forward biased.

ii) perfect insulator with infinite resistance when reverse biased.





- The ideal diode acts like an automatic switch. The switch is closed when the diode is forward bias and is open when it is reverse biased.

KNEE VOLTAGE

- The forward voltage at which the current through the junction starts increasing rapidly is called Knee voltage.
- Knee voltage also called as Cut in voltage or threshold voltage.

- The knee voltage foe silicon is 0.7 volt whereas for germanium it is 0.3 volt.

JUNCTION BRAEKDOWN

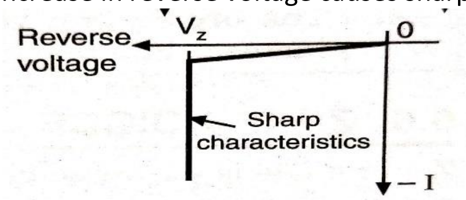
- The reverse voltage at which PN junction breaks down with sudden rise in reverse current.
- The breakdown voltage depends upon the width of the depletion region.

The following two processes cause junction breakdown due to the increase in reverse voltage.

i) Zener breakdown
ii) Avalanche breakdown

ZENER BREAKDOWN

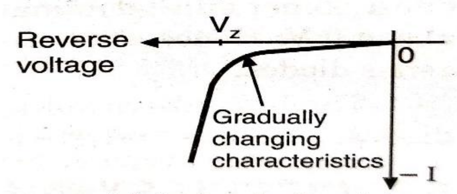
- The zener breakdown takes place in junction which are heavily doped.
- When breakdown voltage is applied, a very strong electric field appears across narrow depletion layer which breaks the covalent bonds. Now electrons-holes pairs are generated.
- A small further increase in reverse voltage causes sharp increase the reverse current.



(a) Zener breakdown

AVALANCHE BREAKDOWN

- The avalanche breakdown occurs in junction which are lightly doped.
- As the reverse voltage increase, minority carriers are accelerated due to which kinetic energy is increases.
- While travelling, these carriers collide with stationary atoms within the crystal structure. Due to this covalent bonds break and generate additional carriers.



(b) Avalanche breakdown

- These additional carriers pick up energy from the applied voltage and generate more carriers. As a result of this, the reverse current increases rapidly.
- This cumulative process of carrier generation (or multiplication) is known as Avalanche breakdown.

PN DIODE CLIPPING CIRCUIT

- The circuit with which the waveform is shaped by removing (or clipping) a portion of the applied wave without disturbing the remaining part of the input signal is known as Clipping circuit.
- The basic components required for a clipping circuits are an ideal diode and a resistor.
- The clipping circuits are of the following types

i. Positive clipper
ii. Negative clipper
iii. Biased clipper
iv. Combination clipper

POSITIVE CLIPPER

- In a positive clipper, the positive half cycles of the input voltage will be removed.
- The diode kept in series with the load. This is called positive series clipper circuit.