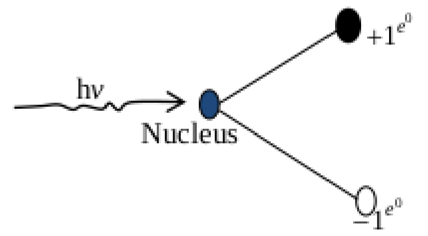
Pair production & Semi Conductor

Elementary Particles

- Collision of energetic photon by nucleus (target) and production of electron-positron pair is known as pair production.



- Rest mass of positron and electron is $9.1 \times 10^{-31}\, kg$.
- Antiparticle of electron is known as positron, charge +e and mass equal to electron.
- Energy of electron or positron is
  $E = m_0 c^2$
- For pair production, essential energy of photon is at least 1.02 Mev.
- Annihilation is the process of combining of positron & electron then after photon of energy released.
  $+1^{\beta^0} + -1^{\beta^0} \rightarrow h\nu$

Particles and Antiparticles

- Particles which are not constituted by any others particle, have no structure one called fundamental particles.
- **Electron:**

  It is fundamental particle discovered by Thomson in 1897. If revolve round the atom in different orbit. It play an important role to explain chemical properties of the substances.
  Its symbol is $-1^{\beta^0}(e^-)$

- **Proton:**

  It is the fundamental particle discovered by Rutherford in 1919. It has +Ve charge & mass equal to 1836 times mass of electron. Symbol is $P^+ \left({}_1H^1\right)$

- **Neutron:**

  It was discovered by Chadwick in 1932, It carries no charge. Mass is 1839 times mass of electrons. Its mean life is 17 minute. It is the stable nucleon along with proton. Symbol is ${}_0n^1$.

- **Positron:**

  It was discovered in 1932. Its charge & mass are equal to charge & mass of an e^- only different is, it is +vely charged. It symbol is ${}_{+1}\beta^0\ (e^+)$. It is antiparticle of electron.

- **Antiproton:**

  It was discovered in 1955. Its charge and mass are equal to that of proton only different is – vely changed. It symbol is p^-.

- **Antineutron:**

  It was discovered in 1956. It has no charge and mass is equal to neutron. The only difference between neutron & antineutron is that they have spin in same direction but their magnetic moment will be in opposite direction. Its symbol is n^-.

- **Neutrino & Antineutrino:**

  The existence of these particle was predicted in 1930 by pauli. They observed experimentally in 1956. Their rest mass & change are zero but they have energy and momentum.
  They are stable particles.
  The spin of neutrino & antineutrino are in opposite direction. Symbols are γ^- and γ respectively.

- **Pi-mesons:**

  The existence of these particles was predicted by Yukawa in 1935 as originator of exchange forces between the nucleons but they are actually discovered in 1947 in cosmic rays.

Pi-mesons are:

- ### Positive π- meson

  It is +vely charged particle change equal to electric charge & mass is 274 times electronic mass. It is unstable and mean life is of the order of $10^{-8}\ sec.$ symbol is π^-

- ### Negative π - meson

  It is – vely charged particle whose charge equal to electronic charge & mass is 274 times electronic mass. Its mean life is $10^{-8}\ sec$ and symbol is π

- ### Neutral Pi-meson

  These particle has no charge. Its mass is 264 times electronic mass. Mean life of neutral Pi-meson is of the order $10^{-15}\ sec.$ Its symbol is π^0 and its disintegration is :
  $\pi^0 \to \nu + \nu$

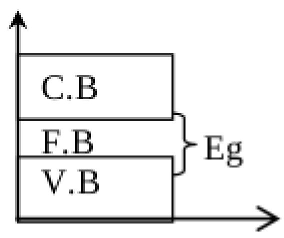
Photon

These are the bundles of electromagnetic energy and travel with speed of light. Energy of photon is hc/λ and momentum is $h\nu/c$.

Semiconductor, Conductor and Insulator

Semiconductor

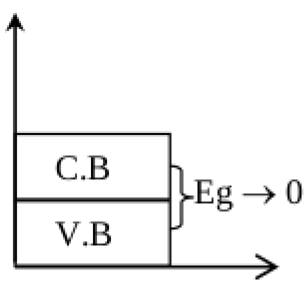
- The outermost orbit is called valence shell.



- Electrons are revolving round to the valence shell are called valance electrons.
- In solids, there are three energy bands.
- Energy band corresponding to valance electrons is called valence band (V.B.)
- Energy band corresponding to free electrons is called conduction bond (C.B.)
- The energy band (gap) between the V.B. & C.B is known as forbidden band (F.B.). Actually energy difference between the V.B. & C.B. is known as energy gap denoted by Eg.

Conductor

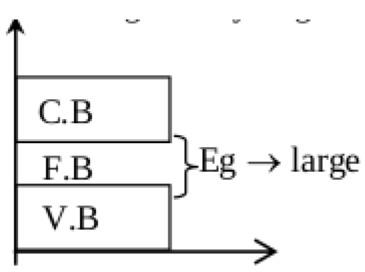
- Energy gap between V.B. & C.B. is negligible (tends to zero).



- Valence band & conduction band are overlapped. No distinction between them
- Valence electrons are the valence shell is less than four.
- Both valence band & conduction band are partially filled.
- Valance electrons are easily conduct into the conduction bond

Insulators

- In case of an insulator, energy gap between V.B. and C.B. is generally large.

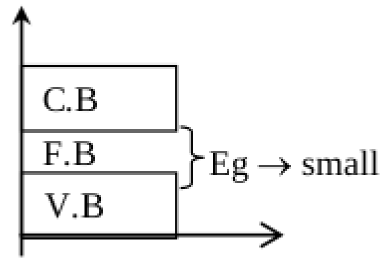


- No valence electrons can reach to conduction band due to large energy gap.
- Valence electrons in the valence shell is more than four.

- V.B. is totally filled but conduction band is empty

Semi-Conductors

- Energy gap between V.B. & C.B. is small ie. Less than insulator but greater than conductor



- At absolute zero, semi conductor act as an insulator.
- Rise is temp. (electron cross the energy gap) semi-conductor act like the conductor
- Valence electrons is the valence shall equal to four.
- Materials whose all electrical properties lies is between good conductor and an insulator.

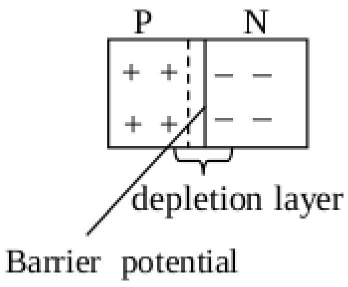
- ## Types of semi-conductors:
  - ### Intrinsic semi-conductors (Pure semi-conductor)
    - Pure semi-conductors are called intrinsic semi-conductor.
    - Good examples are Si & Ge.
    - Carrier concentration are equal.
    - Electrical conductivity is negligible.
    - No remarkable use.
    - Conductivity depends on only temperature.
  - ### Extrinsic semi-conductors
    - Impurity atoms are doped to pure semi-conductor, extrinsic semi-conductor is formed.
    - Impurity atoms having no four valence electrons are doped.
    - Atoms having three valence electrons in the valence shell are called trivalent impurities eg. Aluminum, Indium, Gallium etc.
    - Atom having valence electrons equal to five are called pentavalent impunities. Eg. Phosphorus, Arsenic, Antimony etc.
    - Process of mixing of the impurities to the pure semi-conductors, phenomenon is known as doping.
    - Mixed impurities are called doping agents.
    - According to the doping impurities to that of pure semi-conductors like Ge or Si.
    - Extrinsic semi-conductors are two types

      i. **P-type semi-conductor**
        - When trivalent impurities are doped to pure Si or Ge, p – type doped semi-conductor is formed.
        - Trivalent impurity atoms are acceptor type
        - So formed p-type is acceptor type semi-conductor
        - In time of mixing of the impurity to the pure one more electron is accept by the impurity from the surrounding to complete its stable octet.
        - A vacancy is created in the system that vacancy has tendency to accept one electron is known as hole.
        - In p-type, majority are holes carriers.
        - Minority are electrons carriers.
        - In P-type, current flow due to holes.

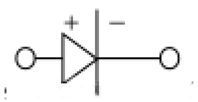
      ii. **N- type Semi-Conductor**
        - Pentavalent impurity atoms are doped to pre Si or Ge.
        - Pentravalent impurities are donar type impurity.
        - During successive doping of pentavalent impunities to the pure semi-conductors many electrons are donated to the system.
        - Majority are electrons carries.
        - Minority are holes carries.
        - In N- type, semi-conductor, current flow due to electrons.
        - Finally, due to mixing of impurities, electrical conductivity increased in case of extrinsic semi-conductors.
        - Conductivity and resistivity depends on temp.

PN junction diode

- When p-type material is sandwiched with PN- type material as shown in fig, then, PN junction diode is formed. The contact point of P & N type materials is called junction.

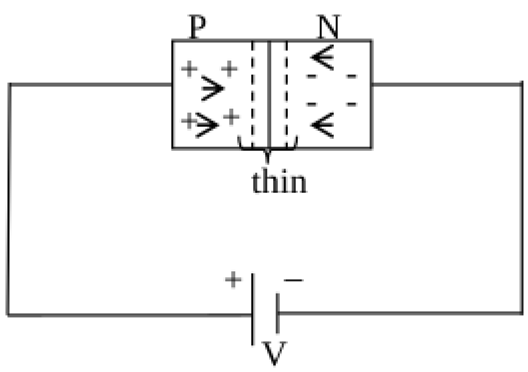


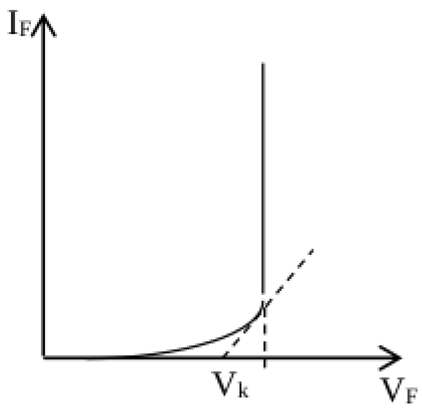
- A layer is created at the junction due to recombination of holes & electrons is known as depletion layer.
- Potential difference in maintained at the junction due to the concentration of +Ve & -Ve charge is known as barrier potential (Barrier field) denonated by V_B.
- It is (P-N junction) also known as junction diode or semi-conductor diode.
- Electronic symbol is:



- The triangular shape indicate +Ve (P-type) & line –ve (N- type)

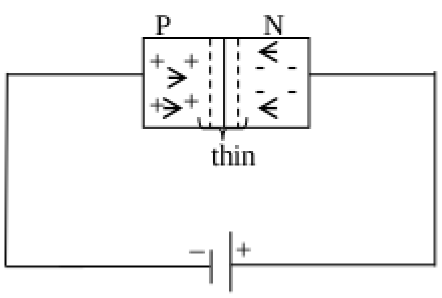
- ## Biasing of junction diode
  - ### Forward bias/Forward Characteristics



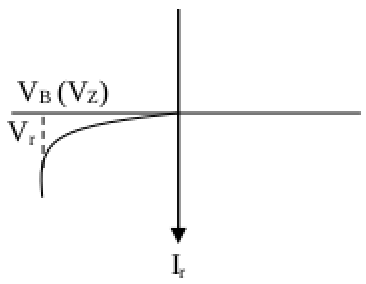


- When P-type material is connected with +ve terminal where as N-type material is connected with –ve terminal of the battery as known in fig., combination is said to be in forward bias.
- Majority carriers are drift towards the junction due to polarities of the battery.
- Depletion layer is thin.
- Resistance offered by diode is low.
- Amount of current is passed through the junction due to majority carries, known as forward current denoted by I_F.
- When forward voltage is vary 0 to higher value, corresponding value of forward current changes.
- When a graph is potted between the dataes of V_F & I_F , nature of forward characteristics is known in fig.
- Amount of forward voltage at which diode starts to conduct is known as knee voltage denoted by V_K.

  - ### Reverse Bias/ Reverse Characteristics



- When P-type material connected with –ve whereas N – type material connected with +ve terminal of the battery, combination is said to be reverse bias.
- Majority carriers are pulled away from the junction due to polarities of the battery.
- Depletion layer is thick
- Resistance offered by diode is high.
- No current is passed through the junction due to majority carriers.
- Negligible current is passed through the junction due to minority carriers is known as reverse current denoted by I_r.
- At different values of reverse voltage, the corresponding values of reverse current are noted.
- When graph is potted between the different of reverse voltage & current, nature of reverse characteristics is shown in following graph.

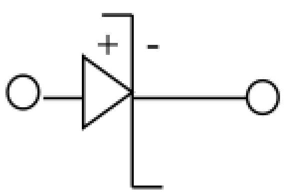


- The maximum value of reverse voltage at which sharp breakdown is occurs is known as breakdown voltage denoted by V_B or V_Z.
- Diode has unidirectional current flow property ie current is passed through the junction only when it is in forward bias.
- Due to such unique property, diode used in rectifier circuit for rectification.

- **Rectification**
  - Rectification is the process of conversion of a.c. power into d.c. power.
  - In half wave rectifier circuit, only one half cycle of a.c. input is obtained as d.c. output across the load resistor.
  - In half wave rectification, output is pulsating (not smooth)
  - In full ware rectifier both half cycle of a.c. input, are obtained as d.c. output across R_L.
  - Output is continuous (Smooth)
  - For rectification purpose, we choose full wave rectifier circuit.

- **Zener diode**

  A special type of semi-conductor diode which works on reverse bias only is known as zener diode, symbolically zener diode is represented by:



  Zener diode works in breakdown region.

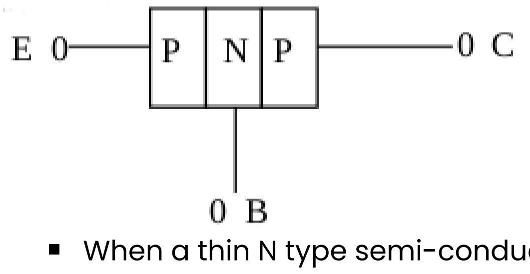
- **Filter Circuit**
  - Filter circuit is an arrangement in which pulsating d.c. is made smooth d.c. as output.
  - Output is free from a.c. ripple.

Transistor

- Transistor is the three terminal semi-conductor device used for amplification can amplify small signal a.c. into amplify a.c.
- Transistor is formed by the combination of two PN junction diode.
- **Types**

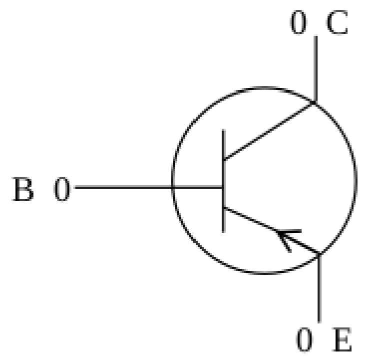
  i) PN P Transistor
  ii) NPN Transistor

  - **PNP transistor**



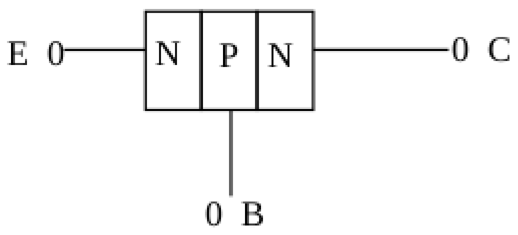
- When a thin N type semi-conductor is sandwich by two P-type semi-conductors, PNP transistor is formed.
- Common N- type act as base

- Two P-types are act as emitter & collector.
- Emitter is heavily doped and base is lightly doped.
- Electronic symbol of PNP is:



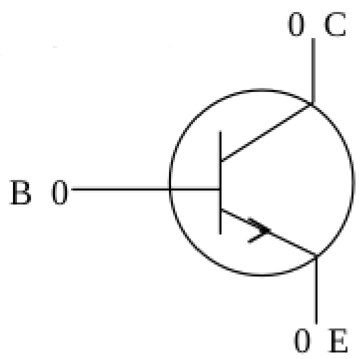
- In PNP, the direction of current flow is inward through emitter.

- NPN – transistor



When a thin & lightly doped P-type semi-conductor is sandwiched by two N-type semi-conductors. Then, NPN transistor is formed. It is formed by the combination of two junction diodes. The common P-type act as base where as two N-types act as emitter and collector.

The electronic symbol of NPN is:



In NPN, current flow through emitter in outward.

- Base
  - It is lightly doped with compared to others.
  - It is opposite type therefore can neutralize majority carriers emitted by emitter,
  - It is denoted by B.

- Emitter
  - It is heavily doped with compared to others.
  - It serves as emitter, emit majority carries carriers and it is in forward bias denoted by E.

- Collector
  - The doping of the collector is intermediate between the base & emitter.
  - It is in reverse bias.
  - It can collects majority carriers diffused from base and it is denoted by C.
  - In transistor current are related by $I_E = I_B + I_C$

    Where,
    $I_E =$ Emitter current
    $I_B =$ Base current
    $I_C =$collector current

  - In PNP, current due to holes
  - In NPN, current due to electrons.

- Configuration of transistor

Configuration of transistor are in three types, they are:

i. Common Base Configuration (CB mode)
ii. Common Emitter configuration (CE mode)
iii. Common Collector configuration (CC mode)

Parameters of transistor

- ### α - parameter:

  It is the ratio of collector current to that of emitter current denoted by α and written as :

  $\alpha = I_C/I_E$
  $\alpha < 1$ since $I_E > I_C$

- ### β- Parameter:

  The ratio of collector current to that of base current denoted by and written as:

  $\beta = I_C/I_B$,
  $\beta \gg 1$
  since $I_C \gg I_B$

- ### Relation between α & β:

  We have,

  $I_E = I_B + I_C \cdots\cdots (i)$

  Dividing equation (i) by I_C on both sides:

  $\mathrm{I_E/I_C = I_B + I_C/I_C}$

  $$\frac{1}{I_C/_{I_E}} = \frac{I_B}{I_C} + 1$$

  Or, $\dfrac{1}{I_C/_{I_E}} = \dfrac{1}{I_C/I_E} + 1$

  Or, $\dfrac{1}{\alpha} = \dfrac{1}{\beta} + 1$

  Or, $\dfrac{1}{\alpha} = \dfrac{1+\beta}{\beta}$

  $$\therefore \quad \alpha = \frac{\beta}{1+\beta}$$

  Again,

  $$\frac{1}{\alpha} - 1 = \frac{1}{\beta}$$

  $$\frac{1-\alpha}{\alpha} = \frac{1}{\beta}$$

  $$\therefore \beta = \frac{\alpha}{1-\alpha}$$

- ### Characteristics of transistor in C.E. Mode:

  - #### Input Characteristics

    Variation of input current with input voltage at constant output voltage.

  - #### Output Characteristics

Variation of output current with output voltage at constant input current.

- ### Transfer Characteristics

  Variation of output current with input current at constant output voltage