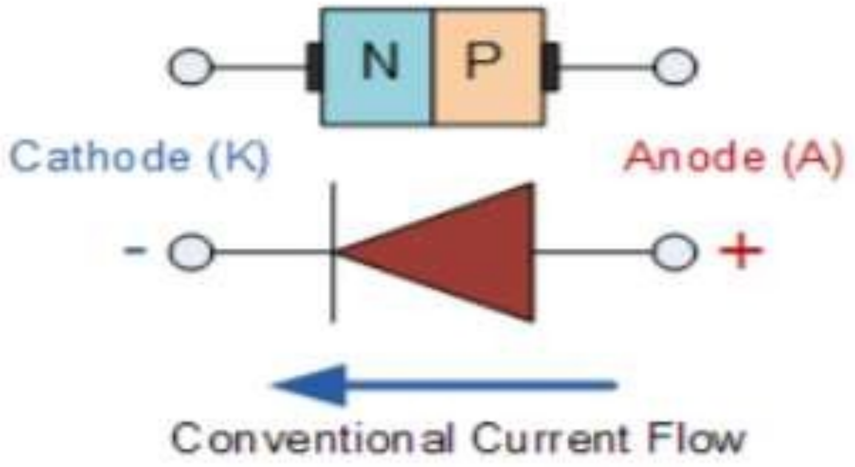
P N Junction Diode

PN Junction Diode

- A PN diode is formed by doping one side of intrinsic material with acceptor atoms and other side donor atoms.

- P-type and N-type semiconductor material side by side on a single crystal represent PN Junction. A PN **junction** forms at the boundary between the two regions and a diode is created.

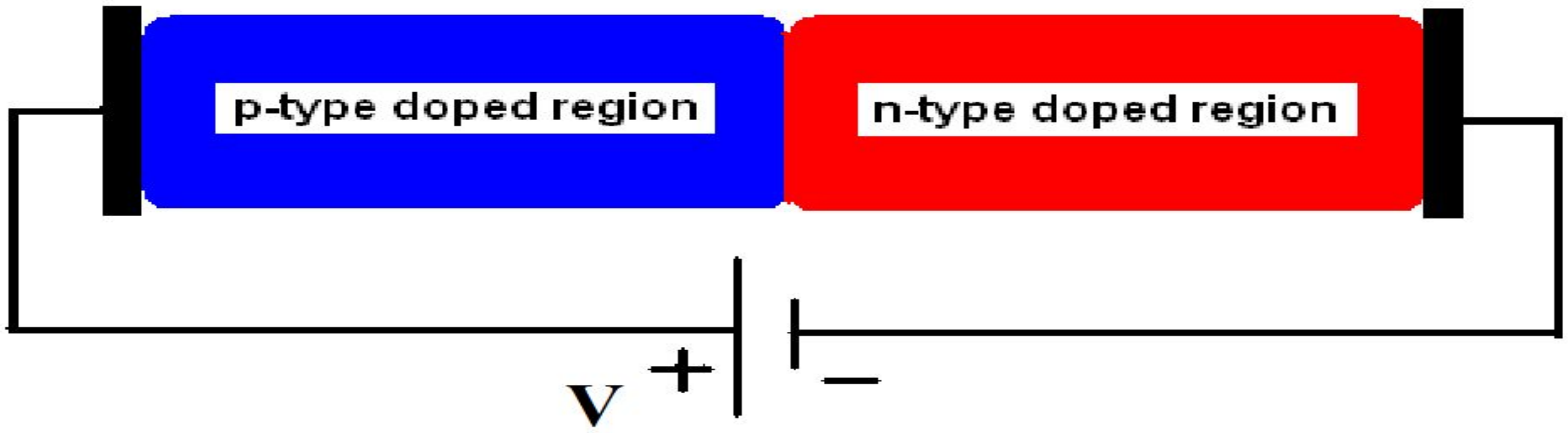
- The p-side is considered as anode and n-side is considered as cathode.



PN Junction Diode

- There are three possibilities in PN junction diode depending upon the application of voltage across the two terminals.

1. No Bias (V = 0)
2. Forward Bias (V > 0)
3. Reverse Bias (V < 0)



No bias mode

- When diode is not connected with any bias voltage (V = 0), then it is called as no bias condition
- The *p* region has holes as majority carriers due to the impurity atoms and only a few thermally generated free electrons as minority carriers.
- The *n* region has free electrons as majority carriers due to the impurity atoms and only a few thermally generated holes as minority carriers.
- When the junction is first formed, due to the concentration gradient, mobile charges transfer near junction.
- Electrons near the junction in the n region begin to diffuse across the junction into p region where they combine with some of the holes.
- Holes and Electrons recombine and uncovered the bound charges. Similarly holes leave p-type region.
- This process creates uncover acceptor ion on P-side and uncover donor ions in N-side of the junction.

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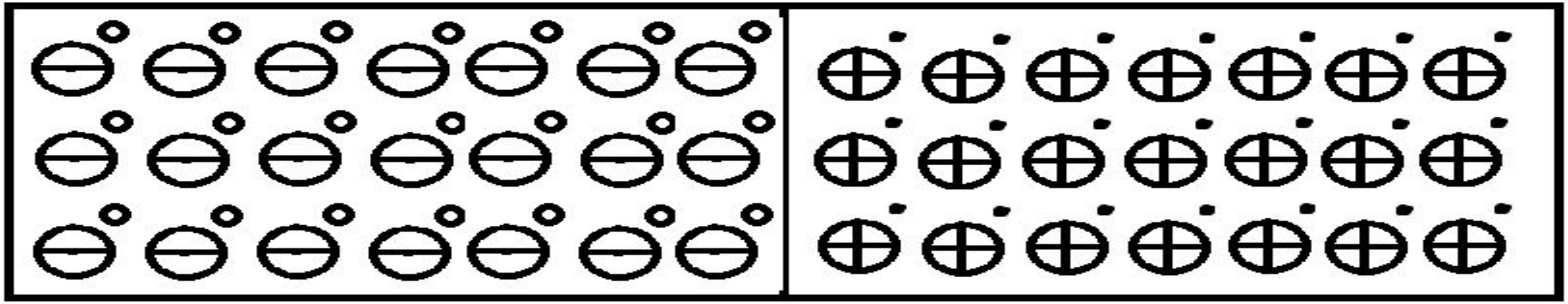
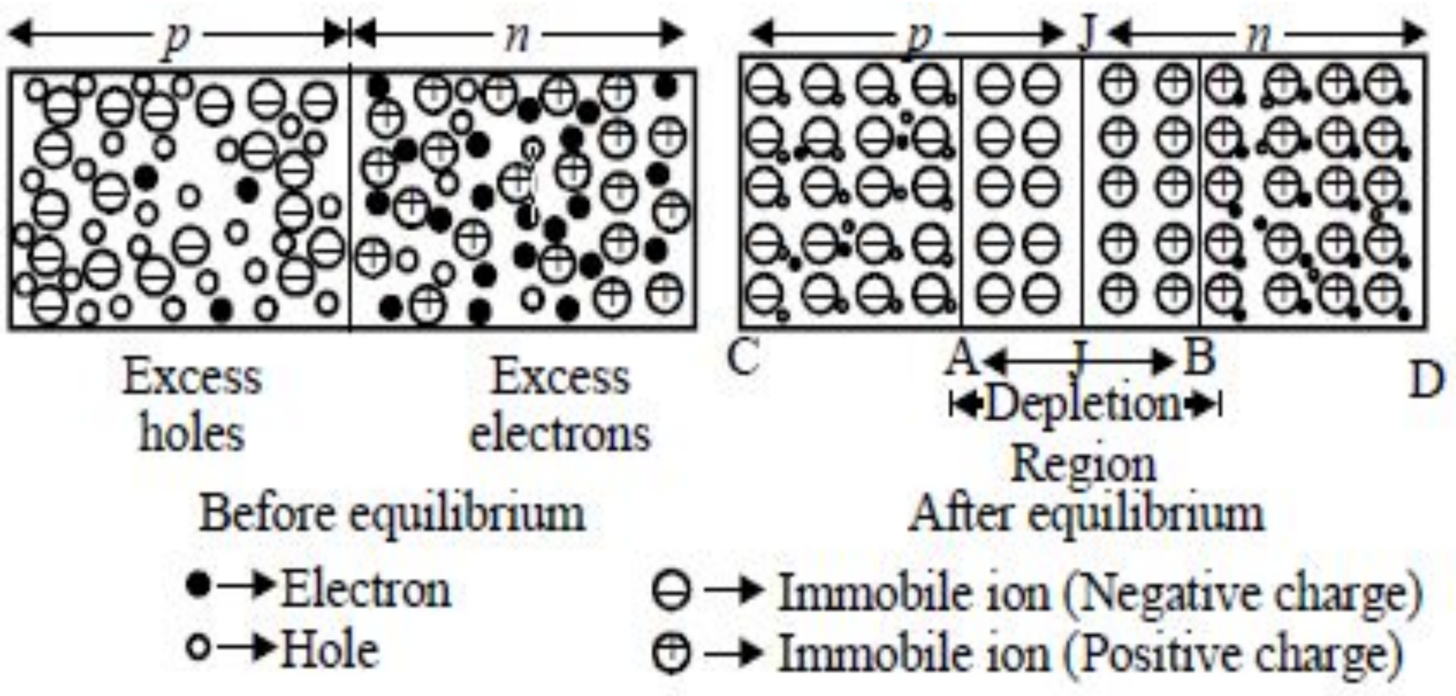
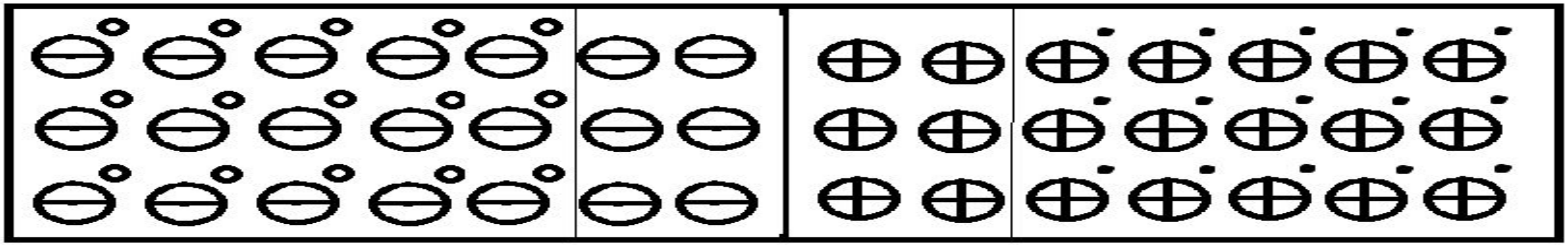
No bias mode



P N

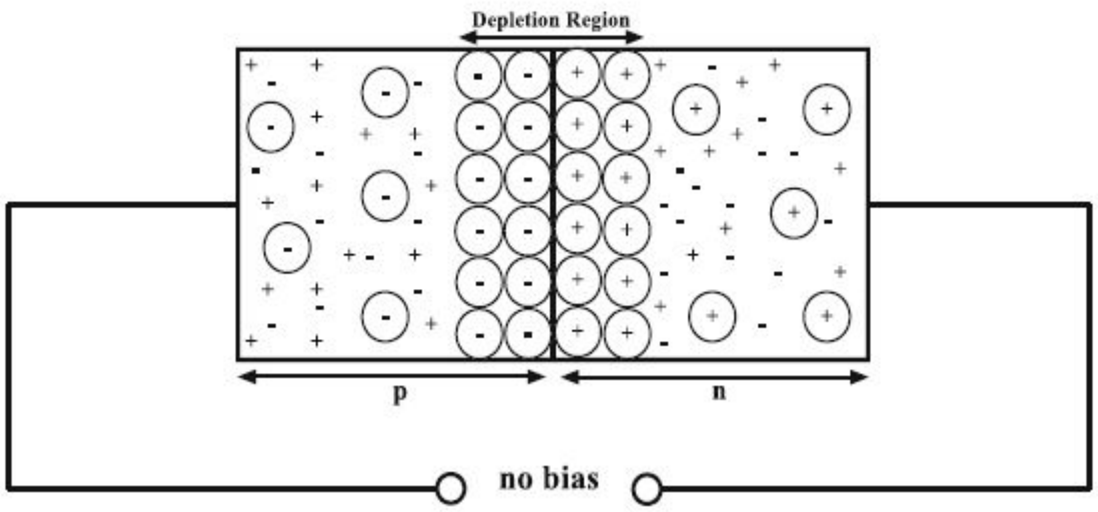

p
n
Excess holes
Excess electrons
Before equilibrium
p
J
n
C
A
J
B
D
Depletion Region
After equilibrium
Electron
Hole
Immobile ion (Negative charge)
Immobile ion (Positive charge)



- The n-type region close to the junction becomes depleted of electrons and positively charged, and the p-type region close to the junction becomes depleted of holes and negatively charged.
- The region near to the pn-junction becomes depleted of majority carriers and is called the depletion region(**Majority charge carrier empty region**). The region where there is no mobile charges only bound or fixed charges are present.
- The depletion region is formed very quickly and is very thin compared to the *n* region and *p* region.
- A point is reached where the total negative charge in the depletion region repels any further diffusion of electrons (negatively charged particles) into the *p* region (like charges repel) and the diffusion stops.
- In the depletion region there are many positive charges and many negative charges on opposite sides of the *pn* junction. So there is a force acting on the charges which form an *electric field directed from n-side to p-side.* The electric field is a barrier to the free electrons in the *n* region.
- An external energy must be applied to get the electrons to move across the barrier of the electric field in the depletion region.
- The potential difference of the electric field across the depletion region is the amount of voltage required to move electrons through the electric field. This potential difference is called the **barrier potential**

- The barrier potential of a *pn* junction depends on several factors, including the type of semi-conductive material, the amount of doping, and the temperature.
- At room temperature(25°C), the barrier potential equals approximately 0.3 V for germanium diodes and 0.6-0.7 V for silicon diodes.
- The barrier potential voltage also called as knee voltage or cut-in voltage of the diode.
- Barrier voltage opposes the diffusion of majority carrier across the junction where as assists drifting of minority carriers.
- Under steady state

  Drift current=Diffusion current
- The net flow of charge in any direction for a semiconductor diode is zero, when the externally applied voltage is zero.



Thresh hold or Barrier voltage

$$V_{th} = \frac{KT}{q} \ln(\frac{N_D N_A}{n_i^2})$$

Width of the Depletion region

$$W_{dep} = \sqrt{\frac{2\varepsilon_s}{q}(\frac{1}{N_A} + \frac{1}{N_D})V_{th}}$$

No bias mode

Direction of flow of charge carrier	Type of current	Direction of current
←	electron diffusion	→
→	hole diffusion	→
→	electron drift	←
←	hole drift	←

At equlibrium the net current across the junction is zero.