ELECTRONICS DEVICES & CIRCUITS

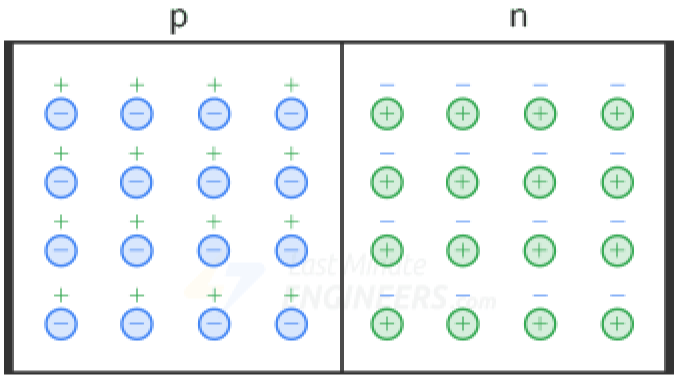
Prof. Kamlesh T. Kahar,
Electronics & Telecommunication Engg. Dept. SSGMCE, Shegaon

LECTURE ON PN JUNCTION DIODE

Prof. Kamlesh T. Kahar,
Electronics & Telecommunication Engg. Dept. SSGMCE, Shegaon

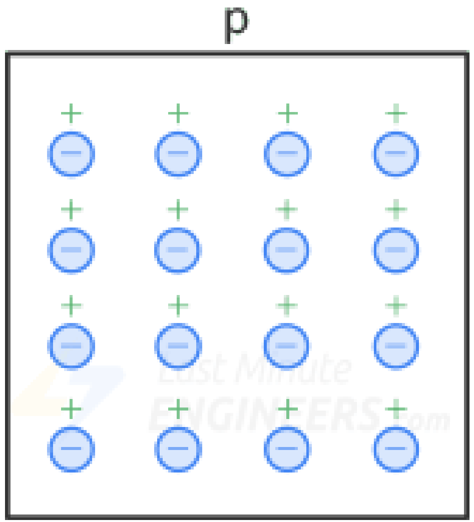
PN Junction

- When a p-type semiconductor is suitably joined to n-type semiconductor, the contact surface is called pn junction.
- A manufacturer dopes a single silicon crystal with p-type material on one side and n-type on the other side, something new comes into existence – the PN junction.



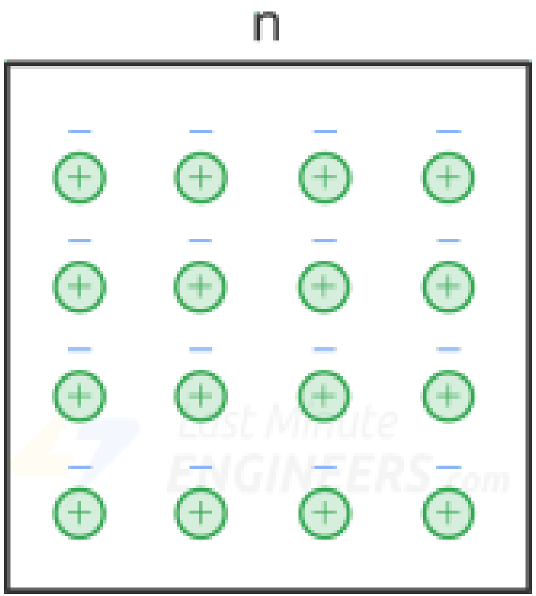
PN Junction

- As we know that p-type semiconductor has trivalent atoms and each of them produces one hole, we can visualize it as shown in the figure. Each circled minus sign is the trivalent atom and each plus sign is the hole in its valence orbit.



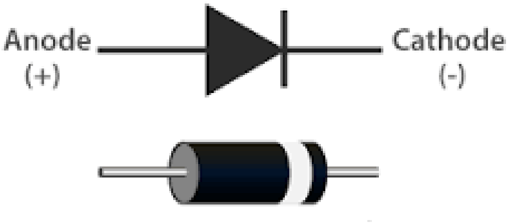
PN Junction

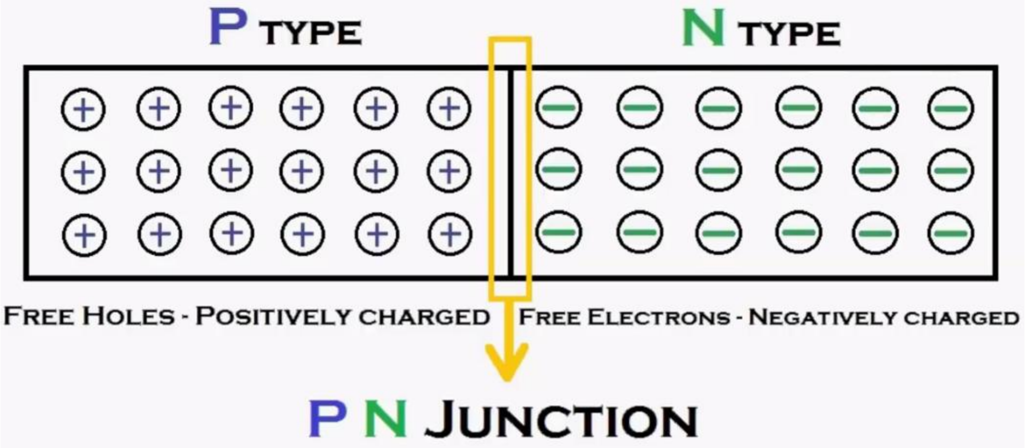
- We also know that n-type semiconductor has pentavalent atoms and each of them produces one free electron, we can visualize it as shown in the figure. Each circled plus sign is the pentavalent atom and each minus sign is the free electron it contributes.



PN Junction

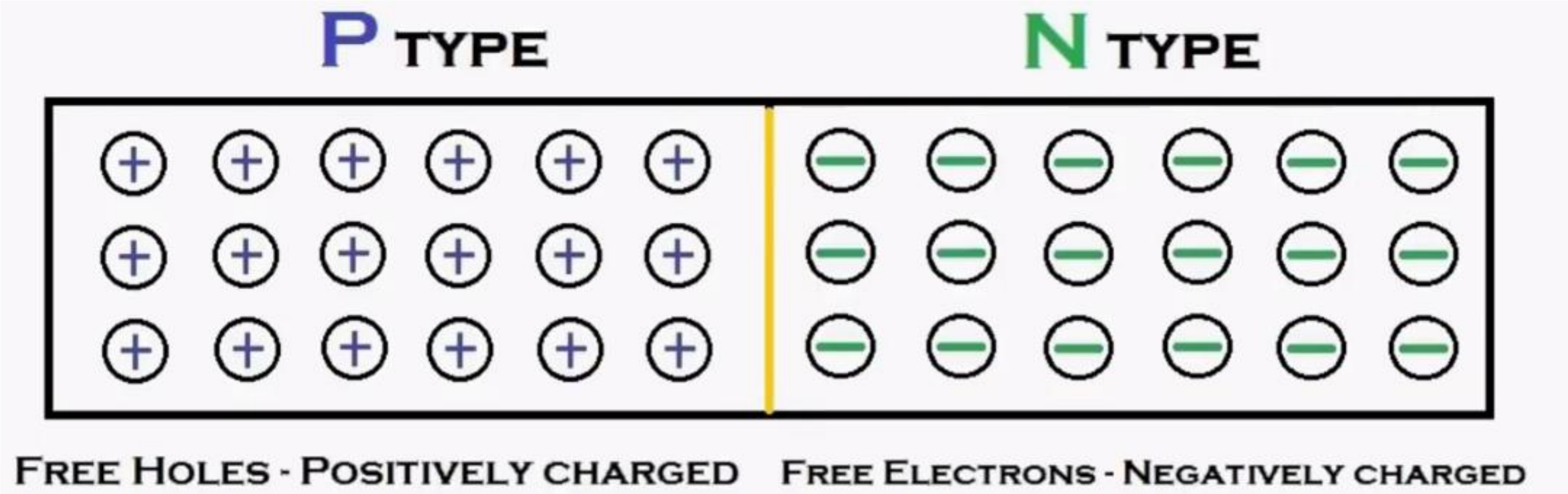
- A manufacturer can produce a single silicon crystal with p-type material on one side and n-type on the other side, as shown in the figure. The border between p-type and n-type is called the PN junction.
- A PN crystal is commonly known as junction diode.
- The word diode is a contraction of two electrodes,
  where di stands for two.



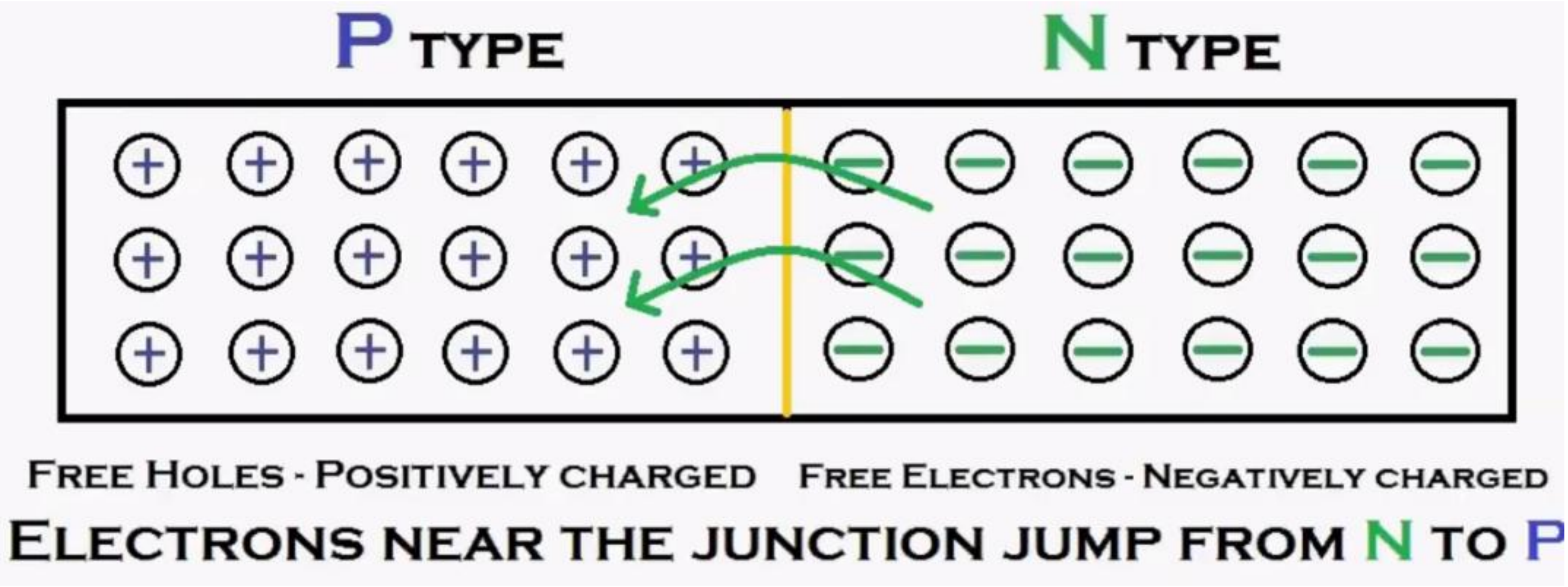


Concept of Depletion Region

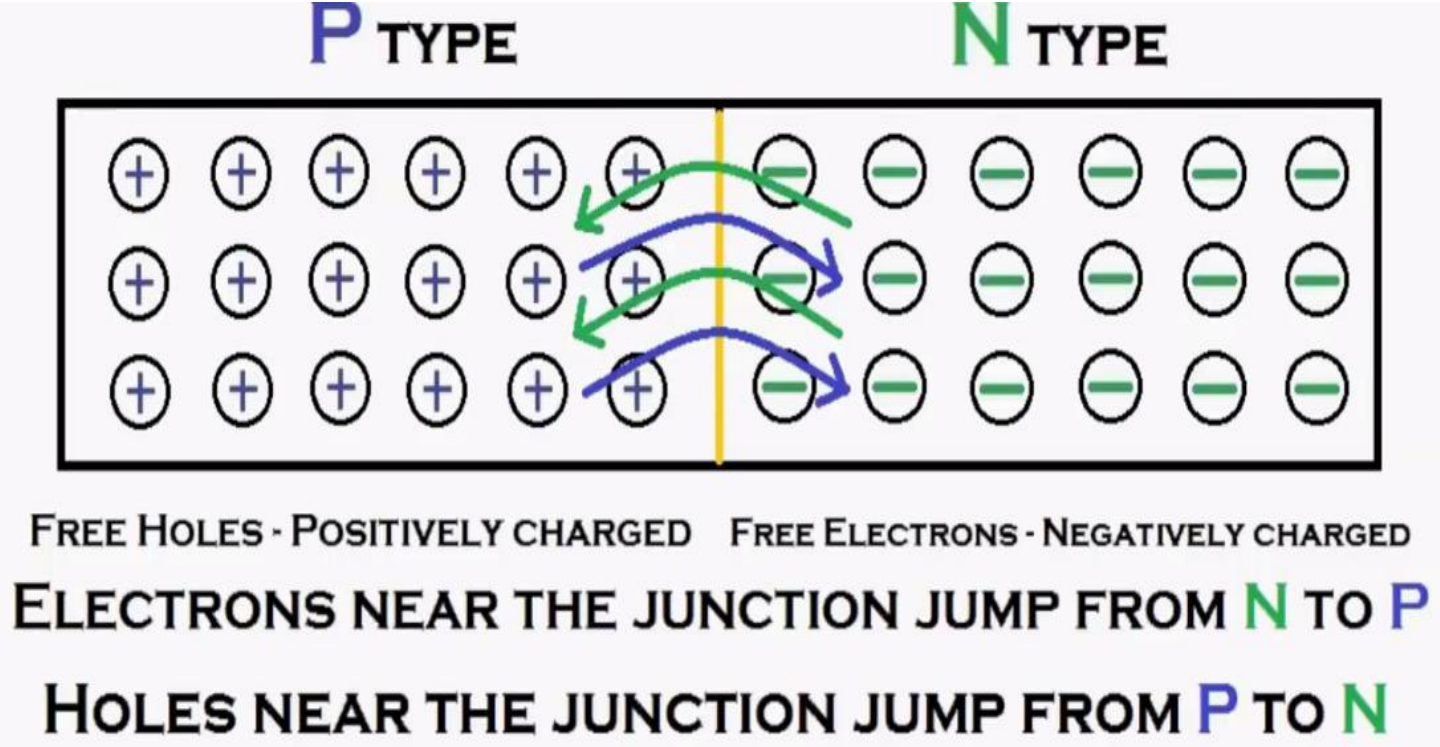
What happens when the PN Junction is made?



Concept of Depletion Region

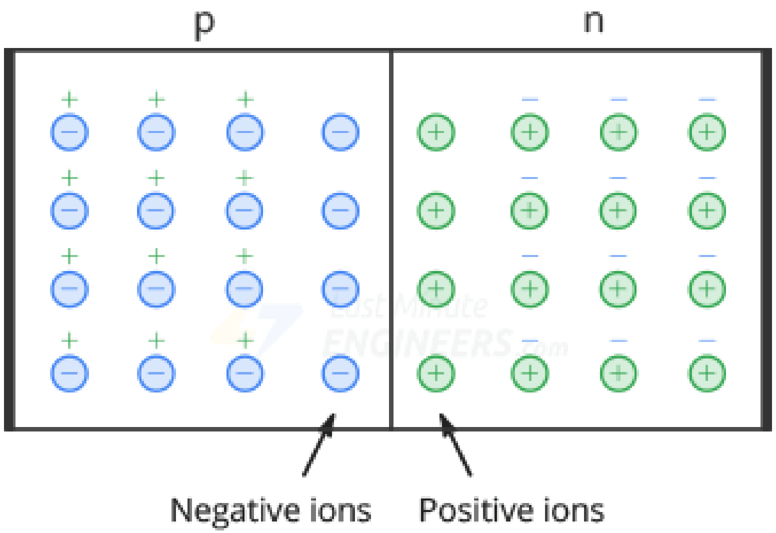


Concept of Depletion Region



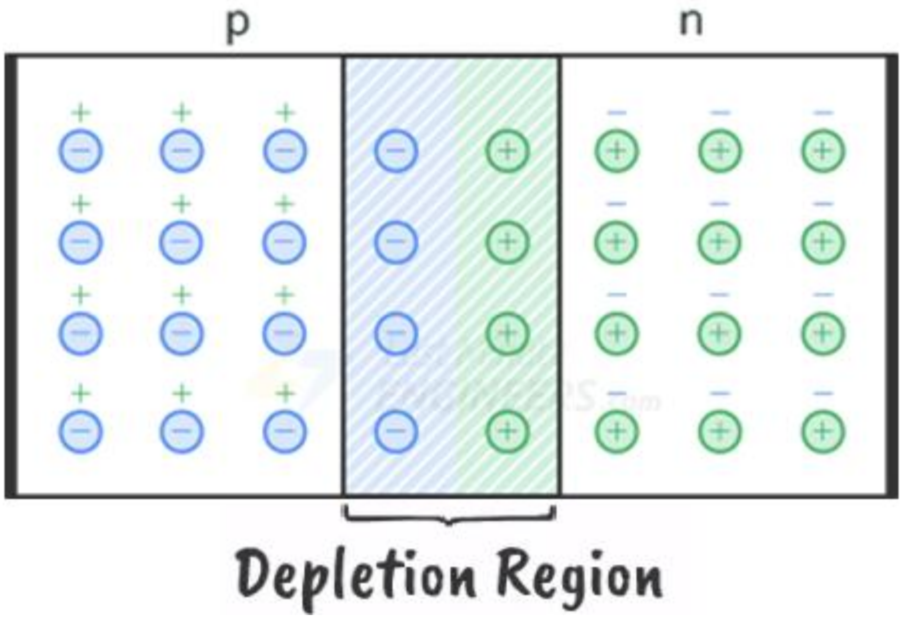
Concept of Depletion Region

- When the free electron falls into a hole on the P-side, the P-side atom gains an extra electron, hence it becomes a negative ion.
- Similarly, each free electron that leaves the N-side atom creates a hole in the N-side atom, due to which it becomes a positive ion.
- So each time an electron crosses the junction and recombines with a hole, it creates a pair of ions.



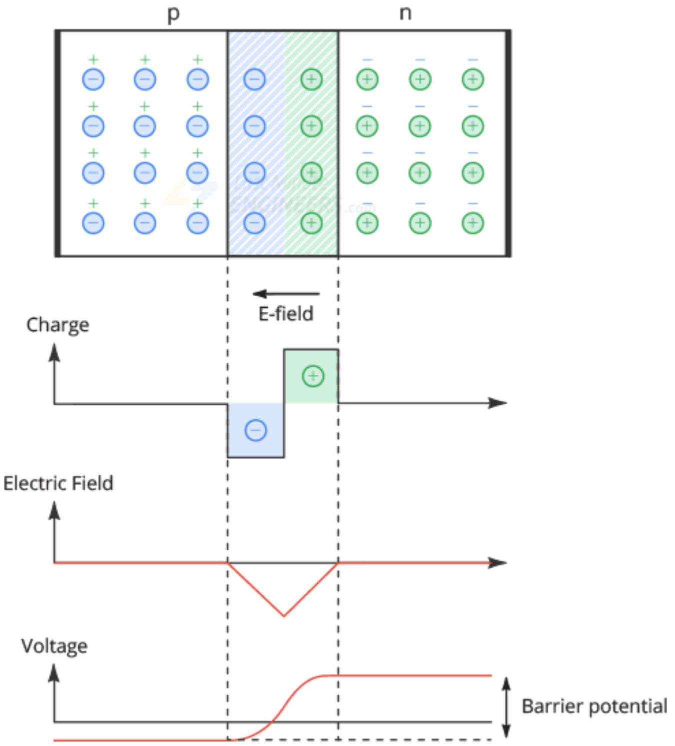
Concept of Depletion Region

- The region near the junction is depleted of majority charge carriers. Therefore we call this charge-empty region The depletion region.



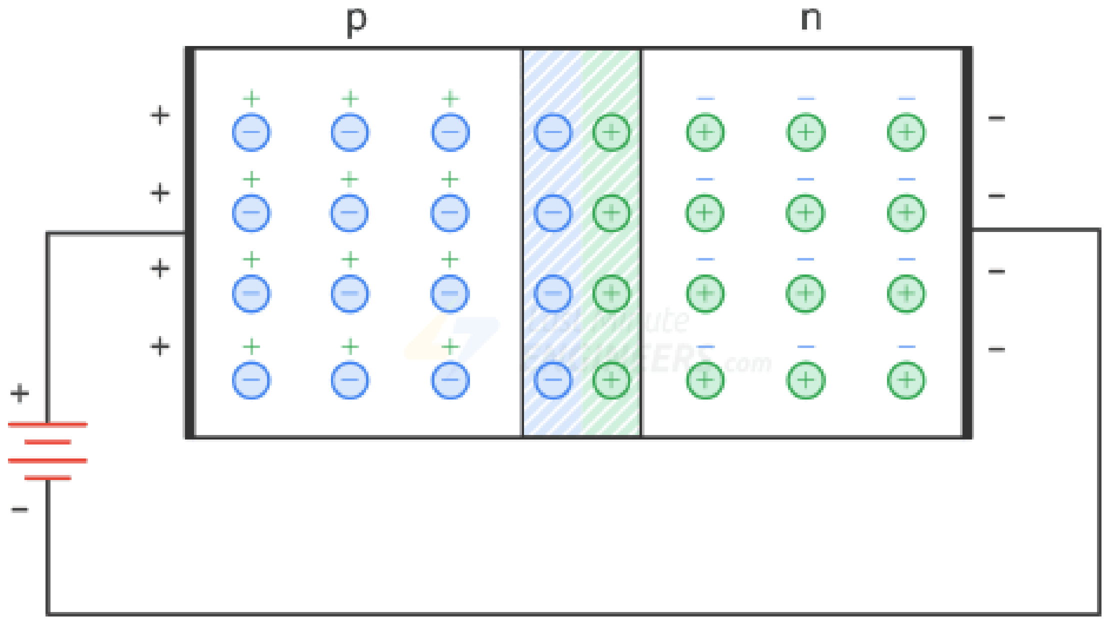
Barrier Potential

- Each pair of positive and negative ions at the junction is called a dipole.
- Each dipole has an electric field between positive and negative ions.
- The electric field between the ions is equivalent to a difference of potential called the barrier potential.
- At room temperature, the barrier potential equals approximately 0.3 V for germanium diodes and 0.7 V for silicon diodes.

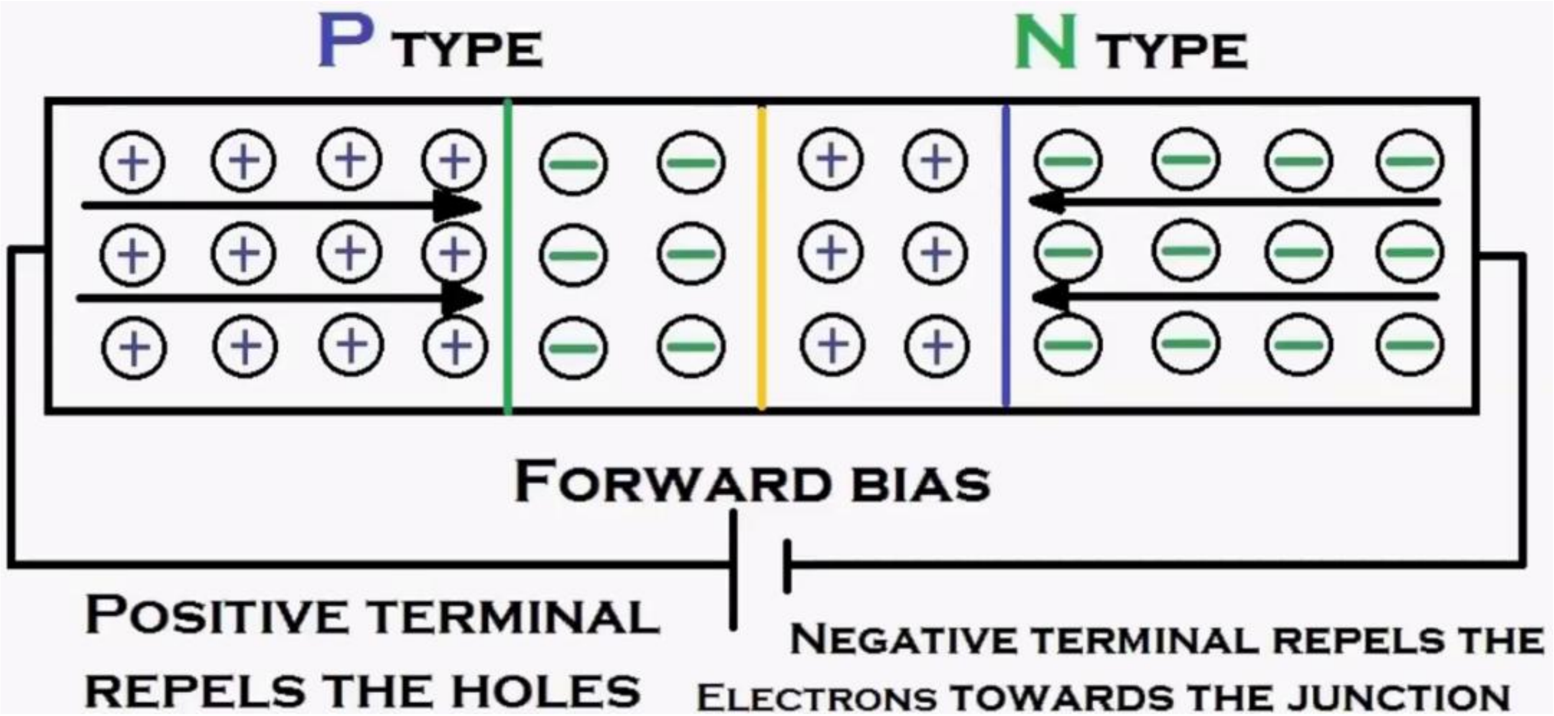


Forward Bias

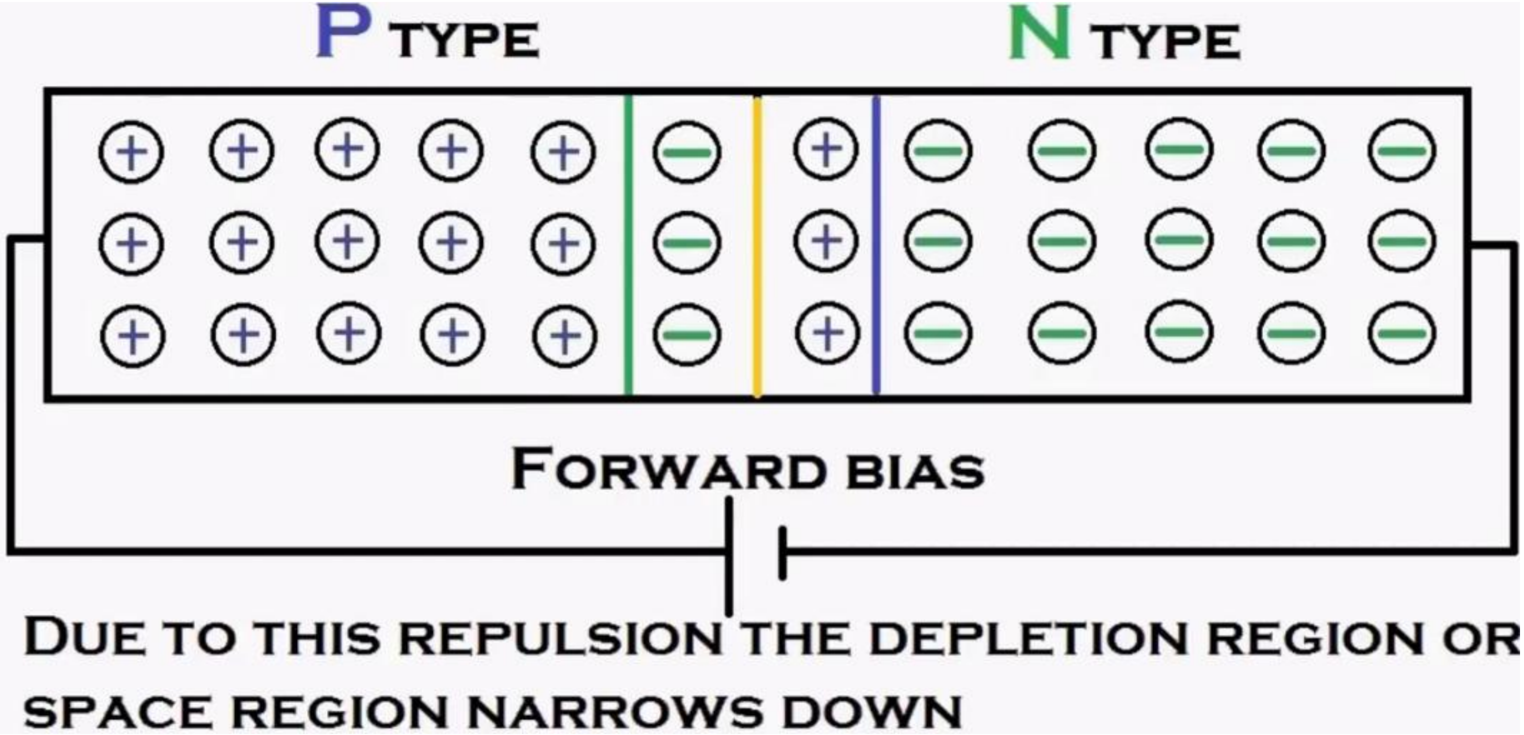
- In forward bias, the p-type is connected with the positive source terminal and the n-type is connected with the negative source terminal.



Forward Bias

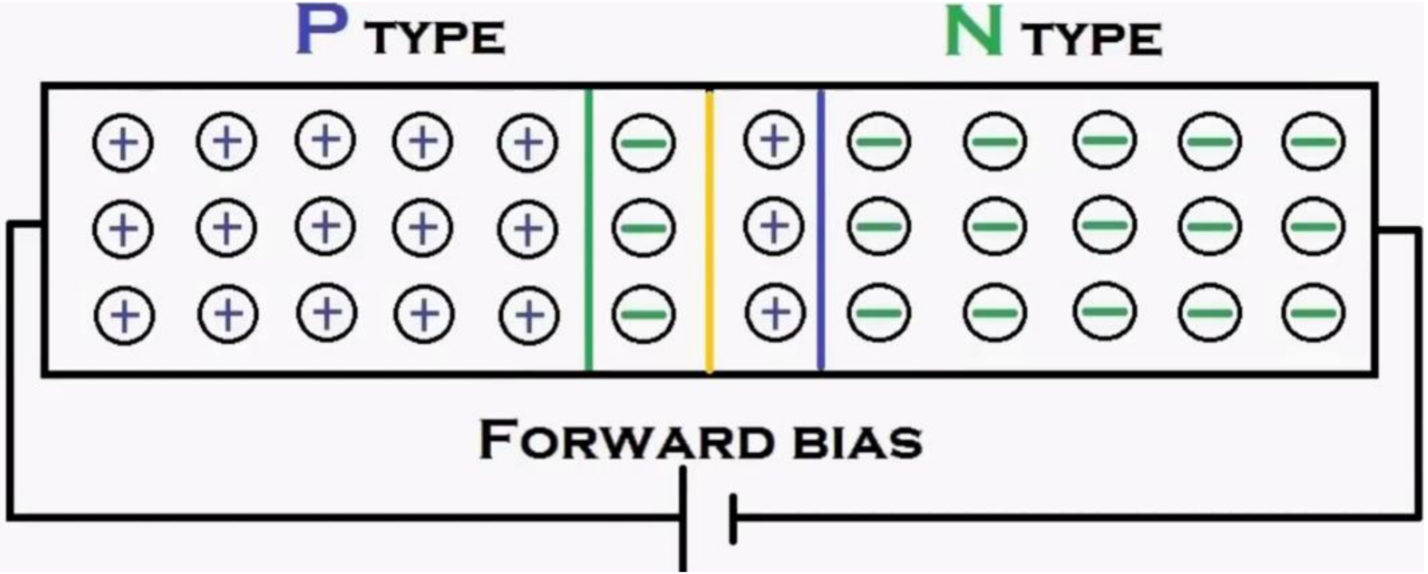


Forward Bias



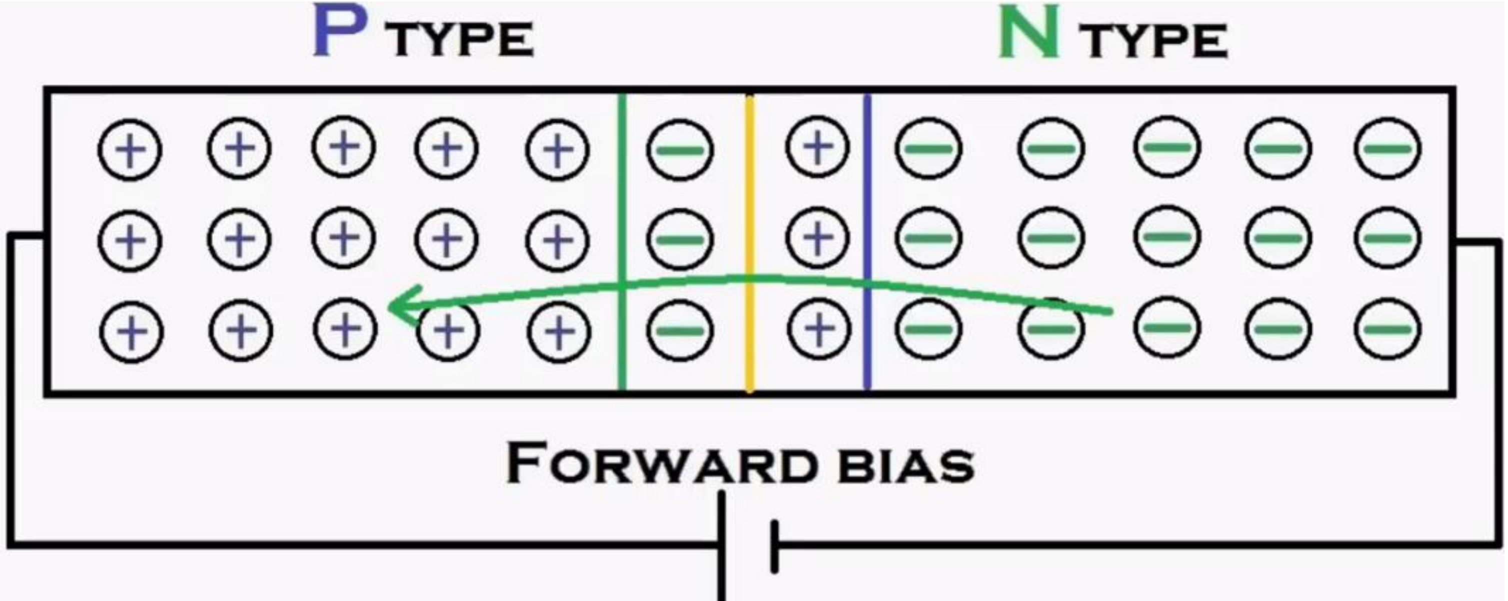
Forward Bias

If the battery voltage is less than the barrier potential (0.7V), the free electrons do not have enough energy to get through the depletion layer. When they enter the depletion layer, the ions will push them back into the n region. Because of this, there is no current through the diode.



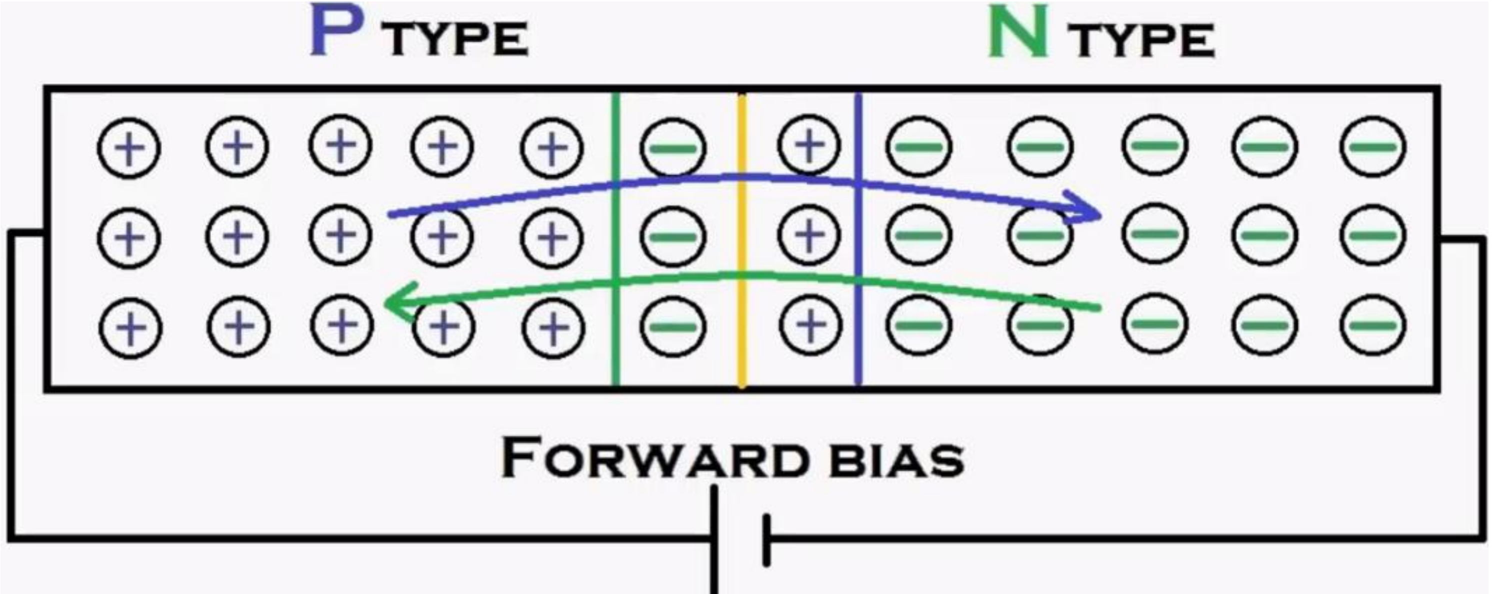
Forward Bias

When the battery voltage is greater than the barrier potential (0.7V), the free electrons have enough energy to pass through the depletion layer and recombine with the holes. In this way they begin to neutralize the depletion region, reducing its width.



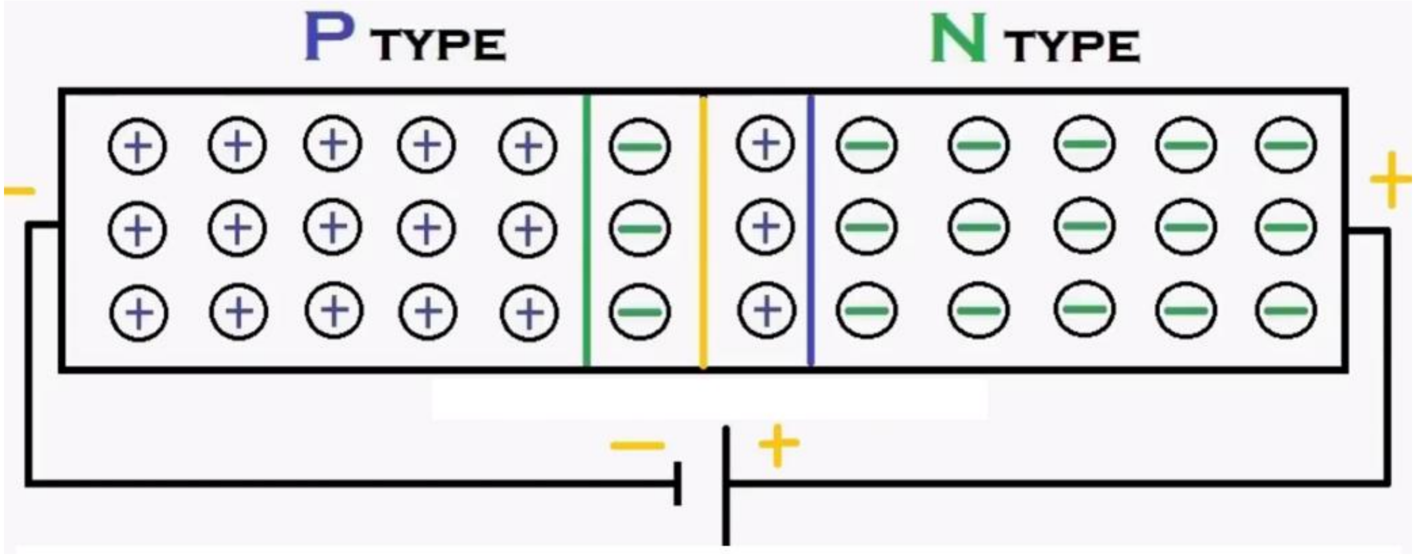
Forward Bias

Electrons in N region drifts through the junction and migrates to P region, while holes in P region drifts through junction & migrates to n region. Due to this, continuous current through the diode. This current is called as drift current.



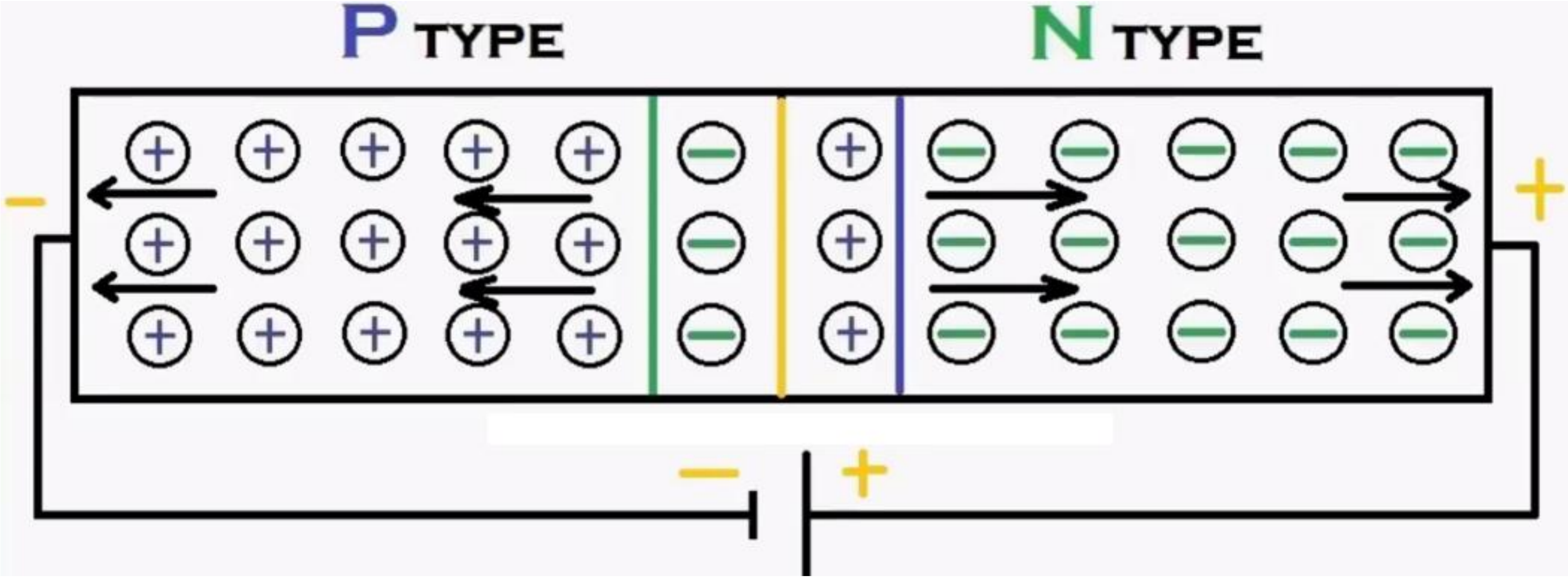
Reverse Bias

- When positive terminal of battery is connected to N region & negative terminal is connected to P region, the PN junction is said to be reversed biased.



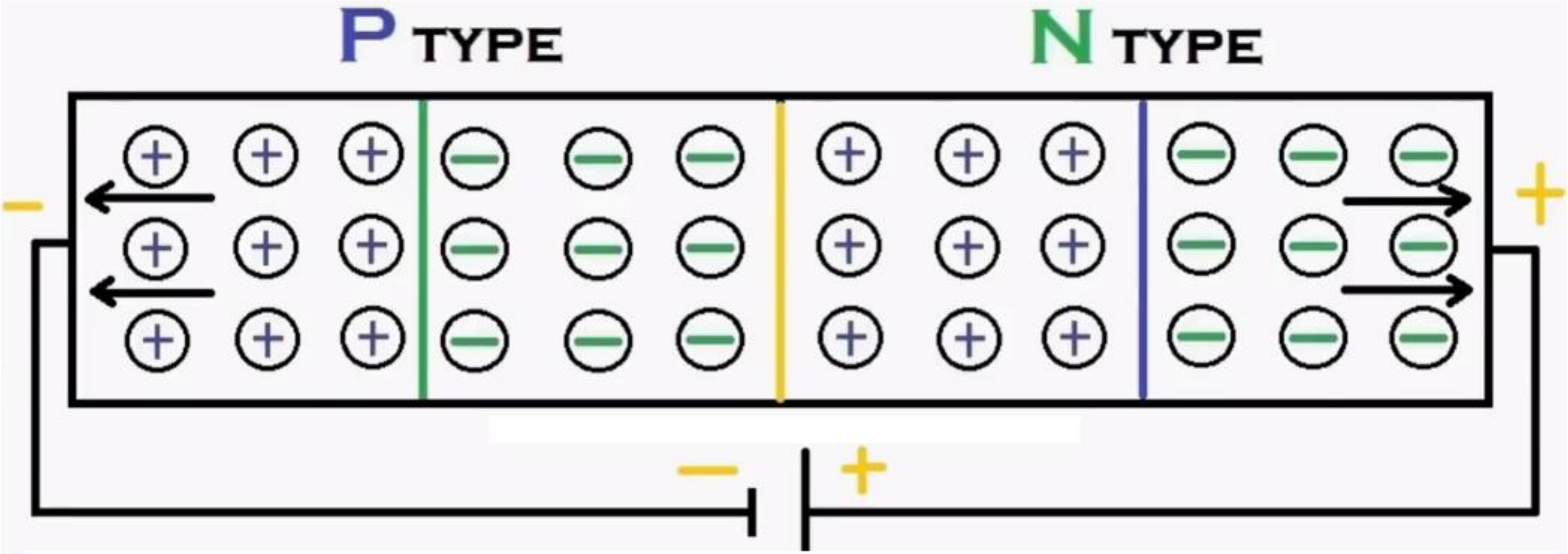
Reverse Bias

- During reverse bias, holes get attracted to the negative terminal of battery & electrons get attracted towards positive terminal.



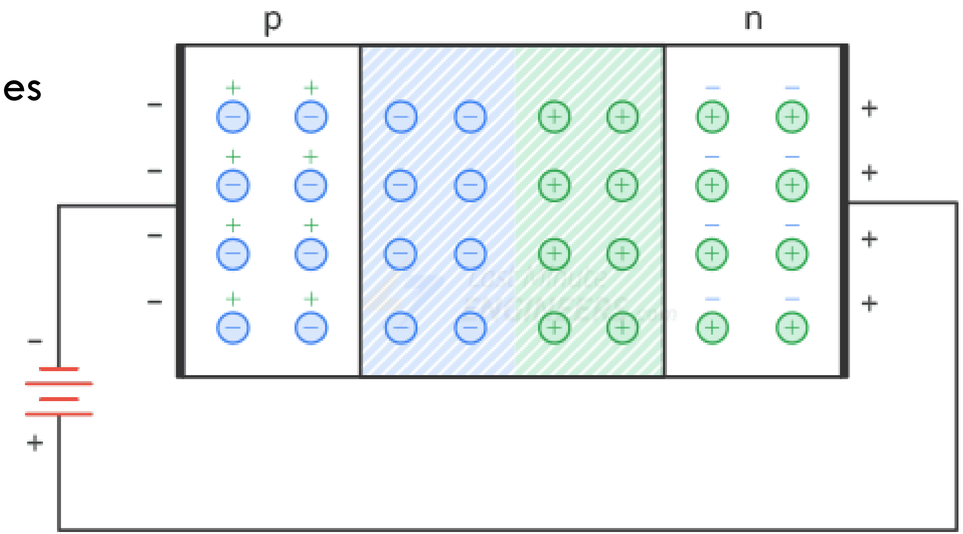
Reverse Bias

- Due to this, holes and free electrons flow away from the junction leaving the positive and negative ions behind. This results in increase in the width of depletion region.



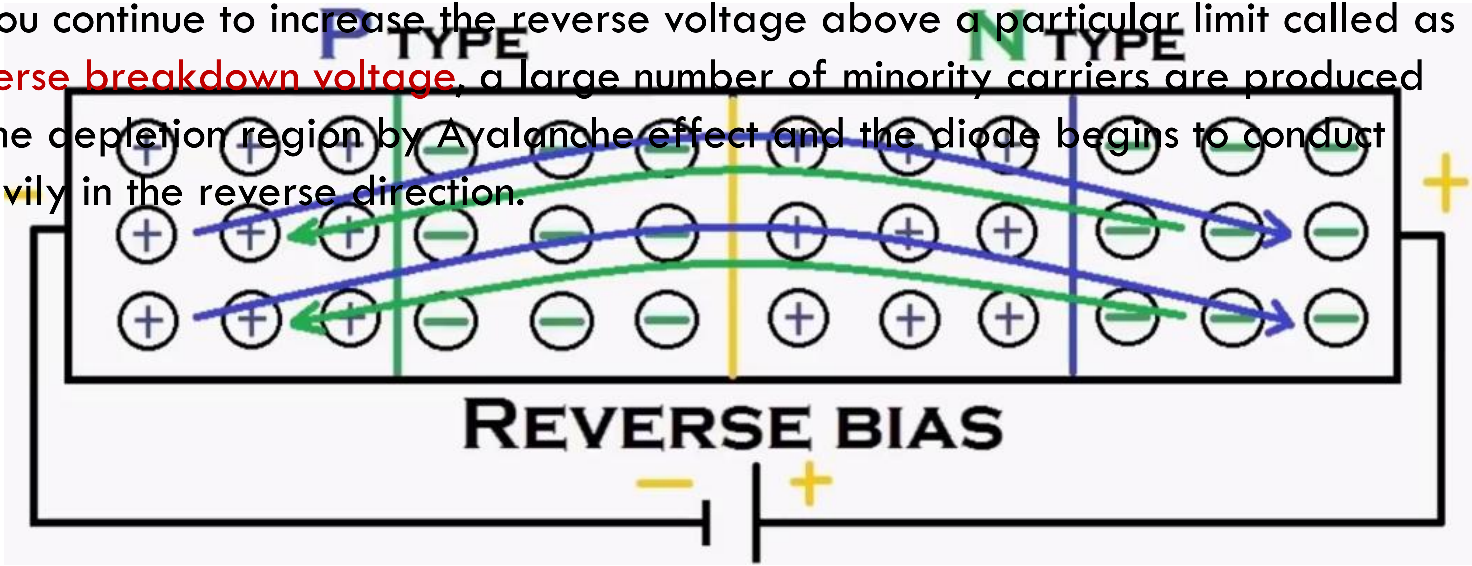
Reverse Bias

- The width of the depletion region is proportional to the reverse voltage. As the reverse voltage increases, the depletion region gets wider.
- The depletion region stops growing when its potential difference is equal to the applied reverse voltage.
- When this happens, electrons and holes stop moving away from the junction.
- In other words, pn junction now acts as insulator & will not allow any current to flow in the circuit.



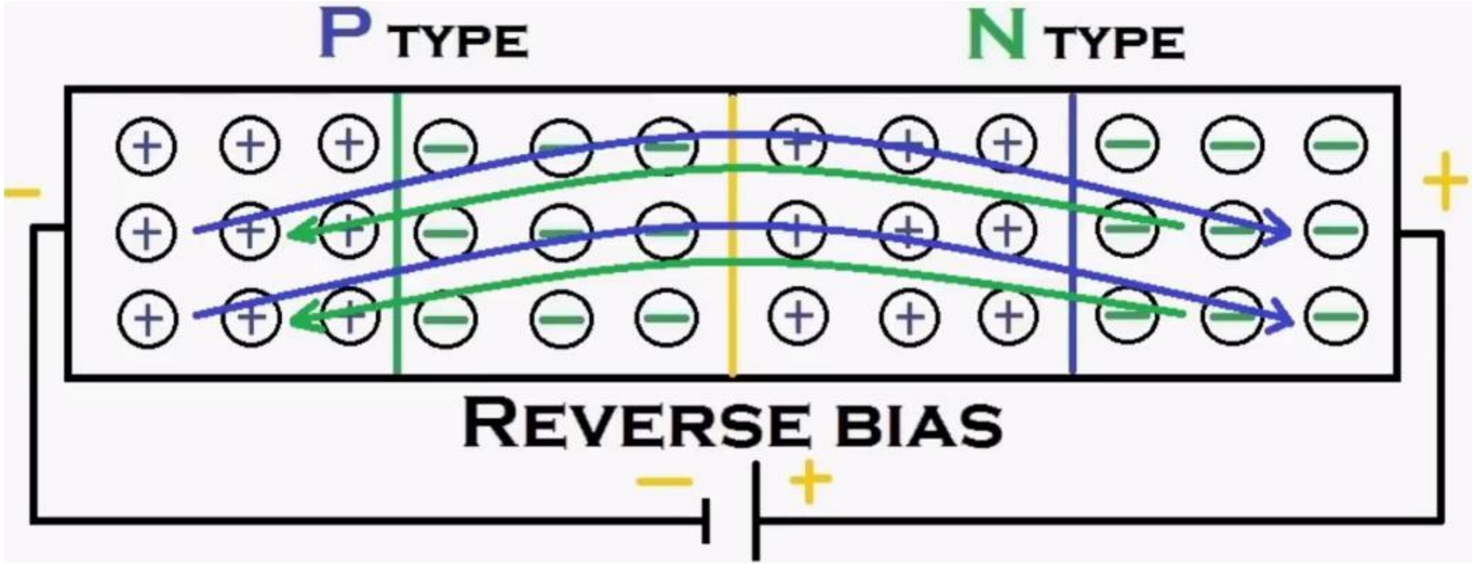
Breakdown

- There is a limit to how much reverse voltage a diode can withstand before getting destroyed.
- If you continue to increase the reverse voltage above a particular limit called as reverse breakdown voltage, a large number of minority carriers are produced in the depletion region by Avalanche effect and the diode begins to conduct heavily in the reverse direction.



Breakdown

- In this process the current flowing through the PN junction is very high & ultimately the PN junction gets damaged due to overheating caused by the excess flow of current.

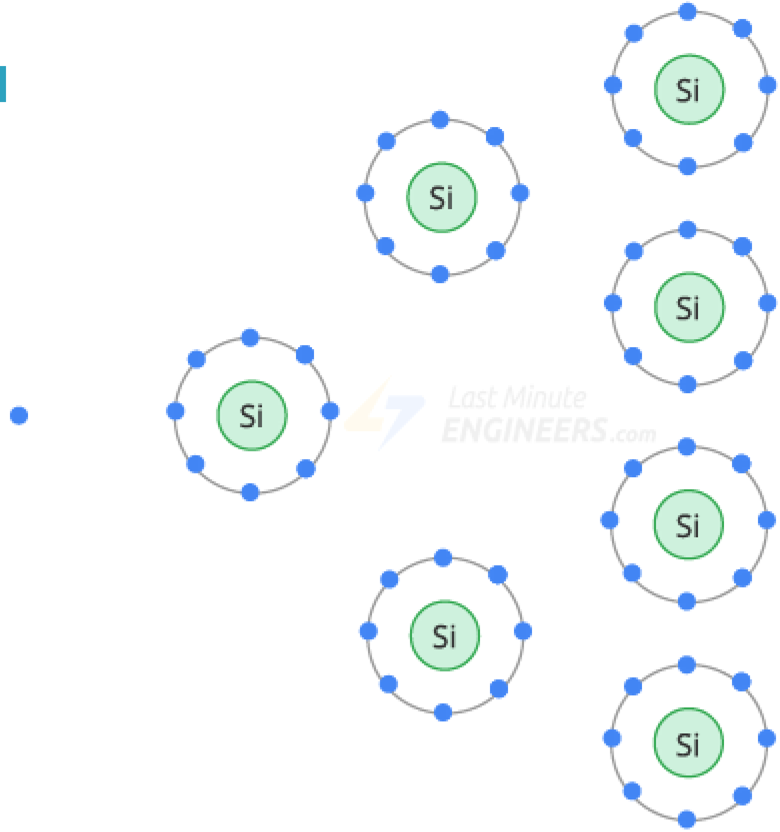


Avalanche Effect

- As we know there is a small minority-carrier current in a reverse-biased diode. When the reverse voltage increases, it forces minority carriers to move faster.
- These minority carriers moving at high speed collide with the atoms of the crystal and knock valence electrons loose, producing more free electrons.
- These new minority carriers join the existing minority carriers and collide with other atoms that knock off more electrons.
- This constant collision with atoms generates a large number of minority carriers that produce a significant amount of reverse current in the diode. And this process continues until the reverse current becomes large enough to destroy the diode.

Avalanche Effect

- One free electron dislodges one valence electron, resulting in two free electrons. These two free electrons then dislodge two more electrons, resulting in four free electrons. In this way the number of electrons increases in Geometric progression: 1, 2, 4, 8, . . .



Thank You