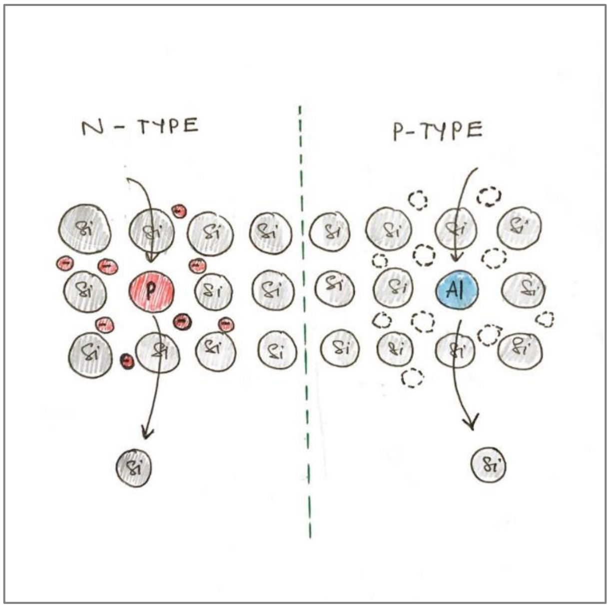
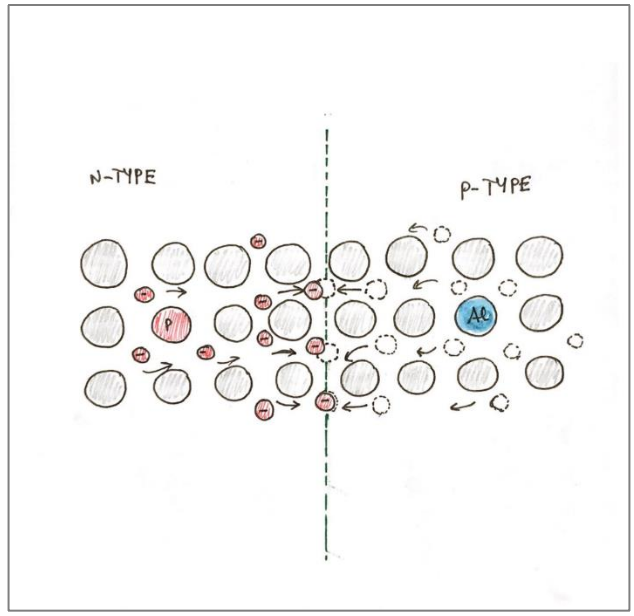
p-n junctions

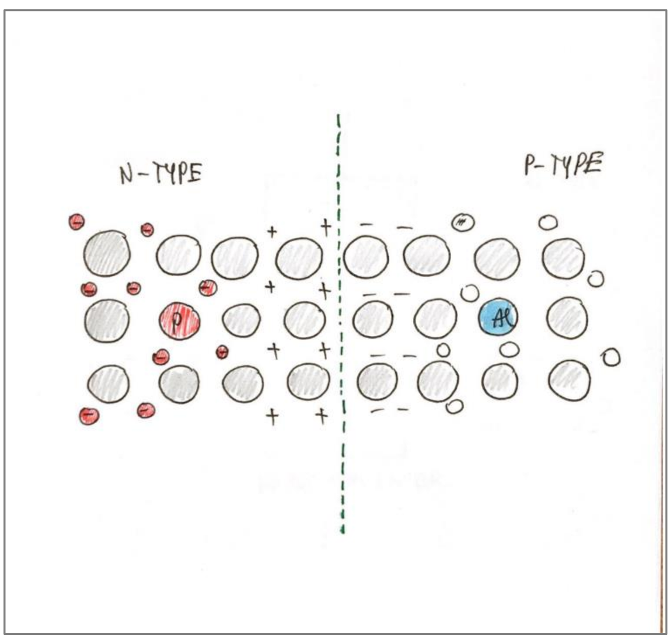
Lesson I



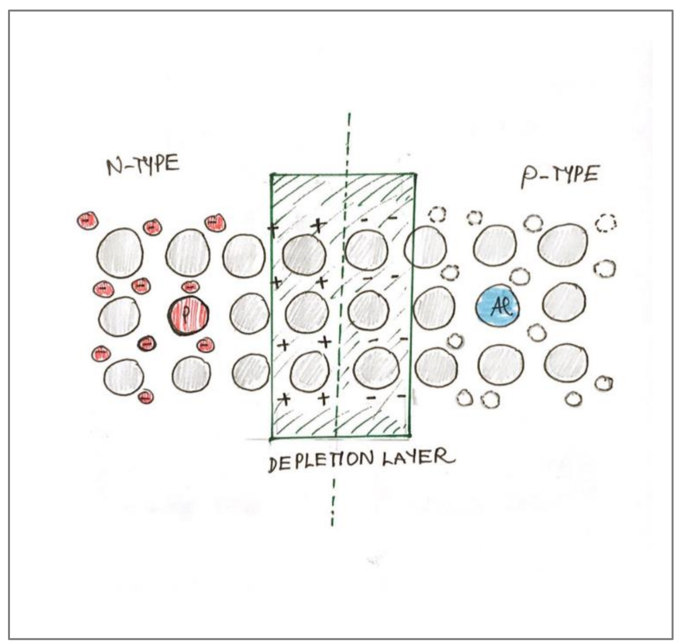
A p-n junction is formed when a p-type and a n-type semiconductor join together. This is achieved by doping 2 ends of an intrinsic semiconductor lattice. p-n juctions are the basic building blocks of many electrical devices including LEDs, transistors, solar cells.



Free electrons from the n-type semiconductors diffuse across the junction and combine with holes available in the p-type semiconductors.

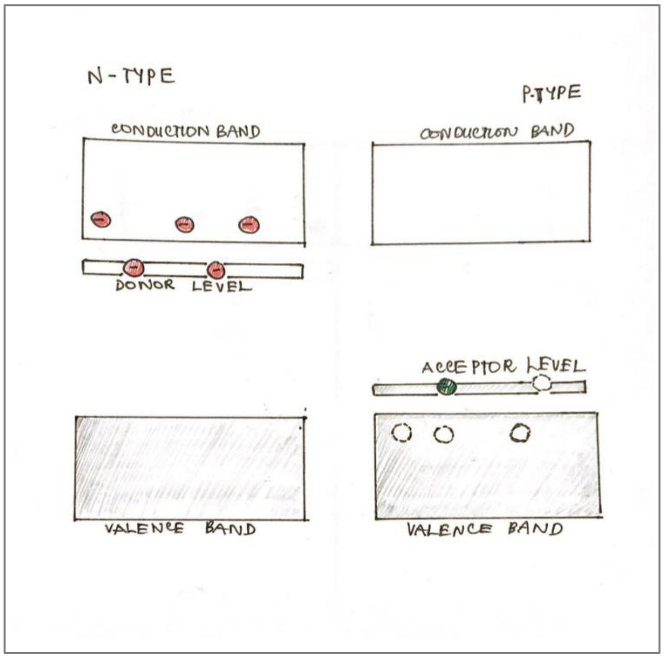


The region of the n-type semiconductor near the junction becomes positively charged as it has lost electrons. The region of the p-type semiconductor near the junction becomes negatively charged as it has gained electrons.

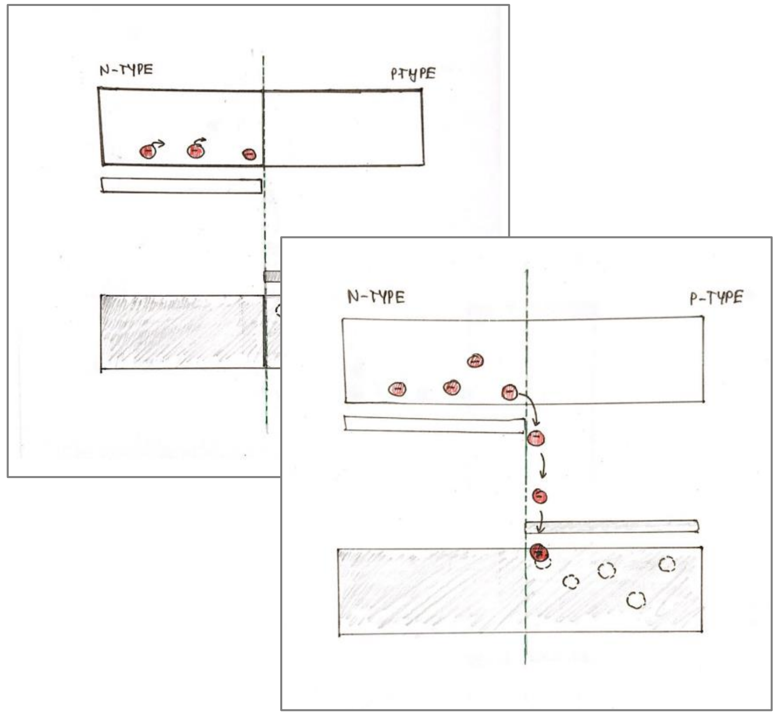


The thin layer of the crystal lattice between these charges has been depleted of majority carriers, thus, is known as the depletion region. It becomes an intrinsic semiconductor, nearly insulating to separate the conductive n-type and the p-type regions.

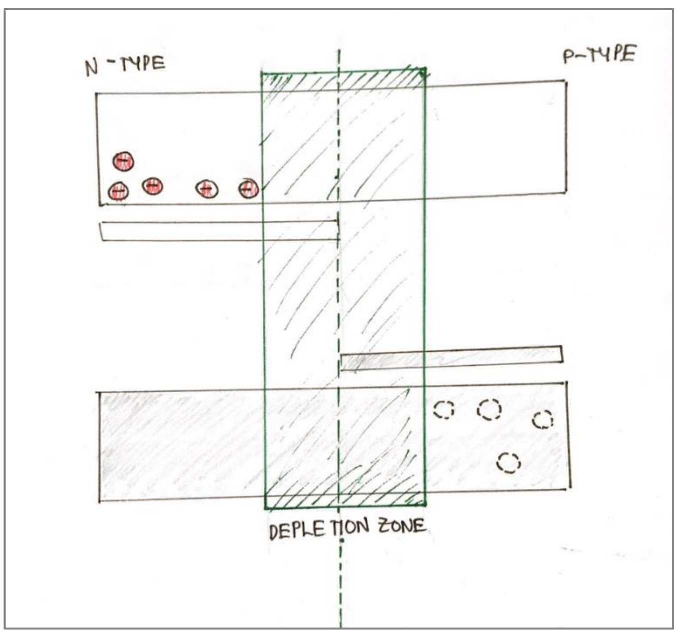
Lesson II



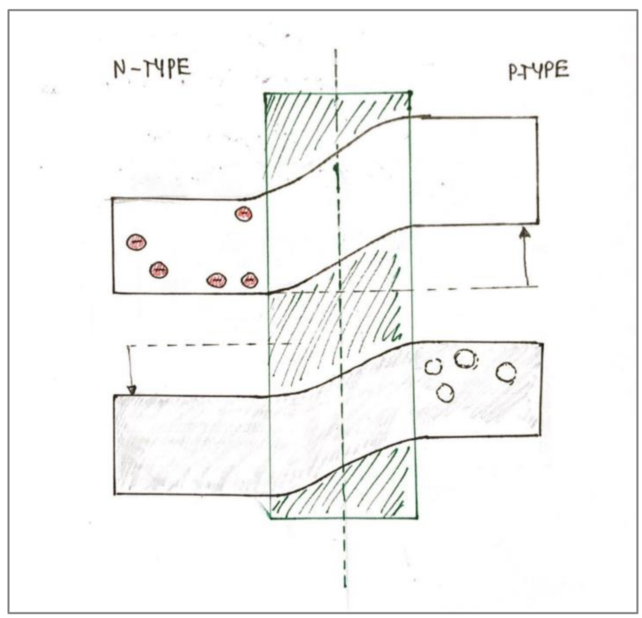
In this lesson, we're going to look at how a p-n junction is formed using band diagram. A n-type semiconductor has free electrons in the conduction band as the major charge carriers. A p-type semiconductor has holes in the valence band as the major charge carriers.



When the 2 semiconductors are initially joined together, n-type electrons will flow into the p-type valence band to lower their energy. Meanwhile, p-type holes flow in the opposite direction.

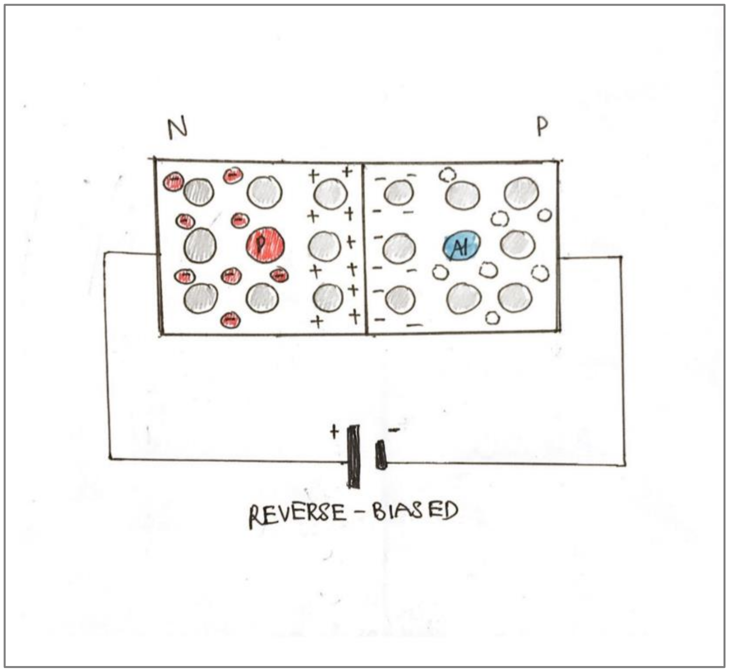


Charge carrier density is therefore depleted at the contact. The width of the depletion region is typically in the range 10nm-1um. A free charge now requires some extra energy to overcome this region with very few charge carriers.

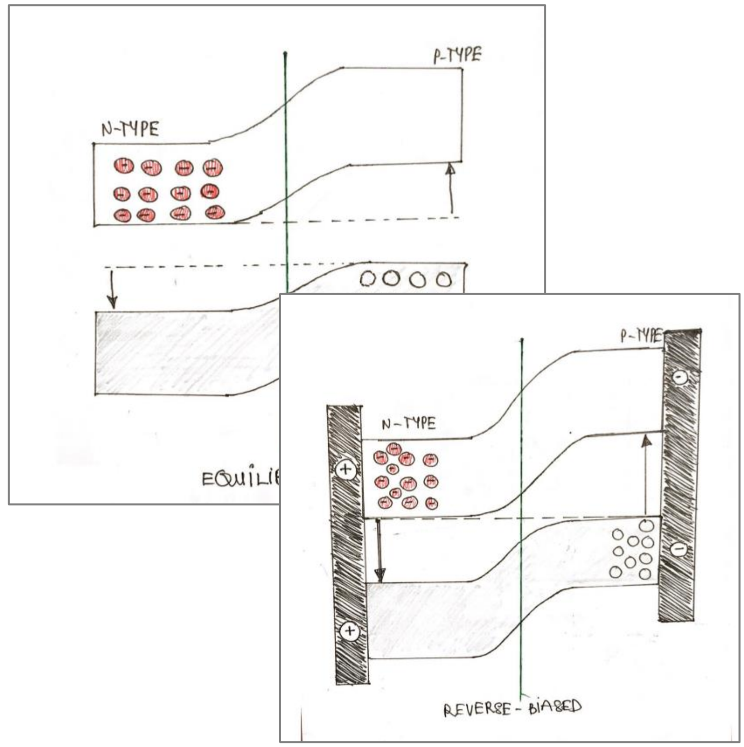


As the chemical potentials of the 2 types of semiconductor come to equilibrium, the band structures are deformed accordingly. Now we can imagine the electrons having to "go uphill" to move from the n-type to the p-type side.

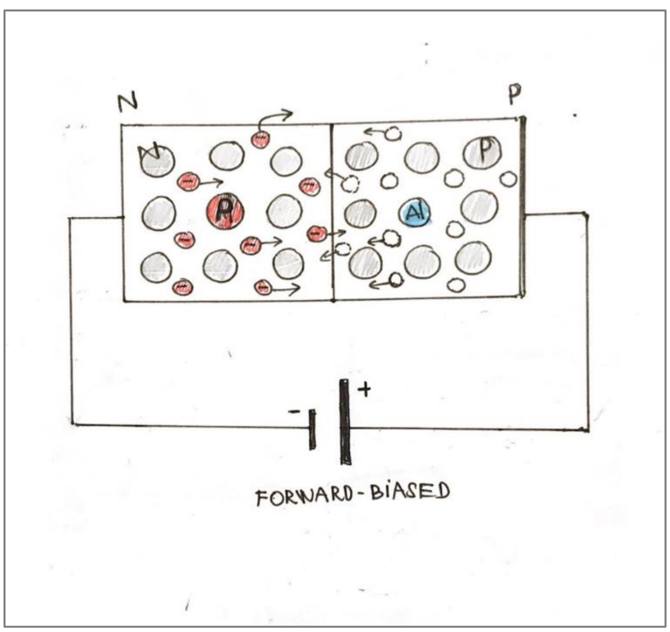
Lesson III



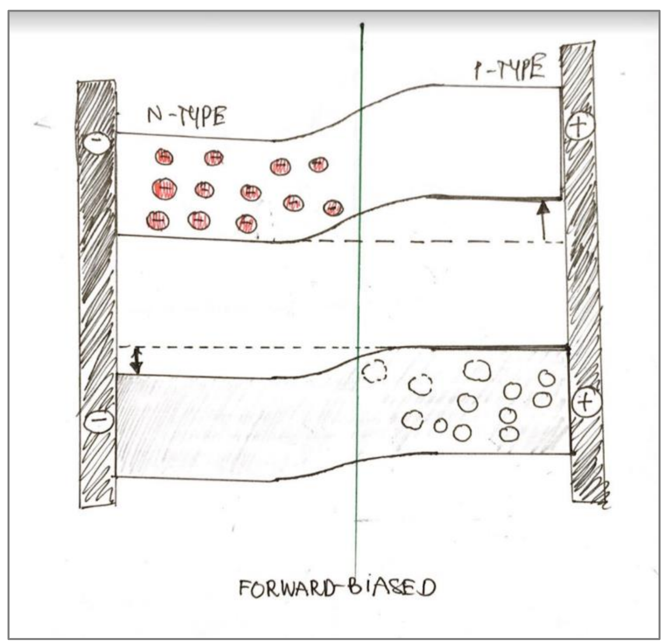
At equilibrium, there is a potential barrier for electrons to diffuse from the n-type to the p-type semiconductor and holes to diffuse in the opposite direction. If the n-type region is connected to the positive terminal of a battery and the p-type is connected to the negative side, the depletion region becomes wider. This is called reverse bias.



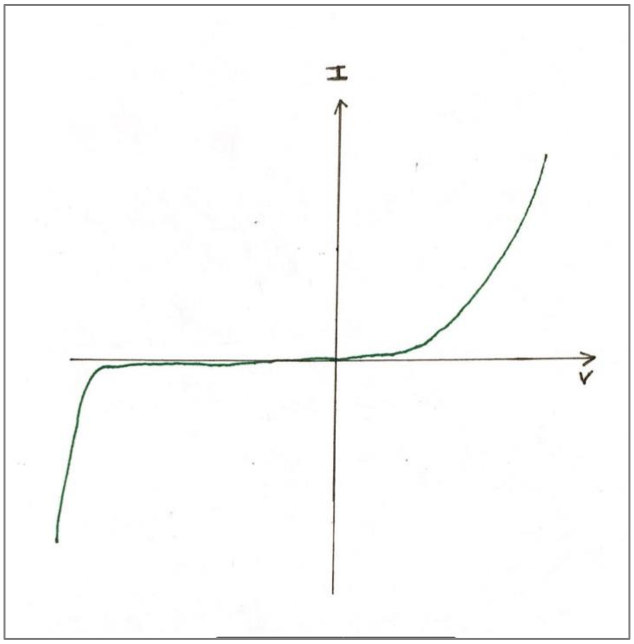
In such reverse-biased situation, the potential barriers for both electrons and holes are increased. The diffusion current is reduced which results in a very small net flow of electrons.



When the voltage is applied the opposite way instead, electrons want to move from n-type to p-type side. The depletion layer becomes narrower. This is called forward bias.



In such forward-biases situation, the potential barriers for both electrons and holes are decreased. The diffusion current is reduced which results in a large net flow of electrons.



The overall current-voltage characteristic of the p-n junction is shown in the graph. An increase in strength of the reverse biasing will eventually lead to an increase in the current due to dielectric breakdown of the semiconductor. The voltage at