# PN Junction: Qualitative Analysis Lesson

**Lesson Topic:** PN Junction: Qualitative Analysis

**Objective of Lesson:** To get a qualitative rather than quantitative understanding of how a p-n junction works.

**Reading Assignment:** Section 5.1

**Discussion Questions:**

1. What happens to the built-in potential, $V_{bi}$, if the doping on either side of the p-n junction is increased? Explain using the band diagram.

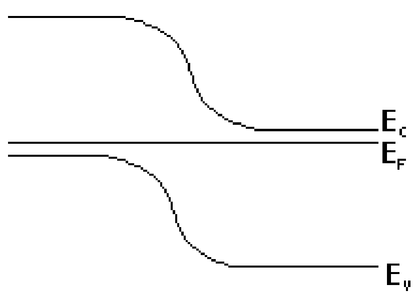
**Homework:** None

**What do you need to know for the exam?:**

1. Understand how doping concentrations affect the barrier height.
2. Be able to draw any band diagram associated with p-n junctions.

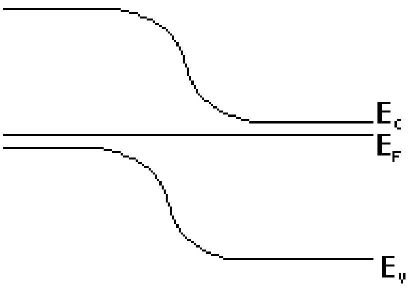
**Summary**
This is a brief introduction to a pn-junction. The discussion is purely qualitative and is based on the foundational understanding you should have developed in the beginning of the course.

**PN Junction: Qualitative Analysis**
I always start discussions of a p- n junction with the band diagram. Let's draw one. Start with a flat Fermi level. Then draw around the left 1/3 of the Fermi level a p-type semiconductor with flat bands. Next draw at the right 1/3 of the Fermi level an n-type semiconductor with flat bands. Finally, connect the dots—connect the conduction and valence band lines with smooth lines with gentle curves. See below. This is a skill you need to learn—being able to draw an equilibrium band diagram for any device in the future. You will find out later that the curves that connect p-type and n-type semiconductors are pairs of parabolas.




Take a look at what we have drawn. What do you see? Do you see an electric field? Do you see a potential difference from one side to another? That potential difference is a barrier to electrons like a ramp is a barrier to a ball rolling up it. We have already learned that electrons tend to flow down conduction band lines as balls tend flow down conduction band lines. A conduction band electron at the top of the barrier will be pushed by the field down the slope to the right side. Note also that there are many more holes on the left side than on the right side so there must be diffusion of holes from left to right. Concurrently, holes drift from right to left. In equilibrium, as we have learned, those two hole currents must perfectly balanced everywhere.

Look at the height of the barrier. What would happen to the barrier if we increased the doping on the n-type side? Well, to see it, recognizing that the Fermi level is going to be flat again, what you would see is the conduction band will be closer to the Fermi level. That results in an increase in the barrier height, as shown in the figure below.




What else can you see in the band diagram of a p-n junction? On either side are flat bands—if one goes far enough away from the junction, the bands should be flat. There is a transition region in the middle that is called the depletion region or the space charge region. That transition region has an electric field that slowly increases toward the middle and then slowly decreases back to zero. The electric field is negative. The electric field is always changing inside that transition region—you can tell by the changing slope of $E_c$—so there must be charge throughout the “space charge region” (Poisson’s equation, $\rho = \frac{d\mathcal{E}}{dx}$).

These are the types of things you should be able to see when you “read” a band diagram. What we will be doing next is quantifying the analysis so we can figure out what is the shape of the electric field, what is the nature of the charge, and what equations define the change in potential across the junction.