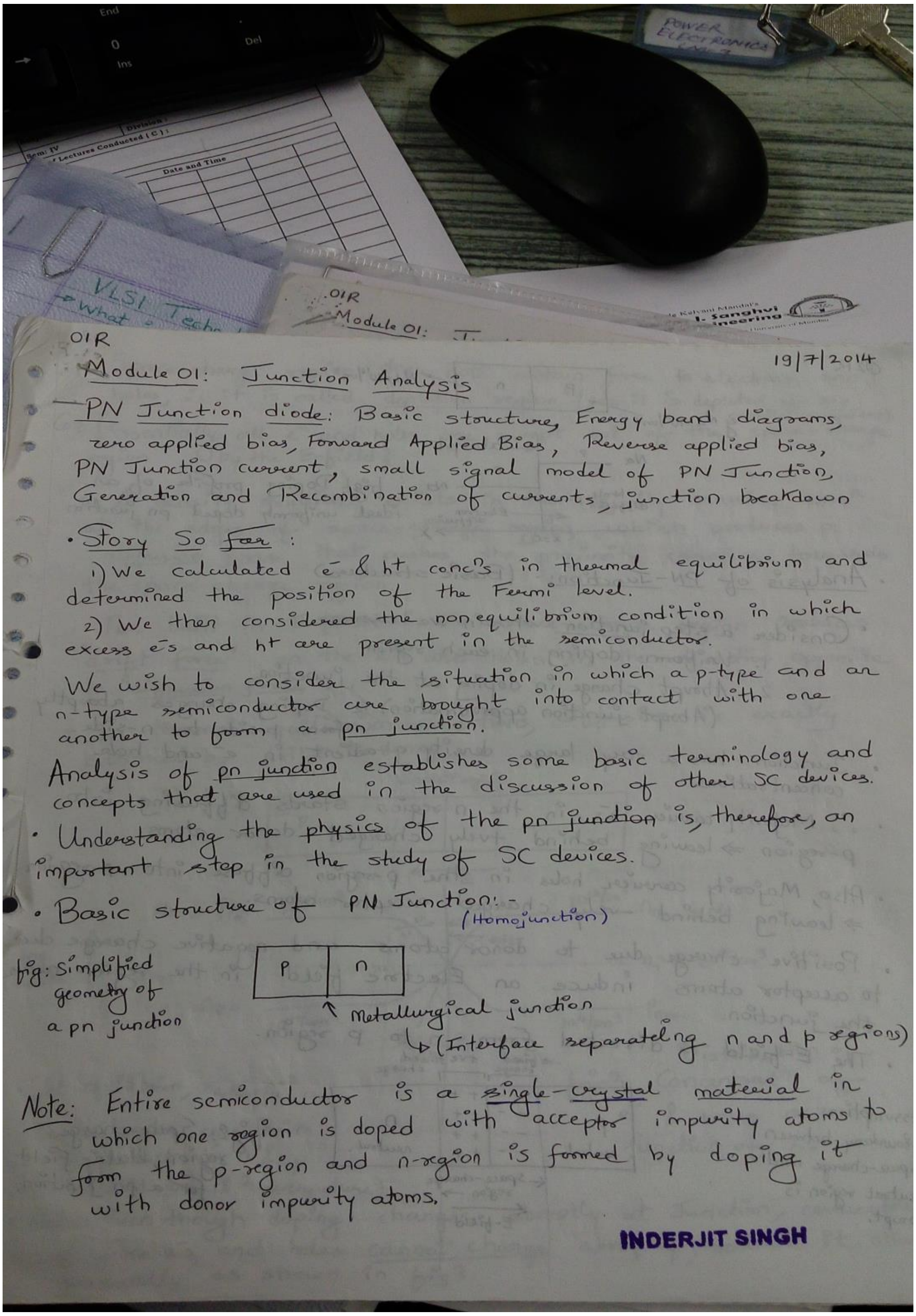
EDC 01

PN Junction – pn junction analysis under Zero Applied Bias



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Module 01: Junction Analysis

PN Junction diode: Basic structure, Energy band diagrams, zero applied bias, Forward Applied Bias, Reverse applied bias, PN Junction current, small signal model of PN Junction, Generation and Recombination of currents, junction breakdown

• Story So Far:

1) We calculated e⁻ & h⁺ conc's in thermal equilibrium and determined the position of the Fermi level.

2) We then considered the nonequilibrium condition in which excess e⁻s and h⁺ are present in the semiconductor.

We wish to consider the situation in which a p-type and an n-type semiconductor are brought into contact with one another to form a pn junction.

Analysis of pn junction establishes some basic terminology and concepts that are used in the discussion of other SC devices.

• Understanding the physics of the pn junction is, therefore, an important step in the study of SC devices.

• Basic structure of PN Junction: - (Homojunction)

fig: Simplified geometry of a pn junction

p	n

↑ Metallurgical junction
↳ (Interface separateling n and p regions)

Note: Entire semiconductor is a single-crystal material in which one region is doped with acceptor impurity atoms to form the p-region and n-region is formed by doping it with donor impurity atoms.

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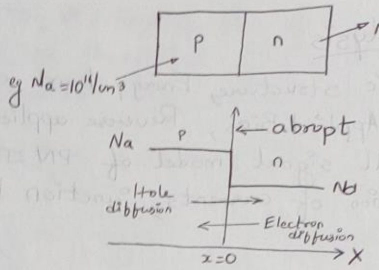

fig1: Doping profile of an ideal uniformly doped pn junction

· Analysis of PN-Junction: · (Basic structure)

· Consider a step junction wherein we assume
1. Uniform doping in each region.
2. Abrupt change in doping at the junction.
(Abrupt junction approximation) ie Doping changes abruptly from p-side to n-side.

· Junction has a very large density gradient in e^- and hole concentrations.

· ∴ Majority carrier e^-s in the n-region starts diffusing into p-region ⇒ leaving behind +vely charged donor atoms.

· Also, Majority carrier holes in the p-region diffuse into n-region ⇒ leaving behind -vely charged acceptor atoms.

· Positive charge due to donor atoms and negative charge due to acceptor atoms induce an Electric field in the region near the junction.

· The E-field is directed from n to p region.

· Assumptions:
1. Boundary between space-charge and neutral region is abrupt.

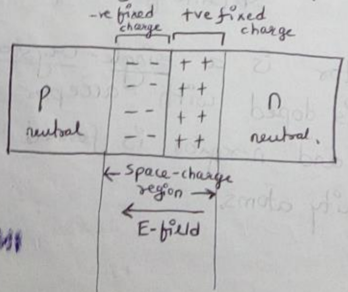

fig2: Space-charge region, electric field for a pn junction.

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- Space-charge region does not contain free ~~to~~ electrons and holes, ∴ it is called "depletion region." (coz it is depleted of any mobile carriers)
- coz (Essentially all e^- and holes are swept out of the space-charge region by the E-field.)
- A density gradient exists in the majority carrier conc^n at the edges of space-charge region, which produces a diffusion force that pushes the majority carriers towards the space-charge region.
- The built-in E-field in the space-charge region produces "drift force" on the e's and holes in the direction opposite to "diffusion force".
- In thermal equilibrium conditions, diffusion is exactly balanced by drift tendency.

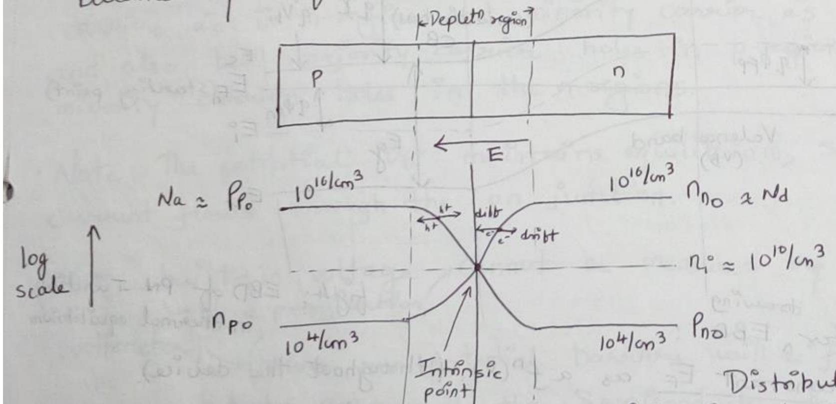

fig3: Distribution of Concentratn of e^- & holes as a function of x.

- At equilibrium, $n_{no} p_{no} = n_i^2$
- (Device under equilibrium so product of n & p should be n_i^2 everywhere).
- Note: Even though doping changes abruptly at Junction, concentration of free e's and holes cannot change abruptly, rather it changes gradually. as shown in fig3.