EI-27003: Electronics Devices and Circuits
Lecture - 15

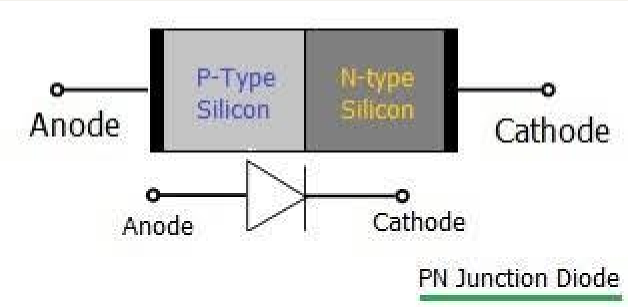
Subject Incharge: Mr. Rajesh Khatri
Associate Professor

LECTURE - 15

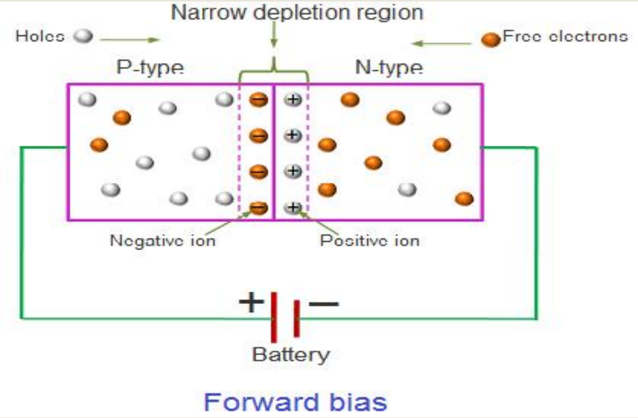
Year: 2020-21

Unit – 2/3 : Diode and BJT Modeling

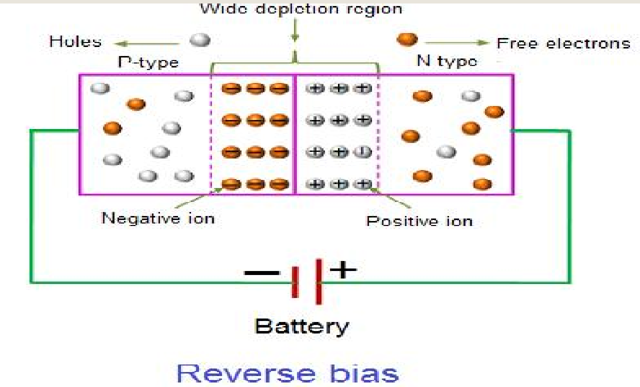
- PN Junction Diode



- Forward Bias Diode:

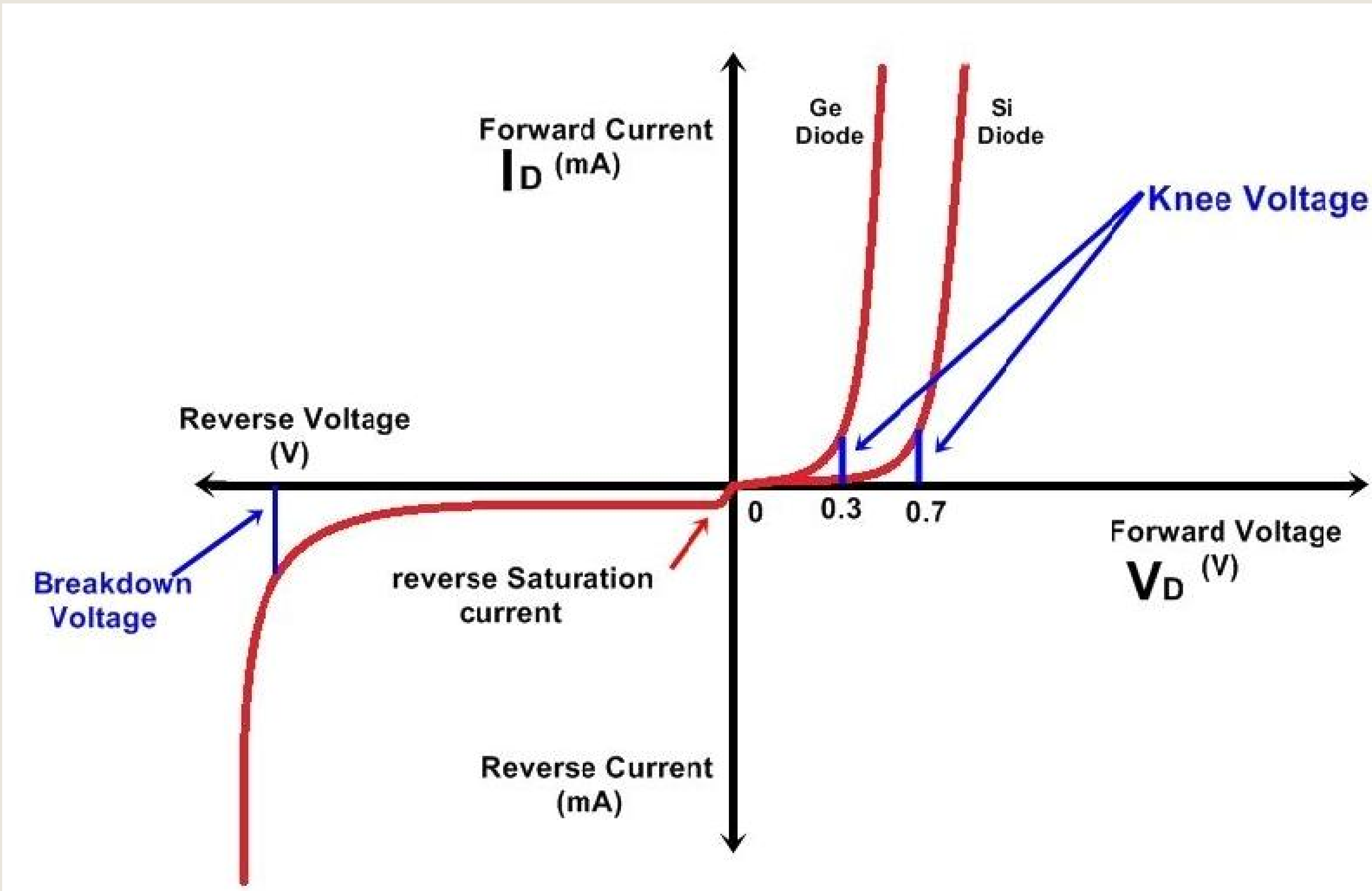


- Reverse Bias Diode:



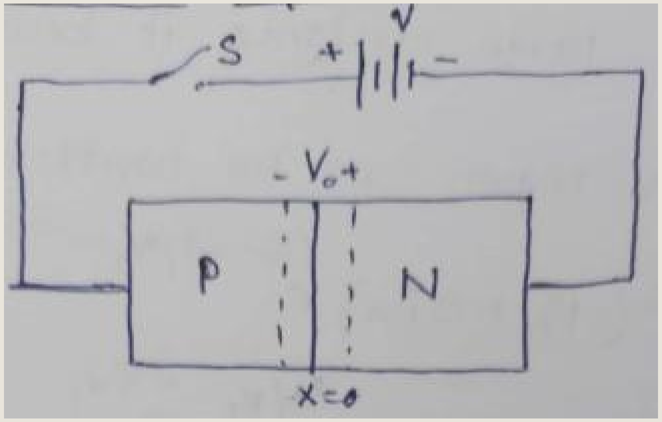
VI Characteristics of PN Junction Diode

- Forward and Reverse Characteristics:



Diode Equations

- Here we will obtain the equations:
- Diode current Equation: I_D
- Built-in Potential V_0
- Width of Depletion layer W



- Let us consider an open circuit PN junction
- Let hole and electron densities in p-region be P_p and n_p respectively.
- Let hole and electron densities in N-region be P_n and n_n respectively.

Diode Current Equation

- The density of holes in p-region and density of holes in n-region are related by Boltzman relation as:
  - $P_p = P_n e^{V_B/V_T}$
- Where V_B is barrier potential across depletion layer and V_T is 'Volt-equivalent of Temp'.
  - $V_T = \frac{KT}{q}$
- For open circuited PN junction: $V_B = V_0$
  - Hence $P_p = P_n e^{V_0/V_T}$ -----(1)
- Now consider PN junction is biased in forward direction by applying a voltage V by closing switch S
- Now the barrier potential decreases from its equilibrium value V_0 by V
  - i.e. $V_B = V_0 - V$

Diode Current Equation

- With forward bias, hole density in p-region remains constant upto depletion region while in N-region just at junction it increases from p_n to $p_n + \Delta p_n$ due to diffusion of holes across the junction.
- As the holes diffuse further in N-region, they combined with electron and their density decreases with increase of distance from the junction.
- Ultimately at large distance it becomes the same as p_n
- Now the hole density in N-region can be written as
  - $P_p = (P_n + \Delta P_n)e^{(V_0 - V)/V_T} = (P_n + \Delta P_n)\, e^{V_0/V_T}\, e^{-V/V_T}$ -------(2)
  - Substituting the value of P_p from eq.(1) into eq.(2)
  - $P_n e^{V_0/V_T} = (P_n + \Delta P_n)\, e^{V_0/V_T}\, e^{-V/V_T}$
  - $P_n = (P_n + \Delta P_n)\, e^{-V/V_T}$

Diode Current Equation

- $P_n \, e^{V/V_T} = (P_n + \Delta P_n)$
- OR
- $\Delta P_n = P_n \, (e^{V/V_T} - 1)$ -------(3)
- From eq.(1) $P_n = P_p e^{-V_0/V_T}$ -----(4)
- Substitute eq(4) in eq(3)
- $\Delta P_n = P_p e^{-V_0/V_T} (e^{V/V_T} - 1)$ ------(5)
- The diffusion of holes constitutes hole current. This hole current I_p is proportional to ΔP_n
- $I_p \propto \Delta P_n$ or $I_p \propto P_p e^{-V_0/V_T} (e^{V/V_T} - 1)$
- $I_p = I_{sp} \, (e^{V/V_T} - 1)$

Diode Current Equation

- Similarly, electron current due to diffusion of electrons from N-region to P-region is:
  - $I_n = I_{sn} (e^{V/V_T} - 1)$

- Hence the total current is sum of hole current and electron current
  - $I = I_p + I_n = I_{sp} (e^{V/V_T} - 1) + I_{sn} (e^{V/V_T} - 1)$
  - OR
- $I = I_0 (e^{V/V_T} - 1)$ where $I_0 = (I_{sp}+I_{sn})$ is called reverse saturation current

- $I = I_0(e^{V/V_T} - 1)$ is diode current equation
- More generalize

- $I = I_0(e^{V/\eta V_T} - 1)$
- Where η =1 for Ge and η =2 for Si

Google form - Attendance

https://forms.gle/jkSGtH4U14NB2PAYA