Unit - I

(I) P-N Junction Diode.

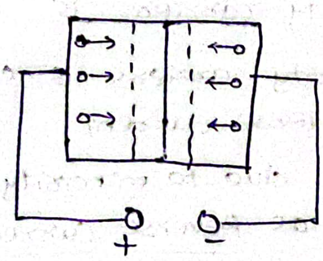
(A) P-N Junction Diode :-

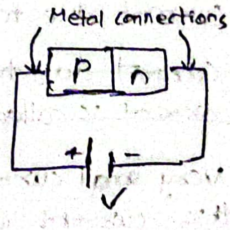
→ The main electrical characteristic of a PN-Junction is conducting the current only in one direction and stops current in opposite direction.

→ Any voltage applied across the junction, then it is called BIAS voltage. When voltage is applied across junction, its depletion region is effected.

→ When Junction is in Forward Bias :-

(i) To make forward bias junction, the positive terminal of battery should be connected to 'p-type' material and the negative terminal should be connected to 'n-type' material





(ii) When positive terminal is connected to 'p-type' and negative terminal is connected to 'n-type', the positively charged carriers repels and move towards junction. The negatively charged carriers (electrons) repels by negative terminal and move towards junction

(iii) Case (i) :- When $V < V_0$,

No current Flows.

Case (ii) :- When $V = V_0$,

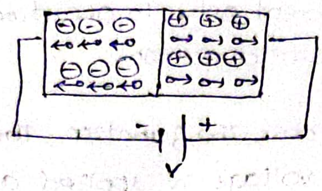
Forward Bias Current Flows

Case (iii) When $V > V_0$,

For small change in voltage, there is a large current change.

When Junction is in Reverse Bias:

(i) To make Reverse Bias Junction, the positive terminal (+ve) of the battery should be connected to 'n-type' and the negative terminal (-ve) should be connected to 'p-type'.



(ii) when (-ve) terminal is connected to 'p-type' and (+ve) terminal is connected to 'n'-type', the positively charged carriers move away from junction, and the negatively charged carriers (electrons) move away from the junction.

(iii) current due to majority carriers is zero.

~~(iv) current due to minority carriers is so less and this current is called as reverse current.~~

(iv) Very small current flows due to minority carriers and this current is called as Reverse current:

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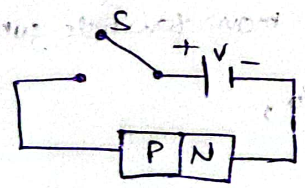
(2) Diode - Current Equation.

(A) → Let us consider an open circuit PN - Junction as shown below with switch 's' open.



→ Density of holes in P-region and n-region is given by Boltzmann relation as,

$$P_p = P_{ne}^{V_B/V_T}$$

→ For open circuit (P-N) junction, $V_B = V_o$, hence

$$\boxed{P_p = P_n e^{V_o/V_T}} \quad \text{——} (1)$$

→ By applying voltage, when junction is forward biased by closing switch 'S', then

$$\boxed{V_B = V_o - V}$$

→ When junction is in forward bias, the p-region hole-density remains constant and n-region hole density increase from P_n to $P_n + \Delta P_n$. Therefore,

$$P_p = (P_n + \Delta P_n) e^{(V_o - V)/V_T}$$

$$\boxed{P_p = (P_n + \Delta P_n) e^{V_o/V_T} \cdot e^{-V/V_T}} \quad \text{——} (2)$$

Sub 'P_p' value from (1) in (2)

$$\Rightarrow \quad P_n e^{V_o/V_T} = (P_n + \Delta P_n) e^{V_o/V_T} \cdot e^{-V/V_T}$$

$$\Rightarrow \quad P_n e^{V/V_T} = (P_n + \Delta P_n)$$

$$\Rightarrow \quad \boxed{\Delta P_n = P_n (e^{V/V_T} - 1)} \quad \text{——} (3)$$

From (1),

$$\boxed{P_n = P_p e^{-V_o/V_T}} \quad \text{——} (4)$$

Sub (4) in (3)

$$\Rightarrow \quad \boxed{\Delta P_n = P_p e^{-V_o/V_T} (e^{V/V_T} - 1)} \quad \text{——} (5)$$

We know that, $\Delta P_n \propto I_p$

Therefore,

$$\boxed{I_p = I_{sp} (e^{V/V_T} - 1)} \quad \text{——} (6)$$

Take 'I_{sp}' as 'I_{sn}' in (6),

$$\boxed{I_n = I_{sn}(e^{V/V_T} - 1)} \quad \text{—— (7)}$$

Total current I is given by,

$$I = P + I_n$$

$$I = I_{sp}(e^{V/V_T} - 1) + I_{sn}(e^{V/V_T} - 1)$$

$$\boxed{I = I_0(e^{V/V_T} - 1)} \quad \text{— 8}$$

Therefore, eqn (8) is known as Diode Current Equation //.

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(3) Static and Dynamic Resistance.

(A) Static and Dynamic Resistance:

→ A resistor is a linear device, its (V–I) characteristics is a straight line passing through origin. Its resistance is given by slope of this straight line.

→ A semi conductor diode is a nonlinear device. Due to non-linear shape of (V – I) characteristics curve, diode offers different resistance at different operating points.

→ Depending on type of applied voltage (or) signal, the diode has two type of resistances,

(i) Static Resistance

(ii) Dynamic Resistance

→ (i) Static Resistance :-

The ratio of voltage to current when PN junction is in forward bias, is known as static resistance.

→ (ii) Dynamic Resistance :-

The reciprocal of slope of Volt – Ampere characteristics is known as Dynamic Resistance

It is given by,

$$I_f = \frac{\text{Change in voltage}}{\text{Resulting change in current}} = \frac{\Delta V}{\Delta I}$$

$$\boxed{I_f = \frac{\Delta V}{\Delta I}} \quad \text{— (1)}$$

$$\boxed{I = I_0\left(e^{V/\eta V_T} - 1\right)} \quad \text{— (2)}$$

Diff eqn (1),

$$I_f = \frac{\Delta V}{\Delta I} = \frac{dV}{dI}$$

Diff eqn (2) with 'v'

$$dI = I_0\left(e^{V/\eta V_T} - 1\right) \cdot \frac{dV}{\eta V_T}$$

$$\boxed{\frac{dI}{dV} = I/\eta V_T}$$

Therefore,

$$I_f = \frac{dV}{dI} = \frac{1}{\left(\frac{dI}{dV}\right)} = \frac{1}{\left(I/\eta V_T\right)} = \frac{\eta V_T}{I}$$

$$\boxed{\therefore I_f = \frac{\eta V_T}{I}}$$

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