UNIT-IV

Fundamentals of semiconductor devices and digital circuits

Lecture 29

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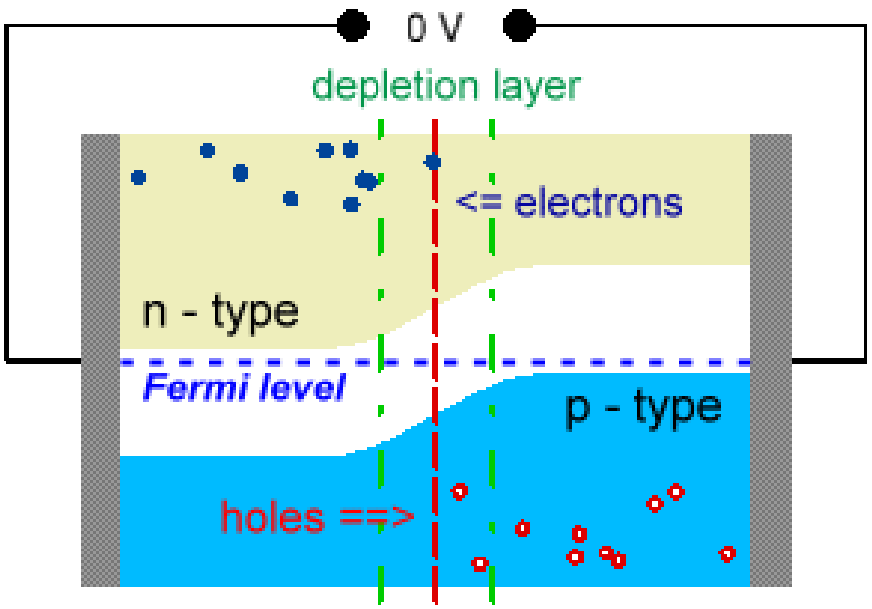
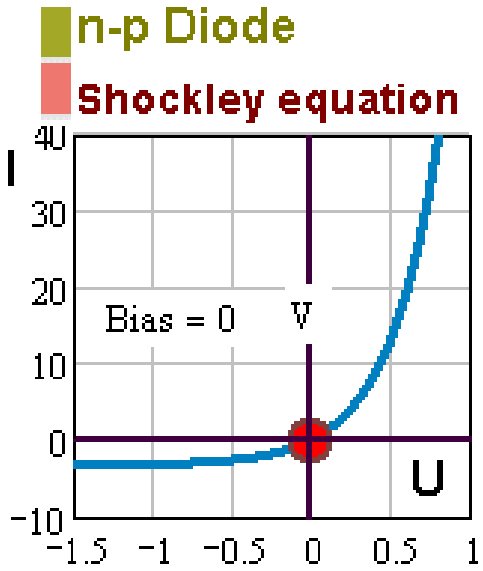
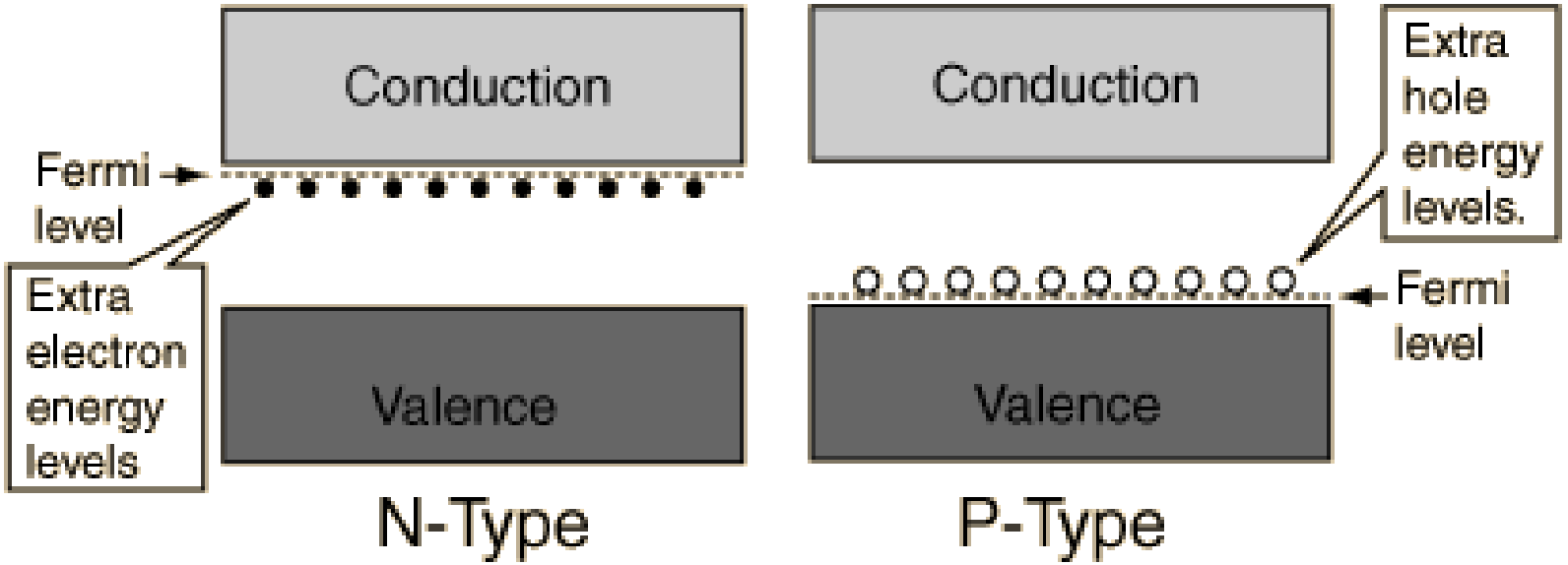
P-N Junction





We create a p-n junction by joining together two pieces of semiconductor, one doped n-type, the other p-type.

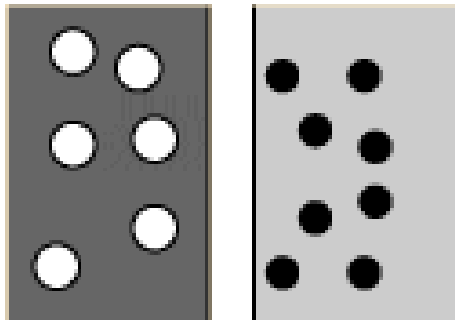
P-N Junction



In the n-type region there are extra electrons and in the p-type region, there are holes from the acceptor impurities .

P-N Junction

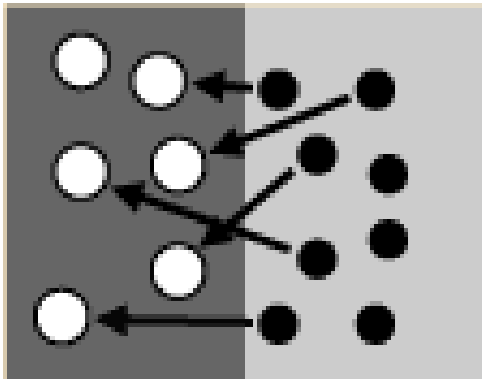
In the p-type region there are holes from the acceptor impurities and in the n-type region there are extra electrons.



● Electron ○ Hole ⊖ Negative ion from filling of p-type vacancy. ⊕ Positive ion from removal of electron from n-type impurity.

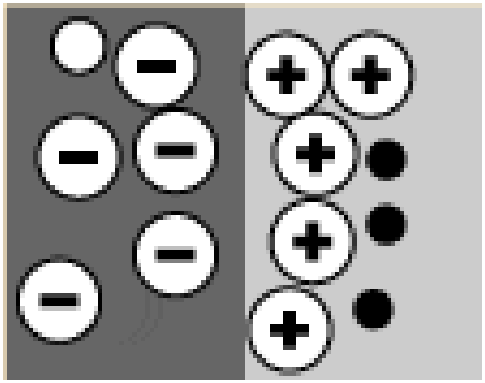
P-N Junction

When a p-n junction is formed, some of the electrons from the n-region which have reached the conduction band are free to diffuse across the junction and combine with holes.



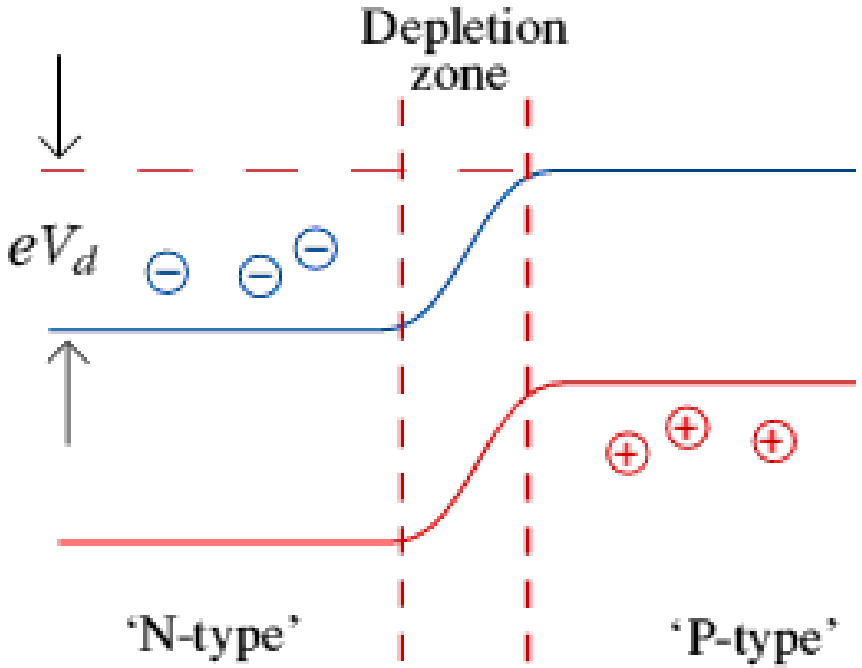
P-N Junction

Filling a hole makes a negative ion and leaves behind a positive ion on the n-side.



A space charge builds up, creating a depletion region.

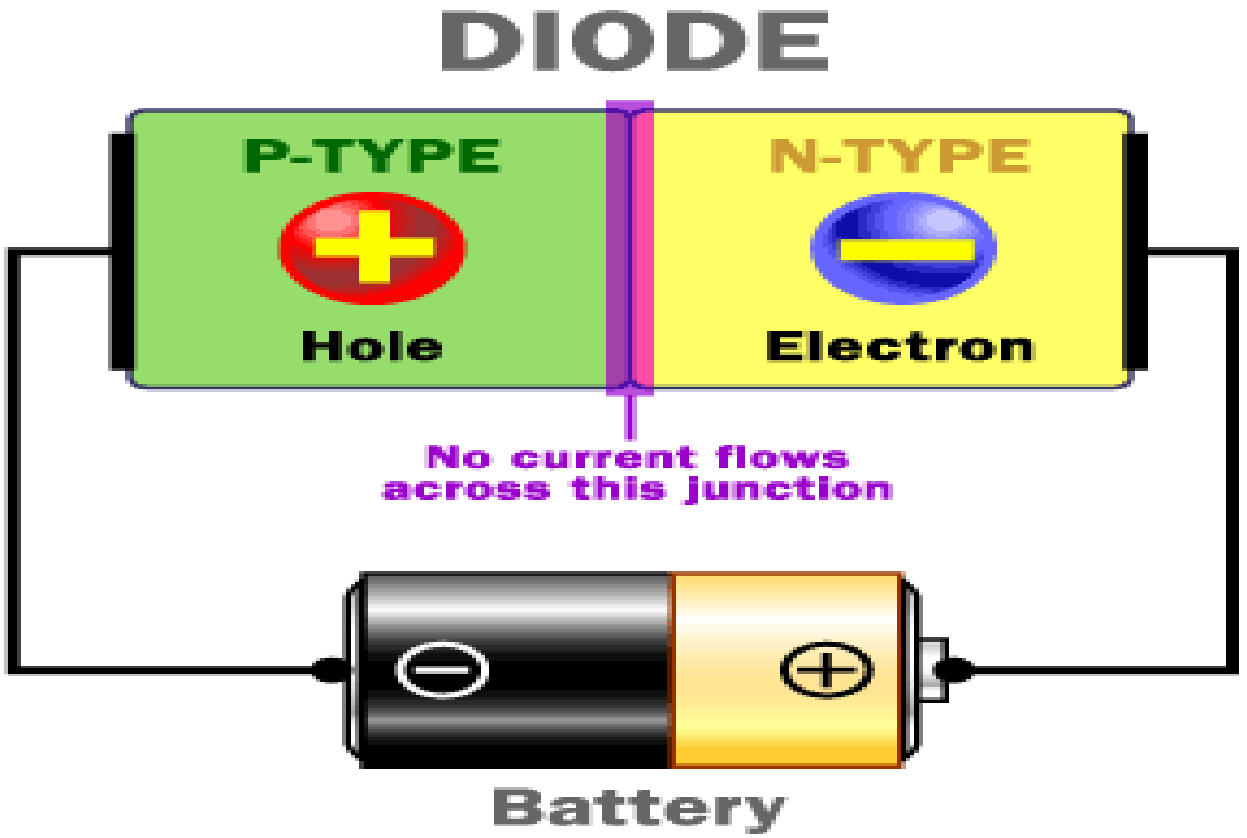
P-N Junction



This causes a depletion zone to form around the junction (the join) between the two materials.

This zone controls the behavior of the diode.

Diode

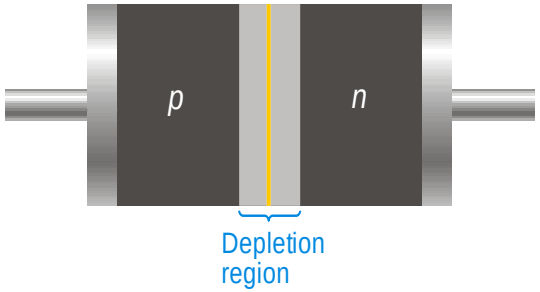


A diode is the simplest possible semiconductor device.

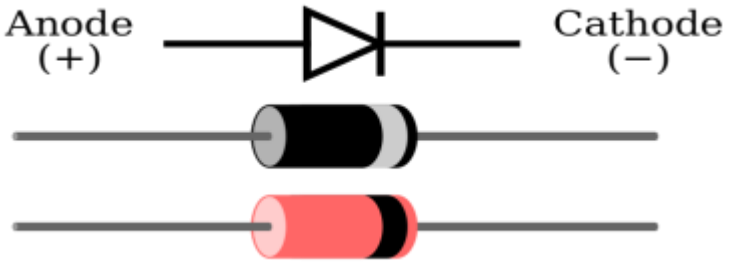
Diodes

- Diode, semiconductor material, such as silicon, in which half is doped as p-region and half is doped as n-region with a pn-junction in between.

- The p region is called **anode** and n type region is called **cathode.**



Diode symbol



One Way Electric “Turnstile”

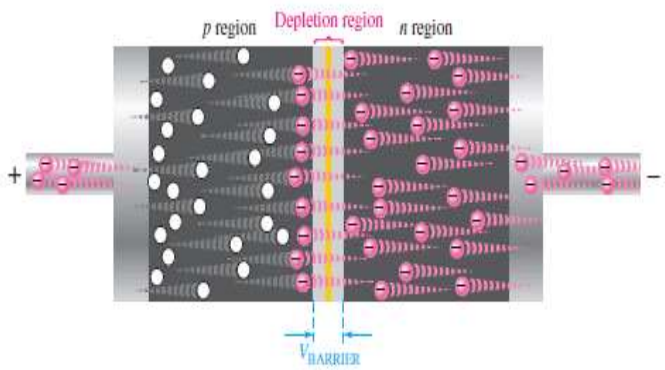
A diode allows current to flow in one direction but not the other.

Jumping

If you apply enough reverse voltage, the junction breaks down and lets current through.

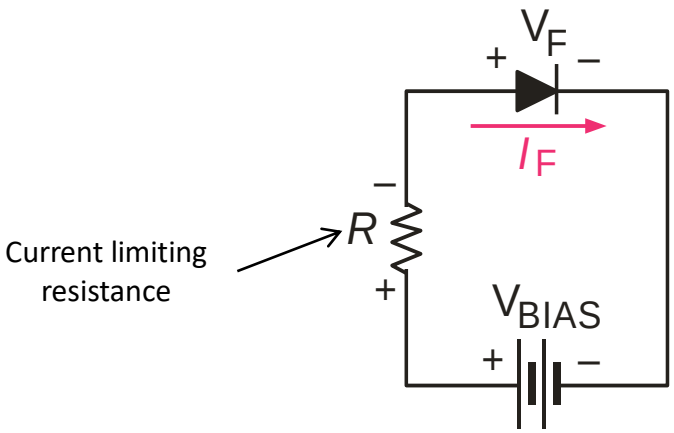
Forward Biased

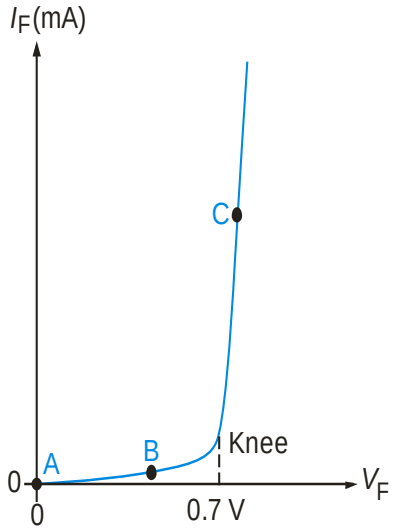
- Forward bias is a condition that allows current through pn junction.
  - A dc voltage (Vbais) is applied to bias a diode.
  - Positive side is connected to p-region (anode) and negative side is connected with n-region.
  - Vbais must be greater than 'barrier potential'



As more electrons flow into the depletion region reducing the number of positive ions and similarly more holes move in reducing the positive ions.

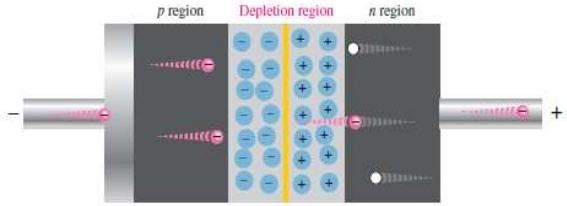
This reduces the width of depletion region.





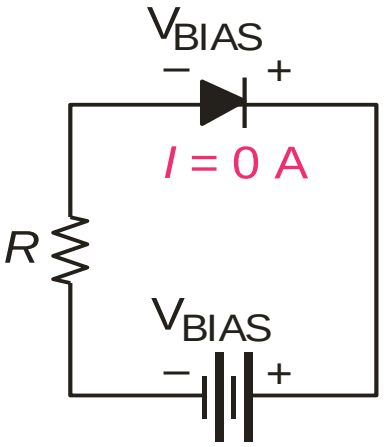
Reverse Biased

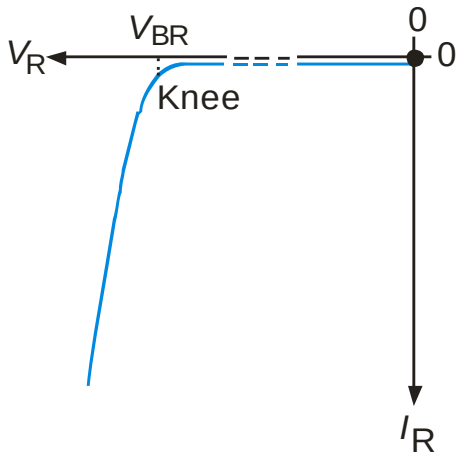
- Reverse bias is a condition that prevents current through junction.
- Positive side of Vbias is connected to the n-region whereas the negative side is connected with p-region.
- Depletion region get wider with this configuration.



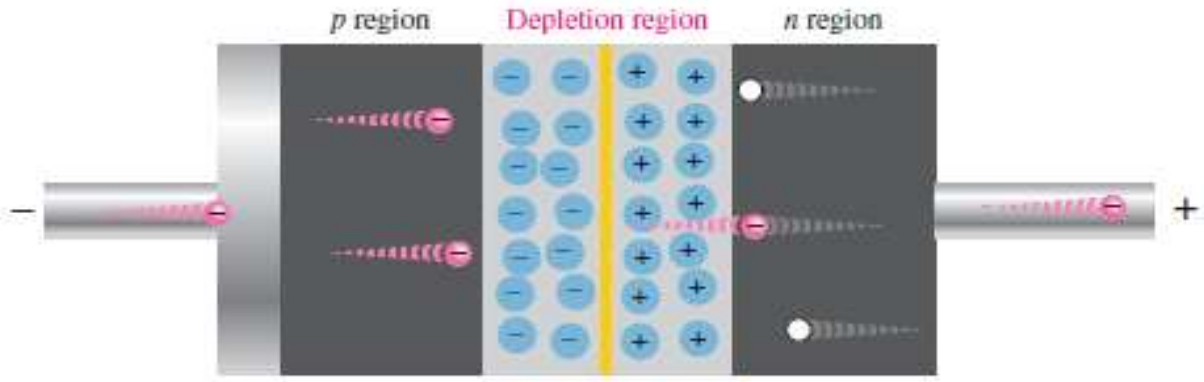
The positive side of bias voltage attracts the majority carriers of n-type creating more positive ions at the junction.

This widens the depletion region.





Reverse Current



- A small amount current is generated due to the minority carriers in p and n regions.
- These minority carriers are produced due to thermally generated hole-electron pairs.
- Minority electrons in p-region pushed towards +ve bias voltage, cross junction and then fall in the holes in n-region and still travel in valance band generating a hole current.

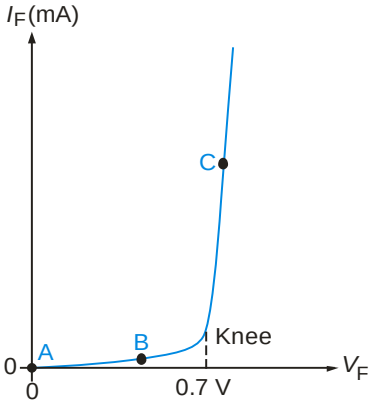
Reverse Breakdown

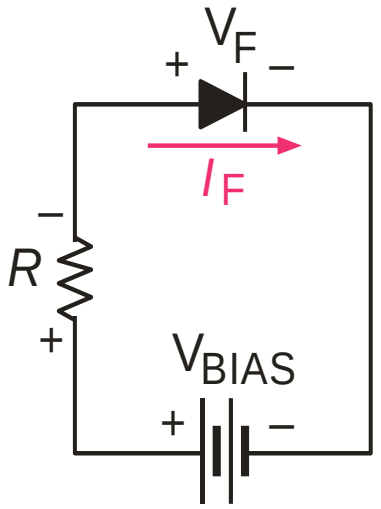
- If the external bias voltage is increased to a value call *breakdown voltage* the reverse current can increase drastically.
- Free minority electrons get enough energy to knock valance electron into the conduction band.
- The newly released electron can further strike with other atoms.
- The process is called ***avalanche effect.***

Diode V-I Characteristic

- **VI Characteristic for forward bias.**

  - The current in forward biased called *forward current* and is designated *If.*
  - At 0V (Vbias) across the diode, there is no forward current.
  - With gradual increase of Vbias, the forward voltage and forward current increases.
  - A resistor in series will limit the forward current in order to protect the diode from overheating and permanent damage.
  - A portion of forward-bias voltage drops across the limiting resistor.
  - Continuing increase of Vf causes rapid increase of forward current but only a gradual increase in voltage across diode.

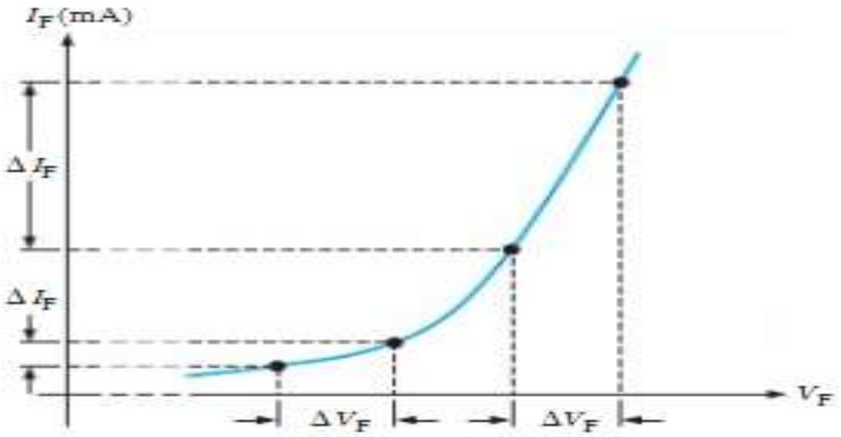




Diode V-I Characteristic

❖ **Dynamic Resistance:**

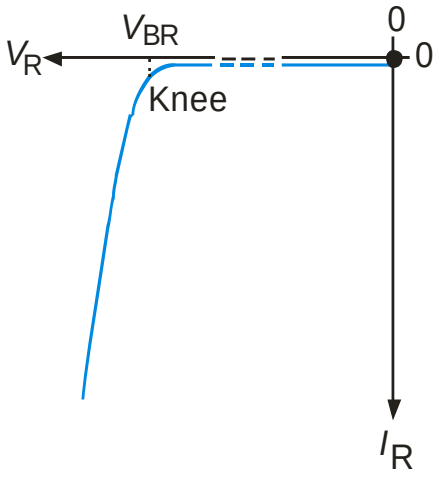
- The resistance of diode is not constant but it changes over the entire curve. So it is called dynamic resistance.



The dynamic resistance r'_d decreases as you move up the curve, as indicated by the decrease in the value of $\Delta V_F / \Delta I_F$.

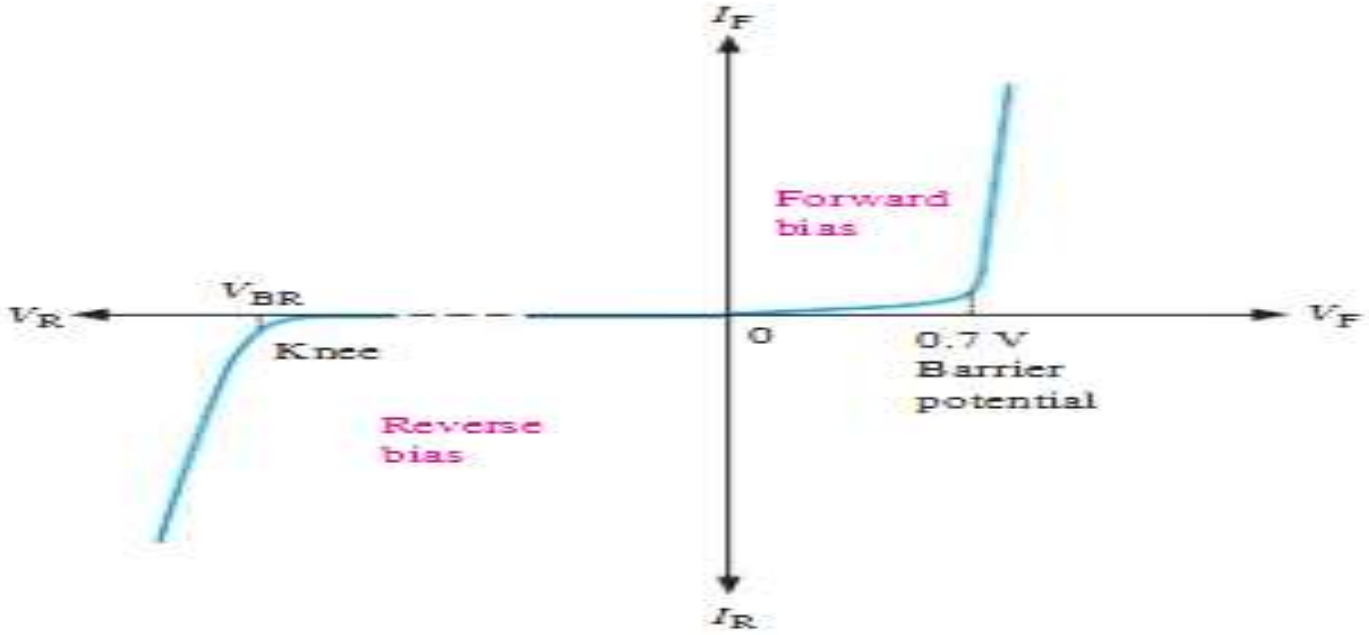
Diode V-I Characteristic

- **VI Characteristic for reverse bias.**
  - With 0V reverse voltage there is no reverse current.
  - There is only a small current through the junction as the reverse voltage increases.
  - At a point, reverse current shoots up with the break down of diode. The voltage called break down voltage. This is not normal mode of operation.
  - After this point the reverse voltage remains at approximately V_{BR} but I_R increase very rapidly.
  - Break down voltage depends on doping level, set by manufacturer.



Diode V-I Characteristic

❖The complete V-I characteristic curve



The complete *V-I* characteristic curve for a diode.

Quick Quiz (Poll 1)

- When PN junction is in forward bias, by increasing the battery voltage

A. Circuit resistance increases

B. Current through P-N junction increases

C. Current through P-N junction decreases

D. None of the above happens

Quick Quiz (Poll 2)

- A reversed-biased PN junction has

  A. Almost zero current
- B. A very narrow depletion layer
- C. A net hole current
- D. A net electron current

Quick Quiz (Poll 3)

- As a PN junction is forward biased

  A. Holes as well as electrons tend to drift away from the junction
- B. The depletion region decreases
- C. The barrier tends to breakdown
- D. None of the above