PHYSICS
GENERIC ELECTIVE
Semester IV

PHSHGE
GE4T
Time-5.30 pm to 7 pm
Duration: 1.30 hour
Date: 04/04/2020
Topic: PN Junction Diode

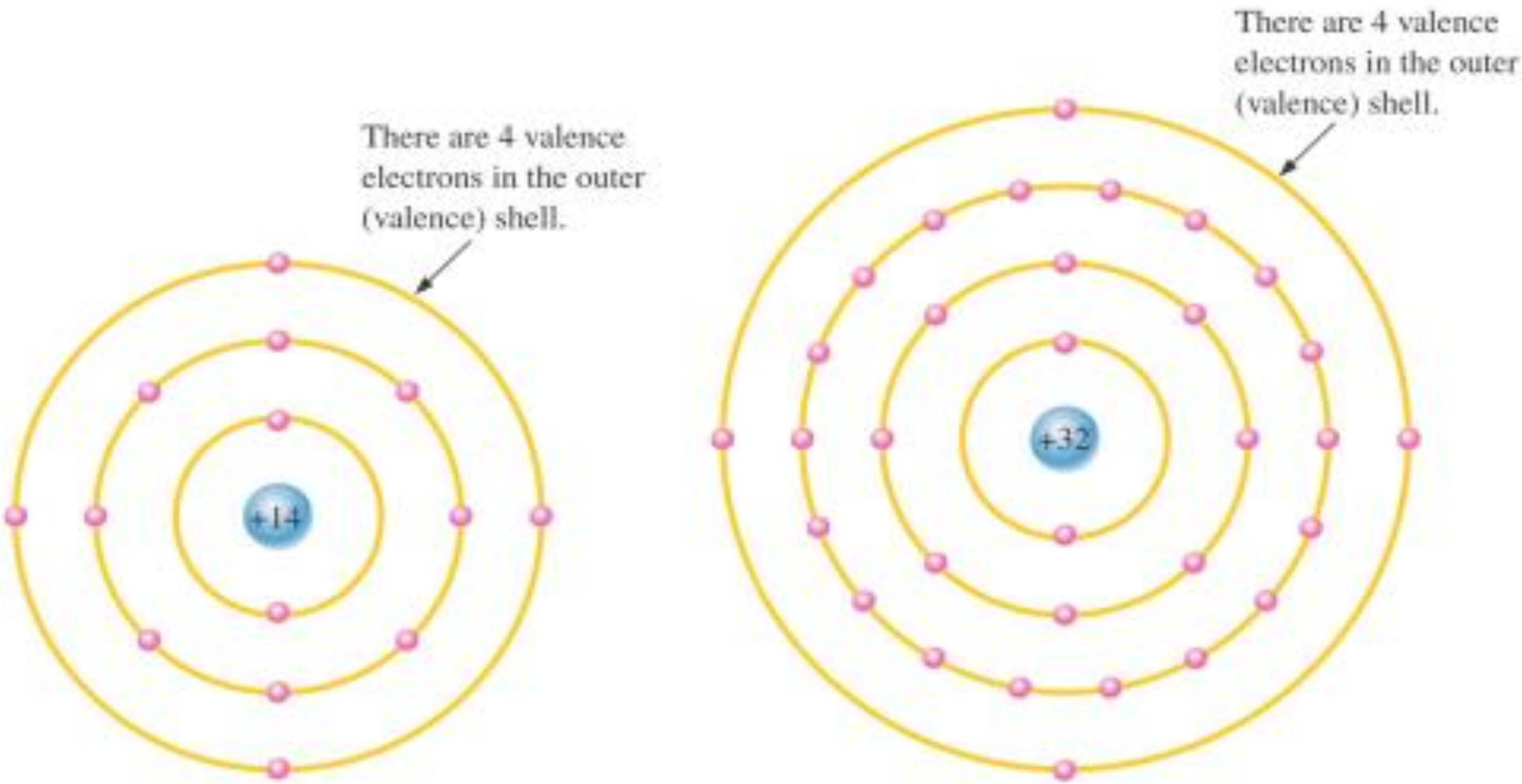
Introduction to Semiconductor Materials

- Two types of semiconductive materials are silicon and germainium
  - both have four valance electrons
- When silicon and germanium atoms combine into molecules to form a solid material, they arrange themselves in a fixed pattern called a crystal
  - atoms within the crystal structure are held together by covalent bonds (atoms share valence electrons)
- An intrinsic crystal is one that has no impurities

Introduction to Semiconductor Materials

- In an intrinsic semiconductor, there are relatively few free electrons
  - pure semiconductive materials are neither good conductors nor good insulators
- Intrinsic semiconductive materials must be modified by increasing the free electrons and holes to increase its conductivity and make it useful for electronic devices
  - by adding impurities, *n*-type and *p*-type extrinsic semiconductive material can be produced

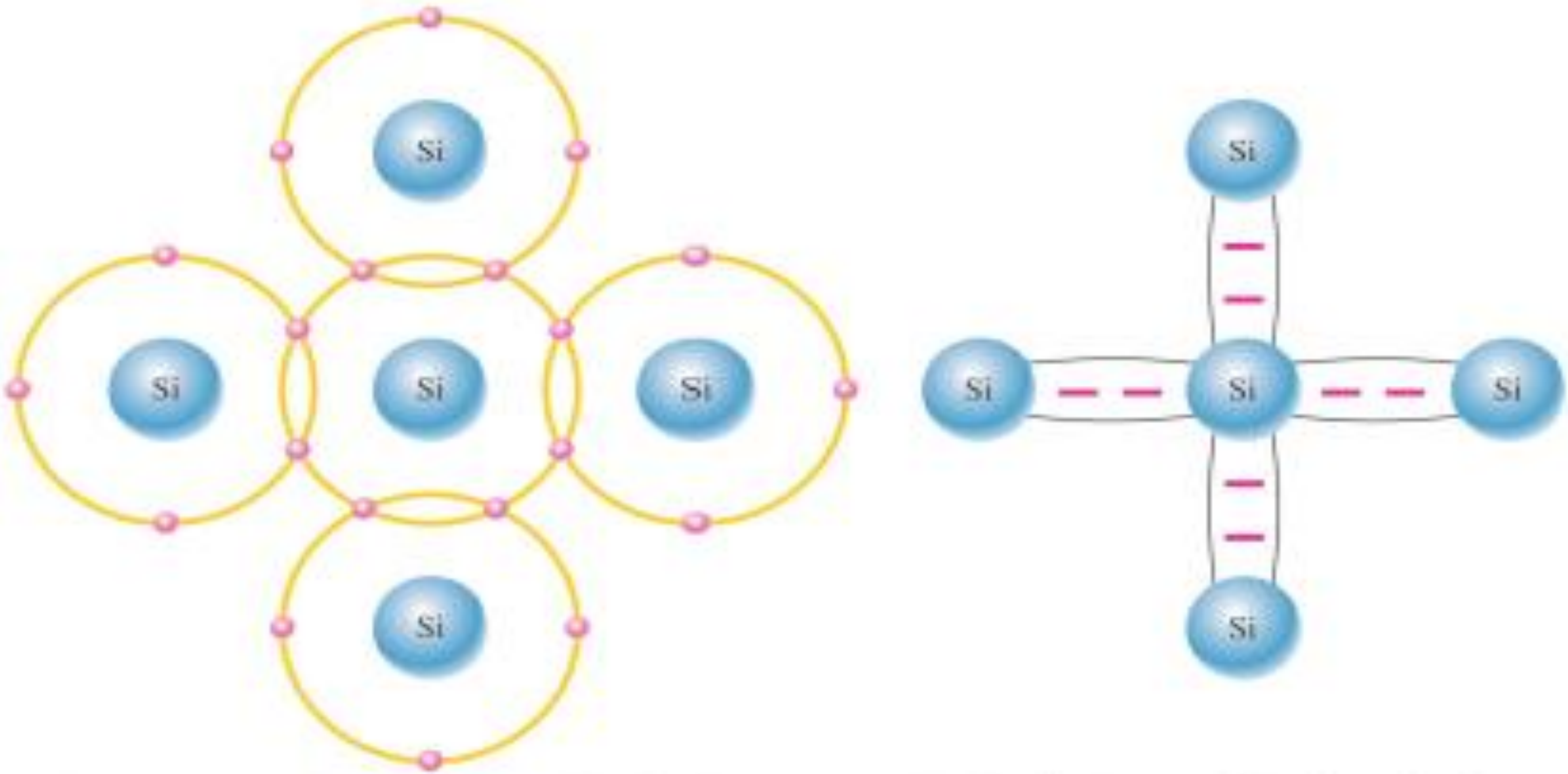
Diagrams of the silicon and germanium atoms



(a) Silicon atom

(b) Germanium atom

Covalent bonds in a silicon crystal. The actual crystal is 3-dimensional.



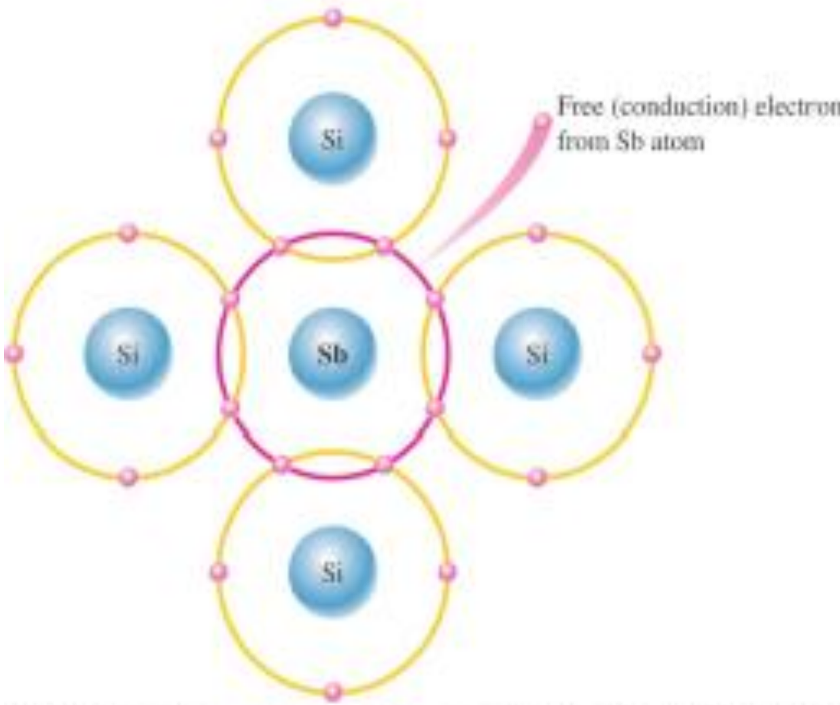
(a) The center atom shares an electron with each of the four surrounding atoms creating a covalent bond with each. The surrounding atoms are in turn bonded to other atoms, and so on.

(b) Bonding diagram. The red negative signs represent the shared valence electrons.

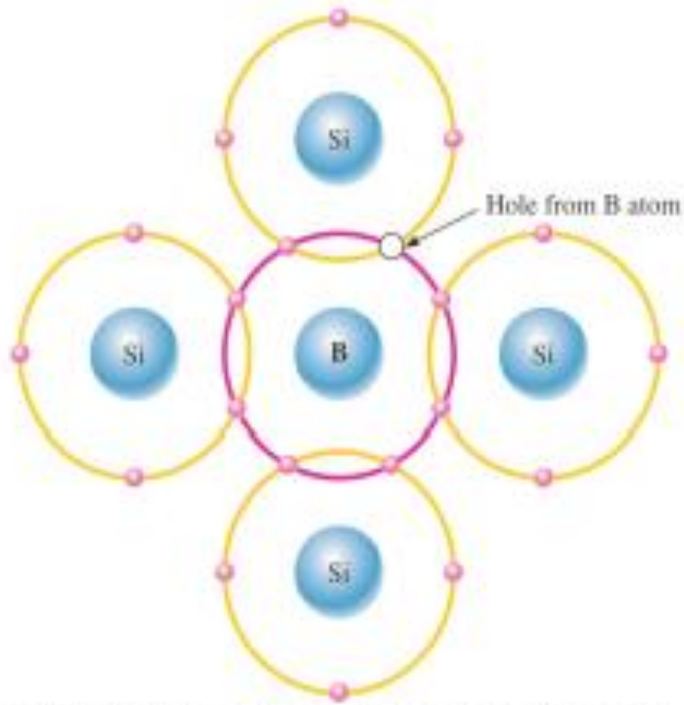
Introduction to Modified Semiconductor Materials

- Doping is the process of adding impurities to intrinsic semiconductive materials to increase anc control conductivity within the material
  - *n*-type material is formed by adding **pentavalent** (5 valence electrons) impurity atoms
    - electrons are called **majority carriers** in *n*-type material
    - holes are called **minority carriers** in *n*-type material
  - *p*-type material is formed by adding **trivalent** (3 valence electrons) impurity atoms
    - holes are called **majority carriers** in *p*-type material
    - electrons are called **minority carriers** in *p*-type material

Impurity atoms



(a) Pentavalent impurity atom in a silicon crystal. An antimony (Sb) impurity atom is shown in the center. The extra electron from the Sb atom becomes a free electron.

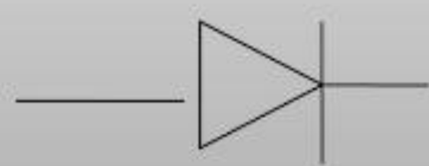


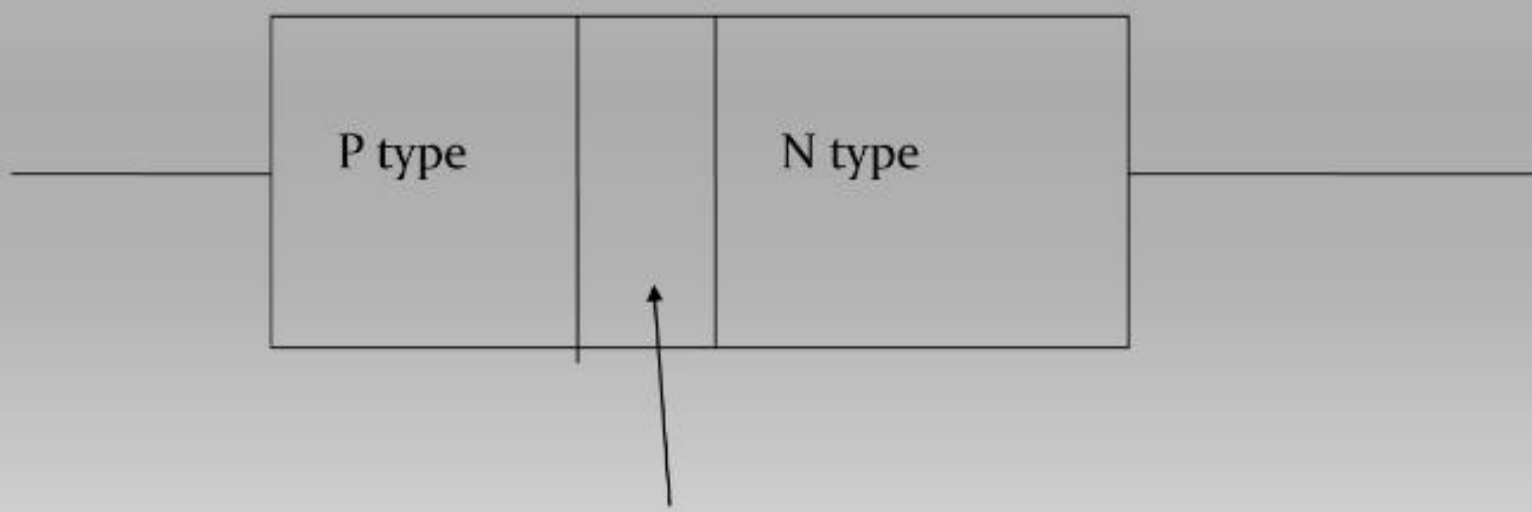
(b) Trivalent impurity atom in a silicon crystal. A boron (B) impurity atom is shown in the center.

p-n Junction

A diode is a two-terminal electronic device consisting of a single p-n junction. This p-n junction is usually created on a single block of silicon by doping the block with donor and acceptor dopants at opposite ends.

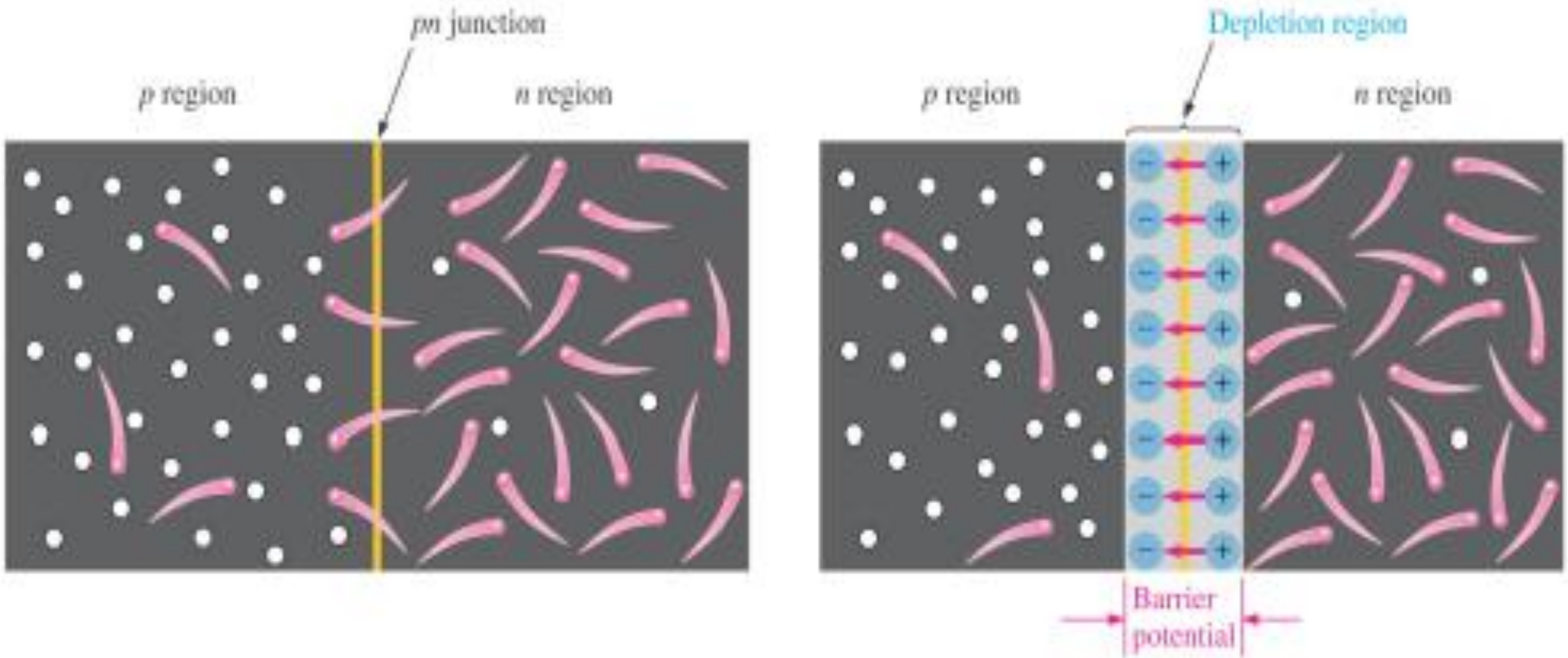
Electronic Symbol .....the triangle shows indicated the direction of current





Depletion layer forms an insulator
between the 2 sides

Formation of the depletion region in a *pn* junction diode



(a) At the instant of junction formation, free electrons in the *n* region near the *pn* junction begin to diffuse across the junction and fall into holes near the junction in the *p* region.

(b) For every electron that diffuses across the junction and combines with a hole, a positive charge is left in the *n* region and a negative charge is created in the *p* region, forming a barrier potential. This action continues until the voltage of the barrier repels further diffusion.

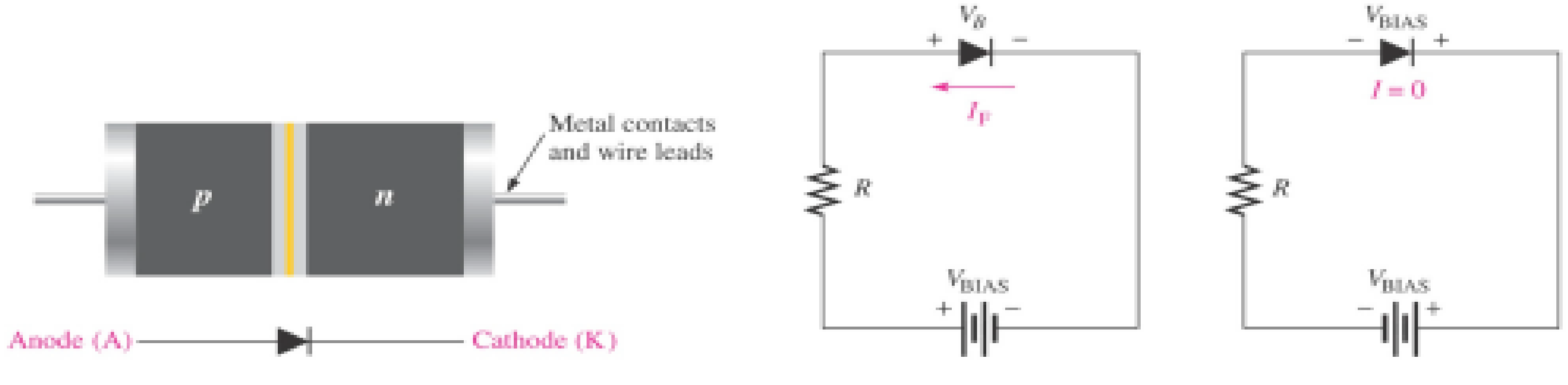
The PN Junction Diode

- The negative terminal of the bias-voltage source pushes the conduction-band electrons in the *n* region toward the *pn* junction, while the positive terminal pushes the holes in the *p* region toward the *pn* junction
- When it overcomes the barrier potential (V_B), the external voltage source provides the *n* region electrons with enough energy to penetrate the depletion region and move through the junction

Forward and Reverse Bias

- Forward Bias : Connect positive of the Diode to positive of supply…negative of Diode to negative of supply
- Reverse Bias: Connect positive of the Diode to negative of supply…negative of diode to positive of supply.

Diode structure, schematic symbol, and bias circuits
V_{BIAS} is the bias voltage, and V_B is the barrier potential



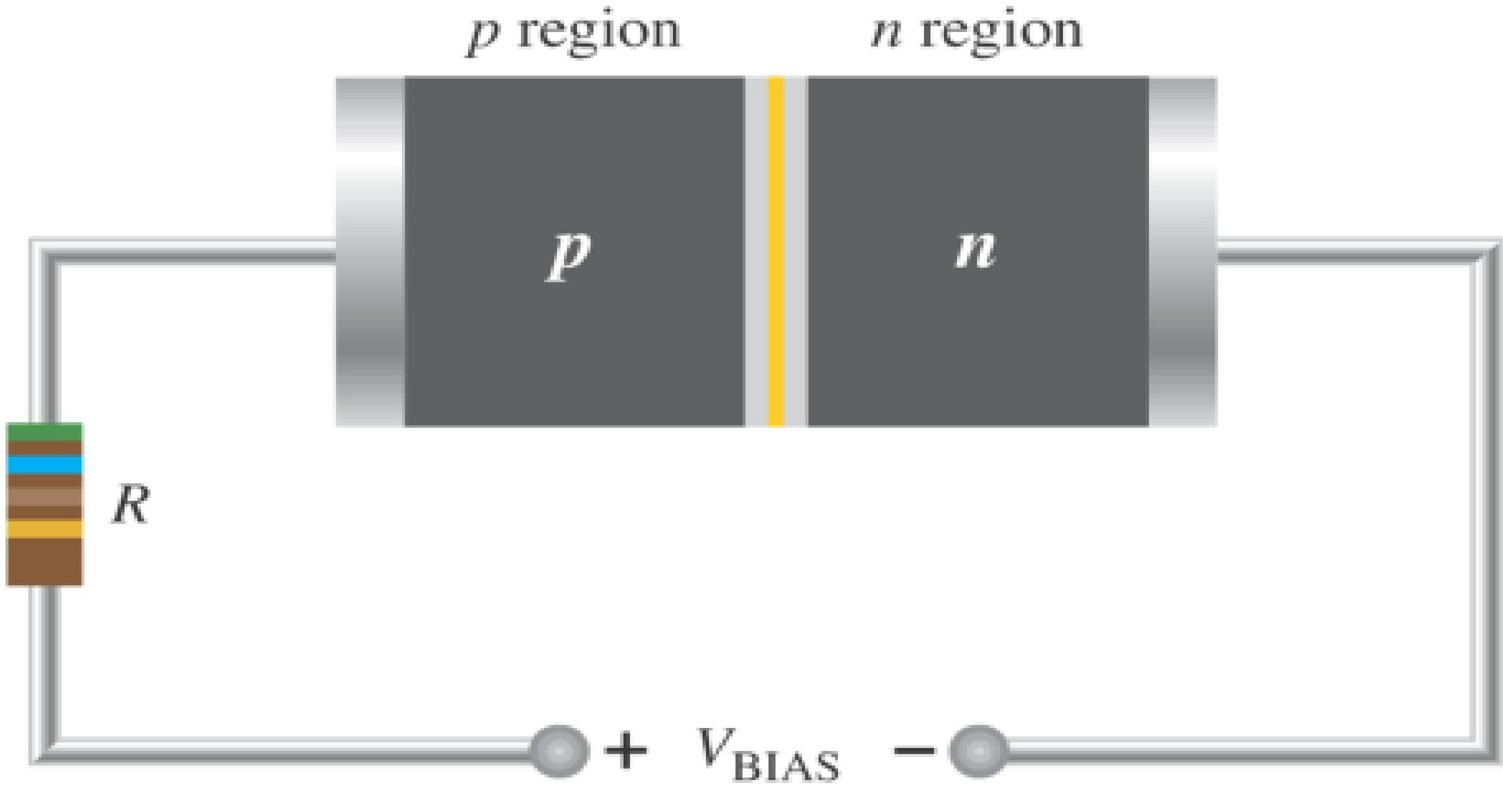
(a) Basic diode structure and symbol (b) Forward bias (c) Reverse bias

Forward Bias

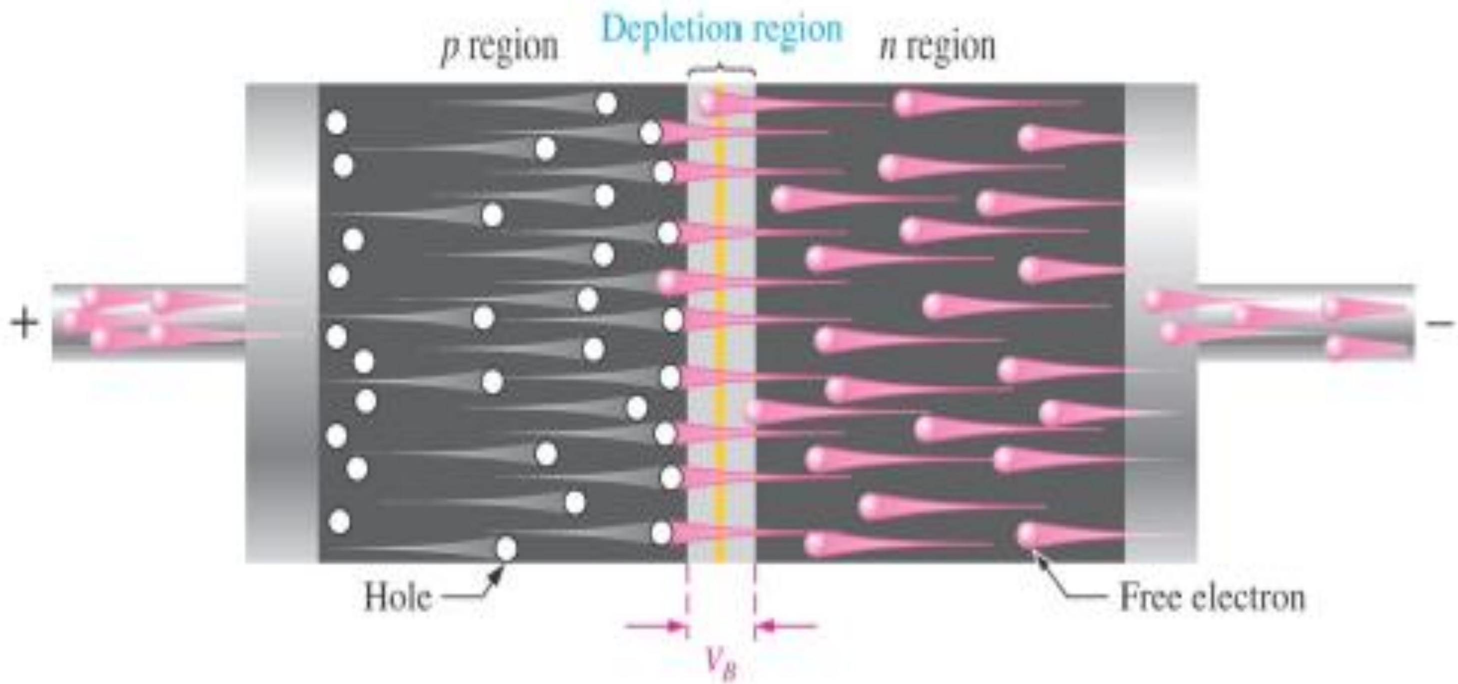
- Forward biasing the p-n junction drives holes to the junction from the p-type material and electrons to the junction from the n-type material.
- At the junction the electrons and holes combine so that a continuous current can be maintained.

Forward-bias connection

The resistor limits the forward current in order to prevent damage to the diode



Current in a forward-biased diode

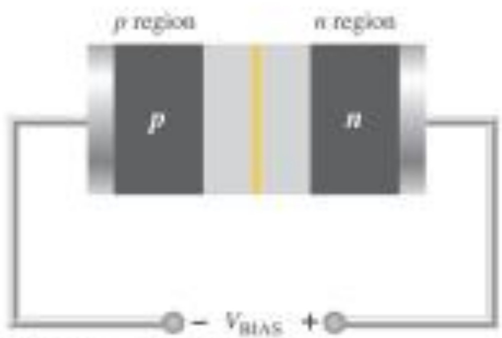


Reverse Bias

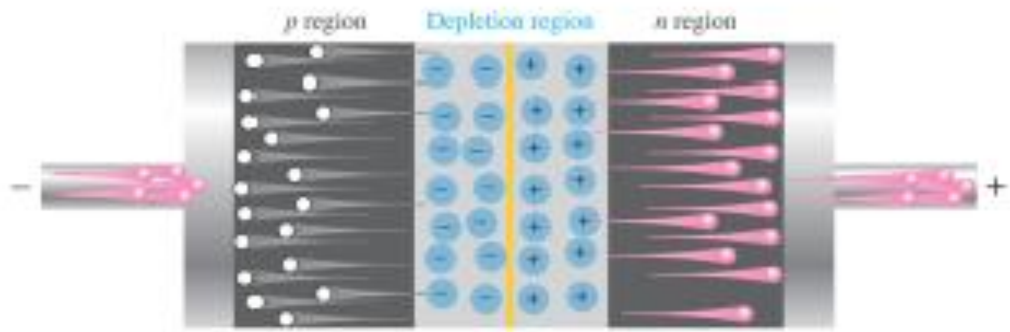
- The application of a reverse voltage to the p-n junction will cause a transient current to flow as both electrons and holes are pulled away from the junction.

- When the potential formed by the widened depletion layer equals the applied voltage, the current will cease except for the small thermal current.

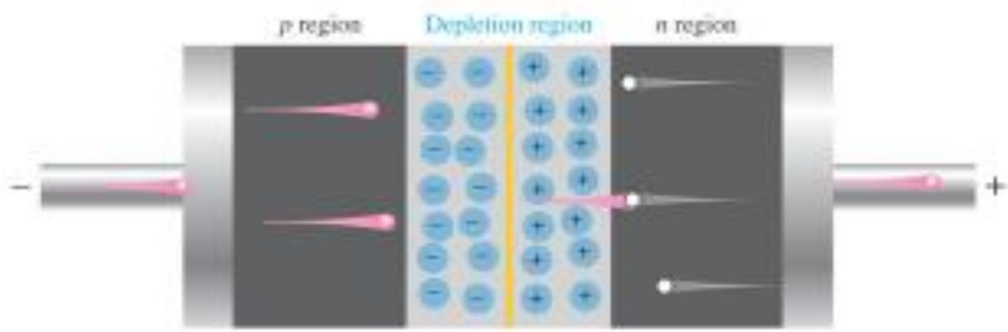
Illustration of reverse bias



(a) Reverse-bias connection.



(b) There is transient current as depletion region widens.



(c) Majority current ceases when barrier potential equals bias voltage. There is an extremely small reverse current due to minority carriers.