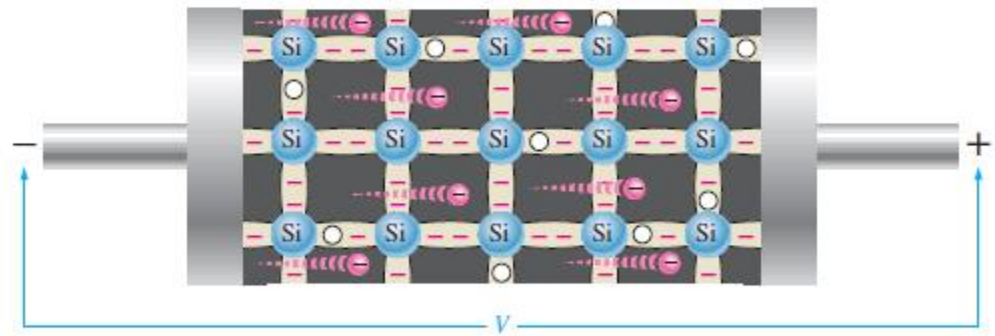
Electron and Hole Current (intrinsic Si)

Conduction in semiconductors is considered to be either the :

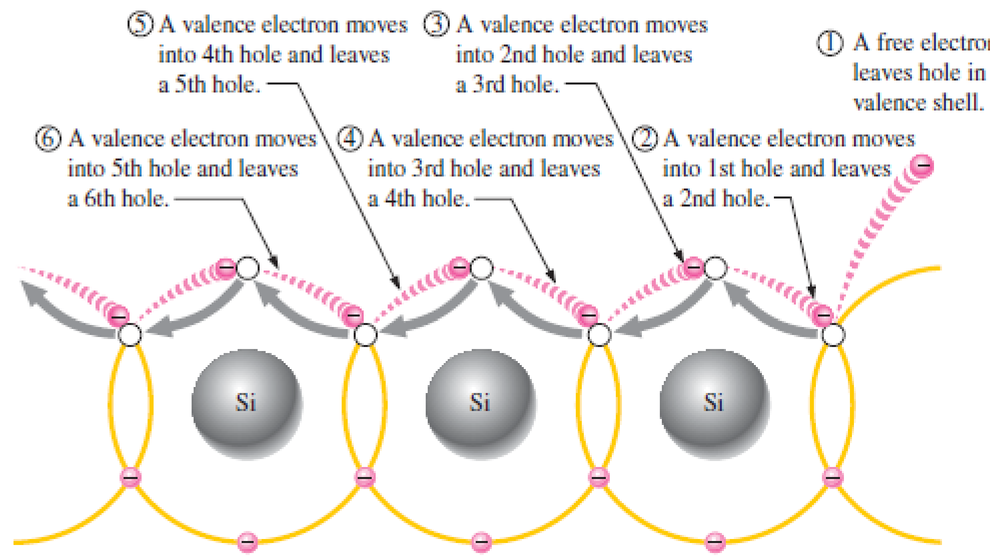
- movement of free electrons in the conduction band
- or the movement of holes in the valence band.

Electron Current: produced by the movement of thermally generated free electrons in conduction band.



Hole Current: current occurs in the valence band, where the holes created by the free electrons exist.

Although current in the valence band is produced by valence electrons, it is called *hole current* to distinguish it from electron current in the conduction band.



When a valence electron moves left to right to fill a hole while leaving another hole behind, the hole has effectively moved from right to left. Gray arrows indicate effective movement of a hole.

1– 4: N-type And P-type Semiconductors

- Semiconductive materials do not conduct current well and are of limited value in their intrinsic state.

- This is because of the limited number of free electrons in the conduction band and holes in the valence band.

- Intrinsic silicon (or germanium) must be modified by increasing the number of free electrons or holes to increase its conductivity and make it useful in electronic devices.

- This is done by adding impurities to the intrinsic material. Two types of extrinsic (impure) semiconductive materials, *n*-type and *p*-type, are the key building blocks for most types of electronic devices.

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- **Doping**: controlled addition of impurities to the intrinsic (pure) semi conductive material to increases the number of current carriers (electrons or holes) and thus to increase the conductivity

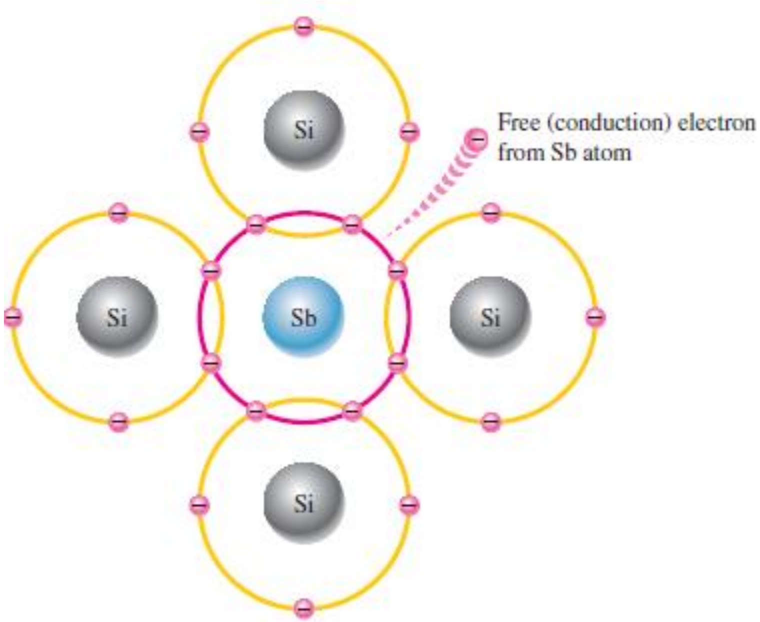
N -Type Semiconductor

- To increase the number of conduction-band electrons in intrinsic silicon, **Pentavalent impurity atoms** are added. These are atoms with **five** valence electrons such as arsenic (**As**), phosphorus (**P**), bismuth (**Bi**), and antimony (**Sb**).

- As shown: Sb (antimony) **donor** atom forms covalent bonds with four adjacent Si atoms. Four of its valence electrons are used to form covalent bonds with Si atoms, leaving **one extra electron** (conduction **e**).

- **Majority carriers**: electrons created by doping

- **Minority carriers**: holes, created when electron-hole pairs are thermally generated



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

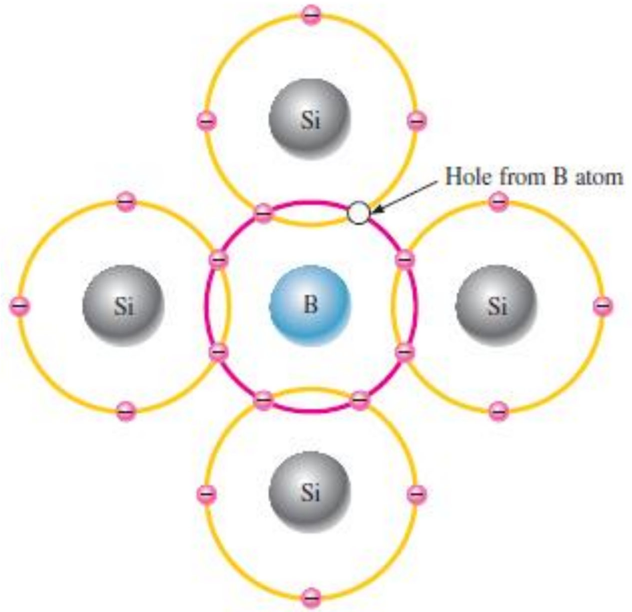
P -Type Semiconductor

- **Trivalent impurity atoms** (**acceptors**) with **three** valence electrons are added. [Boron (**B**), indium (**In**), and gallium (**Ga**)]

- As shown: Boron atom forms covalent bonds with four adjacent silicon atoms. Since four electrons are required, a hole results when each trivalent atom is added.

- **Majority carriers**: holes created by doping

- **Minority carriers**: electrons, created when electron-hole pairs are thermally generated.



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