Band Theory of Solids

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Introduction to Band Theory

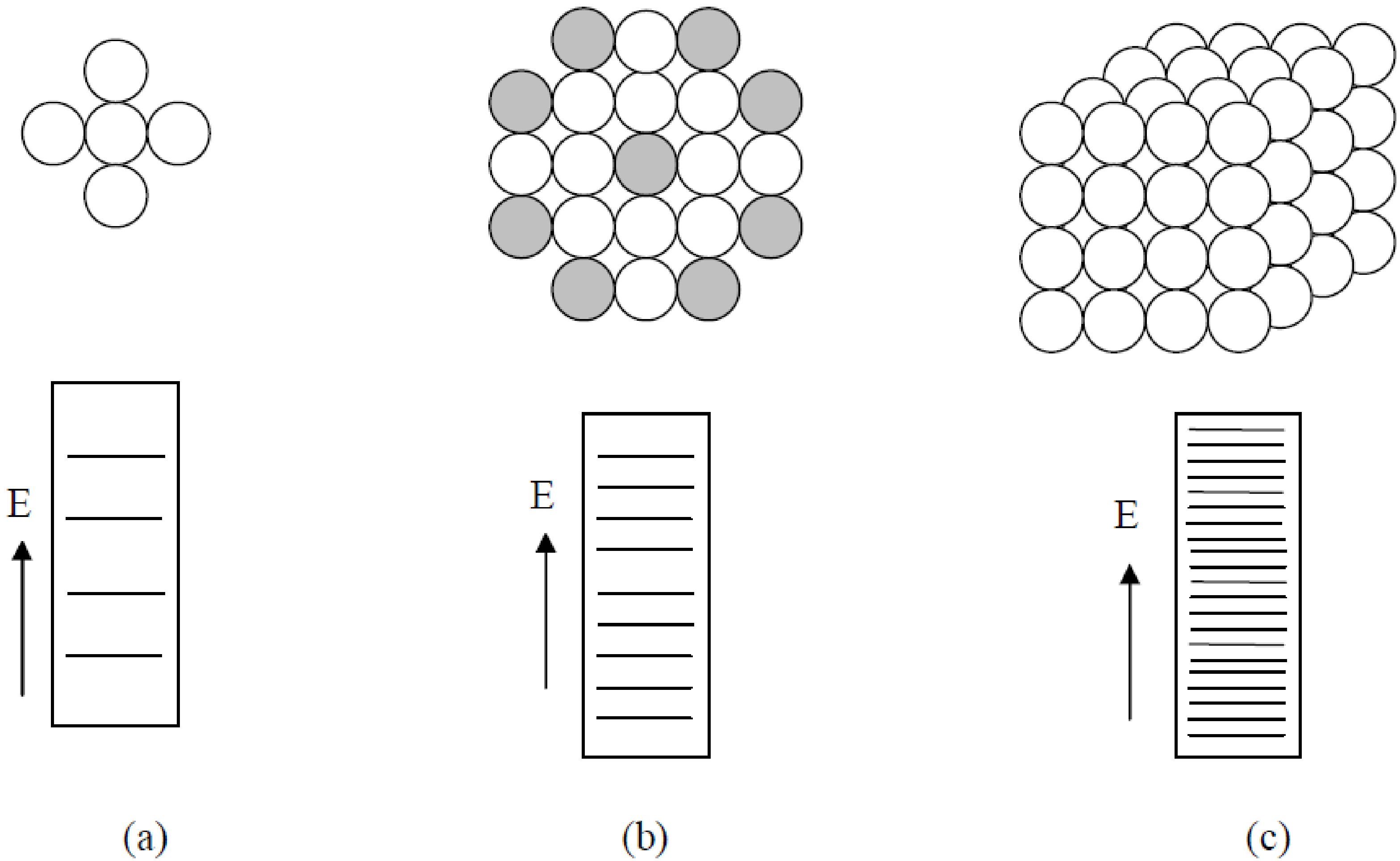
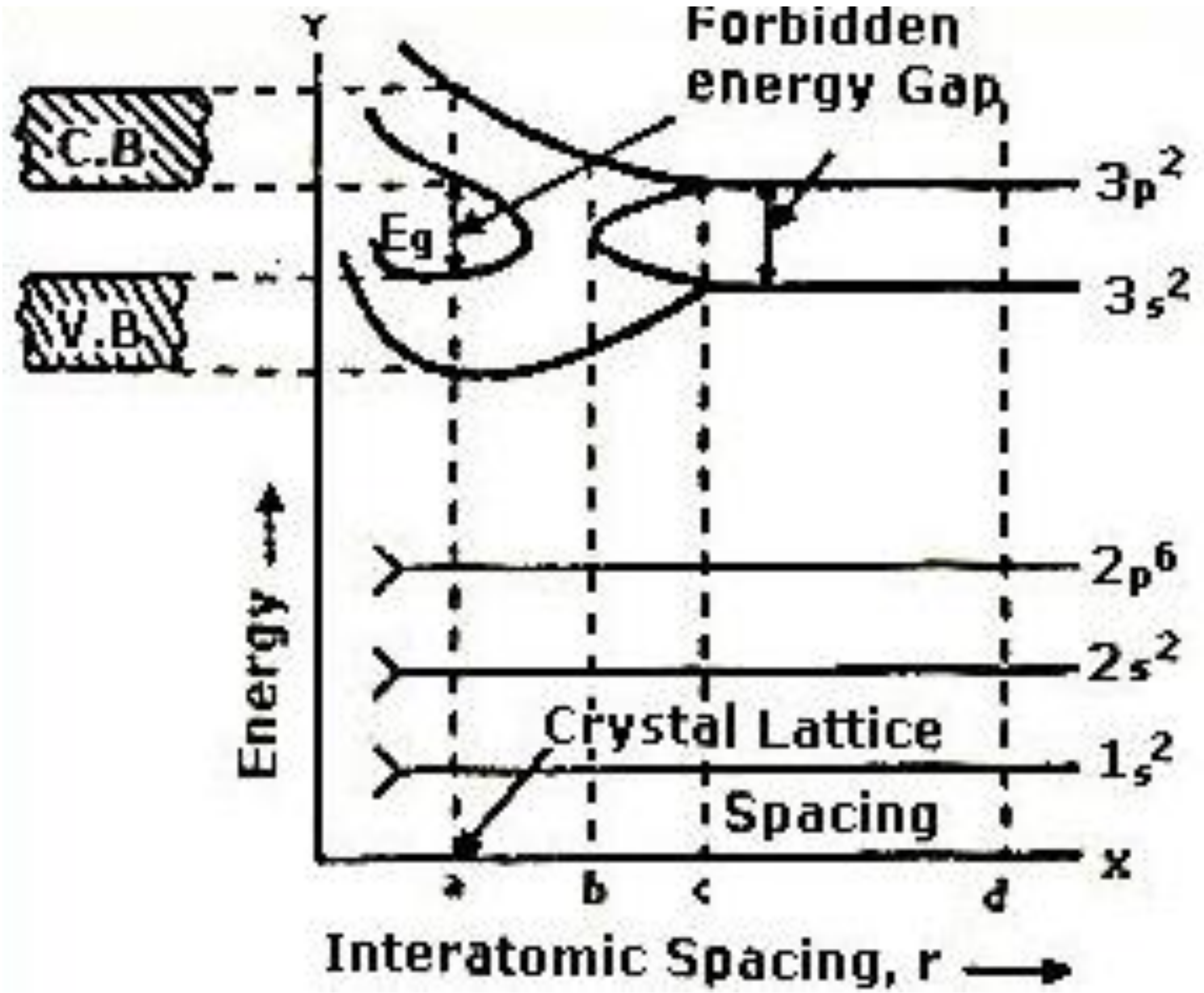


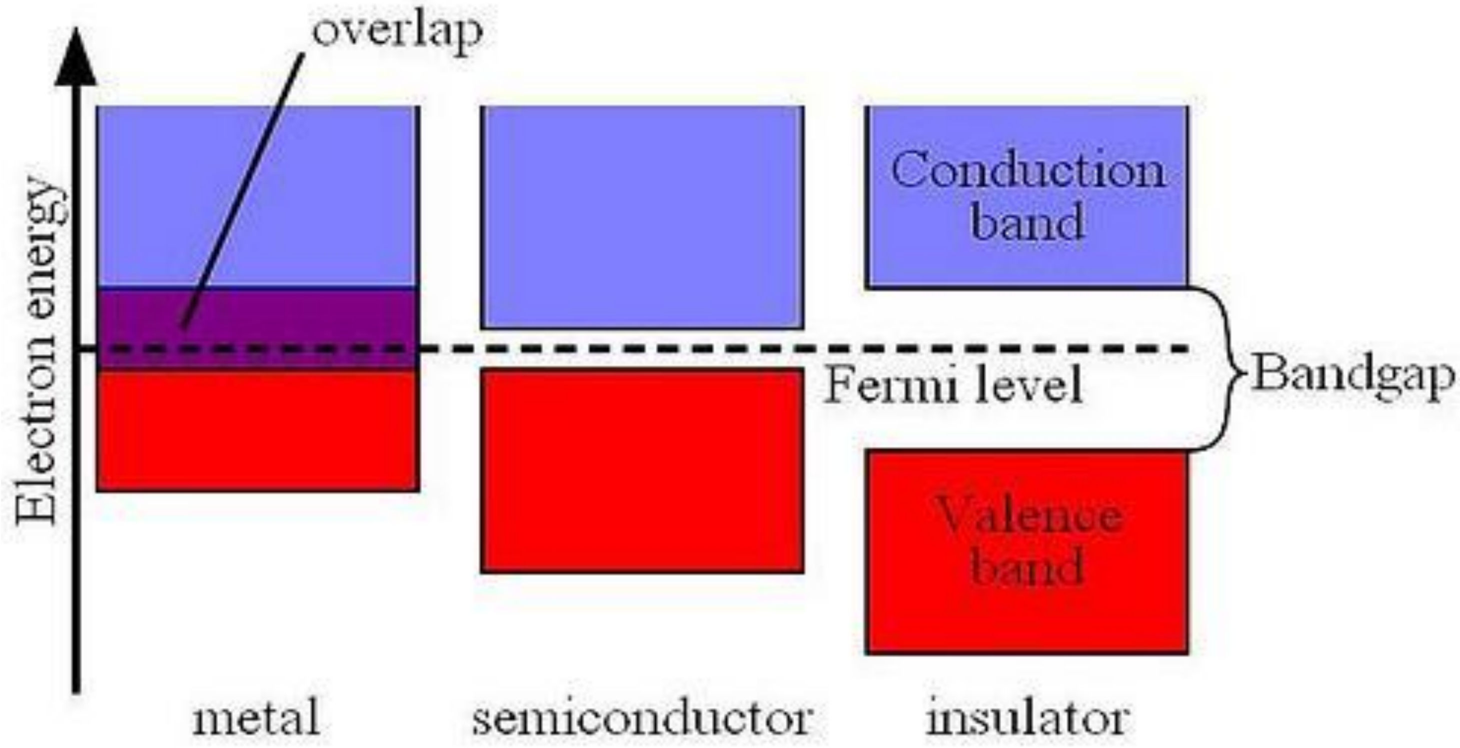
Figure 1: Splitting of valence band

No. of atoms ~ 10^{23} /cm^3

Energy bands of an atom as their interatomic distance decreases



Distinctions between Metal, Semiconductor and Insulator



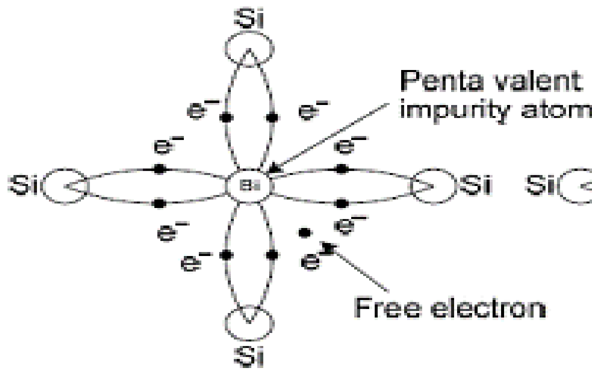
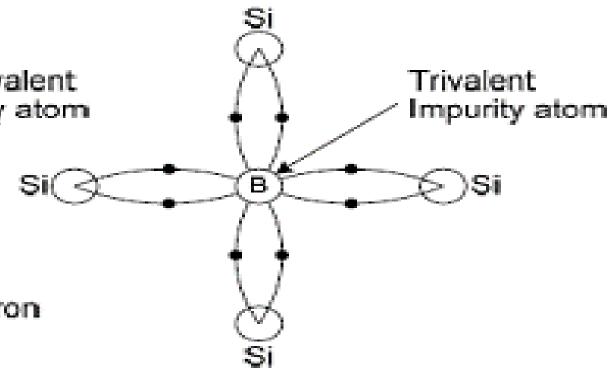
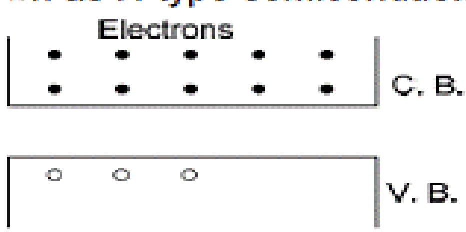
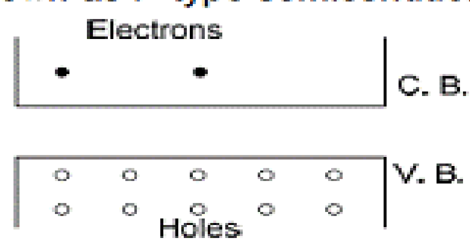
Property	Conductor	Semiconductor	Insulator
Resistivity	10^{-8} Ω-cm	10^{-4} -10^{3} Ω-cm	10^{12} Ω-cm
Electrical conductivity	Good conductor due to the presence of large number of electrons	Conductivity lies between that of conductor and insulator	Bad conductor due to absence of free electrons
Type of bonding	Metallic	Covalent	Ionic and covalent
Energy gap	No gap	~1 eV	> 6eV
Resistance	Increases with temperature	decreases with temperature	Remain constant with temperature
Temperature coefficient of resistance	+ve	-ve	----
Charge carriers	Electrons	Electrons and holes	----
Examples	Ag, Cu, Al, Fe, etc.	Si, Ge, GaAs, ZnO, etc.	Rubber, plastic, ebonite, etc.

Distinctions between Metal and Semiconductor

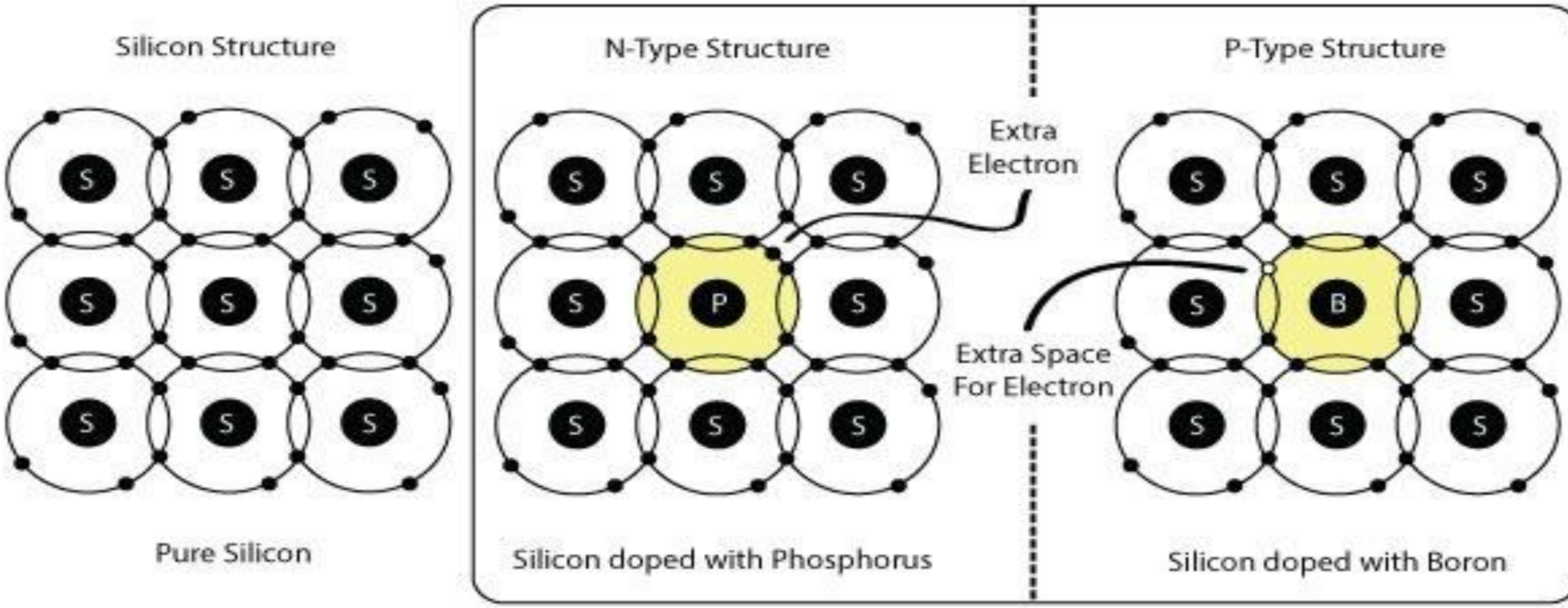
Semiconductor	Metal
Behaves like insulator at absolute temperature (O K). Its conductivity rises with the rise in temperature.	Conductivity falls with the rise in temperature.
Conductivity rises with the rise in potential difference applied.	Conductivity is an intrinsic property and independent of applied potential difference.
Partially obeys Ohm’s law.	Obeys Ohm’s law
Impurity doping increases conductivity.	Alloying with another metal decreases conductivity.

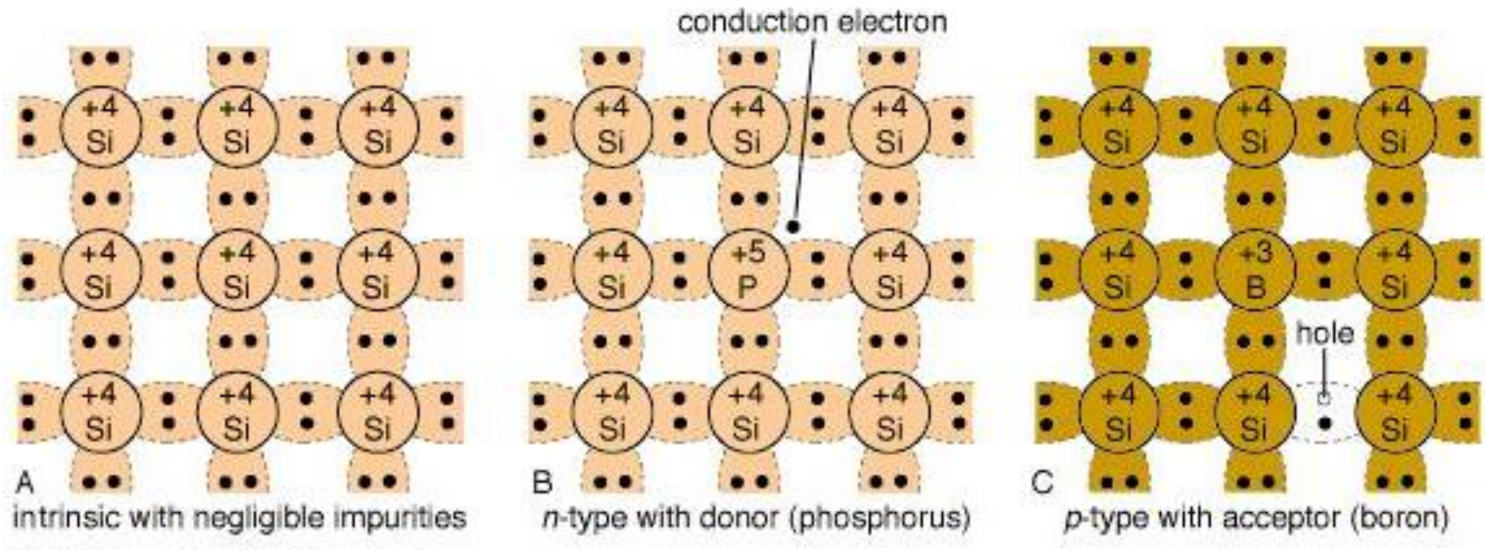
Semiconductors

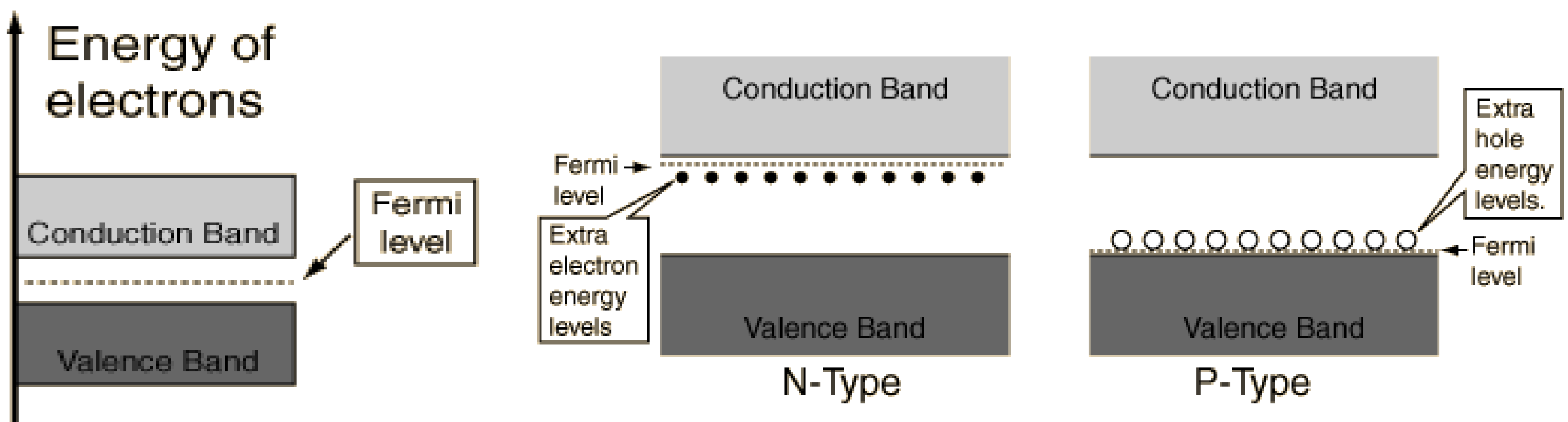
Intrinsic Semiconductor	Extrinsic Semiconductor (n-type and p-type)
Pure and naturally occurring semiconductors.	Semiconductors with added impurity.
Conductivity is poor.	Conductivity is large.
Number of holes and electrons are equal.	Majority carriers: Electrons in n-type Holes in p-type.
Fermi energy level lies at the center of the forbidden energy gap.	In n-type it is near the bottom of the conduction band and in p-type it is near the top of the valance band.
Example: Si, Ge, etc.	Example: n-type: Si or Ge doped with pentavalent impurity (As, Sb, P, N, etc.) p-type: Si or Ge doped with trivalent impurity (B, Al, In, Ga, etc.)

S.No.	N-type semiconductors	P-type semiconductors
1.	In these the impurity of some pentavalent element like P, As, Sb, Bi, etc. is mixed	In these, the impurity of some trivalent element like b, Al, In, Ga etc. is mixed
2.		
3.	In these the impurity atom donates one electrons, hence these are known as donor type semiconductors	In these, the impurity atom can accept one electron, hence these are known as acceptor type semiconductors.
4.	In these the electrons are majority current carriers and holes are minority current carriers. (i.e. the electron density is more than hole density $n_n >> n_p$)	In these the holes are majority current carriers and electrons are minority current carriers i.e. $n_p >> n_n$
5.	In these there is majority of negative particles (electrons) and hence are known as N-type semiconductors 	In these there is majority of positive particles (cotters) and hence are known as P-type semiconductors. 
6.	In these the donor energy level is close to the conduction band and far away from valence band.	In these the acceptor energy level is close to the valence band and far away from conduction band.

Semiconductor Doping




conduction electron
+4 Si
+5 P
+3 B
hole
A
intrinsic with negligible impurities
B
n-type with donor (phosphorus)
C
p-type with acceptor (boron)


Energy of electrons
Conduction Band
Fermi level
Valence Band
Conduction Band
Fermi level
Extra electron energy levels
Valence Band
N-Type
Conduction Band
Extra hole energy levels.
Fermi level
Valence Band
P-Type

Intrinsic