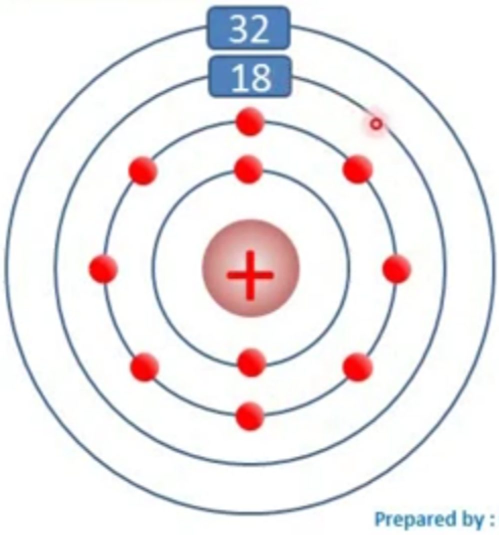
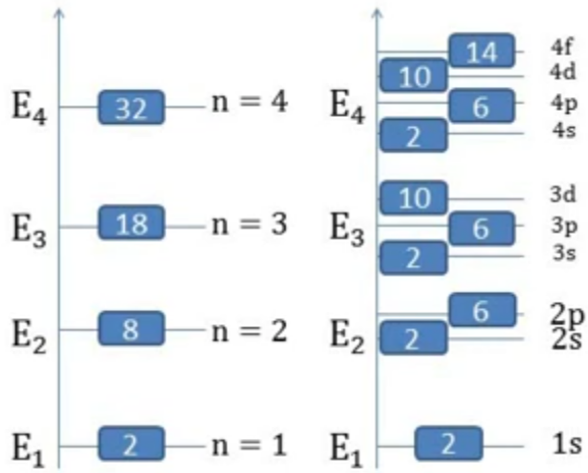
Module 3: Semiconductor Physics

Energy Levels





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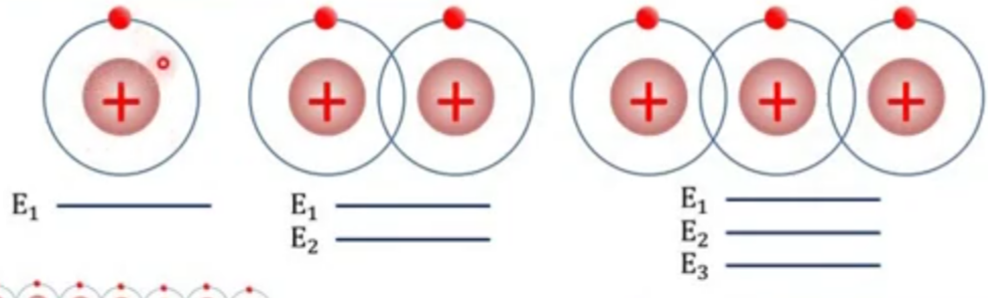
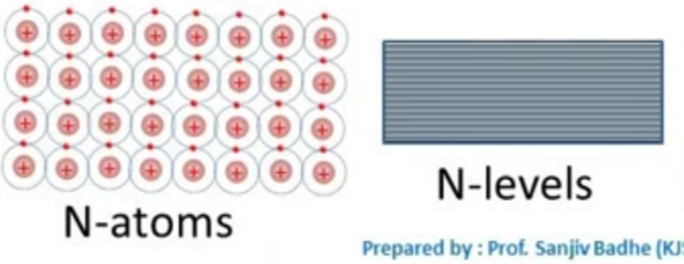
Module 3: Semiconductor Physics

Formation of Energy Bands





Pauli's Exclusion Principle

No two electrons in a given interacting system can have same quantum state and hence same energy.

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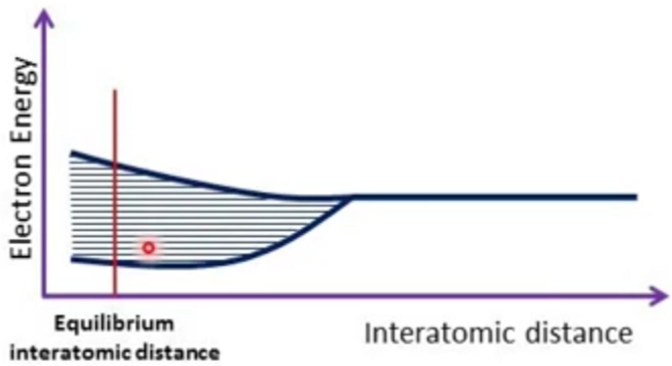
Formation of Energy Bands

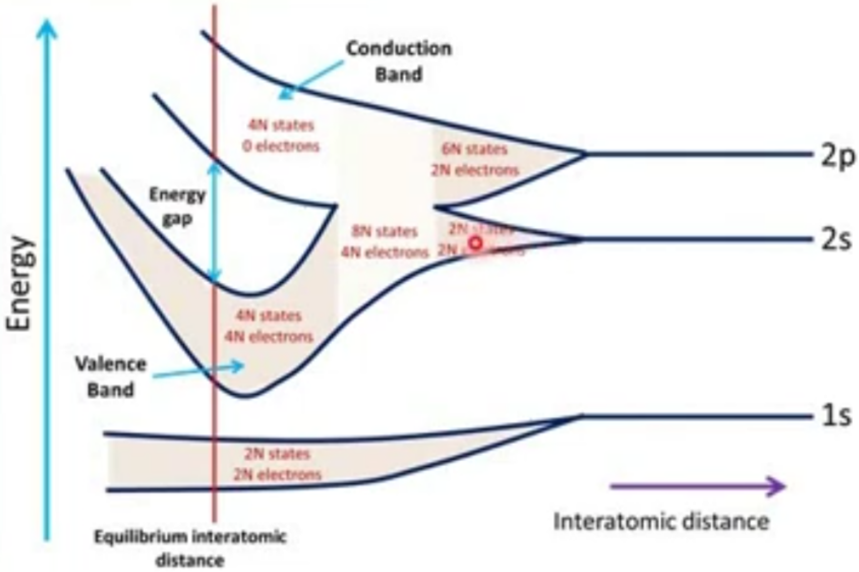


Pushing the atoms together, the initial quantized energy level will split into a band of discrete energy levels.

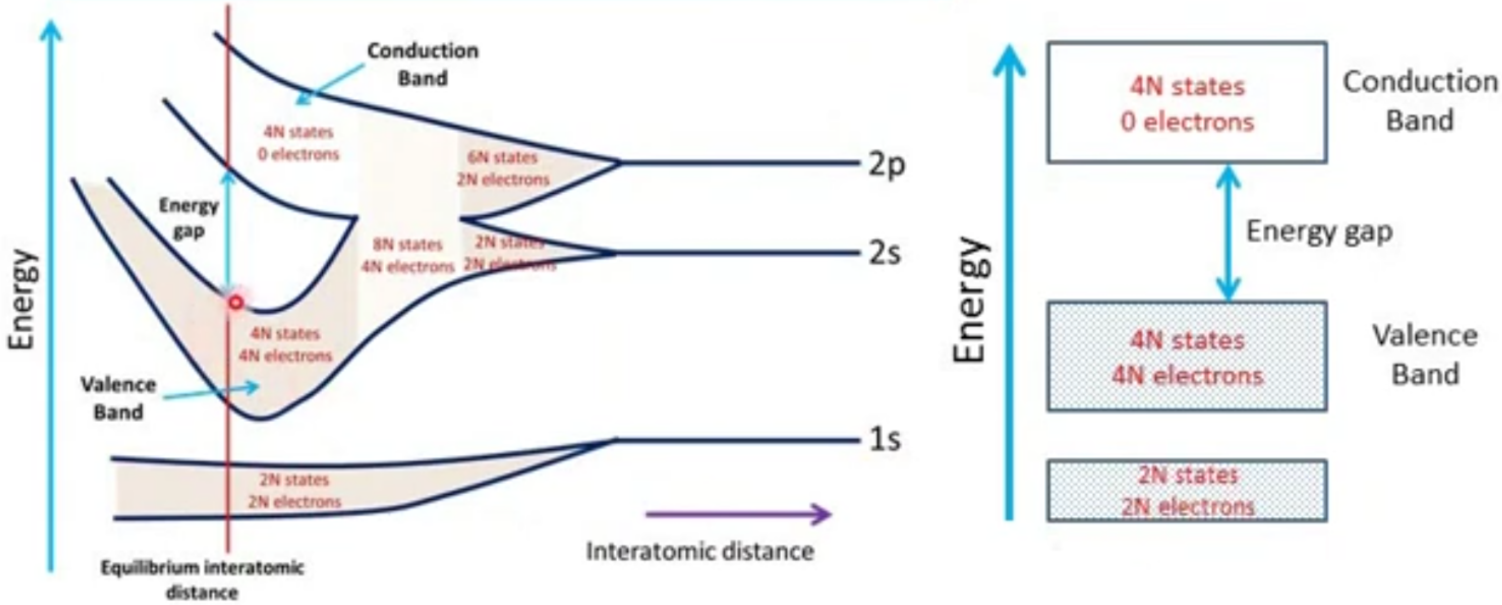
Module 3: Semiconductor Physics

Formation of Energy Bands in Diamond

- Electronic structure individual carbon atom:
  $1s^2\ 2s^2\ 2p^2$
- Each atom has two 1s states, two 2s states, six 2p states and the higher states.
- Hence for N atoms, there will be 2N, 2N and 6N available states of type 1s, 2s, and 2p respectively.



Formation of Energy Bands in Diamond



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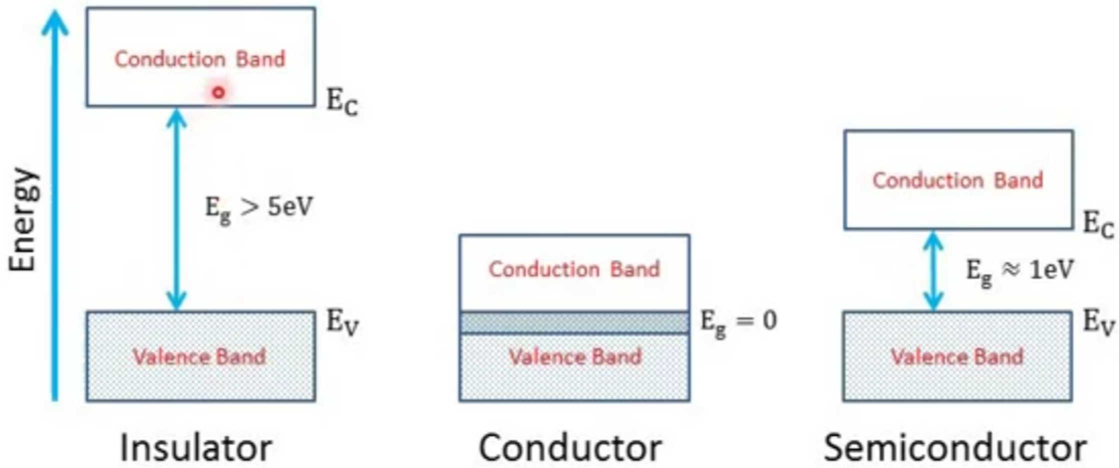
Classification of solids on the basis of band theory



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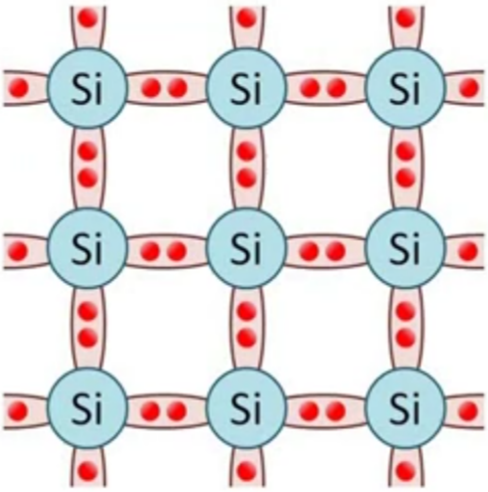
Covalent Bonds in Semiconductors



Neighboring atoms form covalent bonds by sharing electrons with each other

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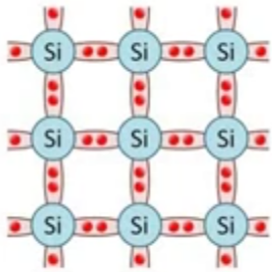
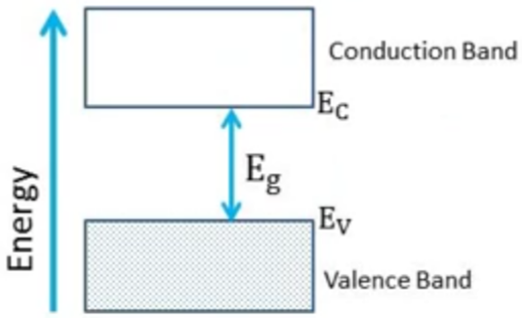
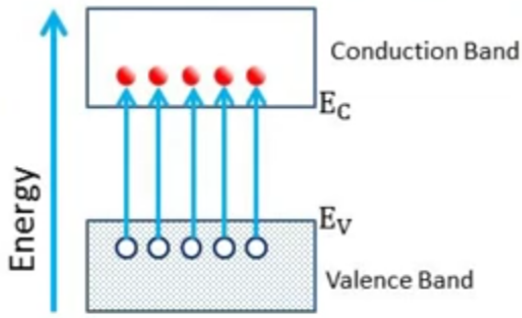
Intrinsic Semiconductors







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Why Silicon is preferred over Germanium?

- Silicon and Germanium are two most widely used semiconductors.
- Silicon is preferred over Germanium because of its superior thermal properties.
- The maximum operational temperature for Ge-devices is 80^0C while Si-devices may be used at up to 160^0C.
- Also, at room temperature, silicon crystal has almost no free electrons compared with Germanium crystal

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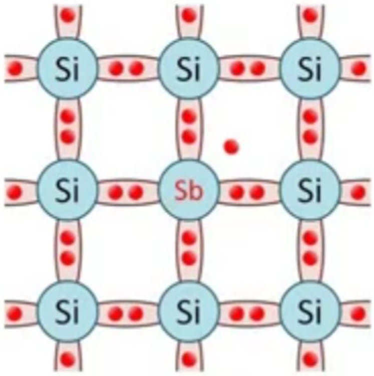
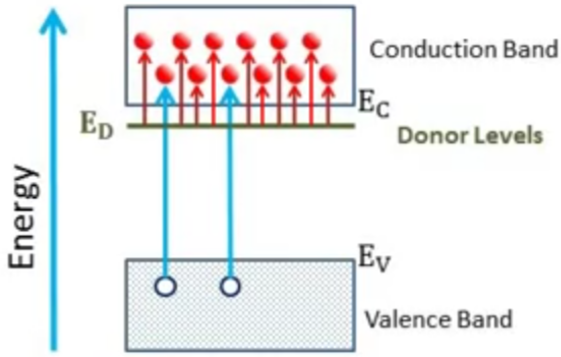
Extrinsic Semiconductors (Doped Semiconductors)

n-type semiconductor





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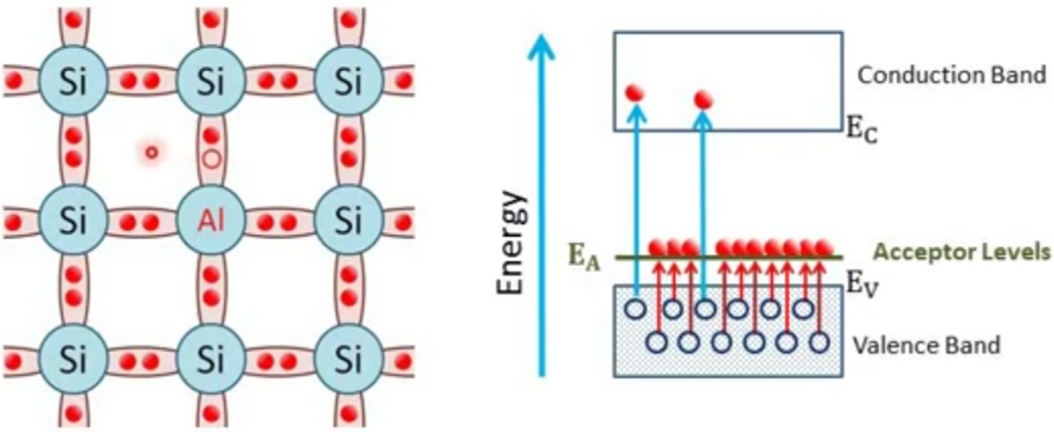
Extrinsic Semiconductors (Doped Semiconductors)

p-type semiconductor



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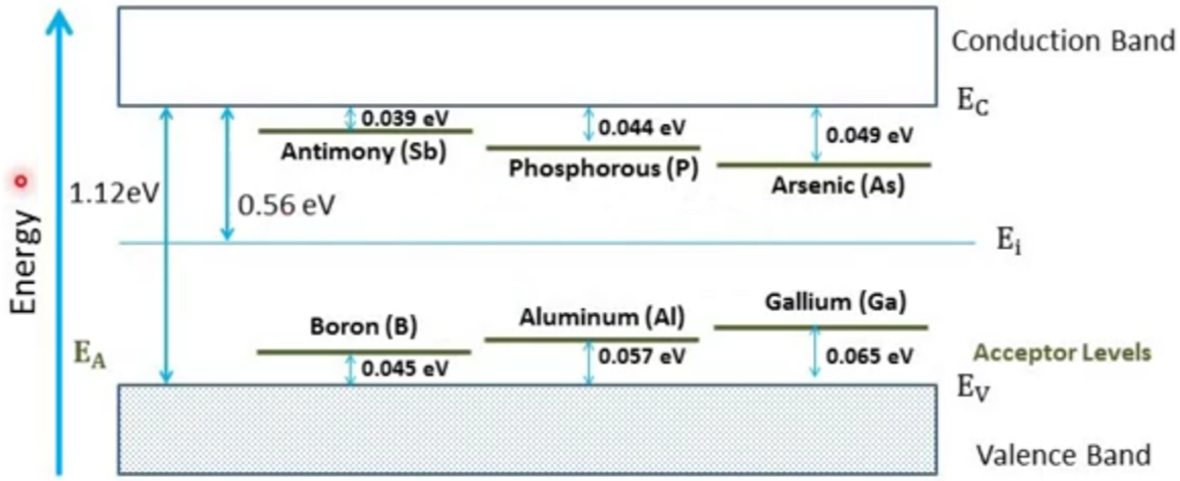
Extrinsic Semiconductors (Doped Semiconductors)



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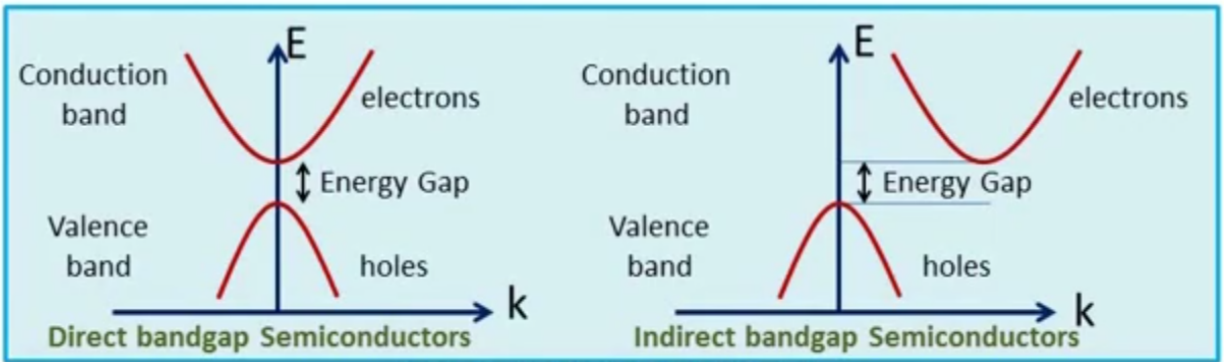
Module 3: Semiconductor Physics

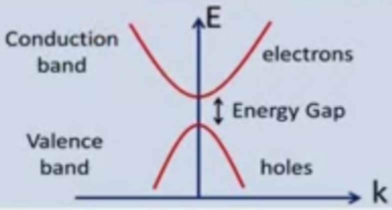
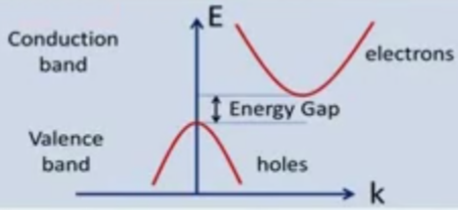
Direct Gap and Indirect Gap Semiconductors

The energy of an electron is given by $E = \frac{p^2}{2m} = \frac{\hbar^2 k^2}{2m}$ where p is momentum, m is mass of an electron, $\hbar$ is Planck's constant and k is propagation constant

Thus $E \propto k^2$ which is an equation of parabola. The graph of E vs k is shown below -



Module 3: Semiconductor Physics

Direct bandgap Semiconductors	Indirect bandgap Semiconductors
	
Maximum of valence band and minimum of conduction band occur at same momentum values	Maximum of valence band and minimum of conduction band occur at two different momentum values.
Electron making a transition from valence band to conduction band need not undergo any change in its momentum.	In order to make a transition from maximum point in valence band to minimum point in conduction band, the electron requires energy for the change in momentum in addition to the energy gap E_g
The compound semiconductors such as GaAs, are direct gap semiconductors	All elemental semiconductors such as Si, Ge, are indirect gap semiconductors
These direct gap semiconductors are used in LED and Semiconductor Lasers.	Not useful for LEDs and Semiconductor Lasers

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