Dr. Ambedkar Institute of Technology

Electronics Devices (19EC31)

Class 4

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Semiconductor BandGap

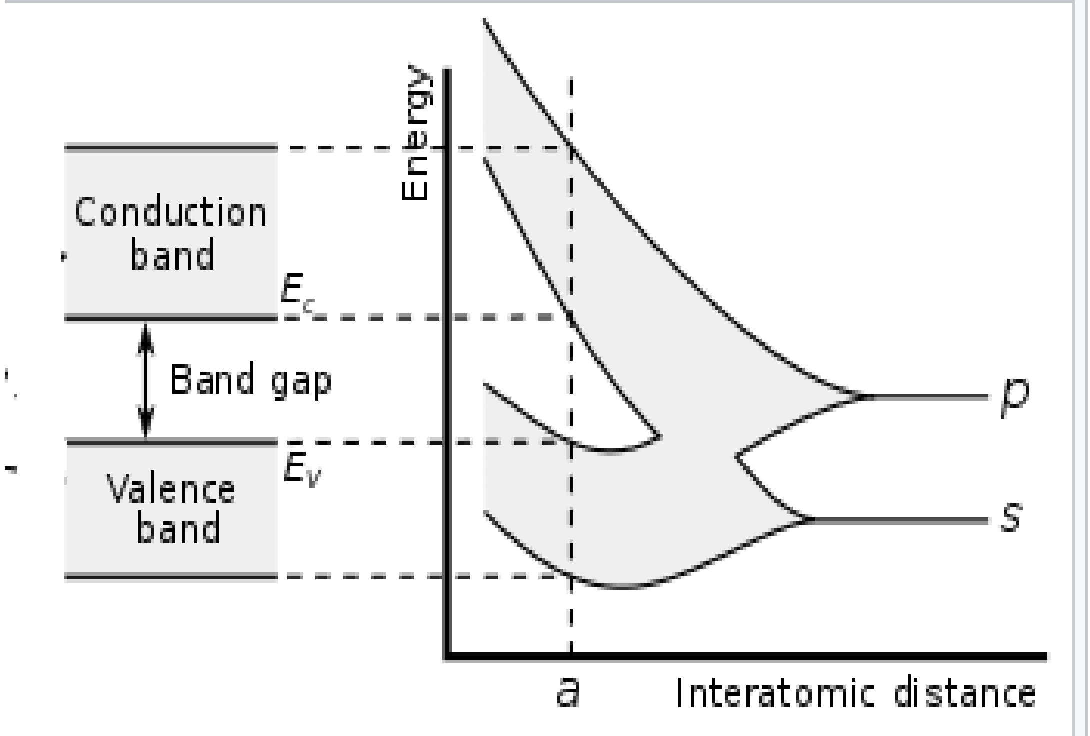
Energy Bandgap (Eg)

1. Energy difference (in electron volts) between the top of the valence band and the bottom of the conduction band.

2. Type of Bandgap

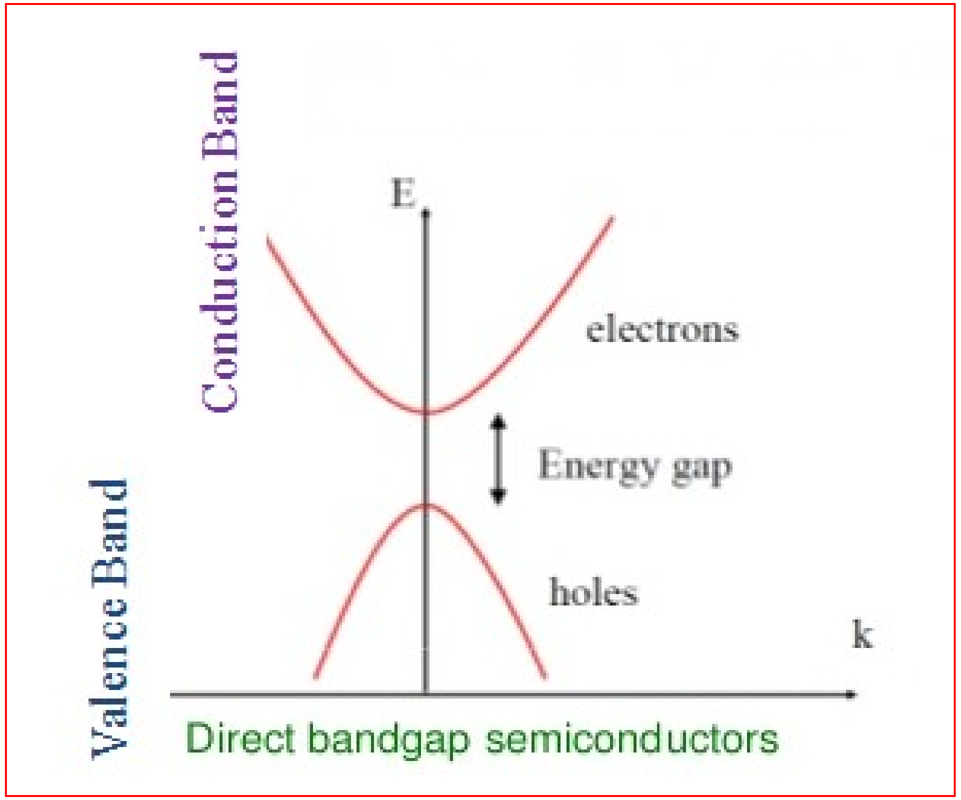
- Direct Bandgap Semiconductor.
- Indirect Bandgap Semiconductor.

Energy Bandgap

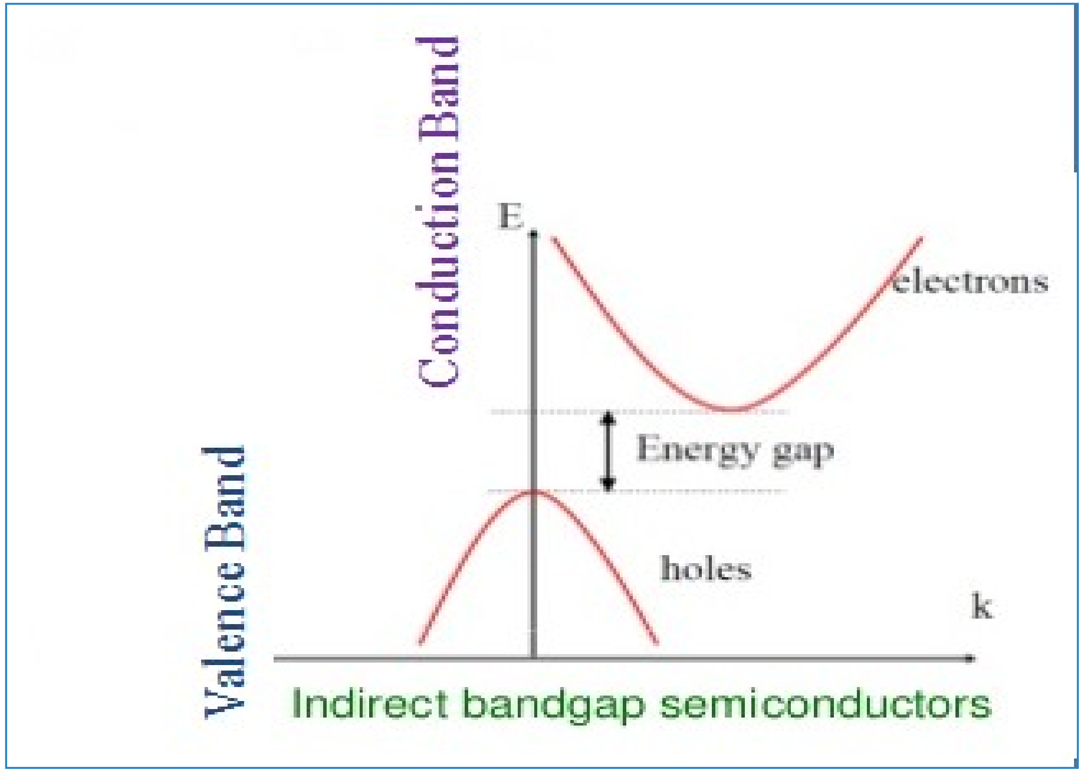


Direct and Indirect BandGap Semiconductor

Direct Bandgap Semiconductor

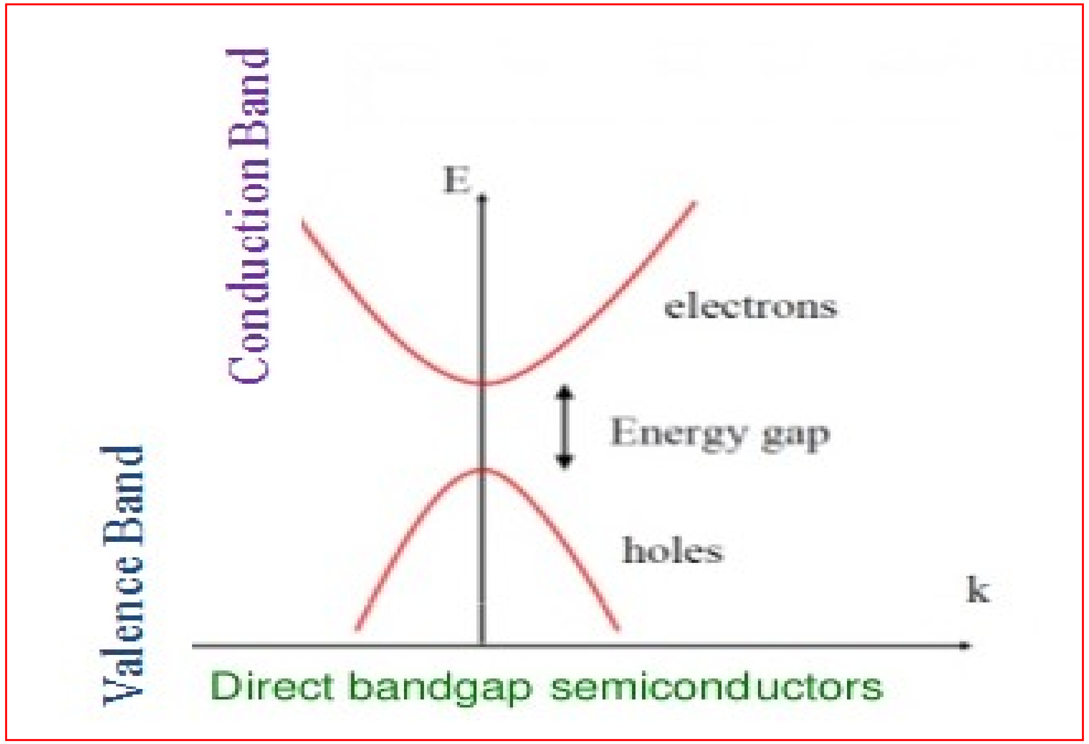


InDirect Bandgap Semiconductor

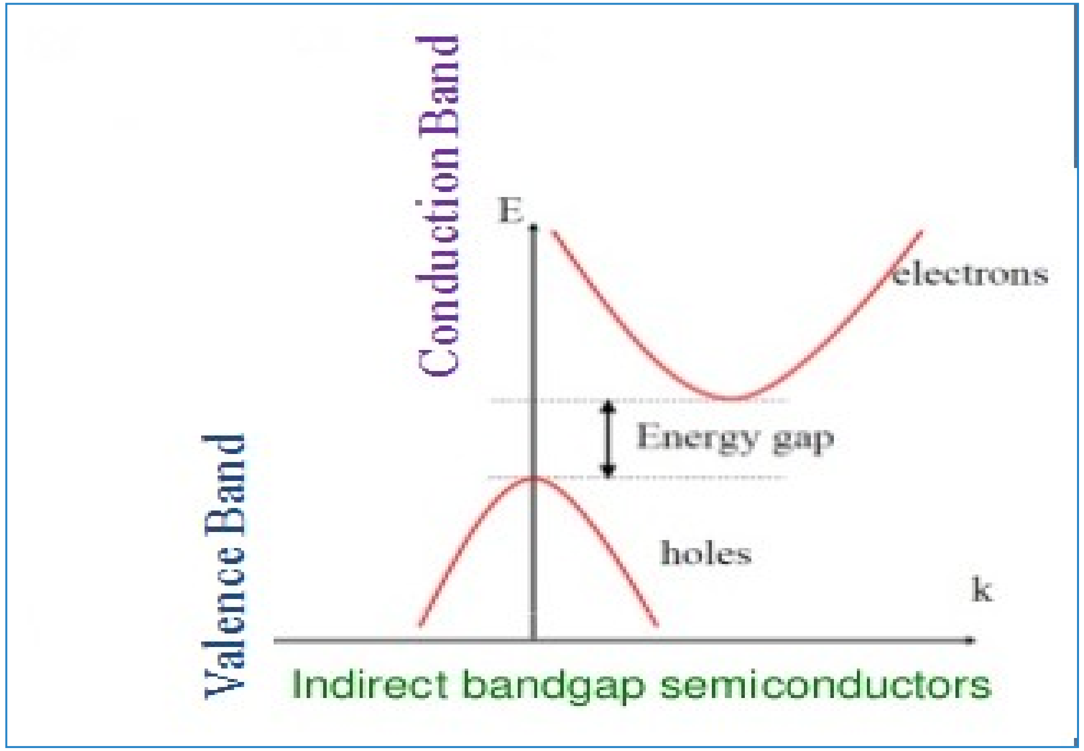


Direct and Indirect BandGap Semiconductor

The material for which maximum of valence band and minimum of conduction band lie for same value of k , k is Propogation constant Ex.GaAs, GaN



The material for which maximum of valence band and minimum of conduction band donot occur at the same value of k, k is Propogation Constant Ex. Si, Ge



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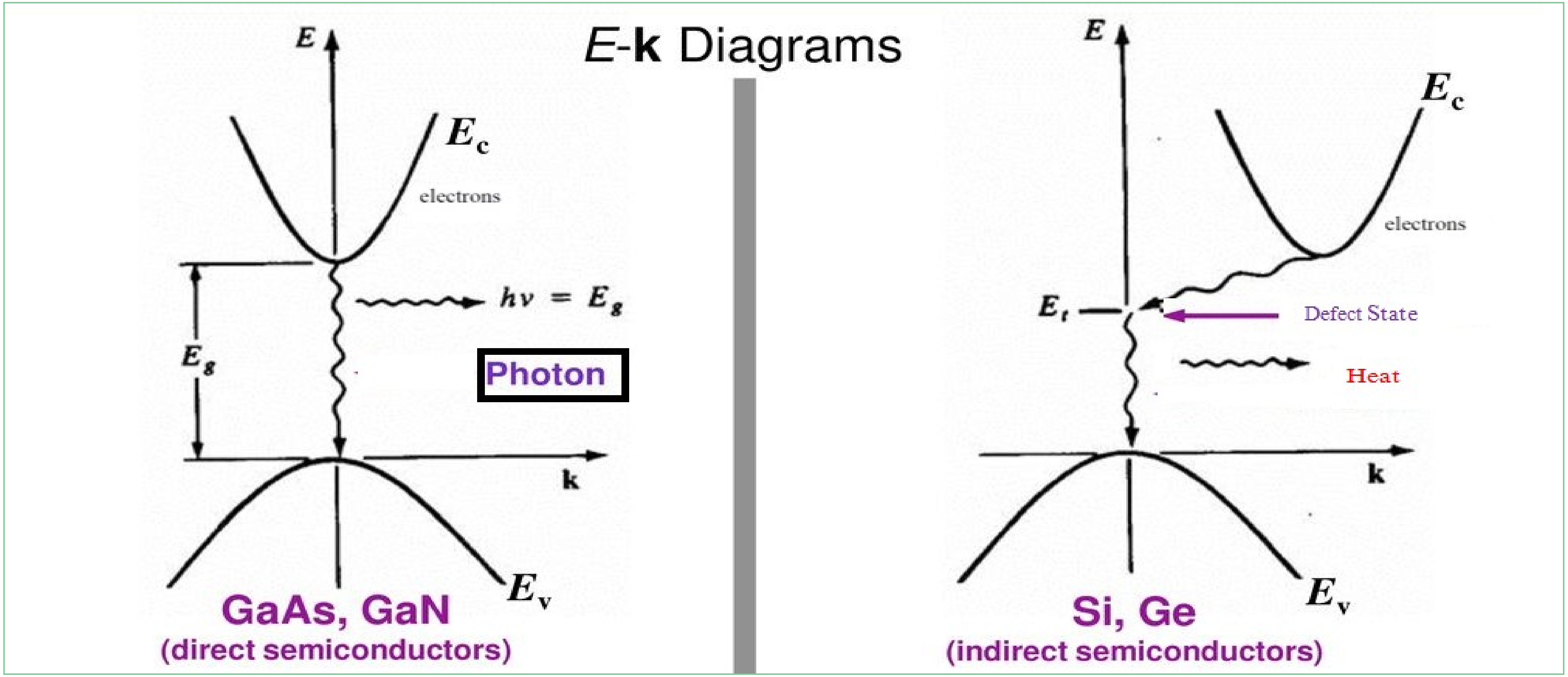
Direct and Indirect BandGap Semiconductor E-k Diagrams



Direct and Indirect BandGap Semiconductor

Direct Bandgap Semiconductor

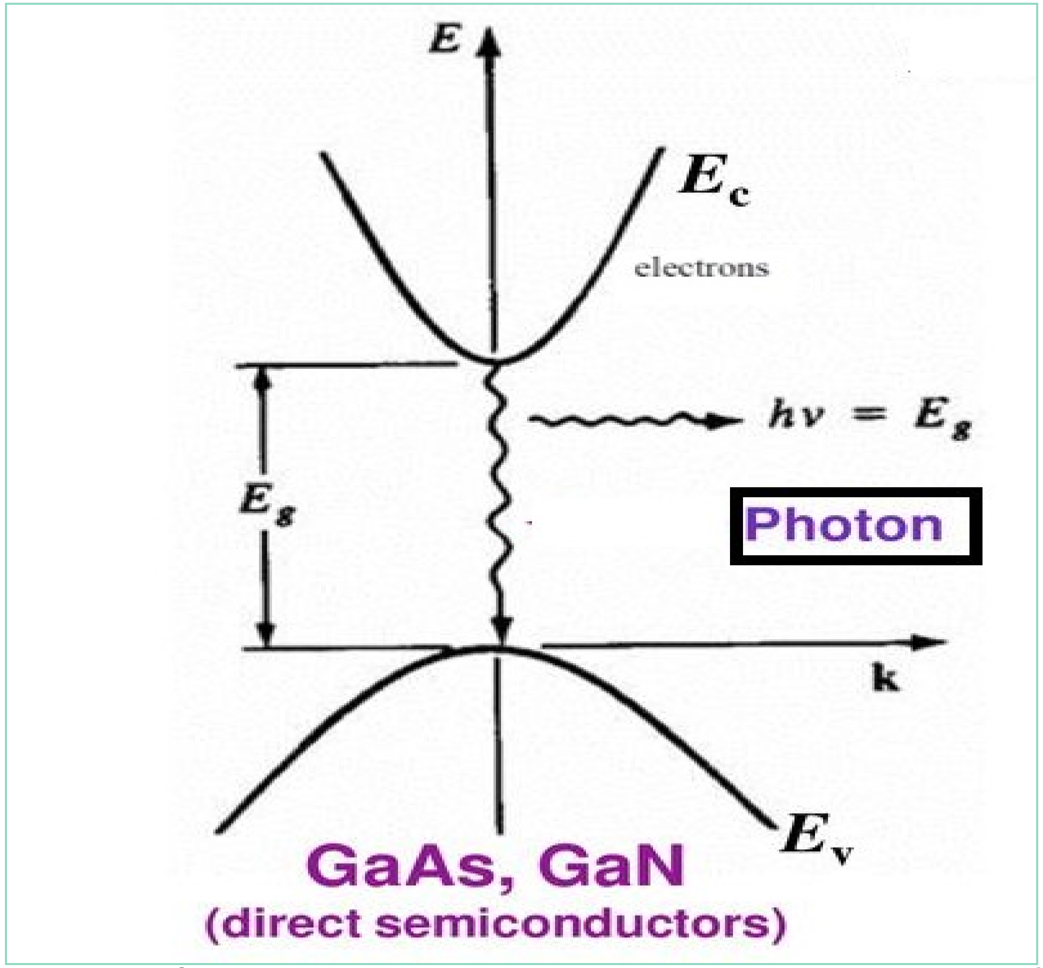
1. Electrons falling from conduction band to an Valence Band gives of lights(photon)

   This process is called ***"Recombination".***

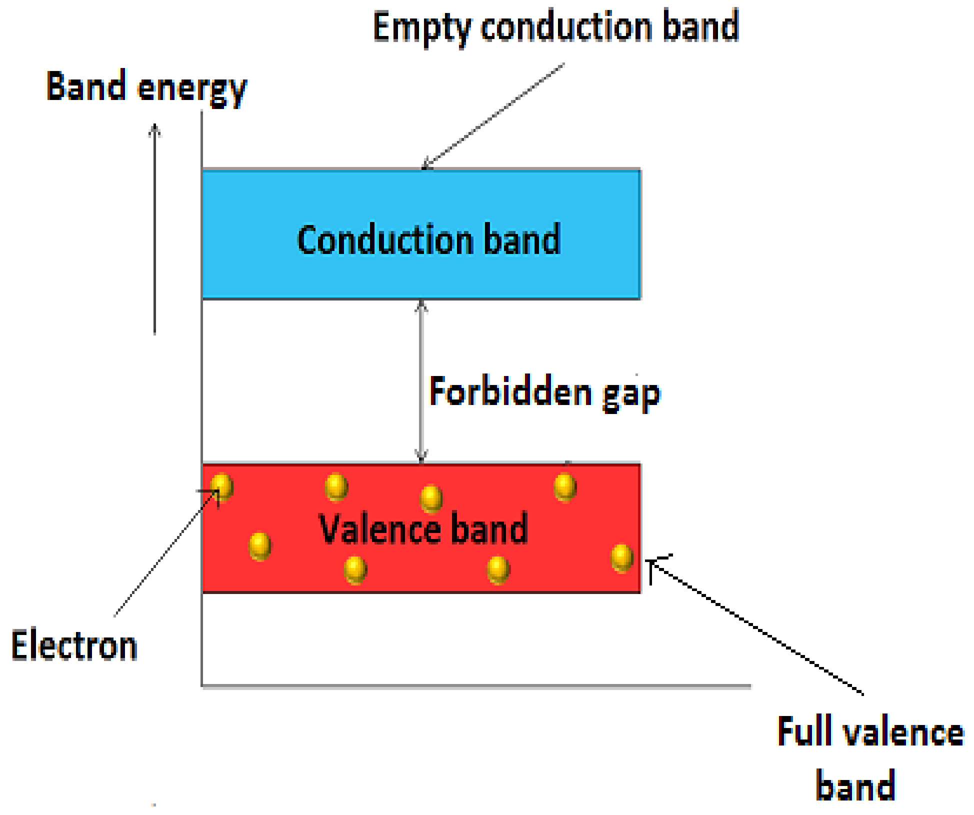
2. Examples GaAs (Gallium Arsenide)

   GaN (Gallium Nitride).

3. Examples light-emitting diodes (LEDs), and laser diodes



Energy Band Diagram



The last completely filled (at least at T = 0 K) band is called the **Valence Band**

The next band with higher energy is the **Conduction Band**

- The **Conduction Band** can be empty or partially filed

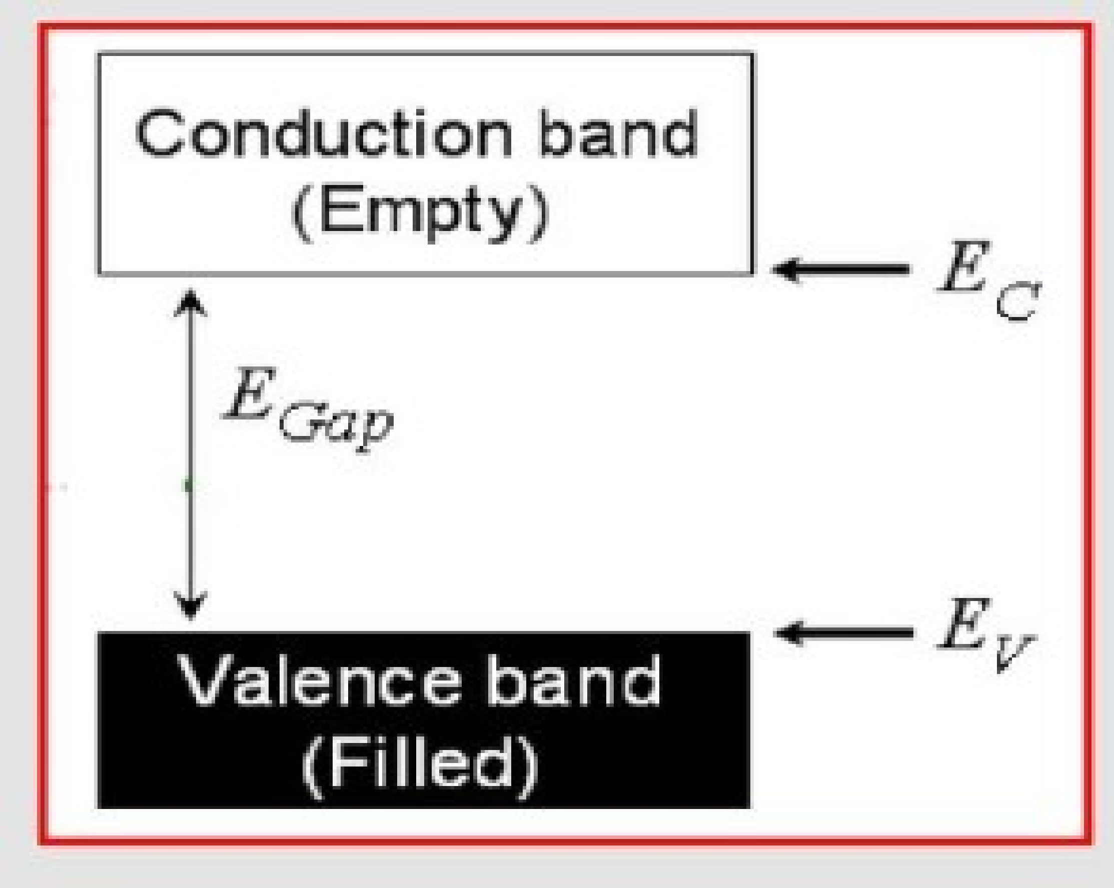
The energy difference between the bottom of the CB and the top of the VB is called the **Band Gap** (or Forbidden Gap)

Insulator

1. In Insulator - the Energy BandGap (E_g) is wider between Conduction Band and Valence Band.
   Diamond -- Eg = 5eV

2. If electric field applied, the electrons in Valence Band (VB) cannot reach Conduction Band.

Energy Diagram of Insulator



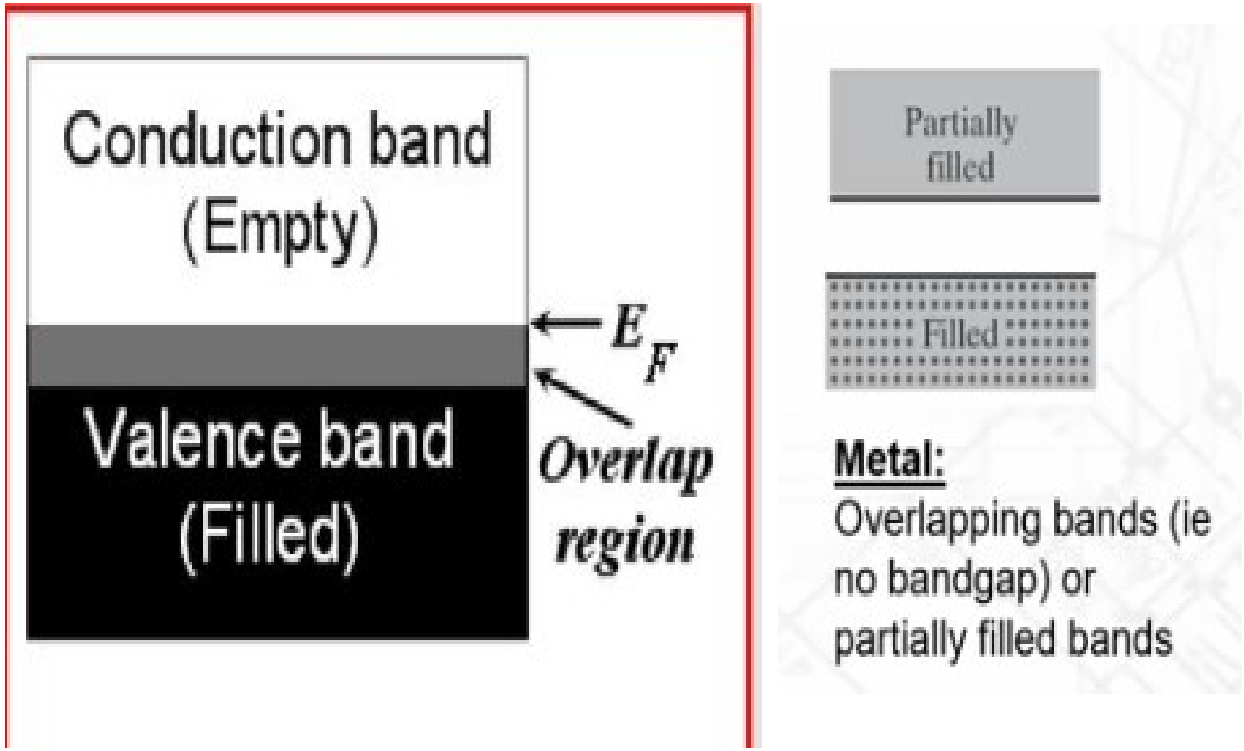
Metals, Semiconductors and Insulators

Metals

1. In Metals, valence band and conduction band overlap each other. Therefore, there is no forbidden gap in a conductor or partially filled conduction band

2. A small amount of applied external energy provides enough energy for the valence band electrons to move in to conduction band.

Energy Diagram of Metals



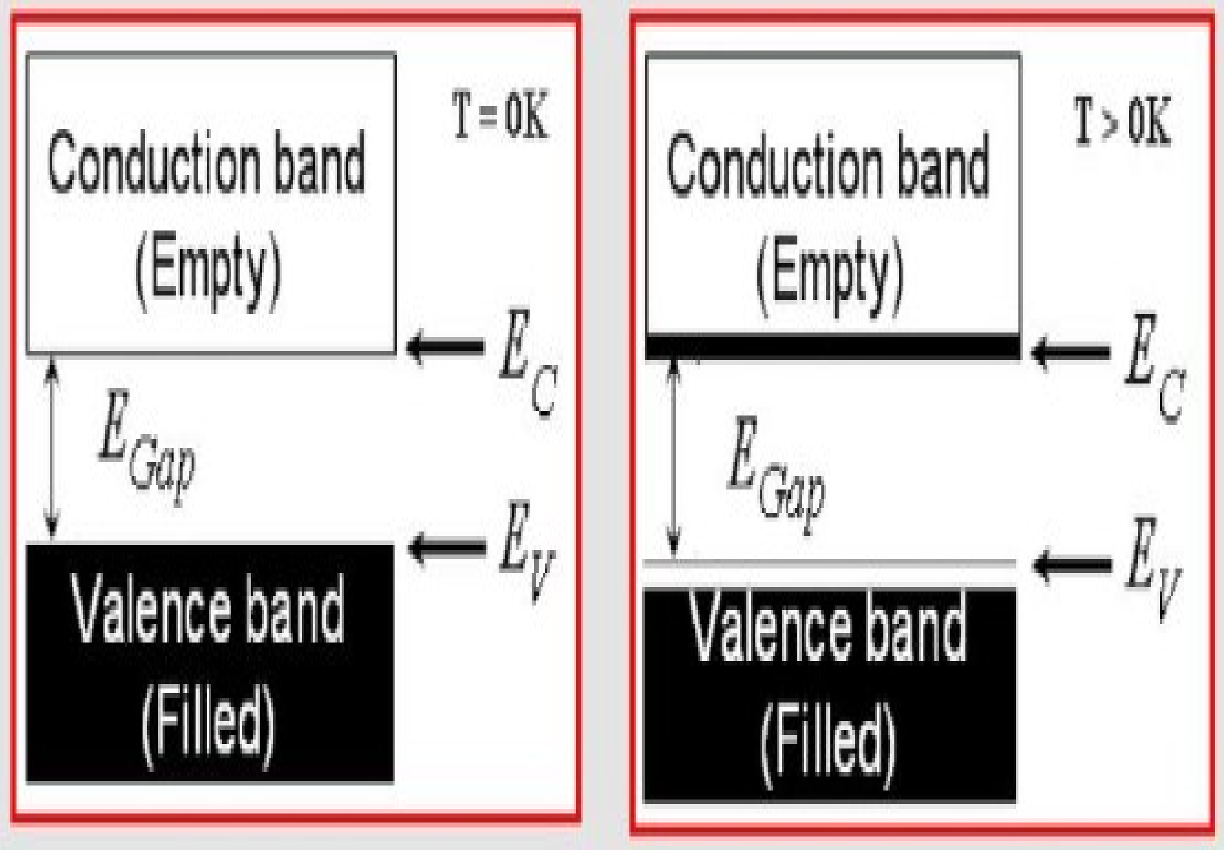
Metals, Semiconductors and Insulators

Semiconductor

1. In Semiconductor - the Energy BandGap (Eg) is smaller between Conduction Band and Valence Band than in insulators.
   Si -- Eg = 1.1eV

2. At 0K, Semiconductor behave as an Insulator.
3. At T> 0K, Semiconductor behave as an Metal

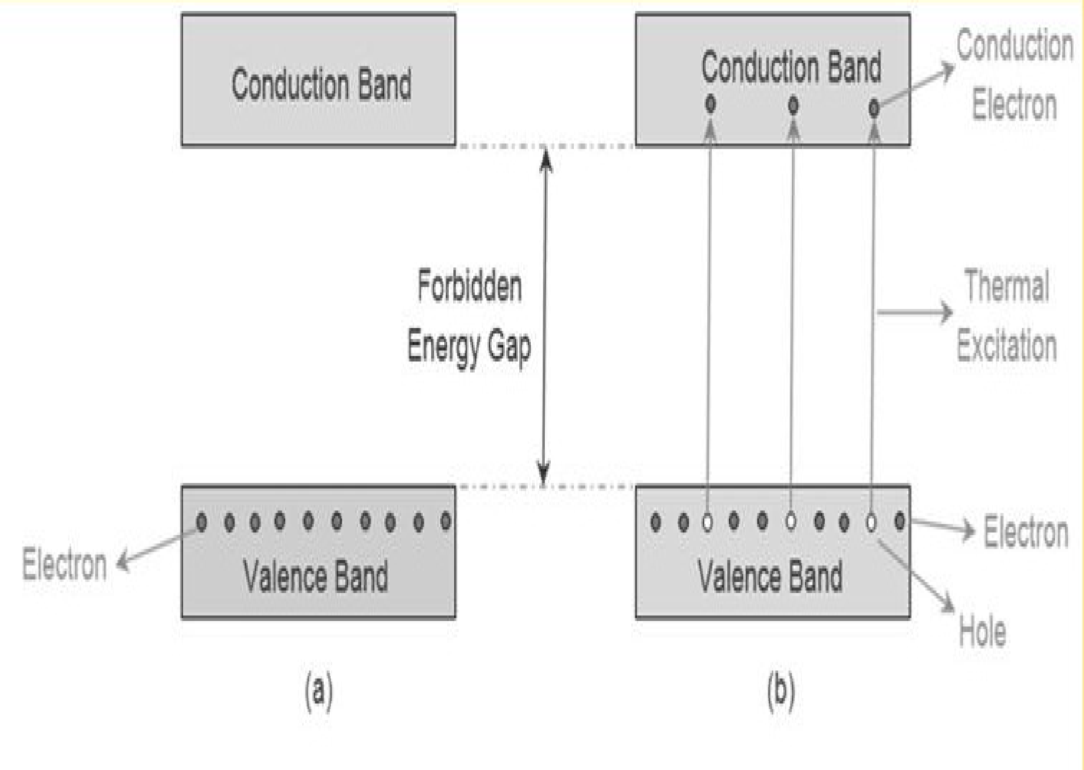
Energy Diagram of Semiconductor



Metals, Semiconductors and Insulators

Semiconductor

1. A small fraction of the electrons is thermally excited into the conduction band. These electrons carry current just as in metals.
2. The smaller the gap the more electrons in conduction band at a given temperature.
3. Resistivity decreases with temperature due to higher concentration of electrons in conduction band



Energy Band Diagram of Intrinsic Semiconductor at (a) 0K (b) Temperature > 0K

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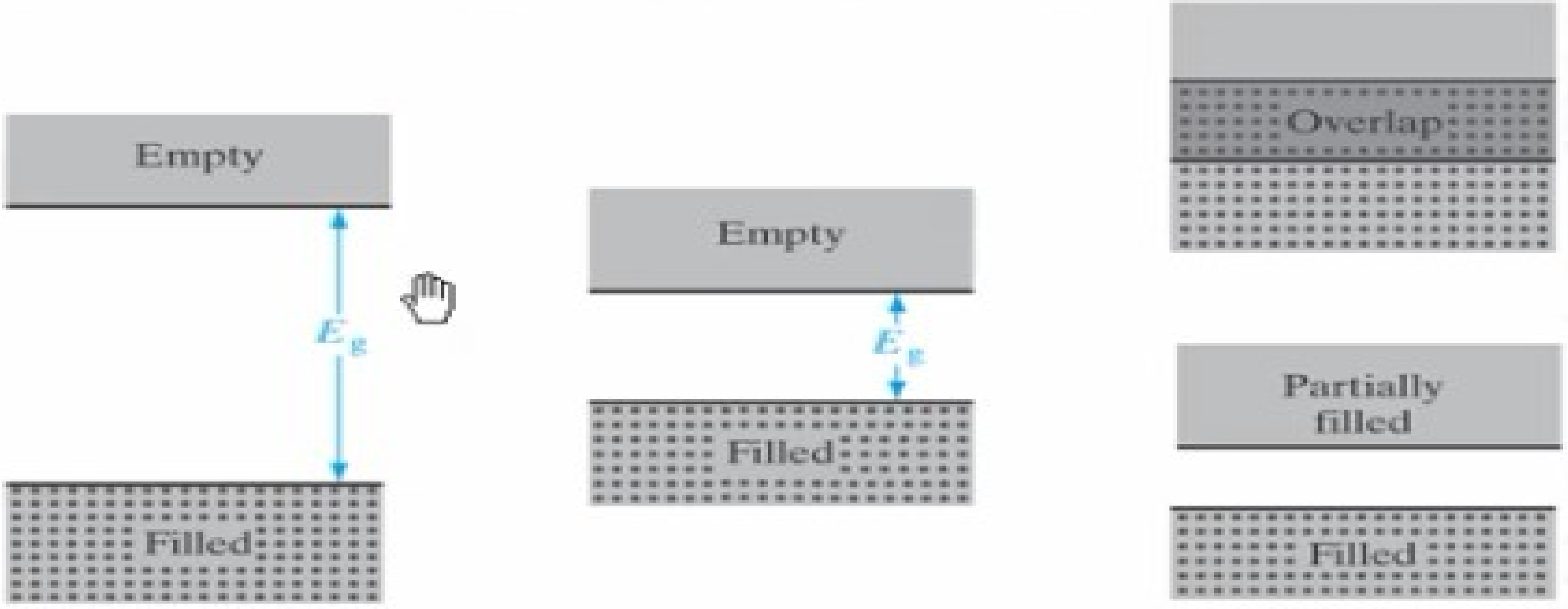
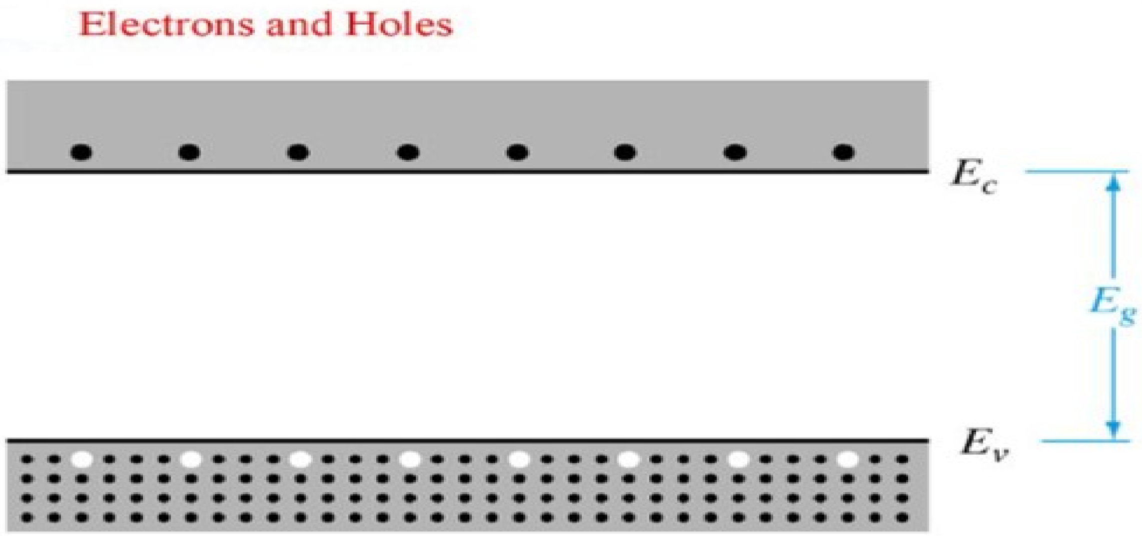
The Energy Band of Metals, Semiconductors and Insulators



Insulator:	**Semiconductor:**	**Metal:**
One filled band, one empty band, large bandgap	Same as insulator except smaller bandgap	Overlapping bands (ie no bandgap) or partially filled bands

Electrons and Holes



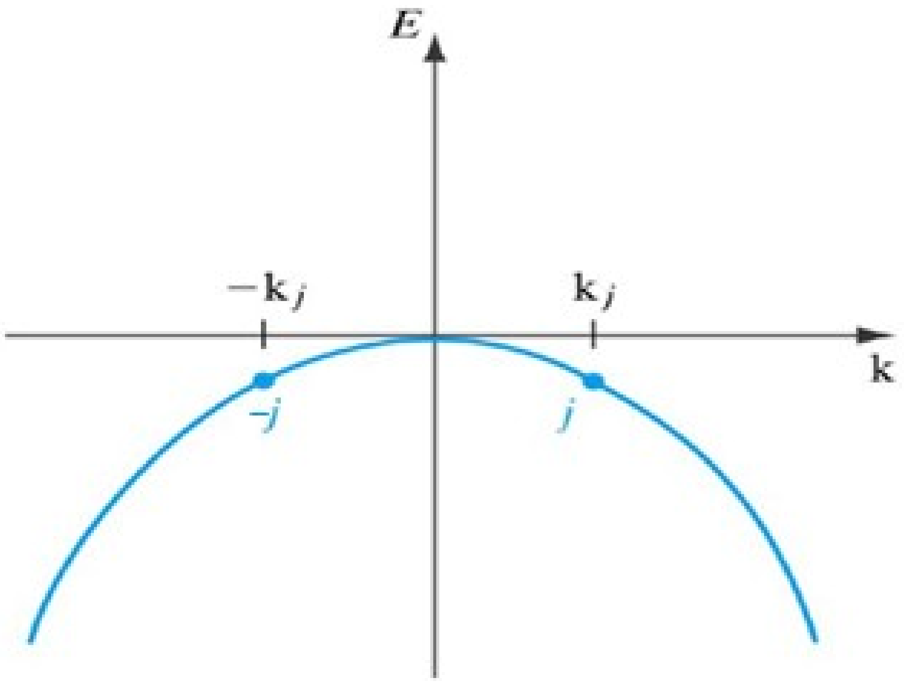
E_c → the bottom of the conduction band
E_v → the top of the valence band
EHP → electron-hole pair generation

- At 0K, a semiconductor is an insulator with no free charge carriers
- At T > 0K, some electrons in the valence band are excited to the conduction band
- The electrons in the conduction band are free to move about via many available states
- An empty state in the valence band is referred as a *hole*

The Valence Band in the Semiconductor

- The valence band of with all states filled (electrons) .
- The electron with wave vector k_j is matched with opposite wave vector $-k_j$.
- There is no net current in band unless an electron is removed.

Valence Band in Semiconductor



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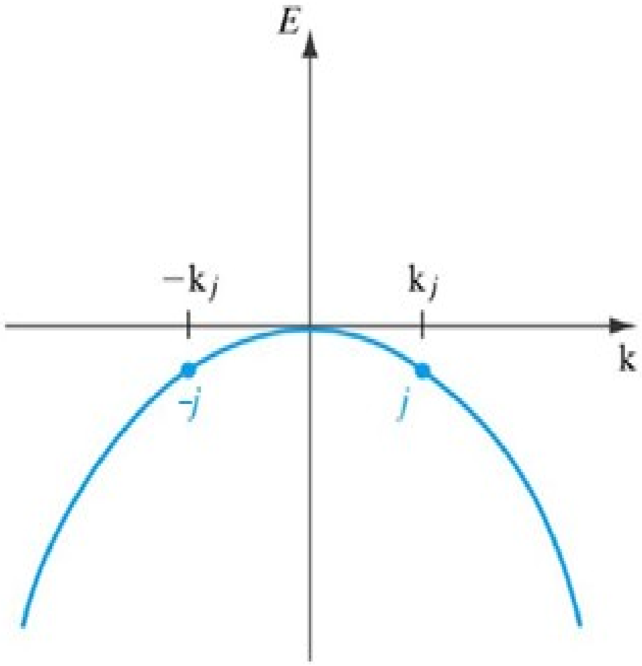
The concept of Hole



The total current due to the electrons in the valence band can therefore be written as

$$J = (-q)\sum_{i=0}^{n} v_i = 0 \qquad --- \quad (1)$$

$n = no\ of\ electrons$

$v = drift\ velocity\ of\ electrons$

$q = charge\ of\ electrons$

The total current with j^{th} electrons missing

$$J = (-q)\sum_{i=0}^{n} v_i - (-q)v_j \qquad --- (2)$$

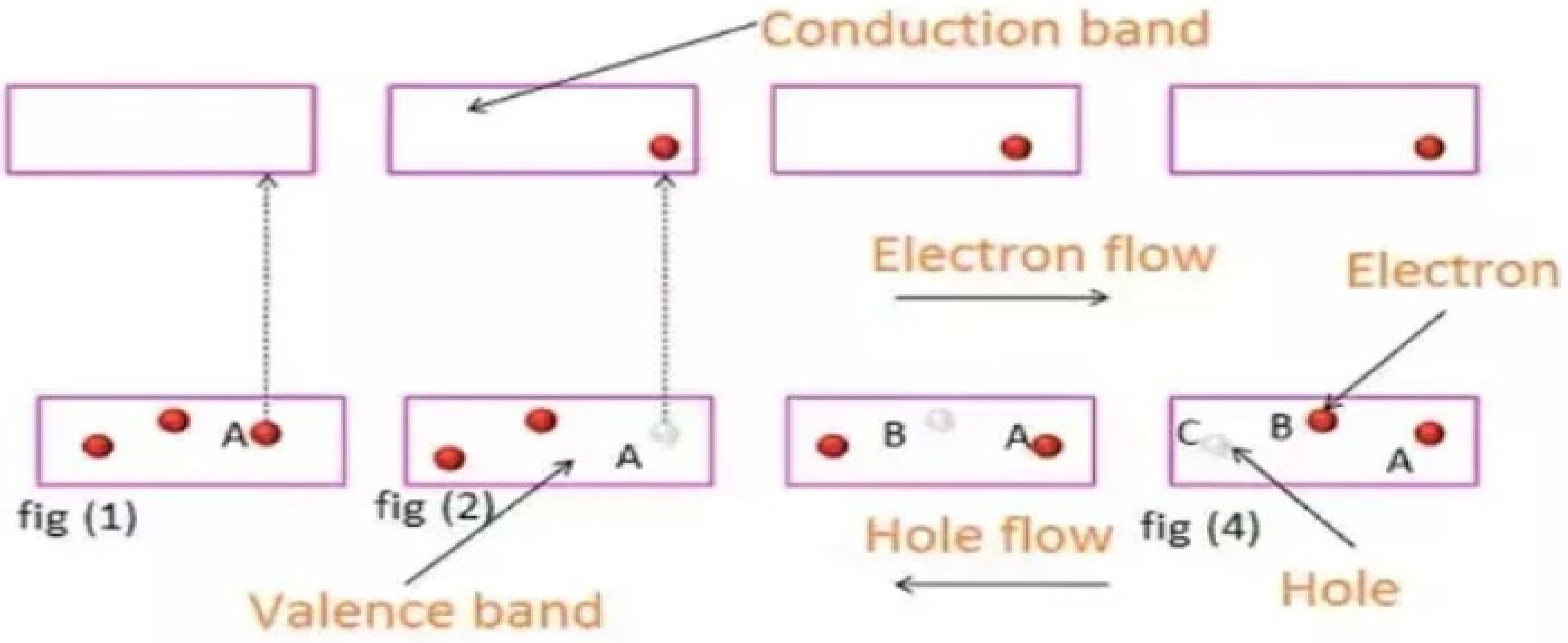
From eqn 1 ,the first term = 0

$J = +qv_j$

$+qv_j$ = positive charge with veleocity v_j

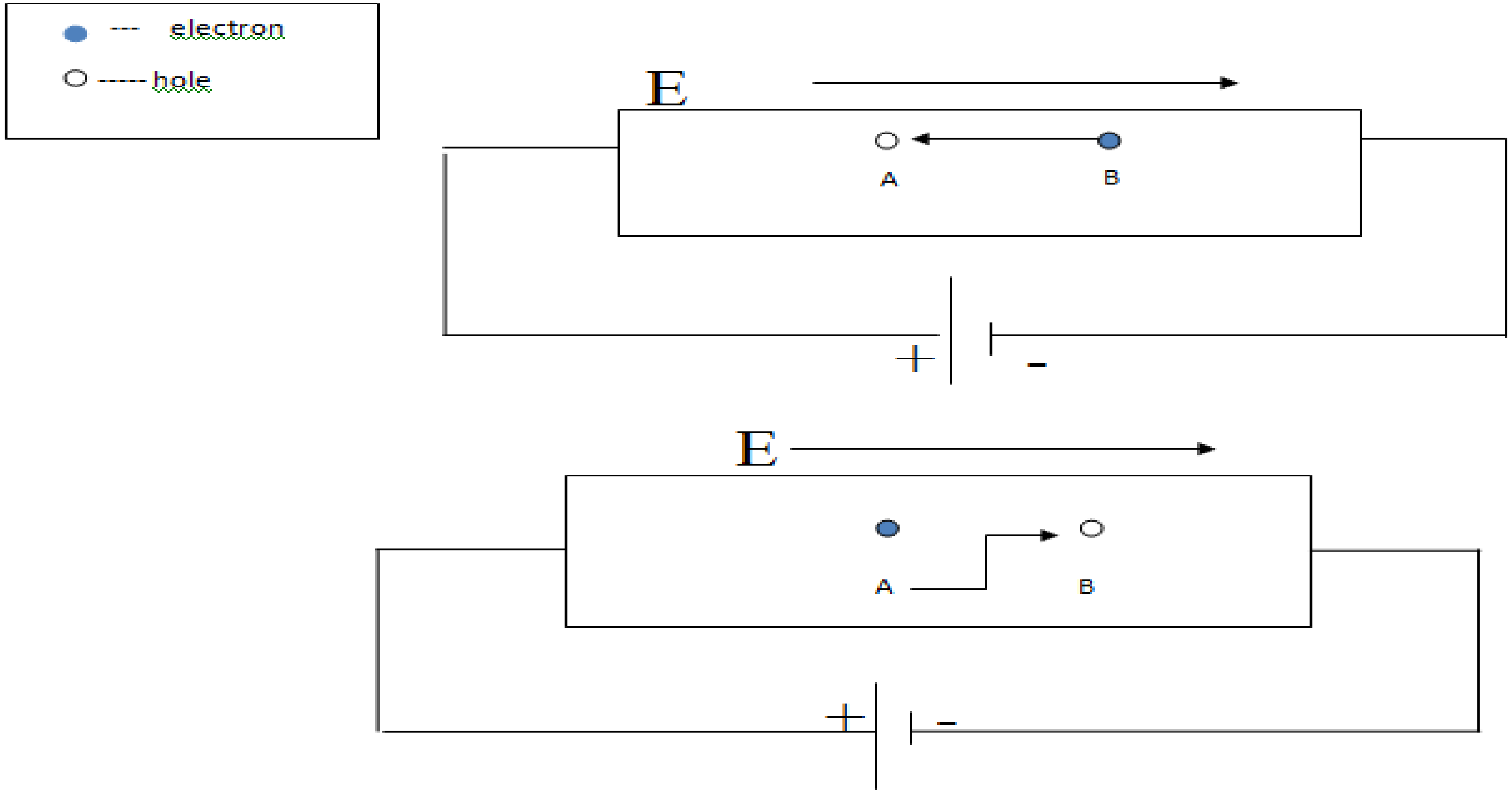
Mechanism of Hole movement

Hole Movement



Movement of Holes in Valence Band

Electrons and Hole directions



Thank You

HAVE A NICE DAY