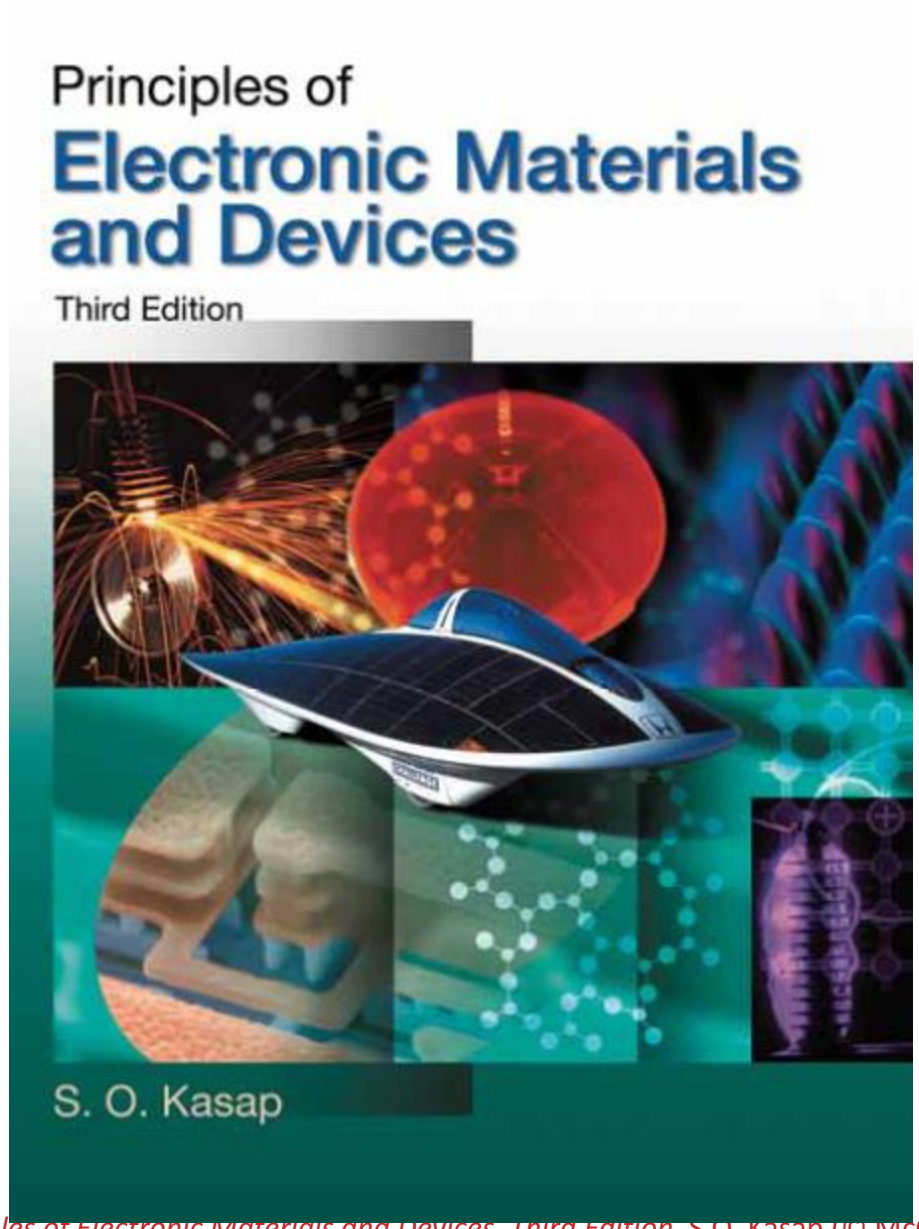
Solid State Electronics EC210
Arab Academy for Science and Technology
AAST – Cairo
Spring 2016

Lecture 12
Band Theory:
E-K Diagram and Energy Gaps

Original Lecture Notes Prepared by:
Dr. Amr Bayoumi, Dr. Nadia Rafat



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Pages

- Kasap:
  - P.355 (Kronig Penny)
  - P.303-304, p. 454-455 (Effective Mass)

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E-K Diagram
using Kronig-Penney Model

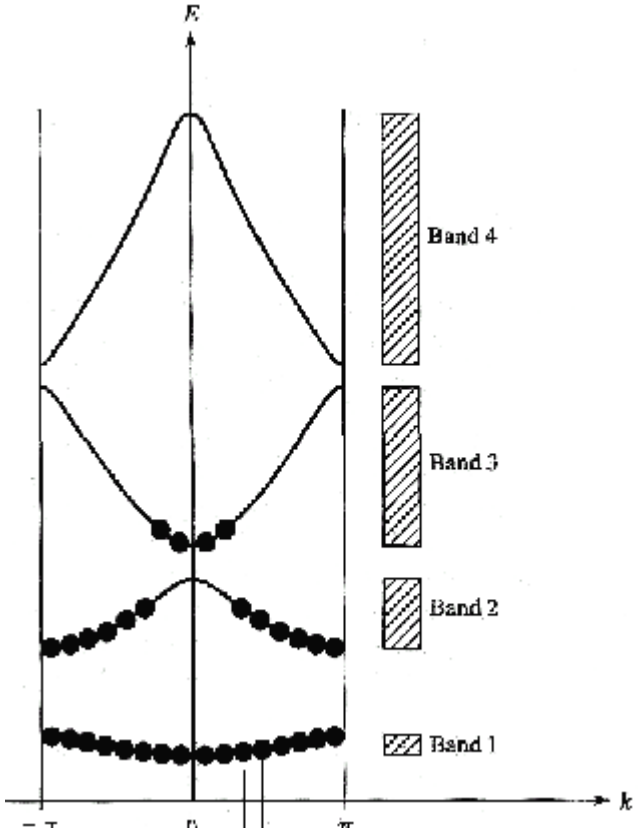
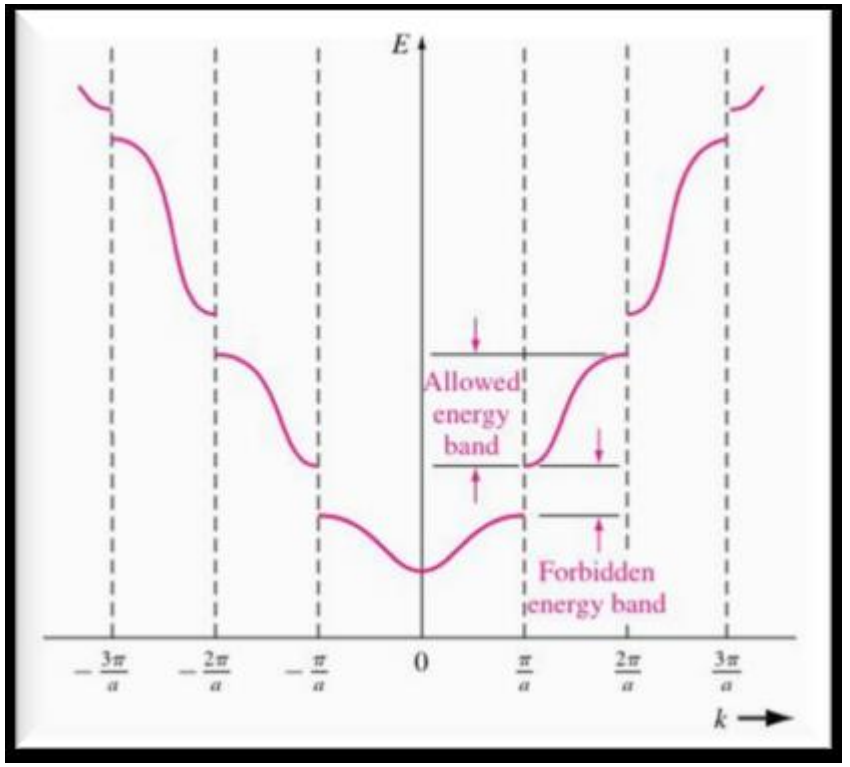
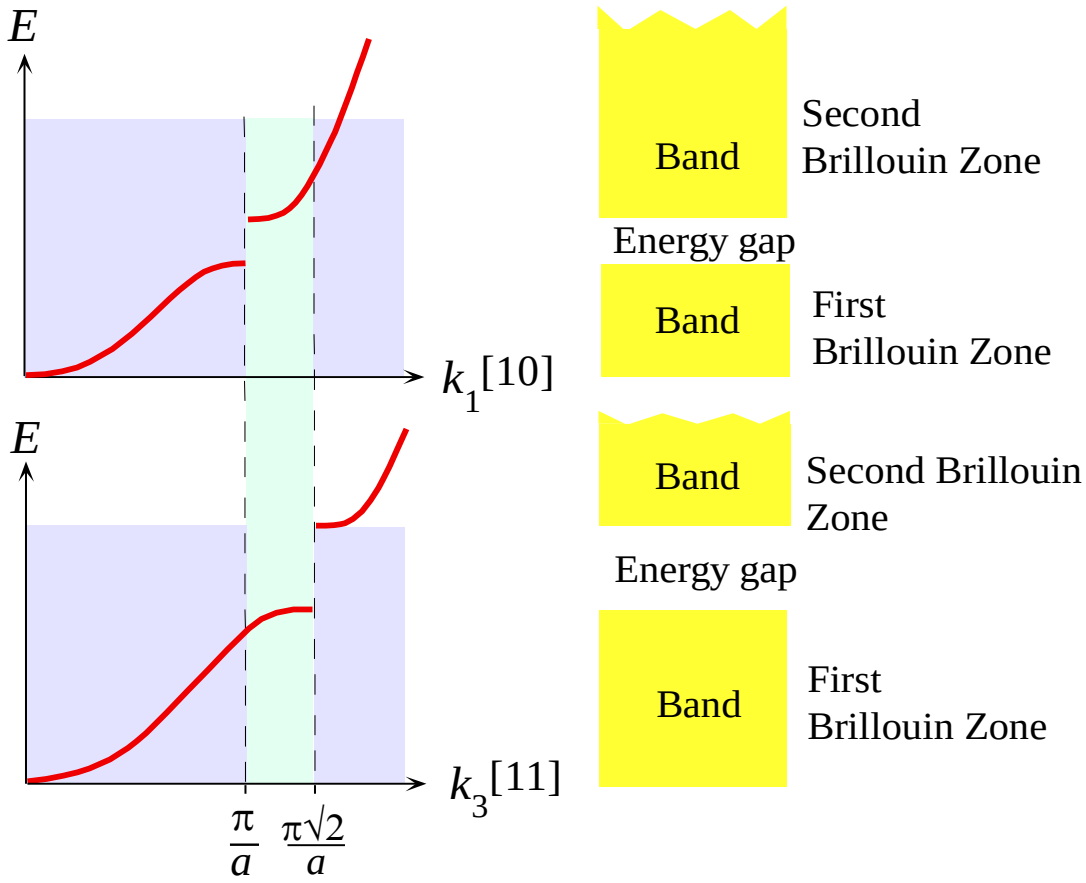


Fig 4.52



Source: Dr. M. Fedawy's Lecture notes

Energy Gap (Bandgaps, Eg)



The *E-k* behavior for the electron along different directions in the two dimensional crystal. The energy gap along [10] is at π/a whereas it is at $\pi\sqrt{2}/a$ along [11].

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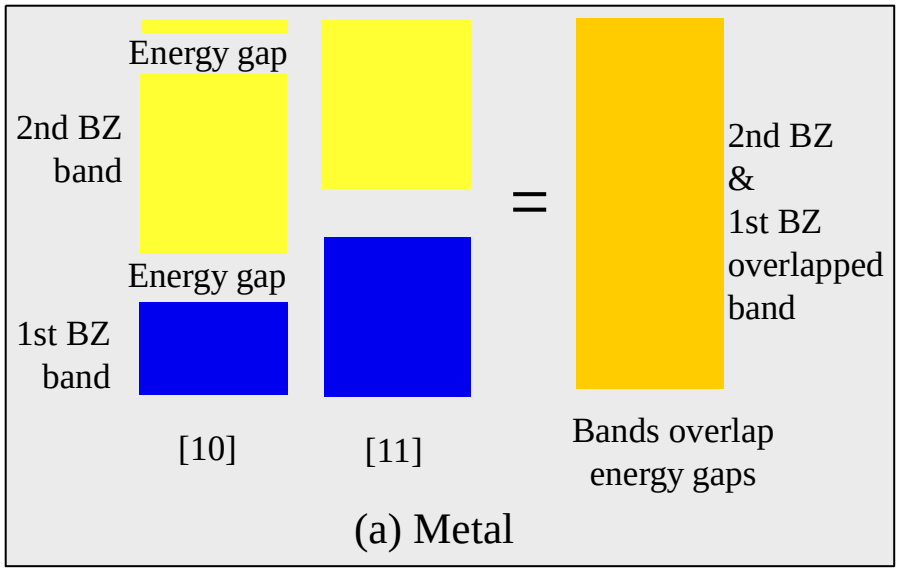
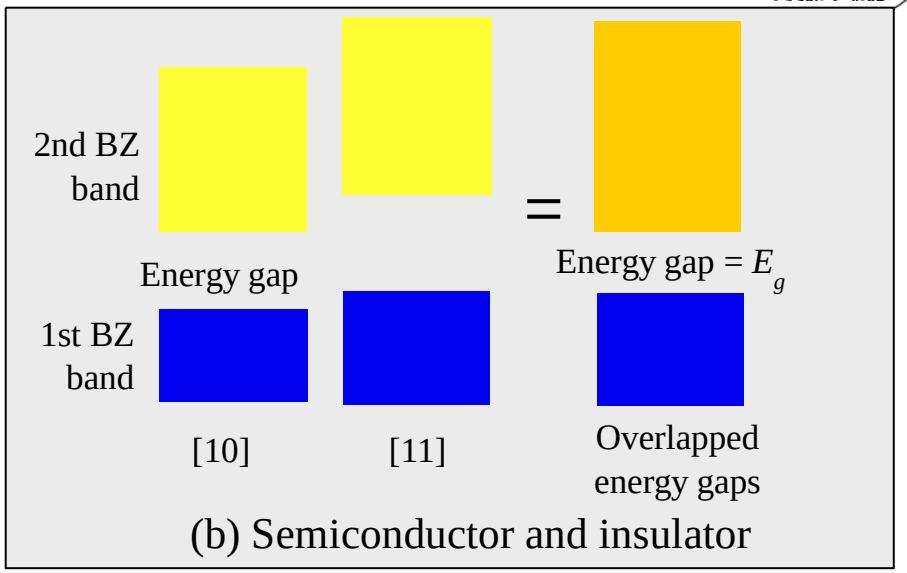
Energy Gaps (Eg)





(a) Metal: For the electron in a metal there is no apparent energy gap because the 2nd BZ (Brillouin Zone) along [10] overlaps the 1st BZ along [11]. Bands overlap the energy gaps. Thus the electron can always find any energy by changing its direction.

(b) Semiconductor or insulator: For the electron in a semiconductor there is an energy gap arising from the overlap of the energy gaps along [10] and [11] directions. The electron can never have an energy within this energy gap, E_g.

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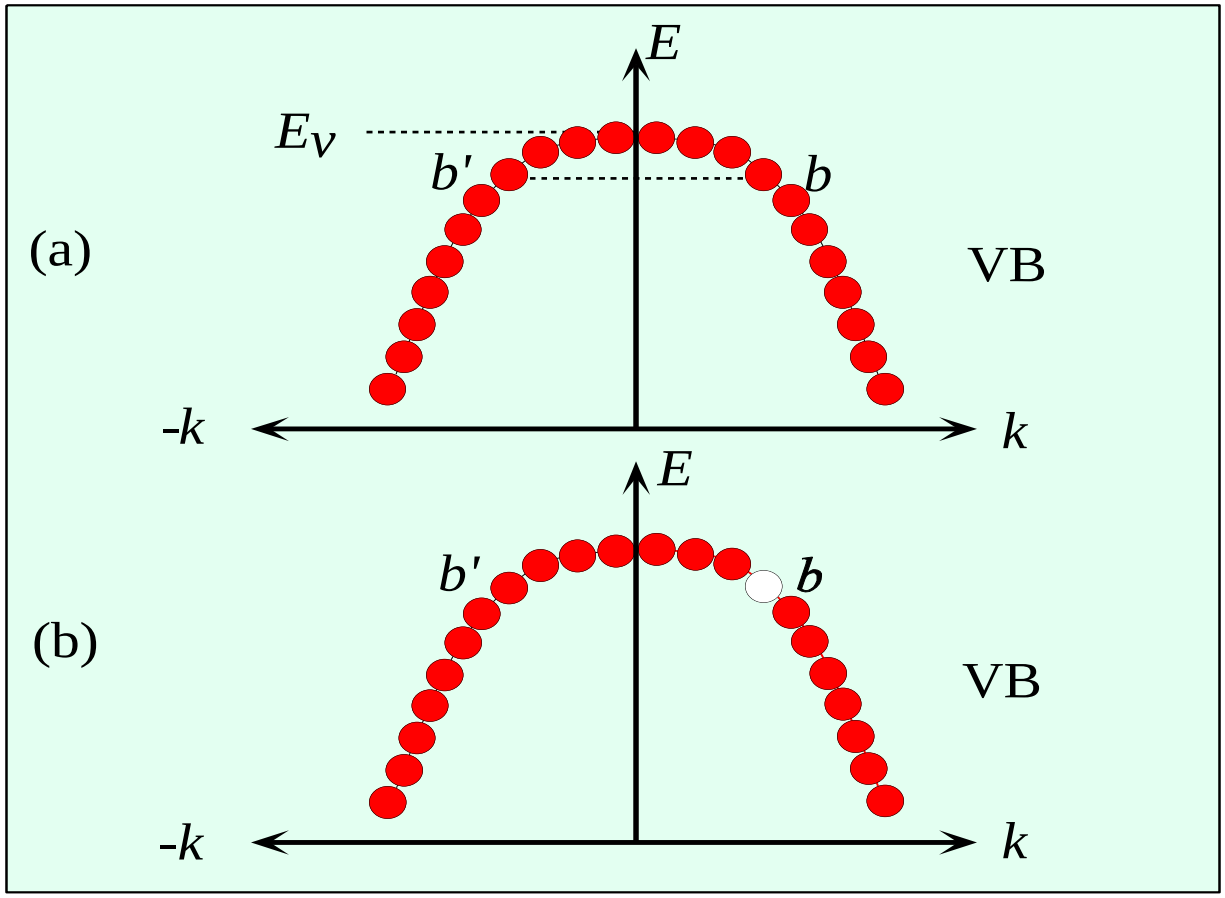
E-k Diagram for Holes in Valence Band



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(a) In a full valence band there is no net contribution to the current. There are equal numbers of electrons (e.g. at *b* and *b'*) with opposite momenta. (b) If there is an empty state (*hole*) at *b* at the top of the band then the electron at *b'* contributes to the current.

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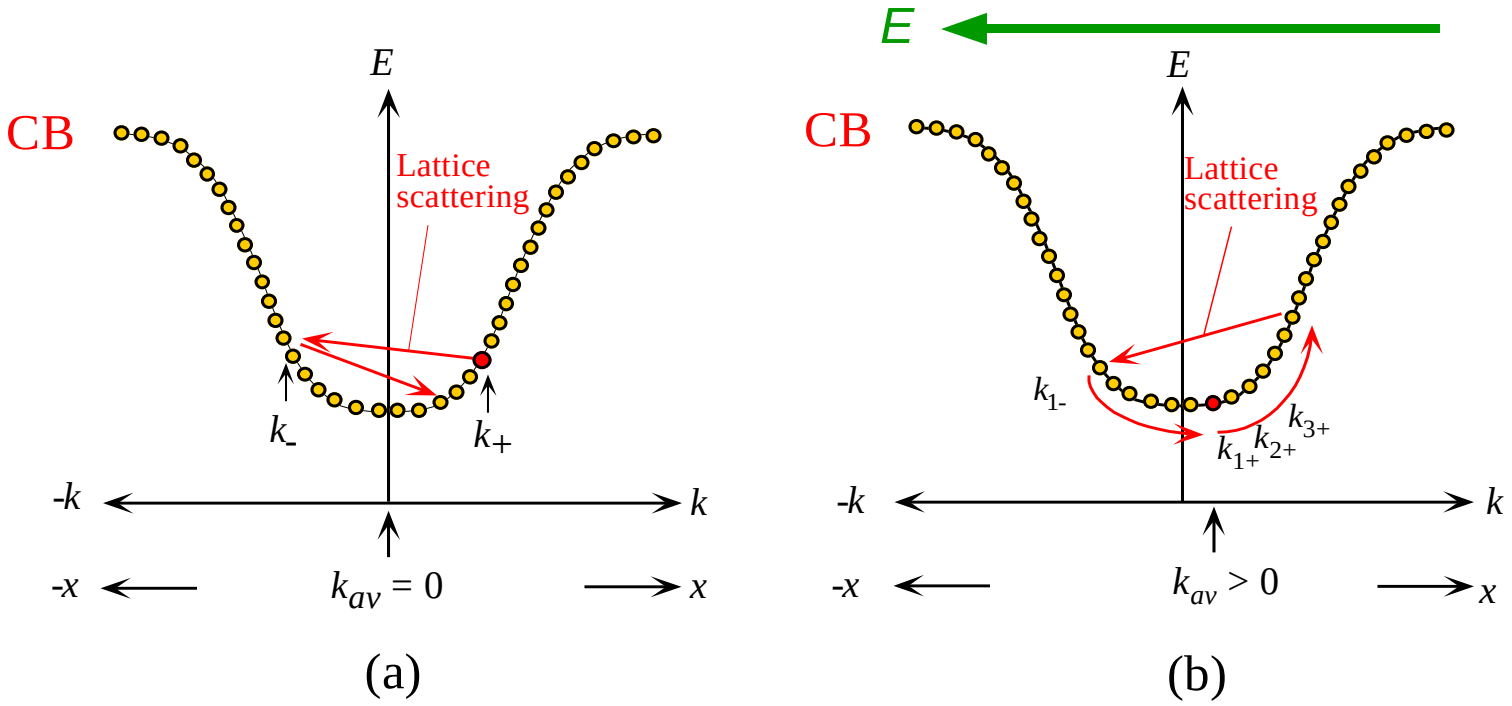
E-k Diagram for Electrons in Conduction Band



(a) In the absence of a field, over a long time, average of all *k* values is zero, there is no net momentum in any one particular direction. (b) In the presence of a field *E* in the -*x* direction, the electron accelerates in the +*x* direction increasing its *k* value along *x* until it is scattered to a random *k* value. Over a long time, average of all *k* values is along the +*x* direction. Thus the electron drifts along +*x*.

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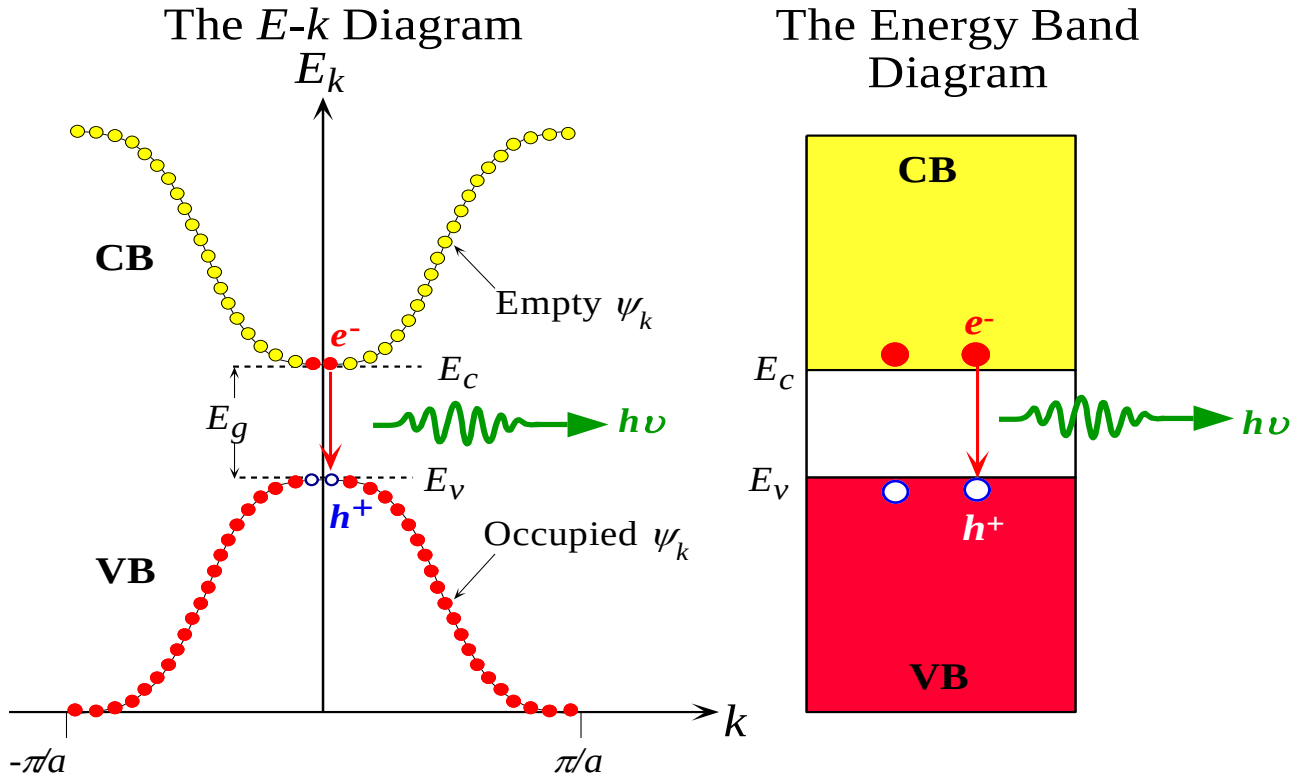
E-k Diagram: Emission of a Photon Due to Electron-Hole Recombination



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The E-k diagram of a direct bandgap semiconductor such as GaAs. The E-k curve consists of many discrete points each point corresponding to a possible state, wavefunction y k(x), that is allowed to exist in the crystal. The points are so close that we normally draw the E-k relationship as a continuous curve. In the energy range Ev to Ec there are no points (yk(x) solutions).

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E-k Diagram: Effective Mass

Reminder: Using E-K diagram:

$$m^* = \left[\frac{1}{\hbar^2}\frac{d^2E}{dk^2}\right]^{-1} = \hbar^2\left[\frac{d^2E}{dk^2}\right]^{-1}$$

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