Effective Mass

Explained By

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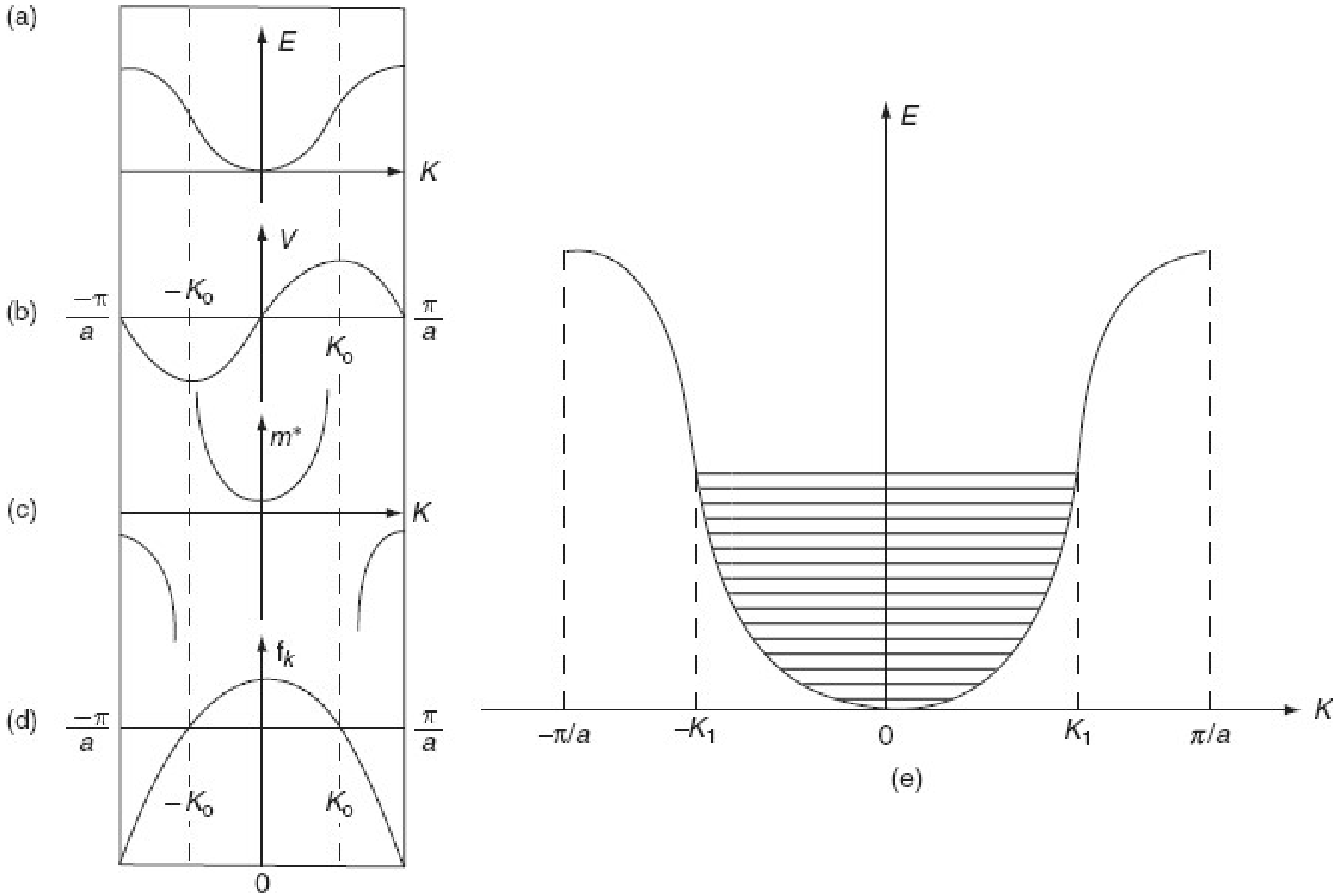
Effective Mass

- The electrons in a crystal are not free, but they interact with the periodic potential of the lattice.
- An electron in crystal may behave as if it had a mass different from the mass of free electron M_0. There are crystals in which the effective mass of the carriers is much larger or much smaller than M_0. The effective mass can be even negative.
- The effective mass of electrons and holes in a band is important for the transport property and also for other electrical and optical properties of the material.



(a)
E
K
(b)
V
−π/a
−K₀
K₀
π/a
(c)
m*
K
(d)
f_k
−π/a
π/a
−K₀
K₀
0
E
K
−π/a
−K₁
0
K₁
π/a
(e)

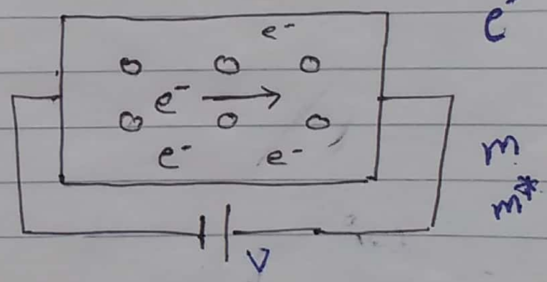
* EFFECTIVE MASS *

Effective mass: The mass exhibited by an electron (say) when inside the semiconductor

⇒ e^- moving in the semiconductor is moving under the influence of atoms and other electrons.

⇒ Due to that there is an electrostatic field act on e^- known as crystal field. this is called Internal electric field

⇒ On applying an external field as shown in figure.



⇒ $F = F_{ext.} + F_{internal}$
this is total force on e^-

⇒ If we define mass of e^- as effective mass then the e^- can be treated as free electron. It is represented by m^*

⇒ So you need not to consider the internal electric field

⇒ When effective mass is smaller (e^-) the mobility is higher. when effective mass is higher (hole) the mobility is smaller

$$m^*_{e^-} < m^*_{h^+} \Rightarrow \mu_{e^-} > \mu_{h^+}$$

We know that De Broglie equation explains when electron moves then a group of wave associate with it.

Group velocity $V_g = \frac{d\omega}{dk}$ — 1

now we know that $E = h\nu = \frac{h\omega}{2\pi} = \hbar\omega$ — 2

from equation 2 $\omega = E/\hbar$ on putting in 1

$$V_g = \frac{1}{\hbar}\frac{dE}{dk}$$

on differentialing with respect to t

$$a = \frac{dV_g}{dt} = \frac{1}{\hbar}\frac{d^2E}{dk^2}\frac{dk}{dt} \quad — 3$$

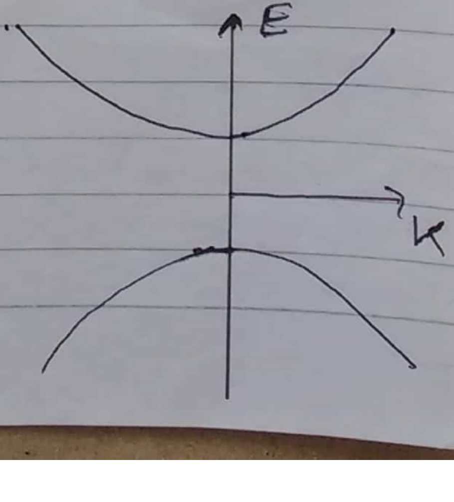
We know that by De broglie $P = \frac{h}{\lambda} \times \frac{2\pi}{2\pi} = \hbar k$

Force acting on e^- $F = \frac{dp}{dt} = \hbar\frac{dk}{dt}$ — 4

now we know that $F = m^* a$

$m^* = \frac{F}{a}$ on putting the value from 3 & 4

$$m^* = \frac{\hbar\cancel{\frac{dk}{dt}}}{\frac{1}{\hbar}\frac{d^2E}{dk^2}\cancel{\frac{dk}{dt}}} \Rightarrow$$



$$\boxed{m^* = \left(\frac{1}{\hbar^2}\right)^{-1}\left(\frac{d^2E}{dk^2}\right)^{-1}}$$