Effective mass

In solid state physics, a particle's effective mass is the mass that it seems to have when responding to force or the mass that it seems to have when interacting with other identical particles in thermal distribution

A/c to Newtonian mechanics the mass of electron inside a crystal is variable. If mass of e^- is -ve then direction of e^- is towards the field. If m^* is effective mass

A/c to newton's law

$$m = \frac{f}{a}$$

And total force experience by e^-

$$f = -eE + f_1$$

$$ma = -eE + m_1 a$$

$$(ma - m_1 a) = -eE$$

$$(m - m_1)a = -eE$$

$$(m - m_1) = \frac{-eE}{a}$$

$$m^* = \frac{f_c}{a} \quad \left(m^* = m - m_1,\ f_c = -eE \right.$$

* The number of charge carriers per unit volum (Intrinsic semiconductors)

~~ni = N =~~

$$n_i = N \exp(-E_g/2KT)$$

N = const for given semiconductor
E_g = band gap energy.
K = boltzmann const.
T = Temperature in K

* ~~intriy intrinsic carrier concentration~~
* conductivity of Intrinsic semiconductor

$$\sigma = n_i e(\mu_e + \mu_h)$$

μ_e = mobility of electron
μ_h = mobility of holes.

* fermi level in An intrinsic semiconductor:-

fermi level energy level E_f lies in the middle of the energy gap i.e. midway b/w the conduction And valence band.

let At temperature T K

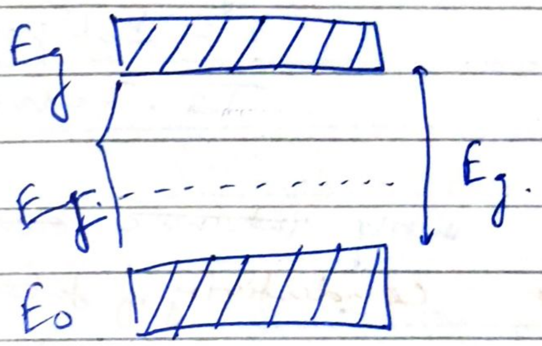
n_c = no. of electron in the conduction band.

n_v = No. of electrons in the valence band.

total no. of electron $N = n_c + n_v$.

Now let us make following Assumptions

1. Width of energy bands are small as compared to forbidden energy gap between them..
2. Since band widths are small all levels in a band have the same energy.
3. energies of all levels in valence band are zero as shown.
4. energies of all levels in the conduction band are E_g.



No of electron in conduction band is given by

$$n_c = N \cdot P(E_g)$$

$P(E_g)$ is probability of an electron having energy E_g And its value can be found by fermi-dirac distribution.

$$\cancel{P(E) = \frac{1}{1+e^{(E-E_g)}KT.}}$$

$$P(E) = \frac{1}{1+e^{(E-E_g)/KT}}.$$

$P(E)$ is the probability of finding an electron having any ~~keshi~~ ~~particulara~~ particular value of energy E and E_F is fermi level

$$P(E_g) = \frac{1}{1+e^{(E_g - E_f)/kT}}$$

$$n_c = \frac{N}{1+e^{(E_c - E_f)/KT}}$$

Number of electron in the valence band is n_v

$$n_v = N P(0)$$

$P(0)$ the probability $P(0)$ of an electron being found in the valence band with zero energy can again be calculated by putting $E=0$ in the fermi-Dirac probable probability distribution function.

$P(0)$

$$P(0) = \frac{1}{1+e^{(0-E_f)/KT}}$$

$$= \frac{1}{1+e^{-E_f/KT}}$$

$$n_v = \frac{N}{1+e^{-E_f/KT}}$$

$$\text{or } N = \frac{N}{1+e^{(E_g - E_f)/KT}} + \frac{N}{1+e^{-E_f/KT}}$$

$$\text{or } \boxed{1 - \frac{1}{1+e^{(-E_f)/KT}} = \frac{1}{1+e^{(E-E_f)/KT}}}$$

on solving Above.

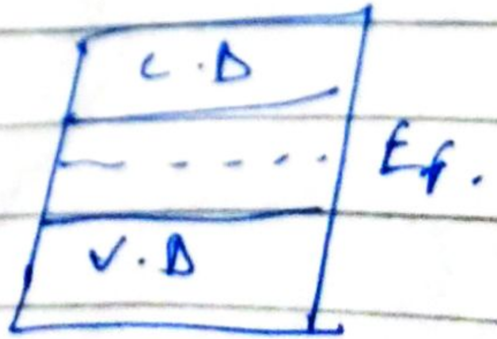
$$\boxed{E_f = E_g/2}$$

Fermi level for Extrinsic Semiconductor:-

concentration of free e^- & holes are given by

$$n = n_c e^{-(E_c - E_f)/kT}.$$

$$p = n_v e^{-(E_f - E_v)/kT}.$$



n_c : no. of e^- in conduction band
n_v : " " in valence band.

E_c = lowest energy in conduction band.
E_v = maximum energy of V.B.

N type :- Donor type impurity are mixed. (at fixed Temp.)
All donor are ionized, then first conduction band will be filled first then it becomes more difficult for e^- from V.B to breach the energy gap by thermal agitation so the e-H pair ~~general~~ generation will be reduced. So measure of probability of occupancy of allowed energy state.
So fermi level will shift upper side.
so $n = N_D$

$$N_D = n_c e^{-(E_c - E_F)/KT}.$$

Taking log on both side.

$$\log_e N_D = \log_e n_c - \frac{E_c - E_F}{KT}$$

$$\boxed{E_F = E_c - KT \log_e \frac{n_c}{N_D}}$$

$$\text{or}\quad \boxed{E_F = E_v - KT \log_e \frac{N_v}{N_A}}$$

for P type extrinsic semicon