Effective mass :

$$\frac{1}{m^*_{ij}} = \frac{1}{\hbar^2} \frac{\partial^2 E}{\partial k_i \partial k_j}$$

curvature of the band determines the effective mass

if $m_0^* = +ve$, we are referring to e^-
for $-ve$, we are referring to holes

for Ge, 8 valley degeneracy for e^-
1 " " for holes

→ E_0 (CB_{min} is at $x = L$) so,
valley degeneracy = # of hexagon faces in the wigner cell

for Si, 6 → e^-
1 → hole

→ # of square faces in the wigner seitz cell because $CB_{min} \Rightarrow x = X$

for GaAs, 1 → e^-
1 → hole
(Direct band gap semiconductor)

→ # = 1 because $CB_{min} \Rightarrow x = \Gamma$ and we are at the center of the wigner cell

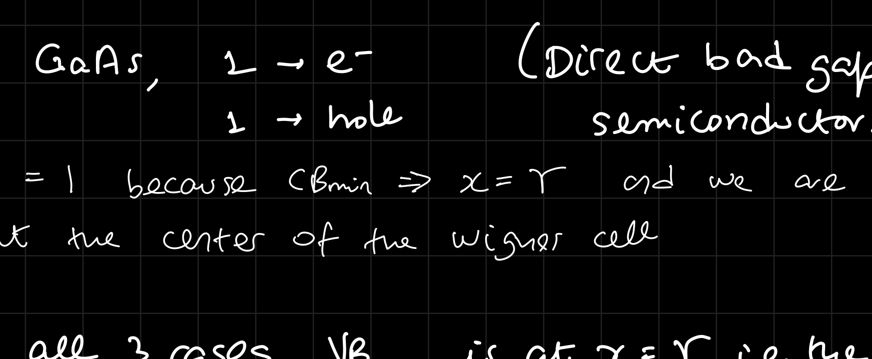
→ for all 3 cases, VB_{max} is at $x = \Gamma$ i.e. the center of the wigner cell → so, # valley degeneracy for holes = 1

how to get more current ?
↓
more charges
↓
more # of degenerate valleys

OR

wider curvature of conduction band

narrow curvature → low effective mass
wider curvature → higher m^*



Curvature can also determine the density of states

remember, for tunelling prob →

$$K = \frac{\sqrt{2m(V-E)}}{\hbar} \quad \text{for 1 particle}$$

$$= \frac{\sqrt{2m^*(V-E)}}{\hbar} \quad \text{generally}$$

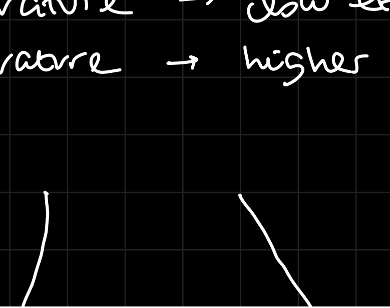
Tunelling prob $\propto \frac{1}{K} \propto \frac{1}{m^*}$

In case of Ge, we have an equienergy surface
↳ isotropic effective mass
↳ direction doesn't matter

$m_l^* = 0.98\,m_0$	$m_t^* = 0.19\,m_0$
longitudinal	transverse
very high m^*	low m^*
low mobility	higher mobility

band gap: Si → 1.12eV
Ge → 0.7eV
GaAs → 1.45eV
} crystal structure is almost similar but the properties differ

Ge → very high off state current
GaAs → very low off state current and same for on state current } only one valley not so ideal
Si → balance between Ge, GaAs



Density of States in 2d

DOS(E) = # of states per energy per unit line / area / volume

# of energy levels per unit energy per unit l/a/v

$$\bar{n} = \int DOS(E)\, f(E)\, dE$$

fermi-dirac distribution

number of e^-/holes

limit : $0 \to \infty$ for e^-
$-\infty \to 0$ for holes

$$DOS_{1d} = \frac{1}{L}\frac{dN}{dE}$$

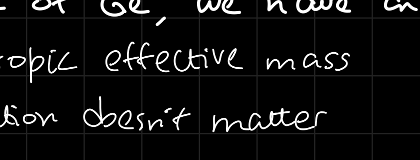
$$DOS_{2d} = \frac{1}{A}\frac{dN}{dE}$$

$$DOS_{3d} = \frac{1}{V}\frac{dN}{dE}$$

* Objective: we need to find N as a func of E

for 1d, in k space → if we had lattic param = L in real space

lowest length in k-space (1st brillouin zone)



we just need the # of e^- in $[-\frac{\pi}{L}, \frac{\pi}{L}]$

for 2d → circle and 3d → sphere

as we move on the brillouin zones (1st → 2nd → .....),
we are increasing the # of states as well

for 2d → area in one quadrant → $\pi k^2 \times \frac{1}{4}$

for 3d → volume in 1 quad → $\frac{4}{3}\pi k^3 \times \frac{1}{8}$

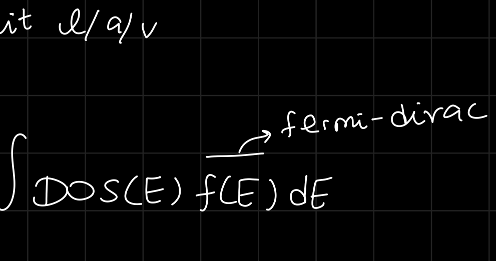
$2e^-$ in every state/cube

for 3d → $N = 2 \times \frac{\left(\frac{1}{8} \times \frac{4\pi}{3}k^3\right)}{(\pi/L)^3}$ } lowest volume of each state

$$DOS_{3d}(E) = \frac{\sqrt{2}\, m^{3/2}}{\pi^2 \hbar^2}\sqrt{E}$$

$DOS_{3d} \propto m^{3/2}$ and also $\propto \sqrt{E}$

RTFM



$$g_{2d}(E) = \frac{m^*}{\pi\hbar^2} \quad \text{} \} \text{ independent of } E$$

just moving from 3d → 2d, we obtain differently behaving DOS.

STRU

we are multiplying f(E) and D(E) and we set # e^-/hole density

$n(E) = p(E) = n_i$ → intrinsic carrier concentration

$\int D(E) \cdot f(E)\, dE$

$np = n_i^2$