ELECTRONS and HOLES

Note:

e = charge of proton ($e > 0$).

$\epsilon(\mathbf{k})$ = band dispersion

$\mathbf{E}$ = electric field

ELECTRONS	**HOLES**

Definitions:

Electrons	Holes
$\mathbf{k}_c \equiv \mathbf{k}$ at Cond. Band Min.	$\mathbf{k}_v \equiv \mathbf{k}$ at Valence Band Max.
$\epsilon_c \equiv \epsilon$ at Cond. Band Min.	$\epsilon_v \equiv \epsilon$ at Valence Band Max.
$\mathbf{k}_e \equiv \mathbf{k} - \mathbf{k}_c$	$\mathbf{k}_h \equiv \mathbf{k}_v - \mathbf{k}$
$q_e \equiv -e$	$q_h \equiv +e$
$m_e^* \equiv +m^*(\mathbf{k}_c)$	$m_h^* \equiv -m^*(\mathbf{k}_v)$
$\epsilon_e(\mathbf{k}_e) \equiv \epsilon(\mathbf{k}_c + \mathbf{k}_e) - \epsilon_c$	$\epsilon_h(\mathbf{k}_h) \equiv \epsilon_v - \epsilon(\mathbf{k}_v - \mathbf{k}_h)$

Then:

Electrons	Holes
$\mathbf{v}_e = \frac{1}{\hbar}\nabla_{\mathbf{k}_e}\epsilon_e(\mathbf{k}_e)$	$\mathbf{v}_h = \frac{1}{\hbar}\nabla_{\mathbf{k}_h}\epsilon_h(\mathbf{k}_h)$
$\left(\frac{1}{m_e^*}\right)_{\alpha\beta} = \frac{1}{\hbar^2}\frac{\partial^2\epsilon_e(\mathbf{k}_e)}{\partial k_{e,\alpha}\partial k_{e,\beta}}$	$\left(\frac{1}{m_h^*}\right)_{\alpha\beta} = \frac{1}{\hbar^2}\frac{\partial^2\epsilon_h(\mathbf{k}_h)}{\partial k_{h,\alpha}\partial k_{h,\beta}}$
$\hbar\dot{\mathbf{k}}_e = q_e\mathbf{E}$	$\hbar\dot{\mathbf{k}}_h = q_h\mathbf{E}$
$\ddot{\mathbf{r}}_e = q_e\left(\frac{1}{m_e^*}\right)\cdot\mathbf{E}$	$\ddot{\mathbf{r}}_h = q_h\left(\frac{1}{m_h^*}\right)\cdot\mathbf{E}$