FUNDAMENTALS OF NANOELECTRONICS

B. Quantum Transport

1. Schrodinger Equation

2. Contact-ing Schrodinger

3. Advanced Examples

4. Spin Transport

1.1. Introduction

1.2. Wave Equation

1.3. Differential to Matrix Equation

1.4. Dispersion Relation

1.5. Counting States

1.6. Beyond 1-D

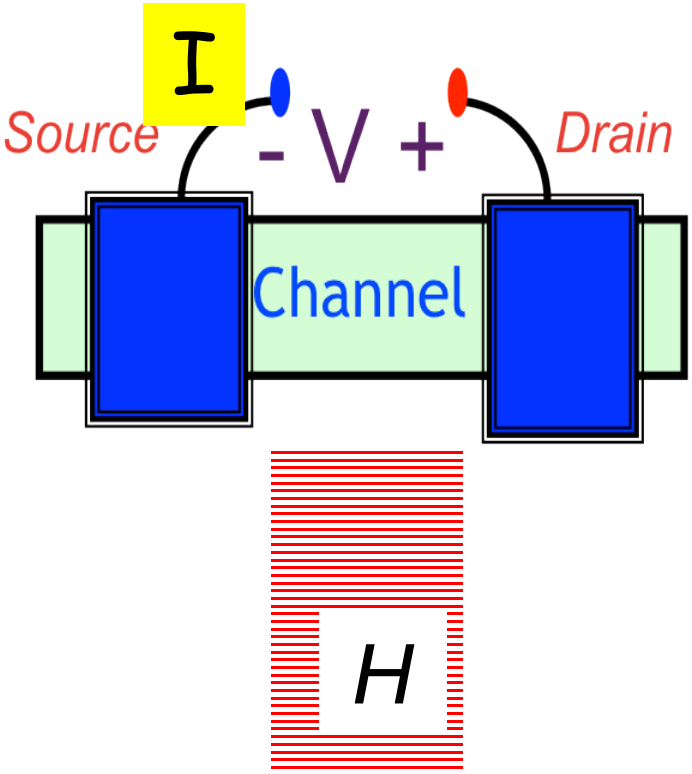
1.7. Lattice with a Basis

1.8. Graphene

1.9. Reciprocal Lattice / Valleys

1.10. Summing up ..

1.10a Summing up ..

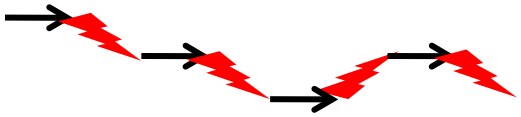


$$E\psi = H\psi$$

Schrodinger + ⚡ = NEGF

Quantum Transport

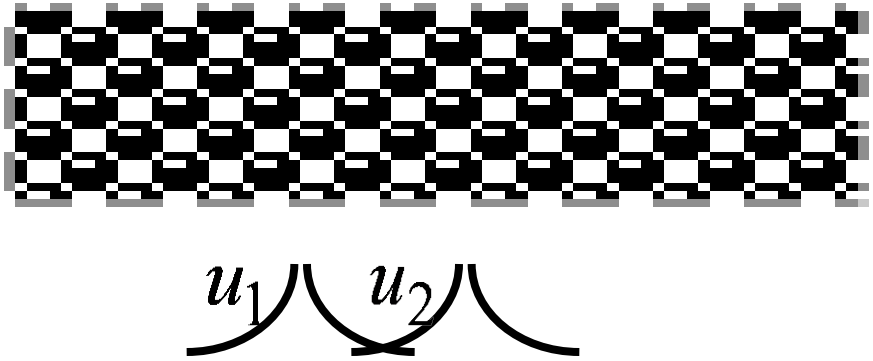
Semiclassical Transport



Entropy driven *Force driven*

Newton + ⚡ =

1.10b Summing up ..



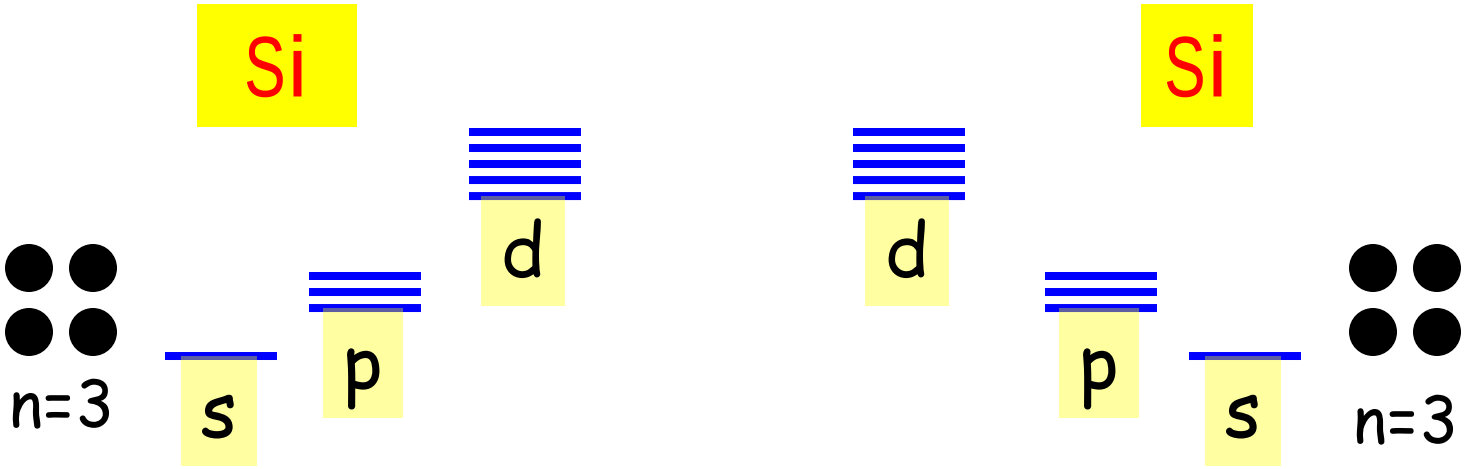
$$E\begin{Bmatrix}\psi_1\\ \psi_2\\ \cdots\\ \cdots\\ \psi_N\end{Bmatrix} = \begin{bmatrix}\cdots & \cdots & \cdots\\ \cdots & H & \cdots\\ \cdots & \cdots & \cdots\end{bmatrix}\begin{Bmatrix}\psi_1\\ \psi_2\\ \cdots\\ \cdots\\ \psi_N\end{Bmatrix}$$

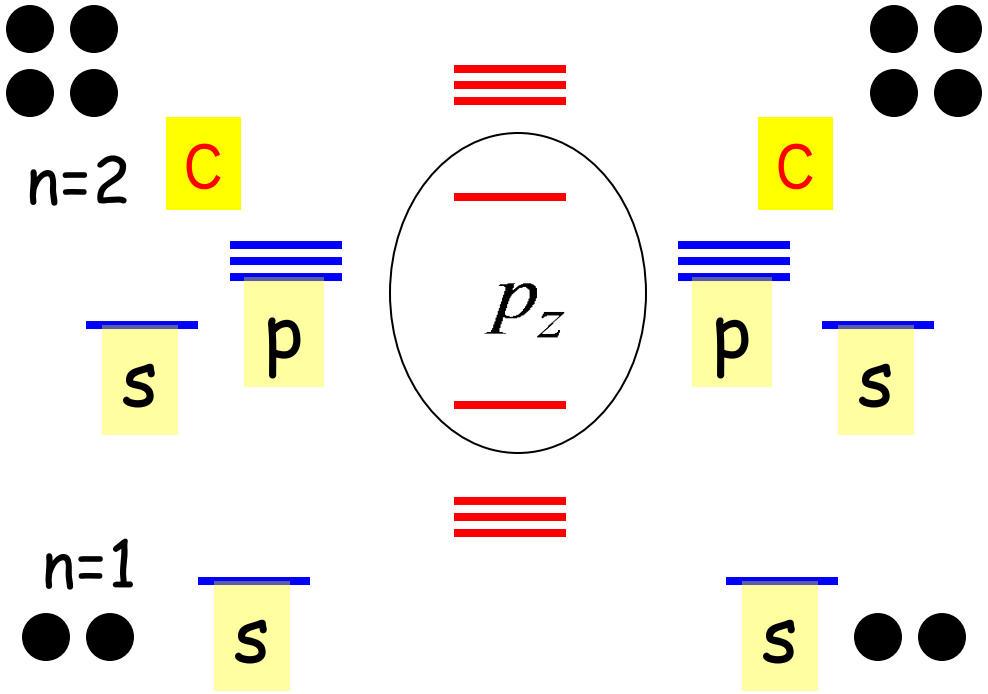
N x N

$$E\psi(\vec{r}) = \left(-\frac{\hbar^2}{2m_0}\nabla^2 + U(\vec{r})\right)\psi(\vec{r})$$

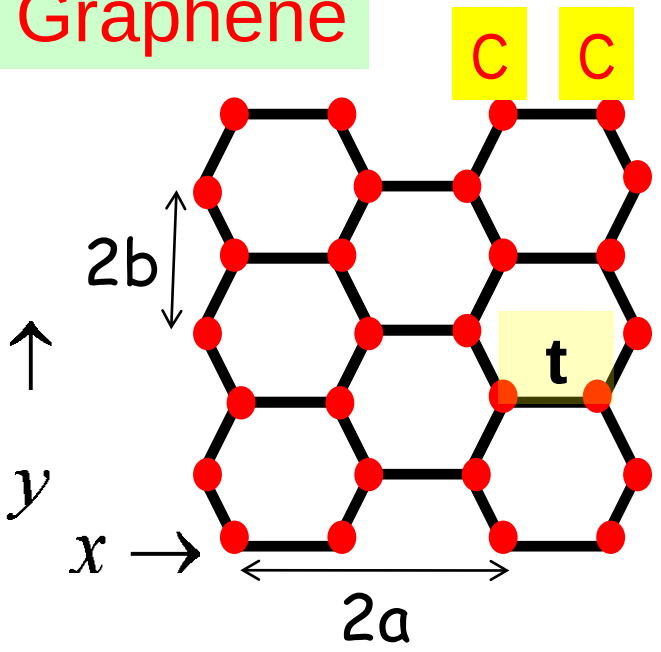
$$\psi(\vec{r}) = \sum_{m=1}^{N} \psi_m\, u_m(\vec{r})$$

N = number of "basis functions"


Si
d
p
s
n=3
Si
d
p
s
n=3

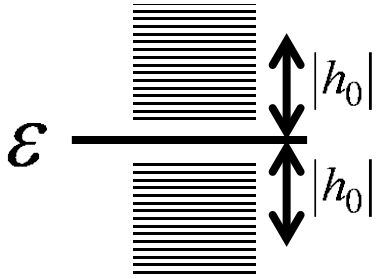


Graphene



1.10e Summing up ..

$$h(\vec{k}) = \begin{bmatrix} \varepsilon & h_0^* \\ h_0 & \varepsilon \end{bmatrix}$$



$$E = \varepsilon \pm |h_0|$$

$$= \varepsilon \pm at\sqrt{k_x^2 + \beta_y^2}$$

$$h_0 = t\left(1 + 2e^{ik_x a}\cos k_y b\right)$$

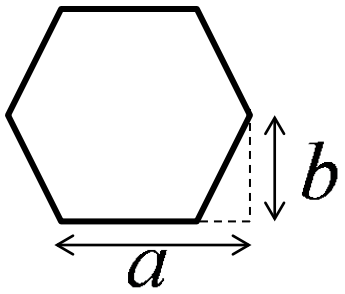
$$\approx -iat\,(k_x + i\beta_y)$$

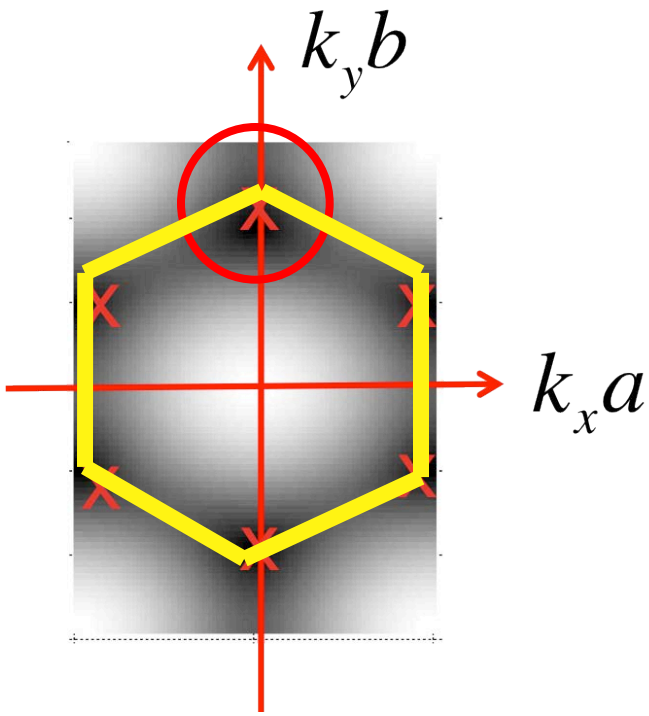
$$\nu = \frac{1}{\hbar}\frac{\partial E}{\partial k} = \frac{at}{\hbar}$$

$a \approx 0.2\ nm$

$\sim 10^6\ m/\text{sec}$

$t \approx 3\ eV$





Coming up next ..

B. Quantum Transport

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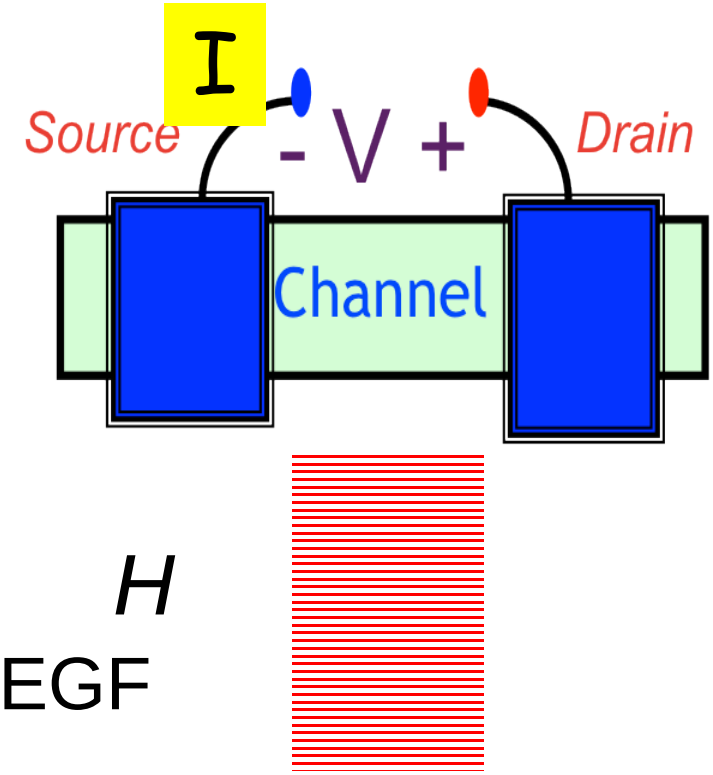
2. Contact-ing Schrodinger
3. Advanced Examples
4. Spin Transport



Schrodinger + ⚡ = NEGF

H