

FUNDAMENTALS OF NANOELECTRONICS

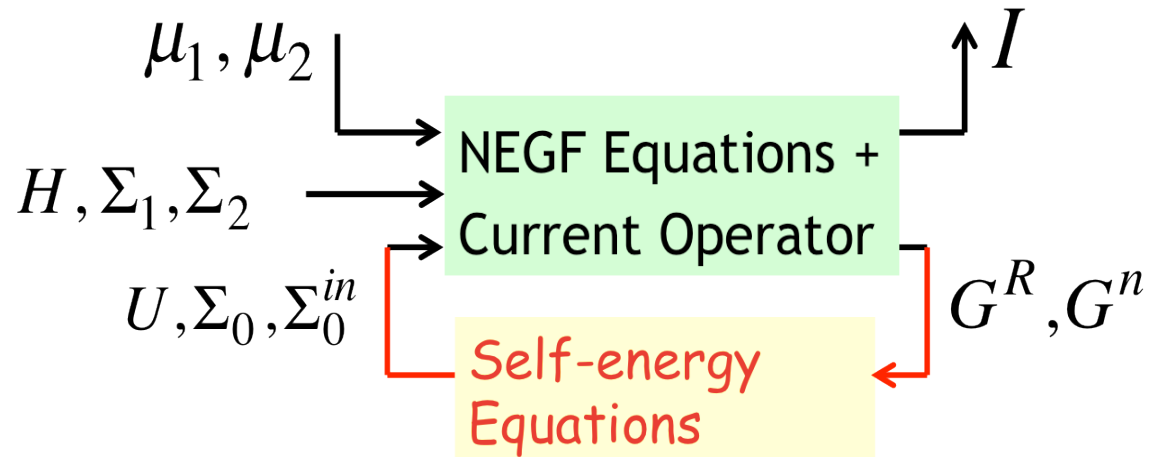
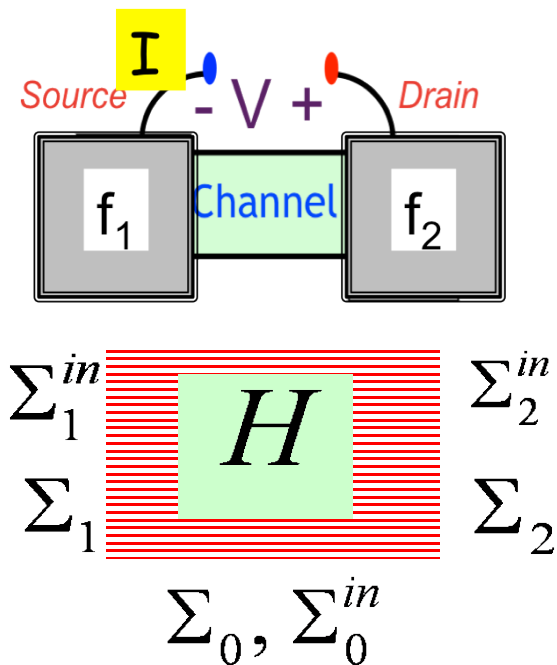
B. Quantum Transport

1. Schrodinger Equation
2. Contact-ing Schrodinger
3. More Examples

4. Spin Transport

- 4.1. Introduction
- 4.2. Magnetic contacts
- 4.3. Rotating contacts
- 4.4. Vectors and spinors
- 4.5. Spin-orbit coupling
- 4.6. Spin Hamiltonian
- 4.7. Spin density/current
- 4.8. Spin voltage
- 4.9. Spin circuits
- 4.10. Summing up ..

4.10a Summing up ..



$$\frac{A}{2\pi} \leftrightarrow D$$

$$\frac{G^n}{2\pi} \leftrightarrow N$$

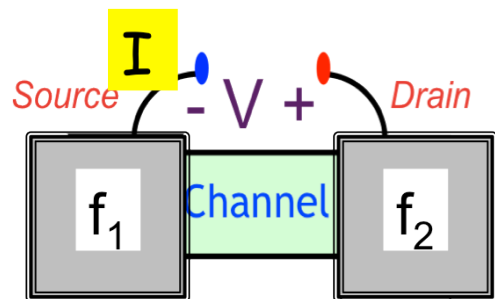
$$G^R = [EI - H - \Sigma]^{-1}$$

$$G^n = G^R \Sigma^{in} G^A \quad \text{NEGF Equations}$$

$$I^{op} = \frac{\Sigma G^n - G^n \Sigma^+}{i\hbar} + \frac{\Sigma^{in} G^A - G^R \Sigma^{in}}{i\hbar}$$

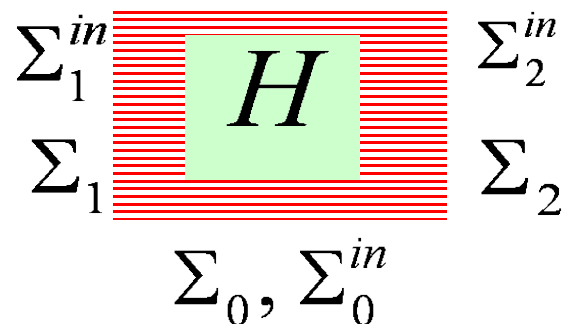
Current Operator

4.10c Summing up ..



ψ has $2n$ components

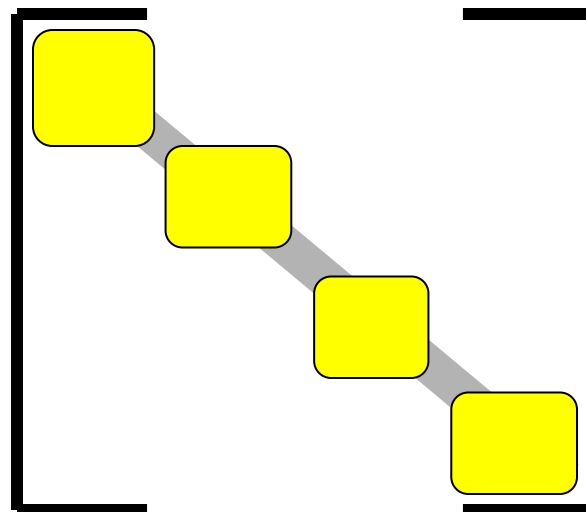
$$\frac{G^n}{2\pi} \rightarrow \psi\psi^+$$



up
dn

$$[N, \vec{S}] \quad \left\{ \begin{matrix} V_c \\ \vec{V}_s \end{matrix} \right\} \quad \left\{ \begin{matrix} I_c \\ \vec{I}_s \end{matrix} \right\} \rightarrow$$

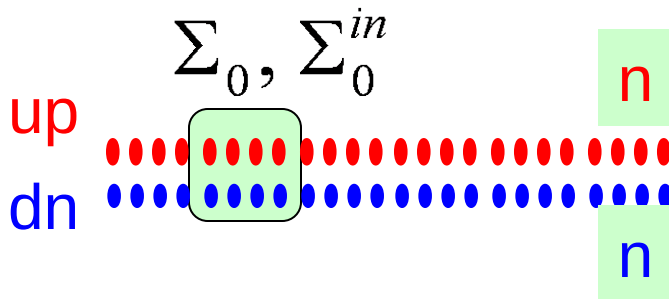
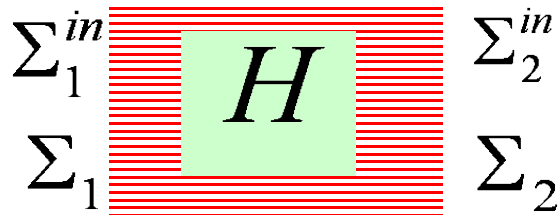
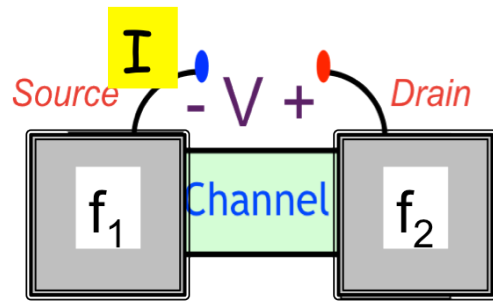
$$\frac{G^n}{2\pi} = \frac{1}{2} \begin{bmatrix} N + S_z & S_x - iS_y \\ S_x + iS_y & N - S_z \end{bmatrix}$$



$$\frac{A}{2\pi} \leftrightarrow D$$

$$\frac{G^n}{2\pi} \leftrightarrow N$$

4.10d Summing up ..



8-component "spin"

64-component
"voltage" + "current"

ψ has $2n$ components

$$\frac{G^n}{2\pi} \rightarrow \psi \psi^+$$

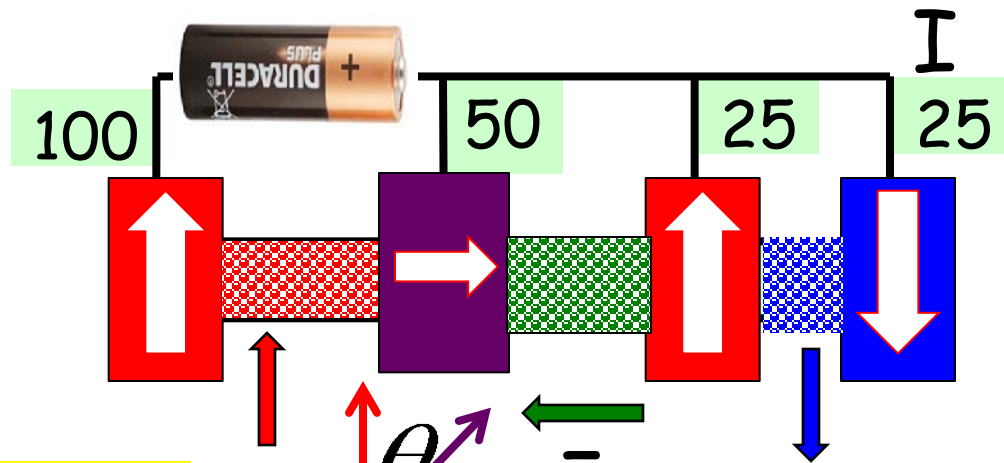
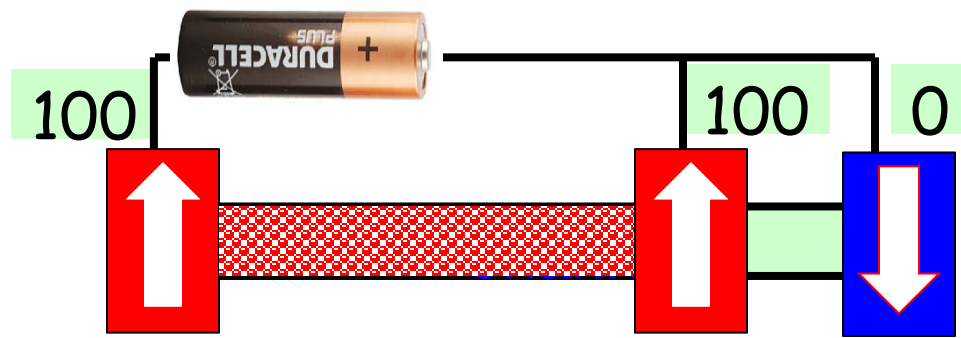
Full NEGF : $4n^2$

Full NEGF treats entire device as a "giant spin"

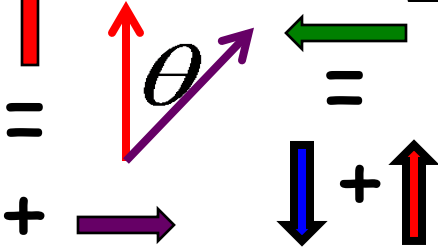
Spin circuit : $4n$

$$\begin{Bmatrix} V_c \\ \vec{V}_s \end{Bmatrix} \begin{Bmatrix} I_c \\ \vec{I}_s \end{Bmatrix} \rightarrow$$

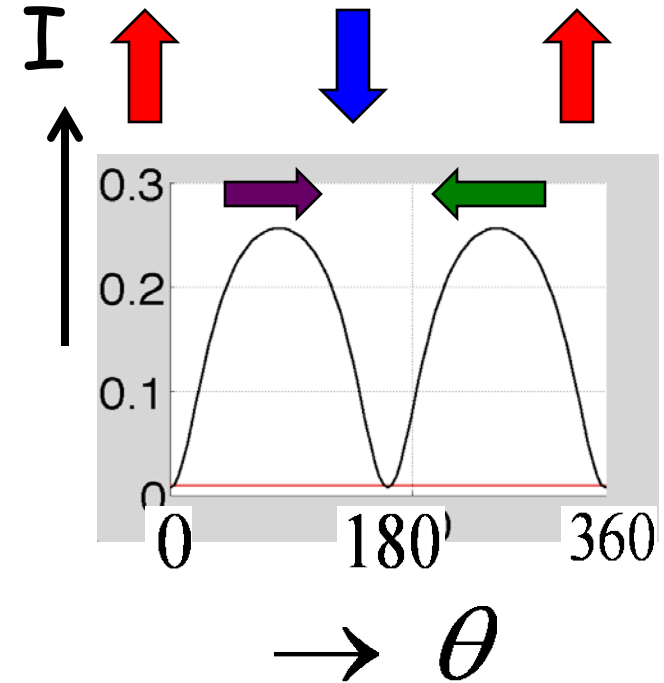
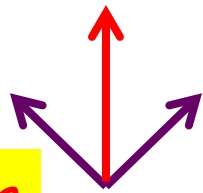
4.10e Summing up ..



spinor



vector



Coming up next ..

FUNDAMENTALS OF NANO ELECTRONICS

A. Basic Concepts

1. The new perspective
2. Energy band model
3. What and where is the voltage?
4. Heat & electricity:
Second law & information

Epilogue

B. Quantum Transport

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