

FUNDAMENTALS OF NANOELECTRONICS

B. Quantum Transport

1. Schrodinger Equation

Contact-ing Schrodinger →

3. Advanced Examples

4. Spin Transport

2.1. Introduction

2.2. Semiclassical Model

2.3. Quantum Model

2.4. NEGF Equations

2.5. Current Operator

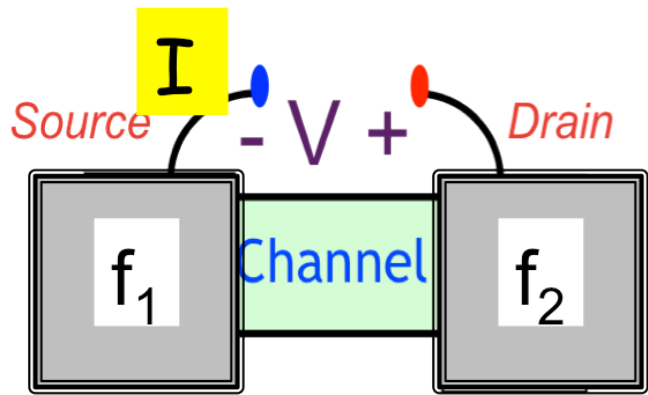
2.6. Scattering Theory

2.7. Transmission

2.8. Resonant Tunneling

2.9. Dephasing

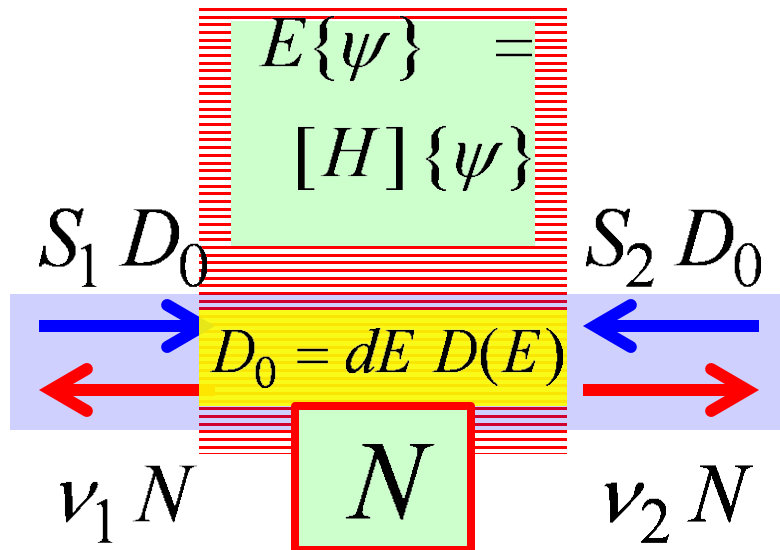
2.10. Summing up ..



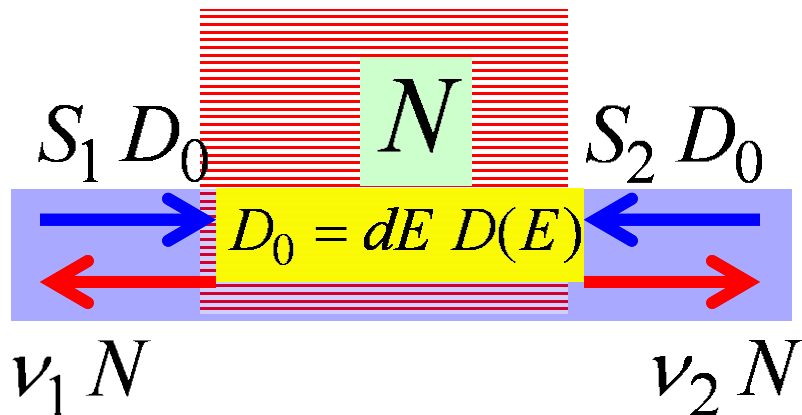
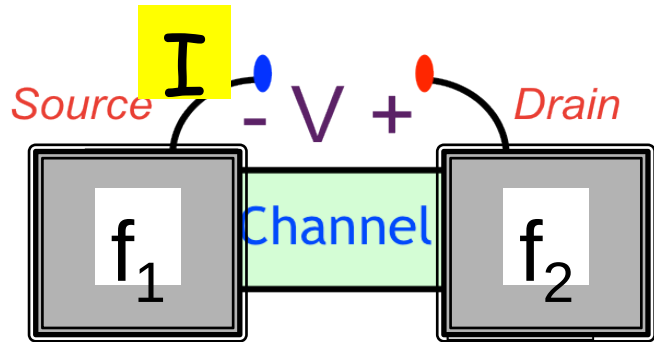
$$E\{\psi\} = [H]\{\psi\}$$

Schrodinger + ⚡ = NEGF

Quantum Transport *Part B*



2.10b Summing up ..



$$E\psi = s_1 + \Sigma_1 \psi + H\psi + \Sigma_2 \psi + s_2$$

$$\Gamma \equiv i(\Sigma - \Sigma^+) \quad A = i[G^R - G^A]$$

$\frac{A}{2\pi} \leftrightarrow D$	$\frac{G^n}{2\pi} \leftrightarrow N$
$\frac{\Sigma^{in}}{\hbar} \leftrightarrow S$	$\frac{\Gamma}{\hbar} \leftrightarrow \nu$

$$\frac{1}{\hbar} \text{Trace}[\Sigma_1^{in} A] \quad \text{Trace}[\Sigma_2^{in} A] \frac{1}{\hbar}$$

$$\frac{1}{\hbar} \text{Trace}[\Gamma_1 G^n] \quad \text{Trace}[\Gamma_2 G^n] \frac{1}{\hbar}$$

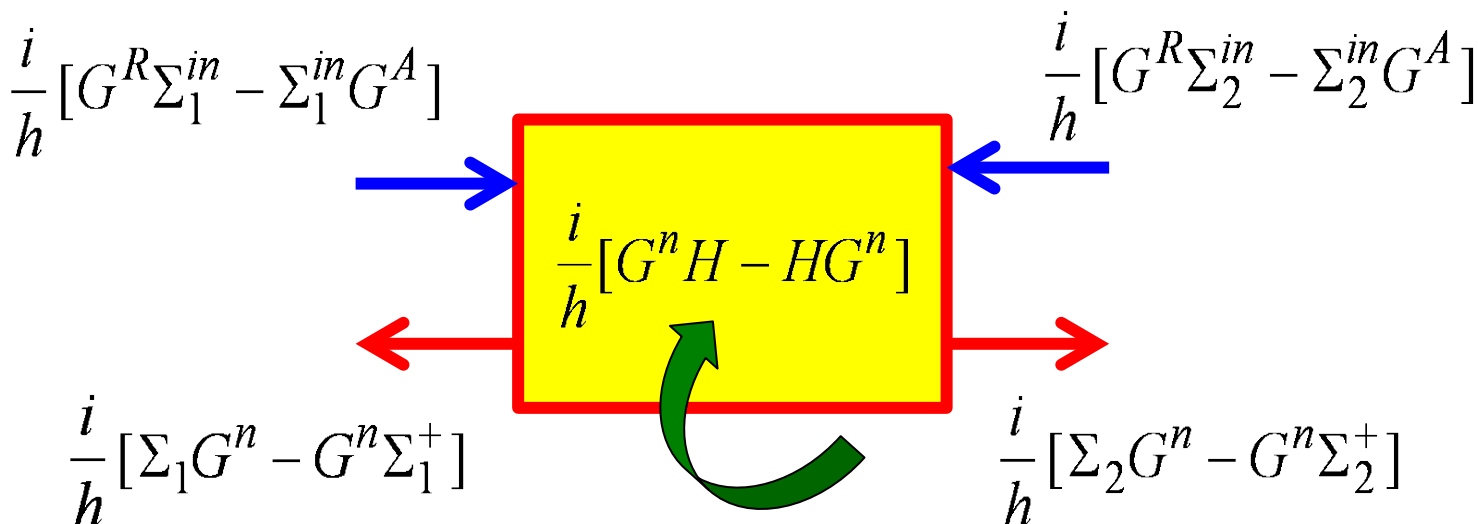
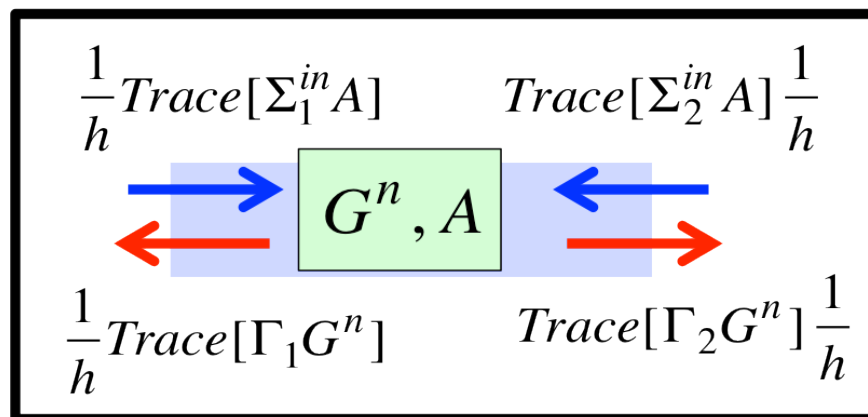
$$\psi \psi^+ = \frac{[G^n]}{2\pi}$$

$$s s^+ = \frac{[\Sigma^{in}]}{2\pi}$$

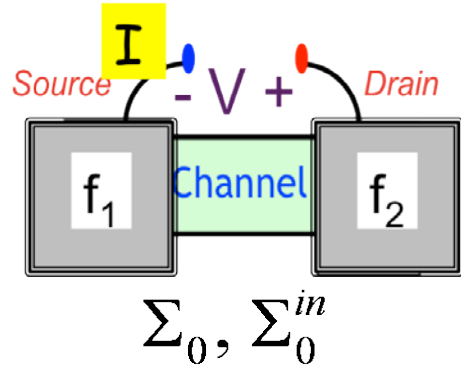
Current Operator

$$I_Y = \text{Trace } Y I_{op}$$

$$\rightarrow Y \text{Trace } I_{op}$$

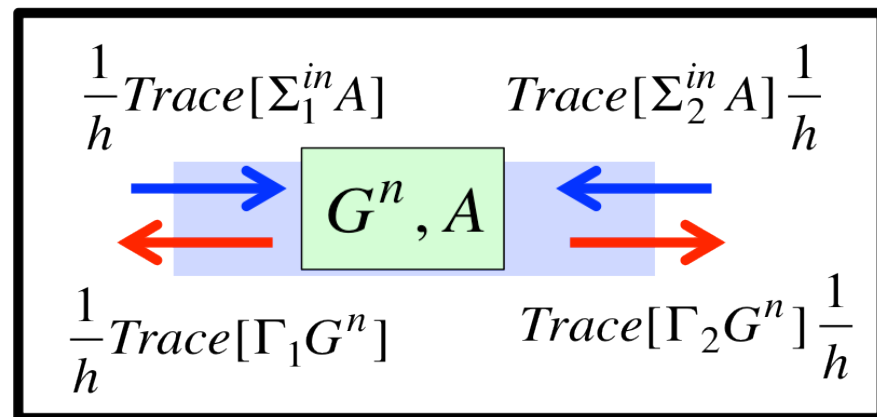
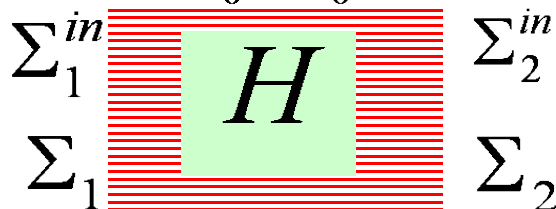


2.10d Summing up ..



$$\Gamma \equiv i(\Sigma - \Sigma^+)$$

$$A = i[G^R - G^A]$$



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

$$G^n = G^R \Sigma^{in} G^A$$

$$\Sigma = \Sigma_1 + \Sigma_2 + \Sigma_0$$

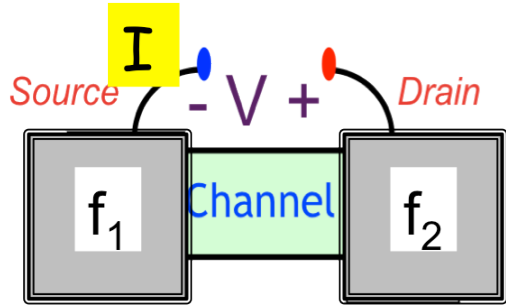
$$\Sigma^{in} = \Sigma_1^{in} + \Sigma_2^{in} + \Sigma_0^{in}$$

$$\Sigma_1^{in} = \Gamma_1 f_1(E)$$

$$\Sigma_2^{in} = \Gamma_2 f_2(E)$$

For the dephasing contact

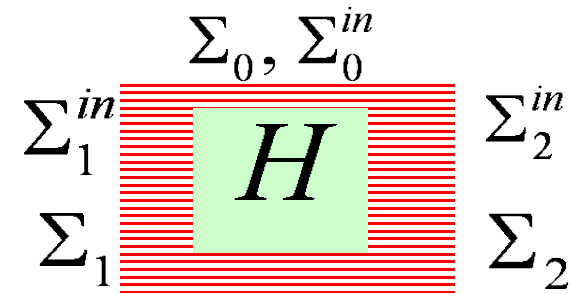
$$\text{Trace}[\Sigma_0^{in} A] = \text{Trace}[\Gamma_0 G^n]$$



$$\Gamma \equiv i(\Sigma - \Sigma^+)$$

$$A = i[G^R - G^A]$$

2.10e Summing up ..



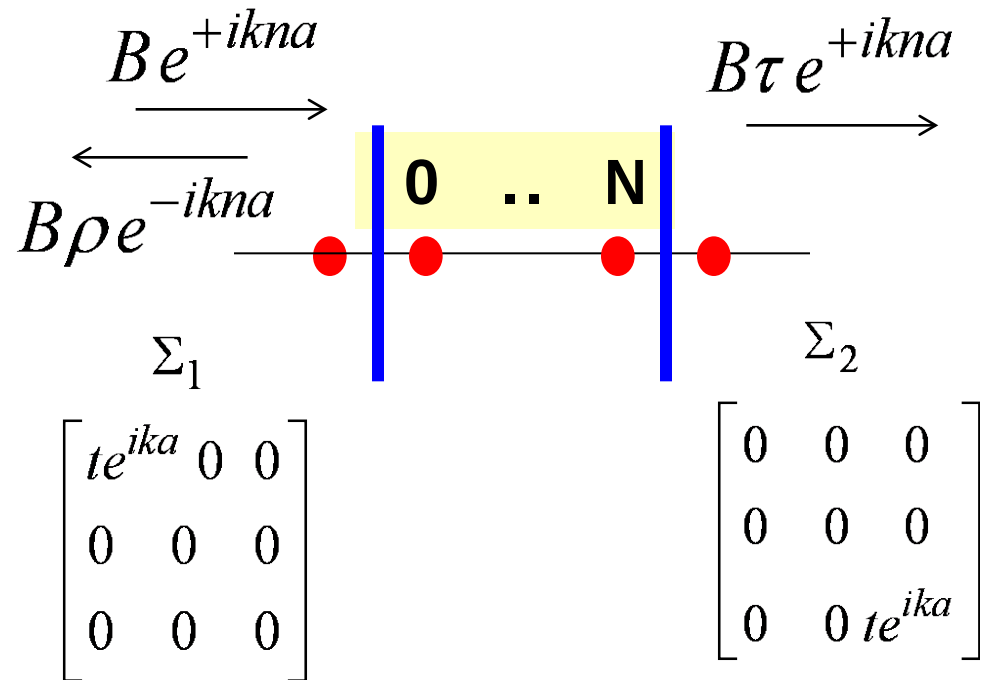
$$G^R = [EI - H - \Sigma]^{-1}$$

$$G^n = G^R \Sigma^{in} G^A$$

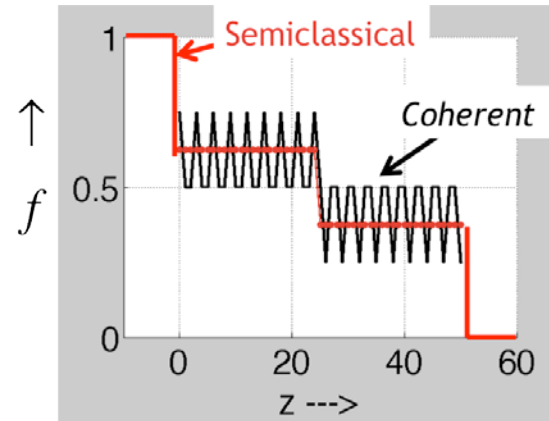
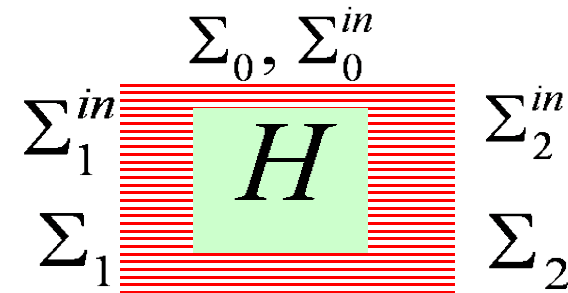
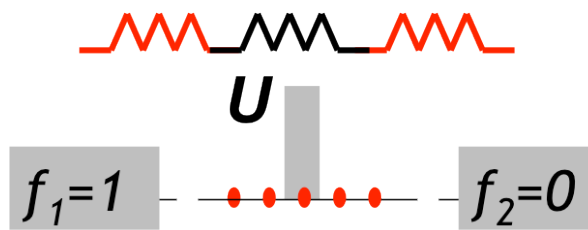
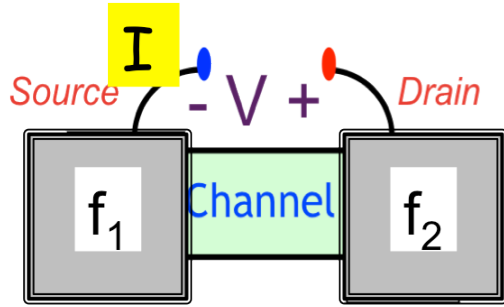
$$\Sigma = \Sigma_1 + \Sigma_2 + \Sigma_0$$

$$\Sigma^{in} = \Sigma_1^{in} + \Sigma_2^{in} + \Sigma_0^{in}$$

1D



2.10f Summing up ..



$$[\Sigma_0]_{ij} = D_{ij} [G^R]_{ij}$$

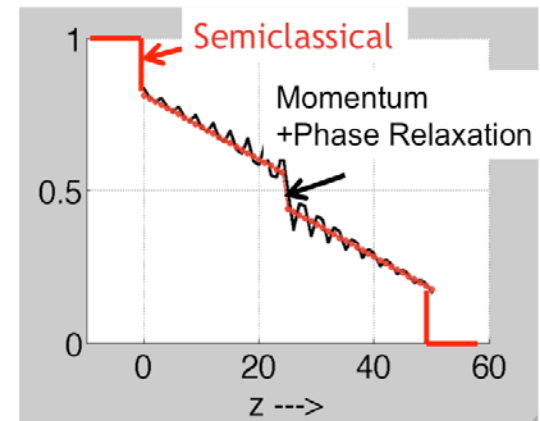
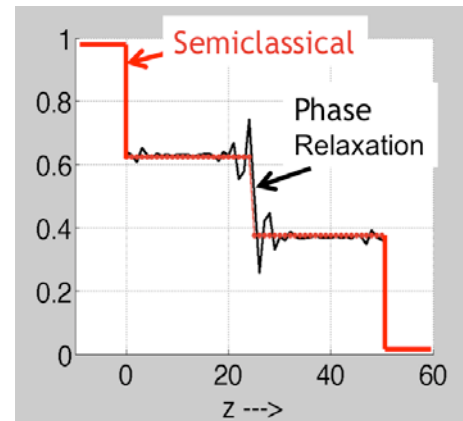
$$[\Sigma_0^{\text{in}}]_{ij} = D_{ij} [G^n]_{ij}$$

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

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

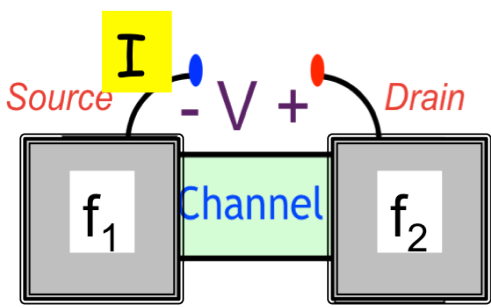
$$\Sigma = \Sigma_1 + \Sigma_2 + \Sigma_0$$

$$\Sigma^{\text{in}} = \Sigma_1^{\text{in}} + \Sigma_2^{\text{in}} + \Sigma_0^{\text{in}}$$



$$\Gamma \equiv i(\Sigma - \Sigma^+) \quad A = i[G^R - G^A]$$

Coming up next ..



The diagram shows a central green square labeled H . It is surrounded by red horizontal bars representing ancilla qubits. Above the central gate are two qubits labeled Σ_0, Σ_0^{in} . Below the central gate are two qubits labeled Σ_1 and Σ_1^{in} . To the right of the central gate are two qubits labeled Σ_2 and Σ_2^{in} .

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

$$G^n = G^R \Sigma^{in} G^A$$

$$\Sigma = \Sigma_1 + \Sigma_2 + \Sigma_0$$

$$\Sigma^{in} = \Sigma_1^{in} + \Sigma_2^{in} + \Sigma_0^{in}$$

$$\Gamma \equiv i(\Sigma - \Sigma^+) \quad A = i[G^R - G^A]$$

B. Quantum Transport

1. Schrodinger Equation
2. Contact-ing Schrodinger

3. Advanced Examples

- ## 4. Spin Transport

UNIT 3

More advanced examples

UNIT 3

More advanced examples