

FUNDAMENTALS OF NANO-ELECTRONICS

Basic Concepts

1. The New Perspective

2. Energy Band Model

**3. What & Where
is the “Voltage”?**

4. Heat & Electricity:

Second Law & Information

3.1. Introduction

3.2. A New Boundary Condition

3.3. Quasi-Fermi Levels (QFL's)

3.4. Current from QFL's

3.5. Landauer Formulas

3.6. What a Probe Measures

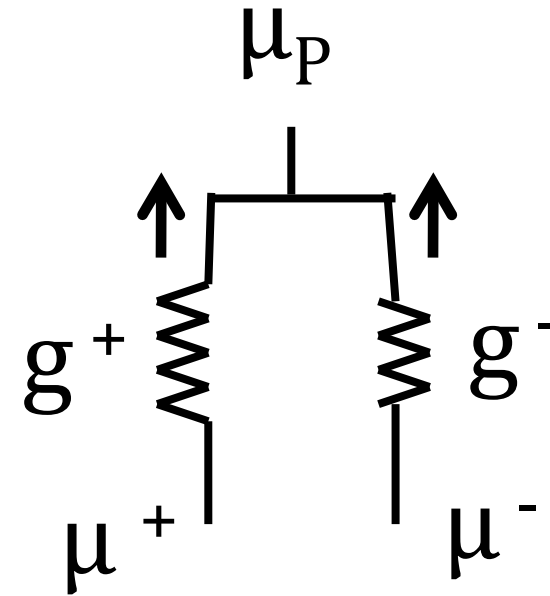
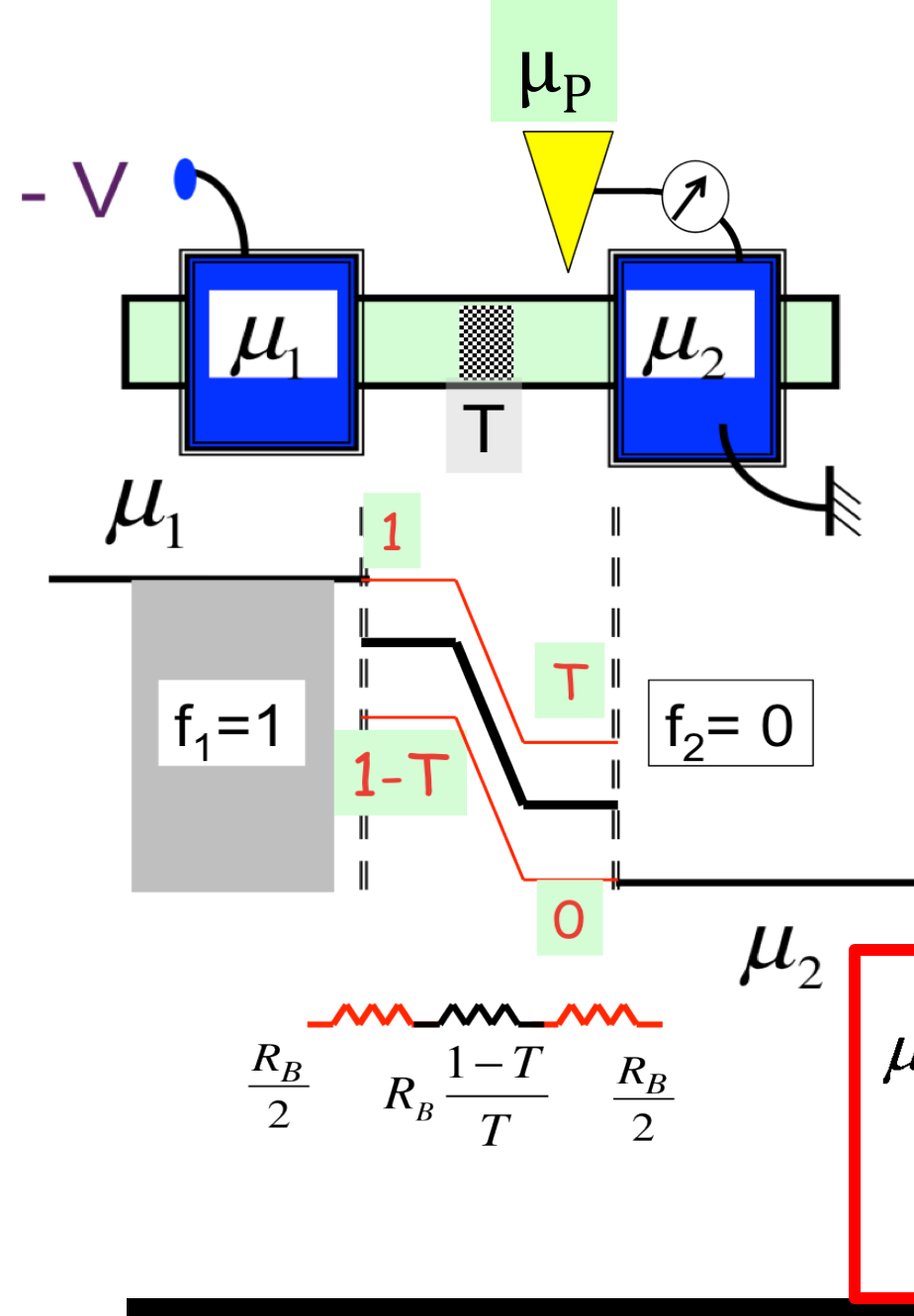
3.7. Electrostatic Potential

3.8. Boltzmann Equation

3.9. Spin voltages

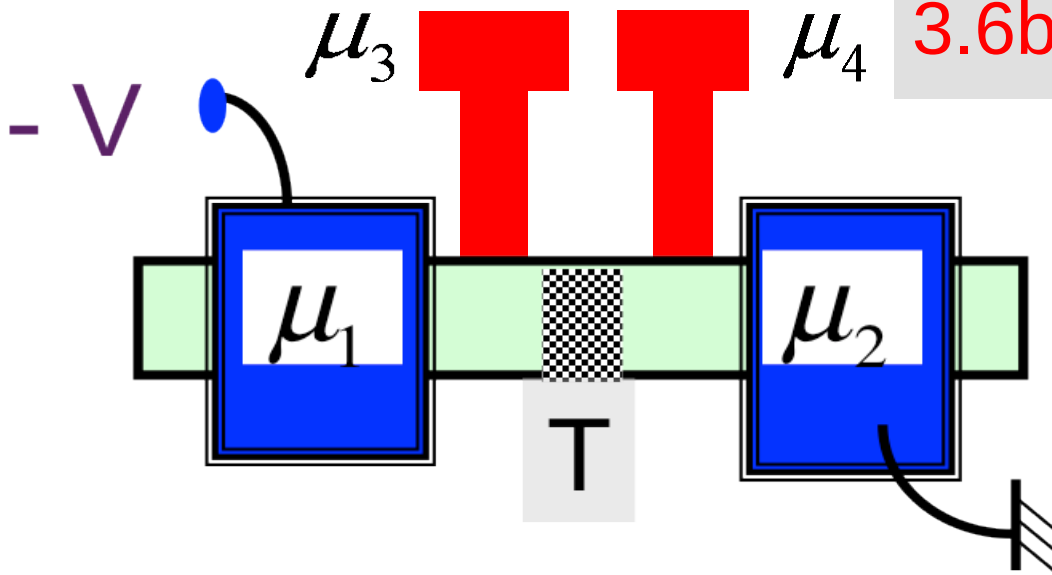
3.10. Summing up ..

3.6a What a Probe Measures



$$\mu_P = \underbrace{\frac{g^+}{g^+ + g^-}}_{\alpha} \mu^+ + \underbrace{\frac{g^-}{g^+ + g^-}}_{1-\alpha} \mu^-$$

3.6b What a Probe Measures



$$\begin{Bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \end{Bmatrix} = \frac{1}{q} \begin{bmatrix} G_{11} & G_{12} & G_{13} & G_{14} \\ G_{21} & G_{22} & G_{23} & G_{24} \\ G_{31} & G_{32} & G_{33} & G_{34} \\ G_{41} & G_{42} & G_{43} & G_{44} \end{bmatrix} \begin{Bmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \\ \mu_4 \end{Bmatrix}$$

Buttiker equations

$$\begin{Bmatrix} I_{12} \\ I_{34} \end{Bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{Bmatrix} \mu_{12} \\ \mu_{34} \end{Bmatrix}$$

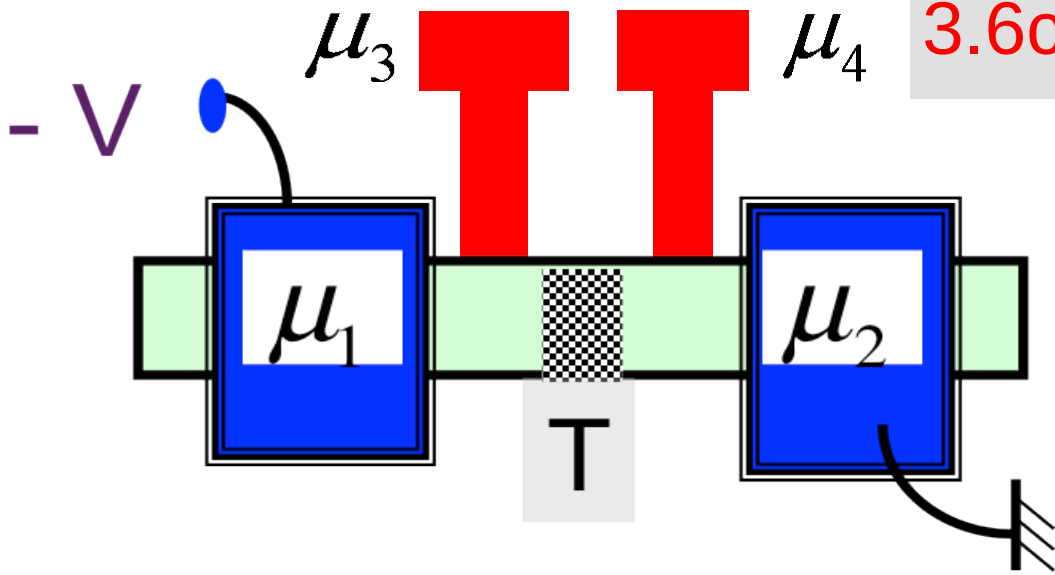
$$C\mu_{12} + D\mu_{34} = \{0\}$$

$$\rightarrow \mu_{34} = -D^{-1}C \mu_{12}$$

$$\rightarrow I_{12} = [A - BD^{-1}C] \mu_{12}$$

*Given any four,
we can find the other four*

3.6c What a Probe Measures



$$I/V \equiv G_0 = \int_{-\infty}^{+\infty} dE \left(-\frac{\partial f_0}{\partial E} \right) G(E)$$

$$\begin{Bmatrix} I_1 \\ I_2 \end{Bmatrix} = \frac{1}{q} \begin{bmatrix} G_0 & -G_0 \\ -G_0 & G_0 \end{bmatrix} \begin{Bmatrix} \mu_1 \\ \mu_2 \end{Bmatrix}$$

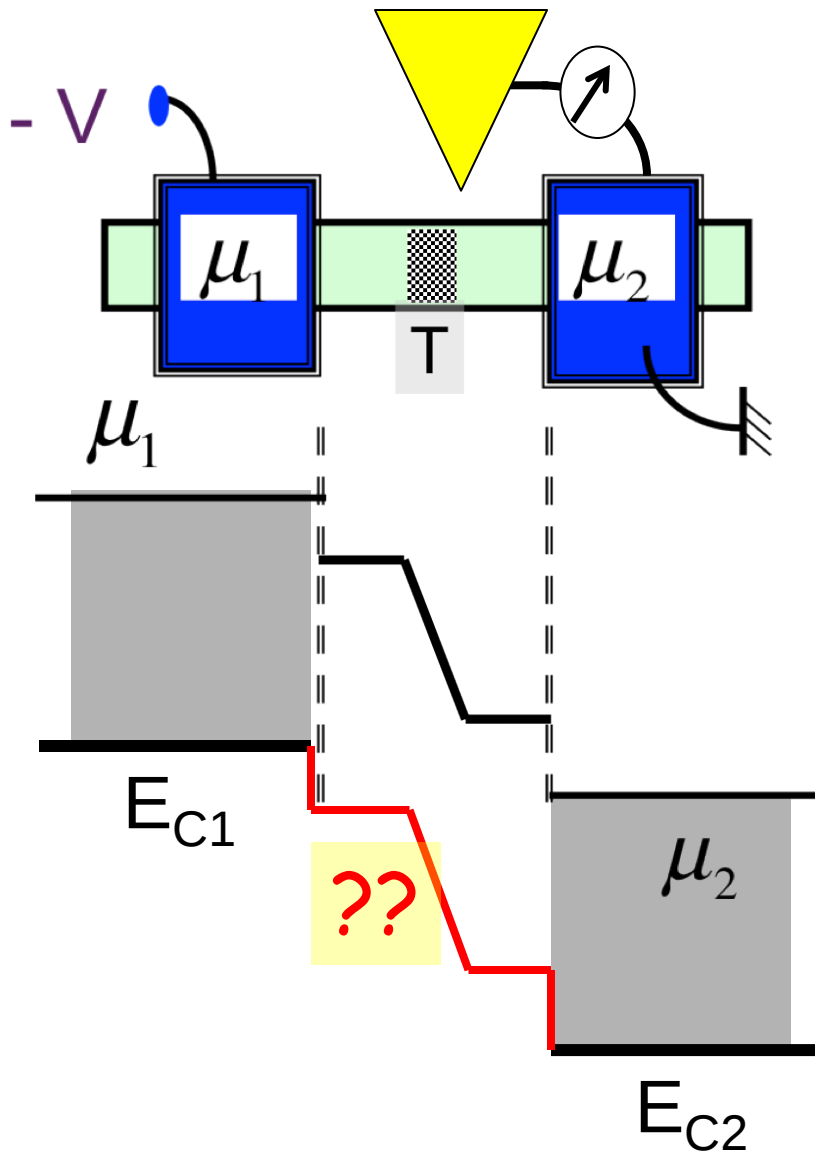
$$\begin{Bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \end{Bmatrix} = \frac{1}{q} \begin{bmatrix} G_{11} & G_{12} & G_{13} & G_{14} \\ G_{21} & G_{22} & G_{23} & G_{24} \\ G_{31} & G_{32} & G_{33} & G_{34} \\ G_{41} & G_{42} & G_{43} & G_{44} \end{bmatrix} \begin{Bmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \\ \mu_4 \end{Bmatrix}$$

$$I = \frac{G_0}{q} (\mu_1 - \mu_2)$$

Sum Rules

$$G_{12} \neq G_{21} \quad , \quad G_{12}(+B) = G_{21}(-B)$$

Coming up next ..



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