FUNDAMENTALS OF NANOELECTRONICS

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

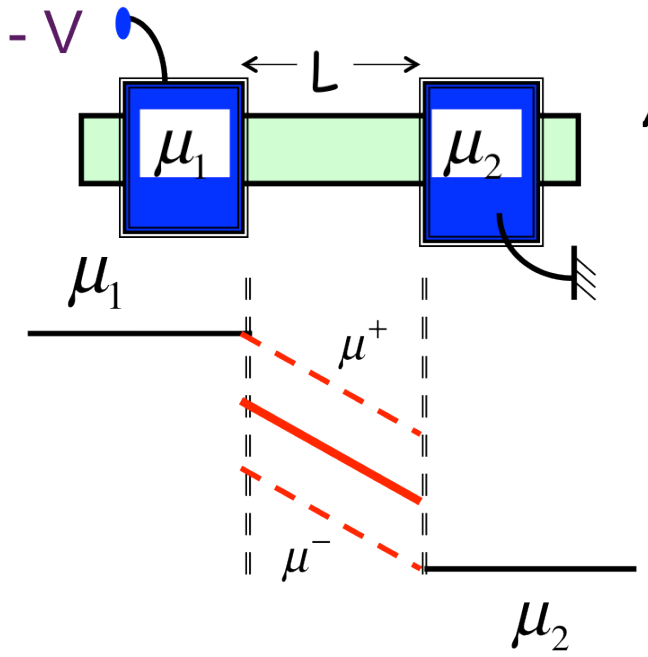
3.7. Electrostatic Potential

3.8. Boltzmann Equation

3.9. Spin voltages

3.10. Summing up ..

3.4a Current from QFL's



$$\mu = \frac{\mu^+ + \mu^-}{2}$$

$$= \mu^+ - \frac{\mu^+ - \mu^-}{2} = \mu^+ - \frac{qIR_B}{2}$$

$$= \mu^- + \frac{\mu^+ - \mu^-}{2}$$

$$= \mu^- + \frac{qIR_B}{2}$$

z = 0

z = L

$$I = \frac{G_B}{q}\left(\mu^+ - \mu^-\right)$$

$$\rightarrow \mu^+ - \mu^- = qIR_B$$

QFL Boundary Conditions

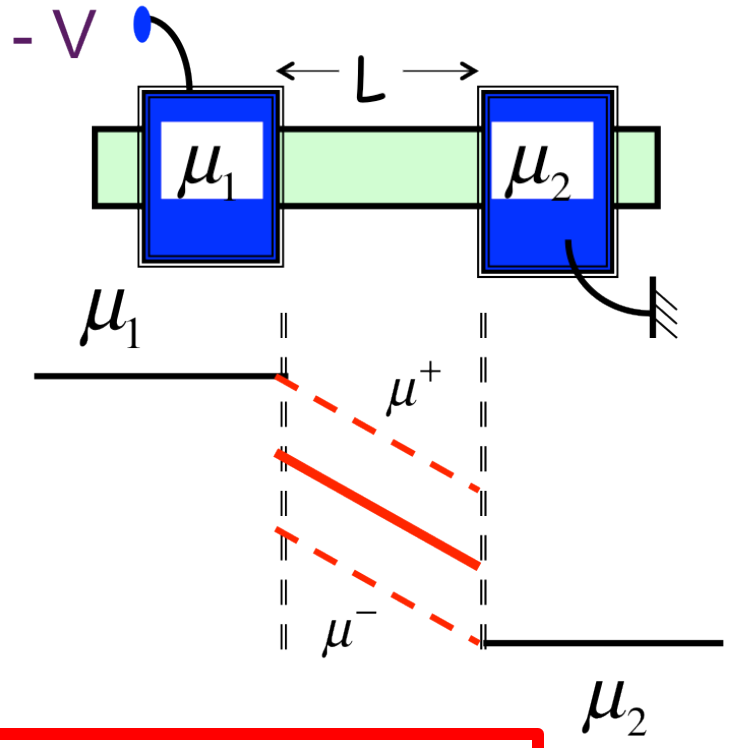
$$\mu^+(z=0) = \mu_1$$

$$\mu^-(z=L) = \mu_2$$

$$\mu(z=0) = \mu_1 - \frac{qIR_B}{2}$$

$$\mu(z=L) = \mu_2 + \frac{qIR_B}{2}$$

3.4b Current from QFL's



$$I^+ = \frac{q}{h} M(E) * f^+(E)\,dE$$

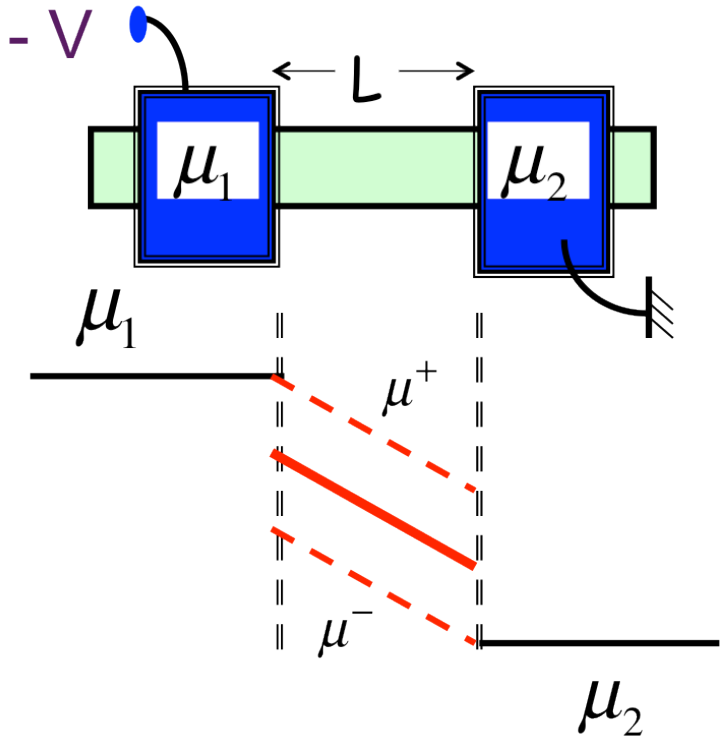
$$I^+ = q * \frac{D(E)\bar{u}}{2L} * f^+(E)\,dE$$

$$I^+ = q * \underbrace{\frac{D(E)\,dE}{2} * f^+(E)}_{\text{Number of right-moving electrons}} * \underbrace{\frac{1}{L/\bar{u}}}_{\text{Time spent}}$$

$$I = \frac{G_B}{q}\left(\mu^+ - \mu^-\right)$$

$$\frac{Graduates}{year} = \#\ of\ students * \frac{1}{Years\ spent}$$

3.4c Current from QFL's



$$I^+ = \frac{q}{h} M(E) * f^+(E)\, dE$$

$$I = I^+ - I^-$$

$$= \frac{q}{h} M(E) * \left(f^+(E) - f^-(E) \right) dE$$

$$\approx \frac{q}{h} M(E) * \left(-\frac{\partial f_0}{\partial E} \right) dE \left(\mu^+ - \mu^- \right)$$

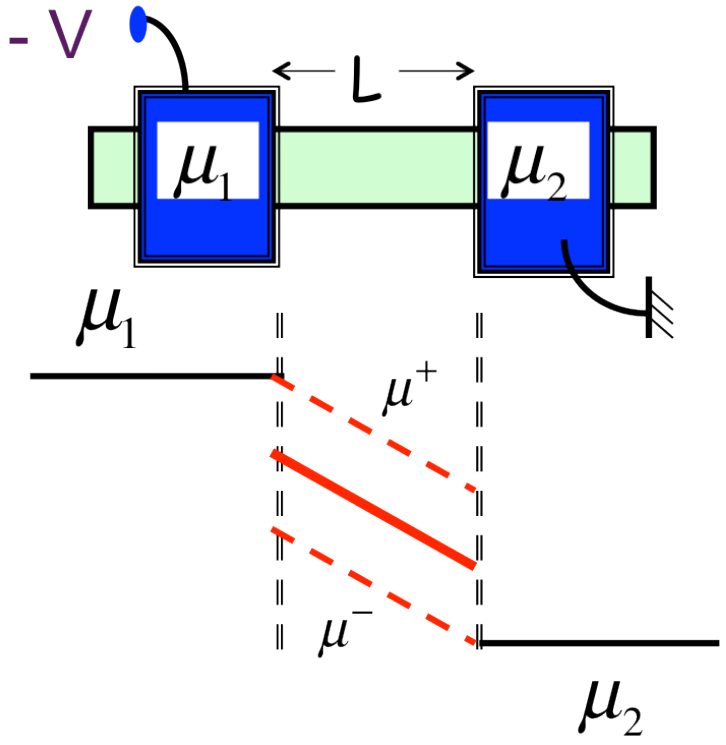
$$I = \frac{q}{h} M_0 \left(\mu^+ - \mu^- \right)$$

$$M_0 = \int M(E) * \left(-\frac{\partial f_0}{\partial E} \right) dE$$

$$G_B = \frac{q^2}{h} M_0$$

$$I = \frac{G_B}{q} \left(\mu^+ - \mu^- \right)$$

3.4d Current from QFL's



$$\mu^+ - \mu^- = (\mu_1 - \mu_2)\frac{\lambda}{L+\lambda}$$

$$\mu^+ - \mu^- = (\mu_1 - \mu_2)\frac{G_0}{G_B}$$

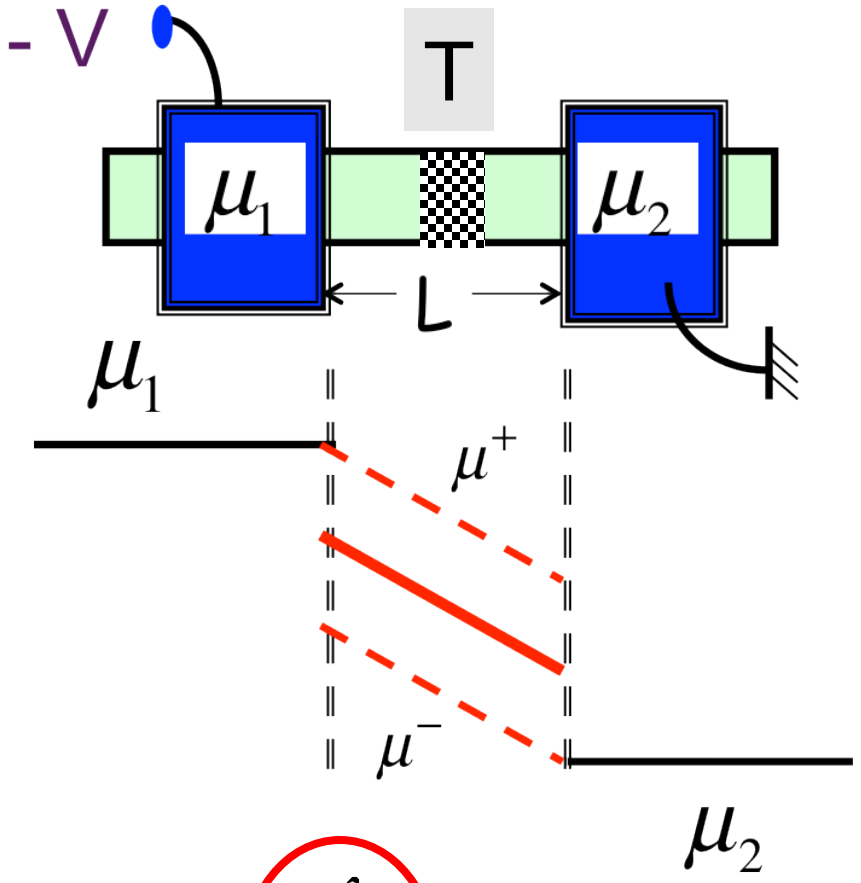
$$I = \frac{G_B}{q}(\mu^+ - \mu^-)$$

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

$$G_B = \frac{q^2}{h} M_0$$

$$G_0 = G_B \frac{\lambda}{L+\lambda}$$

Coming up next ..



$$G_0 = G_B \frac{\lambda}{L+\lambda}$$

T