

ECE 495N

Fundamentals of Nanoelectronics

Fall 2008

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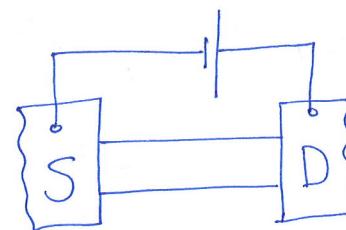
**Lecture: 13
Title: Multi-Electron Picture
Date: September 24, 2008**

**Video Lectures posted at:
<https://www.nanohub.org/resources/5346/>**

**Class notes taken by: Panagopoulos Georgios
Purdue University**

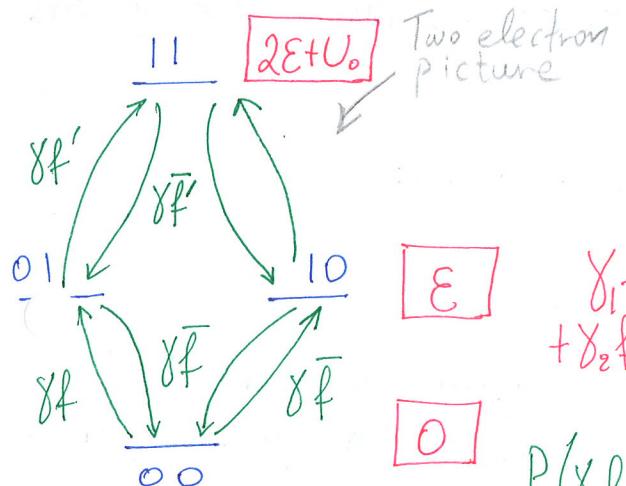


$$I = \frac{q}{\hbar} \frac{\gamma_1 \gamma_2}{\gamma_1 + \gamma_2} (f_1(\varepsilon) - f_2(\varepsilon))$$



$$N = \frac{\gamma_1 f_1 + \gamma_2 f_2}{\gamma_1 + \gamma_2}$$

$$U = U_L + U_0 \Delta N$$



Two electron picture

One electron picture

E
O

$$\frac{1}{P_1} = \frac{\gamma_1 f_1 + \gamma_2 f_2}{\gamma_1 \bar{f}_1 + \gamma_2 \bar{f}_2}$$

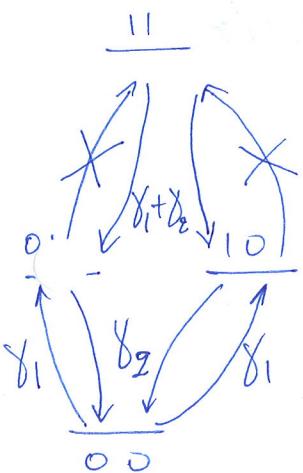
$$P_0 (\gamma_1 f_1 + \gamma_2 f_2) = P_1 (\gamma_1 \bar{f}_1 + \gamma_2 \bar{f}_2)$$

$$\Rightarrow \frac{P_1}{P_0} = \frac{\gamma_1 f_1 + \gamma_2 f_2}{\gamma_1 \bar{f}_1 + \gamma_2 \bar{f}_2}$$

$$\Rightarrow \frac{P_1}{P_0 + P_1} = \frac{\gamma_1 f_1 + \gamma_2 f_2}{\gamma_1 + \gamma_2} = P_1$$

$$N = P_1 \cdot I + P_0 \cdot O = P_1$$

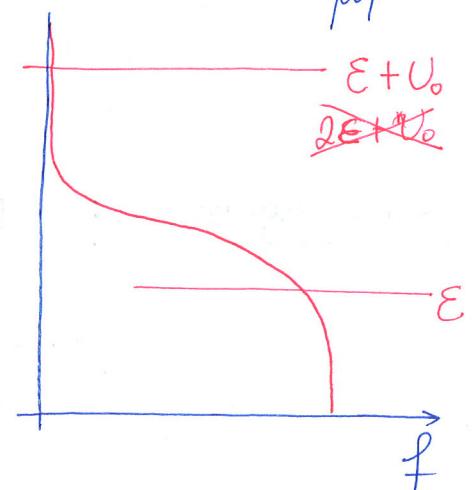
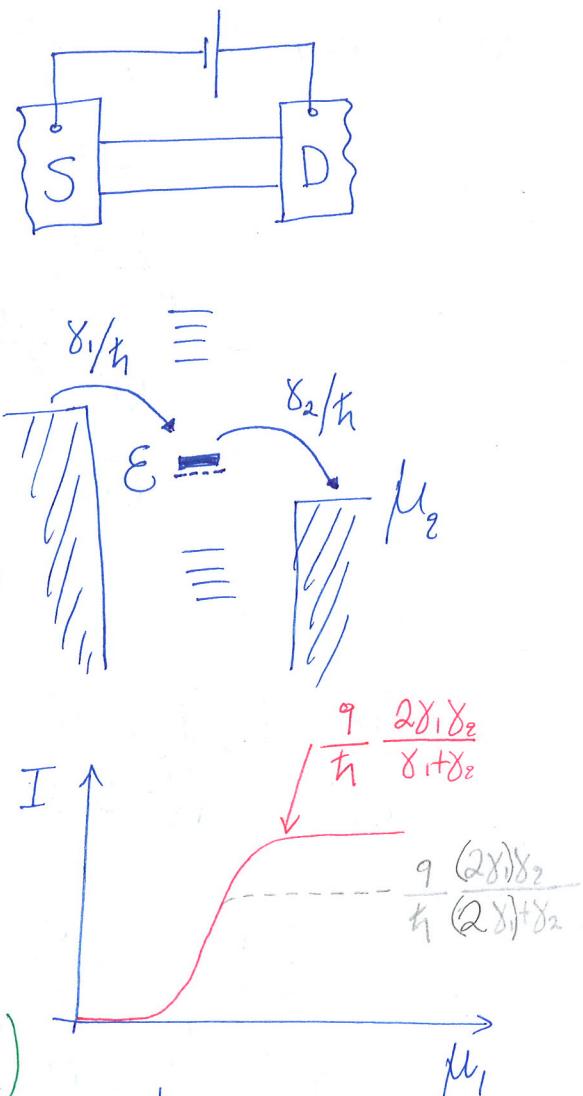
The difference in energy is used in the fermi function.



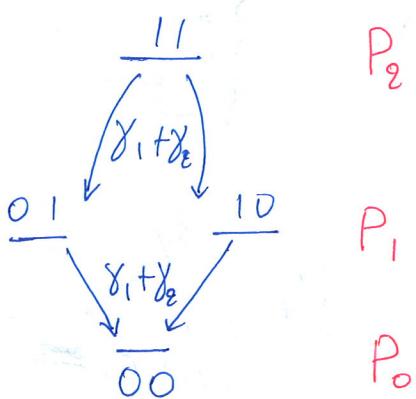
Plateau level

$$f_1 = 1, f_2 = 0$$

$$f'_1 = 0, f'_2 = 0$$



→ If μ_1 is below E (close to μ_2) then also $f_1 = 0$ and then the state diagram becomes:

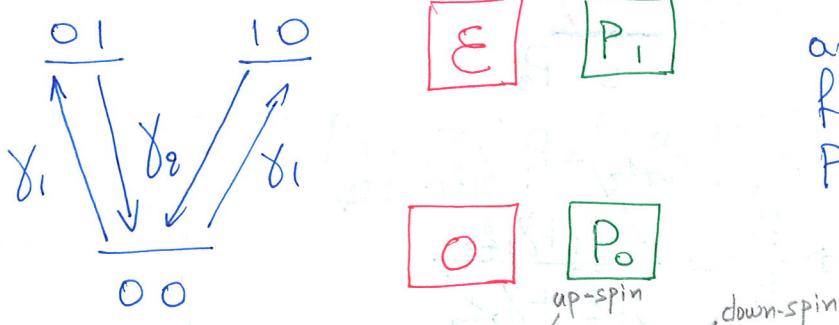


In this case nothing is going up. It doesn't matter from where we will start, we will have:

$$P_0 = 1, P_1 = 0, P_2 = 0$$

Which it makes sense since in this case we do not expect electrons inside the system.

If $\begin{cases} f_1 = 1, f_2 = 0 \\ f'_1 = 0, f'_2 = 0 \end{cases}$ the the system becomes:



and we want to find the probabilities P_0 and P_1

Rate equation: $P_0 \cdot 2\gamma_1 = P_{01}\gamma_2 + P_{10}\gamma_2 = P_1\gamma_2$

$$\Rightarrow \frac{P_1}{P_0} = \frac{2\gamma_1}{\gamma_2} \Rightarrow \frac{P_{01} + P_{10}}{\underbrace{P_{00} + P_{01} + P_{10}}_1} = \frac{2\gamma_1}{2\gamma_1 + \gamma_2}$$

$$I = g \frac{\gamma_2}{\hbar} (P_{01} + P_{10})$$

$$= g \frac{2\gamma_1\gamma_2}{2\gamma_1 + \gamma_2}$$

$$\gamma_1 f_1 + \gamma_2 f_2 = \gamma f$$

Equilibrium means that all of these f 's are equal.

$$\Rightarrow \frac{\text{Down}}{\text{Up}} = \frac{f}{f} = \frac{1-f}{f}$$

$$= \frac{1}{f} - 1 = e^{-(E-\mu)/kT}$$

If we have one contact or if both contacts have the same fermi function, that's we called equilibrium condition. Non-equilibrium means two different electrochemical potentials, two different fermi functions or two different temperatures.

$$P_N = \frac{1}{Z} e^{-(E-\mu)/kT}$$

Law of equilibrium

-if $kT \rightarrow 0$ $P=1$ for state with smallest $(E-\mu_N)$