ECE 659 Quantum Transport: Atom to Transistor

Lecture 40: Correlated Transport

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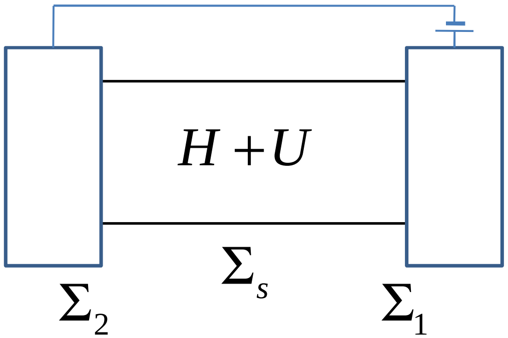
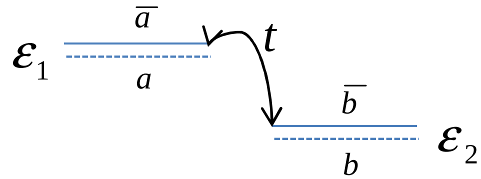
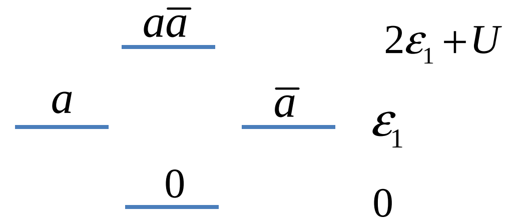
Spring 2009

Notes prepared by Samiran Ganguly







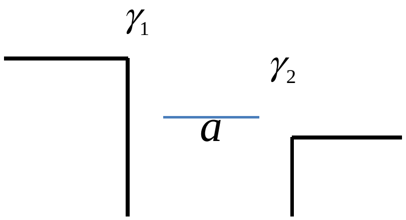
$$
H = \begin{array}{c} \\ a \\ b \\ \bar{a} \\ \bar{b} \end{array}
\begin{array}{c} \begin{array}{cccc} a & b & \bar{a} & \bar{b} \end{array} \\
\begin{bmatrix} \varepsilon_1 & t & & \\ t & \varepsilon_1 & & \\ & & \varepsilon_2 & t \\ & & t & \varepsilon_2 \end{bmatrix} \end{array}
$$

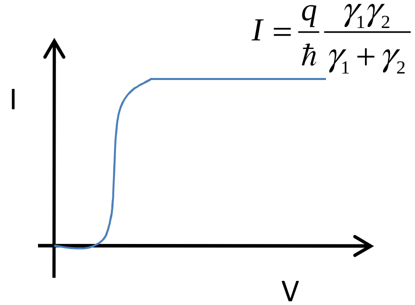
	$a\bar{a}$	$b\bar{b}$	$a\bar{b}$	$b\bar{a}$	ab	$\bar{a}\bar{b}$
$a\bar{a}$	$2\varepsilon_1+U$		t	t		
$b\bar{b}$		$2\varepsilon_2+U$	t	t		
$a\bar{b}$	t	t	$\varepsilon_1+\varepsilon_2$			
$b\bar{a}$	t	t		$\varepsilon_1+\varepsilon_2$		
ab					$\varepsilon_1+\varepsilon_2$	
$\bar{a}\bar{b}$						$\varepsilon_1+\varepsilon_2$

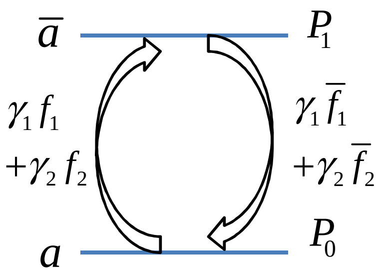
$$\rho = \frac{1}{Z}\exp\left[-\frac{\bar{H}-\mu N}{k_B T}\right]$$

$$Z = Trace(\rho)$$

Single Level:







$$\frac{P_1}{P_0} = \frac{\gamma_1 f_1 + \gamma_2 f_2}{\gamma_1 \bar{f}_1 + \gamma_2 \bar{f}_2} = \frac{f}{\bar{f}} = \exp\left(-\frac{E-\mu}{k_B T}\right)$$

Maximum current: $f_1 = 1, f_2 = 0$

$$\frac{P_1}{P_0} = \frac{\gamma_1}{\gamma_2}$$

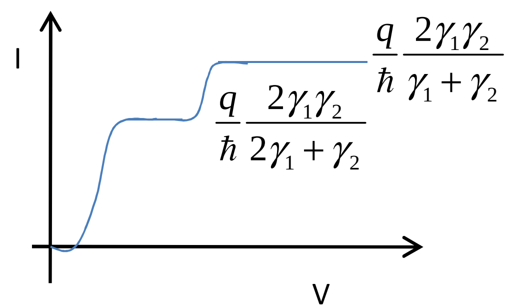
$$I = q\left(\frac{\gamma_1}{\hbar}\right)P_0$$

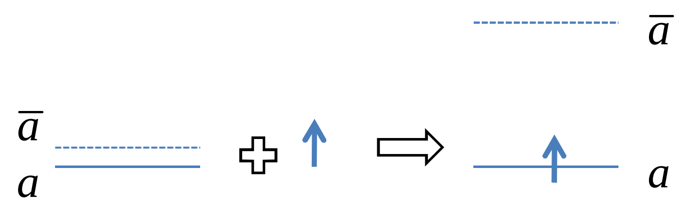
$$P_0 = \frac{1}{1+\gamma_1/\gamma_2}$$

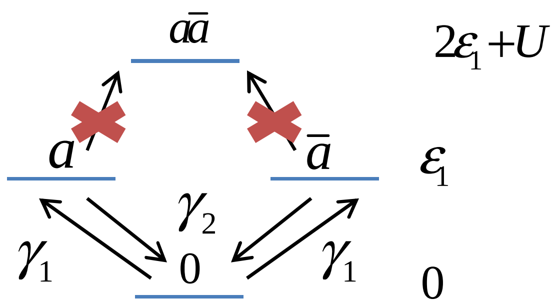
$$P_0 = \frac{\gamma_1/\gamma_2}{1+\gamma_1/\gamma_2}$$

$$\therefore I = \frac{q}{\hbar}\frac{\gamma_1\gamma_2}{\gamma_1+\gamma_2}$$

Two Levels:







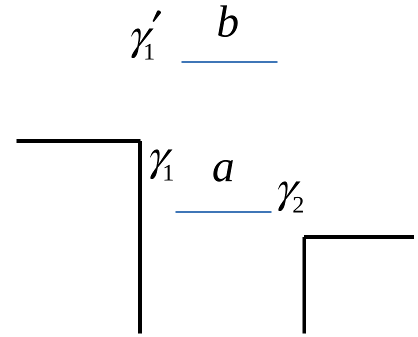
$$\frac{P_a}{P_0} = \frac{\gamma_1}{\gamma_2} = \frac{P_{\bar{a}}}{P_0}$$

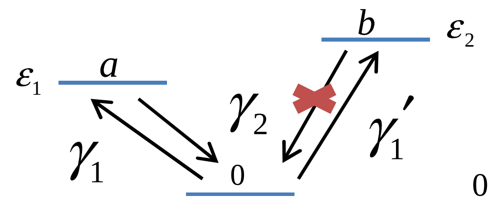
$$\frac{P_a + P_{\bar{a}}}{P_0} = \frac{2\gamma_1}{\gamma_2}$$

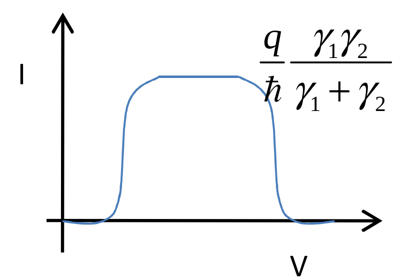
$$P_0 = \frac{1}{1 + 2\gamma_1/\gamma_2}$$

$$P_a + P_{\bar{a}} = \frac{2\gamma_1/\gamma_2}{1 + 2\gamma_1/\gamma_2}$$

$$I = \frac{q}{\hbar} 2\gamma_1 P_0 = \frac{q}{\hbar}\frac{2\gamma_1\gamma_2}{2\gamma_1 + \gamma_2}$$

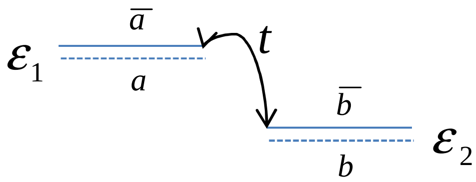




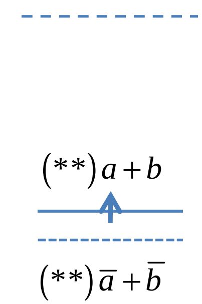


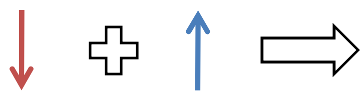
Once 'b' is filled it charges the channel so much that the 'a' level floats up too high making the current go to 0

Singlet and Triplet:



$$H = \begin{array}{c} \\ a \\ b \\ \overline{a} \\ \overline{b} \end{array} \begin{array}{c} \begin{array}{cccc} a & b & \overline{a} & \overline{b} \end{array} \\ \begin{bmatrix} \varepsilon_1 & t & & \\ t & \varepsilon_1 & & \\ & & \varepsilon_2 & t \\ & & t & \varepsilon_2 \end{bmatrix} \end{array}$$





Singlet State $\left[a\overline{b} + b\overline{a} + (*)\, a\overline{a} + (*)\, b\overline{b} \right]$

If we pull out b, the conduction can occur because we are left with $\overline{a}$ & $\overline{b}$

Triplet State