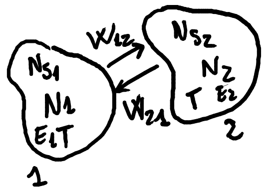


$1:\ N_1$ occupati $\quad N_{S1}-N_1$ stati vuoti

$2:\ N_2 \quad N_{S2}-N_2$

Eq: $N_1 W_{12}(N_{S2}-N_2) = N_2 W_{21}(N_{S1}-N_1)$

$$(1)\quad \frac{W_{12}}{W_{21}} = \frac{N_2(N_{S1}-N_1)}{N_1(N_{S2}-N_2)} = \frac{\frac{N_{S1}-N_1}{N_1}}{\frac{N_{S2}-N_2}{N_2}}$$

$$\binom{N_S}{N} = \frac{N_S!}{(N_S-N)!\,N!}$$

$$F = E - TS \qquad S = k\ln\binom{N_S}{N}$$

$$F_1 = E_1N_1 - TS_1 = E_1N_1 - kT\ln\binom{N_{S1}}{N_1}$$

$$F_2 = E_2N_2 - TS_2 = E_2N_2 - kT\ln\binom{N_{S2}}{N_2}$$

$$F = F_1 + F_2$$

$$\frac{\partial F}{\partial N_1} = 0\ ;\ \frac{\partial F}{\partial N_2} = 0$$

$$\frac{\partial F}{\partial N_1} = \frac{\partial F_1}{\partial N_1} = E_1 - kT\frac{\partial}{\partial N_1}\ln\binom{N_{S1}}{N_1}$$

$$\ln\binom{N_{S1}}{N_1} = \ln\left[\frac{N_{S1}!}{(N_{S1}-N_1)!\,N_1!}\right] =$$

$$= \cancel{\ln(N_{S1}!)} - \ln[(N_{S1}-N_1)!] - \ln[N_1!] =$$

STIRLING $\quad \ln(x!) \simeq x\ln x - x$

$$= \ln(N_{S1}!) - (N_{S1}-N_1)\ln(N_{S1}-N_1) + (N_{S1}-N_1) +$$
$$- N_1\ln N_1 + N_1 = \text{Arg}$$

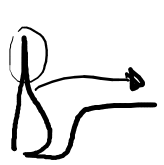
$$\frac{\partial}{\partial N_1}\text{Arg} = \left[\ln(N_{S1}-N_1) - \cancel{\frac{(N_{S1}-N_1)}{N_{S1}-N_1}(-1)} - \cancel{1} + \right.$$
$$\left. - \ln N_1 - \cancel{\frac{N_1}{N_1}} + \cancel{1}\right] =$$
$$= [\ln(N_{S1}-N_1) - \ln N_1]$$

$$\frac{\partial F}{\partial N_1} = E_1 - kT[\ln(N_{S1}-N_1) - \ln N_1] = 0$$

$$\frac{\partial F}{\partial N_2} = E_2 - kT[\ln(N_{S2}-N_2) - \ln N_2] = 0$$

$$kT\ln\left[\frac{(N_{S1}-N_1)}{N_1}\right] = E_1$$

$$\frac{N_{S1}-N_1}{N_1} = \exp\left(\frac{E_1}{kT}\right)$$



$$\frac{N_{S2}-N_2}{N_2} = \exp\left(\frac{E_2}{kT}\right)$$

$$\frac{W_{12}}{W_{21}} = \frac{\exp\left(\frac{E_1}{kT}\right)}{\exp\left(\frac{E_2}{kT}\right)}$$

M $\quad i$ - $\quad f_i$

$\quad j \quad f_j$

$1-f_i$:

$1-f_j$:

$$M f_i W_{ij} M(1-f_j) = M f_j W_{ji} M(1-f_i)$$

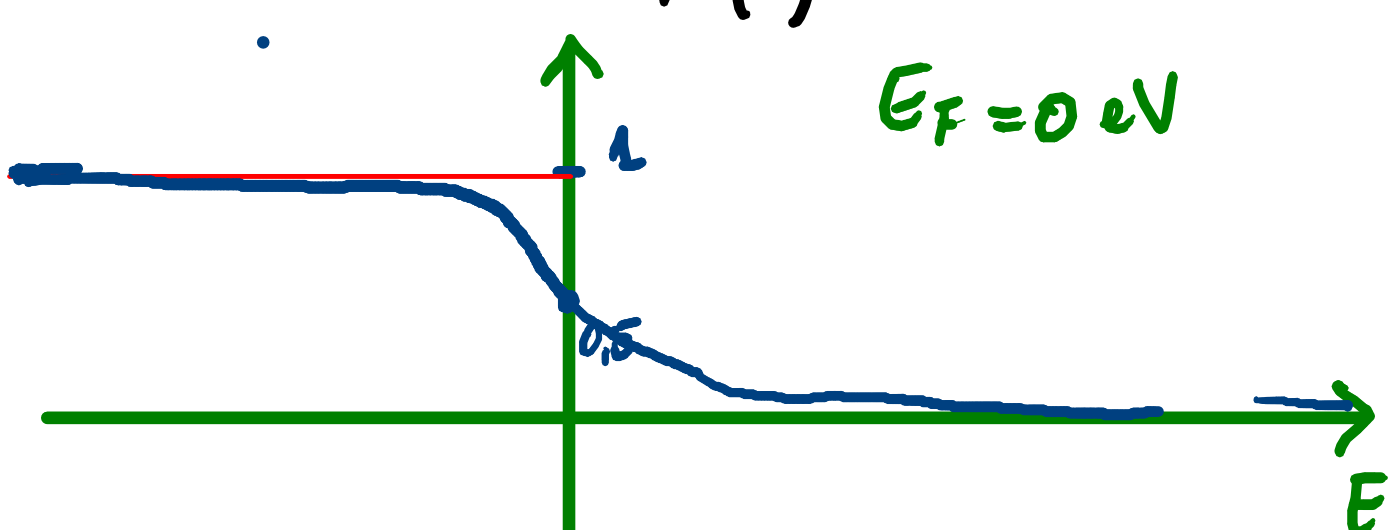
$$\frac{f_i}{1-f_i} W_{ij} = \frac{f_j}{1-f_j} W_{ji}$$

$$\frac{f_i}{1-f_i} \exp\left(\frac{E_i}{kT}\right) = \frac{f_j}{1-f_j} \exp\left(\frac{E_j}{kT}\right) = C$$

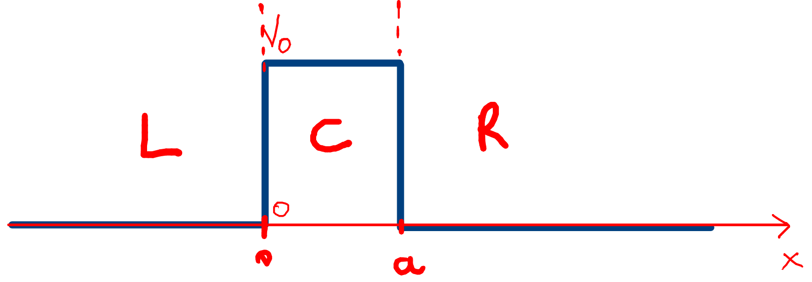
$$f_i = \frac{C}{C + \exp\left(\frac{E_i}{kT}\right)} = \frac{1}{1 + \frac{1}{C}\exp\left(\frac{E_i}{kT}\right)}$$

$$f(E_i = 0) = \frac{1}{2} \Rightarrow C = \exp\left(\frac{E_F}{kT}\right)$$

$$f = \frac{1}{1 + \exp\left(\frac{E - E_F}{kT}\right)}$$



$E - E_F \gg kT \qquad f \rightarrow \exp\left(-\frac{E-E_F}{kT}\right)$



$$\left[-\frac{\hbar^2}{2m}\frac{\partial^2}{\partial x^2}+V(x)\right]\varphi(x)=E\,\varphi(x)$$

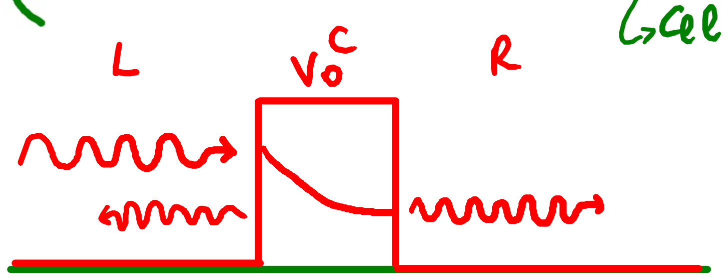
$$\begin{cases} \varphi_L(x) = A_r e^{jk_0x} + A_l e^{-jk_0x} & : x \leq 0 \\ \varphi_C(x) = B_r e^{jk_1x} + B_l e^{-jk_1x} & : 0<x<a \\ \varphi_R(x) = C_r e^{jk_0x} + C_l e^{-jk_1x} & : x>a \end{cases}$$

$$E = \frac{\hbar^2 k^2}{2m} \Rightarrow \begin{cases} k_0 = \dfrac{\sqrt{2mE}}{\hbar} \\ k_1 = \dfrac{\sqrt{2m(E-V_0)}}{\hbar} \end{cases}$$

φ e $\dfrac{\partial \varphi}{\partial x}$ devono essere continui in $x=0$ e $x=a$

$$\begin{cases} \varphi_L(0) = \varphi_C(0) \\ \varphi_C(a) = \varphi_R(a) \\ \left.\dfrac{\partial \varphi_L}{\partial x}\right|_{x=0} = \left.\dfrac{\partial \varphi_C}{\partial x}\right|_{x=0} \\ \left.\dfrac{\partial \varphi_C}{\partial x}\right|_{x=a} = \left.\dfrac{\partial \varphi_R}{\partial x}\right|_{x=a} \end{cases} \qquad \begin{cases} A_r + A_l = B_l + B_r \\ B_r e^{jk_1a} + B_l e^{-jk_1a} = \end{cases}$$

$$\begin{cases} A_r + A_l = B_l + B_r \\ B_r e^{jk_1a} + B_l e^{-jk_1a} = C_r e^{jk_0a} + C_l e^{-jk_0a} \\ k_0(A_r - A_l) = k_1(B_r - B_l) \\ k_1\left(B_r e^{jk_1a} - B_l e^{-jk_1a}\right) = k_0\left(C_r e^{jk_0a} - C_l e^{-jak_0}\right) \end{cases}$$

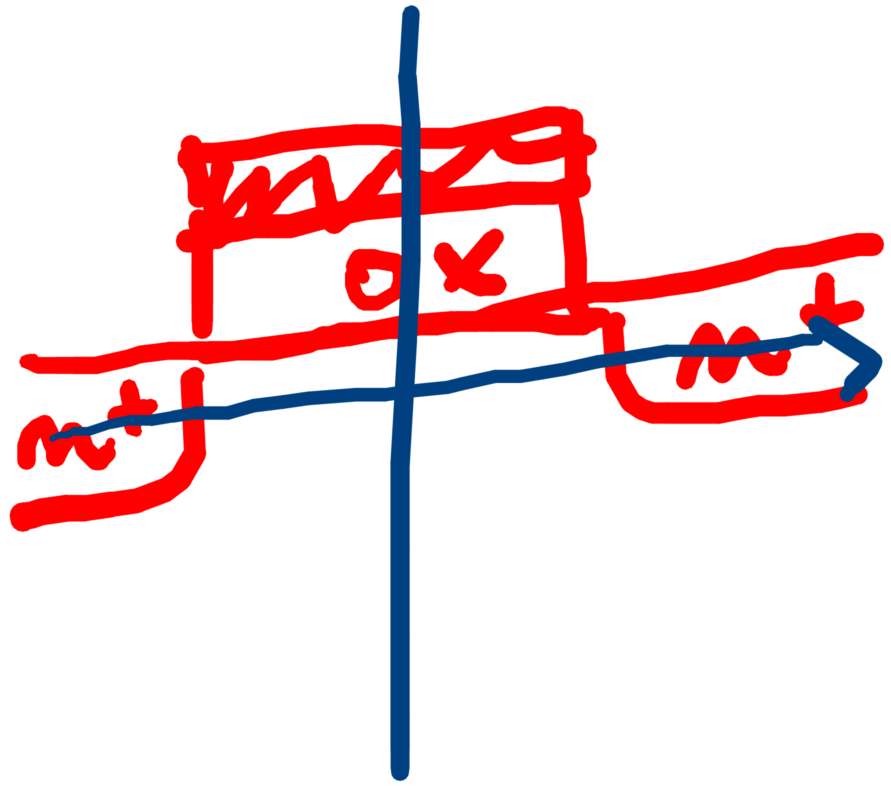


$A_r = 1$; $A_l = r$

$C_l = 0$; $C_r = t$

$$t = \frac{4k_0k_1 e^{-ja(k_0-k_1)}}{(k_0+k_1)^2 - e^{2jak_1}(k_0-k_1)^2}$$

$r + t = 1$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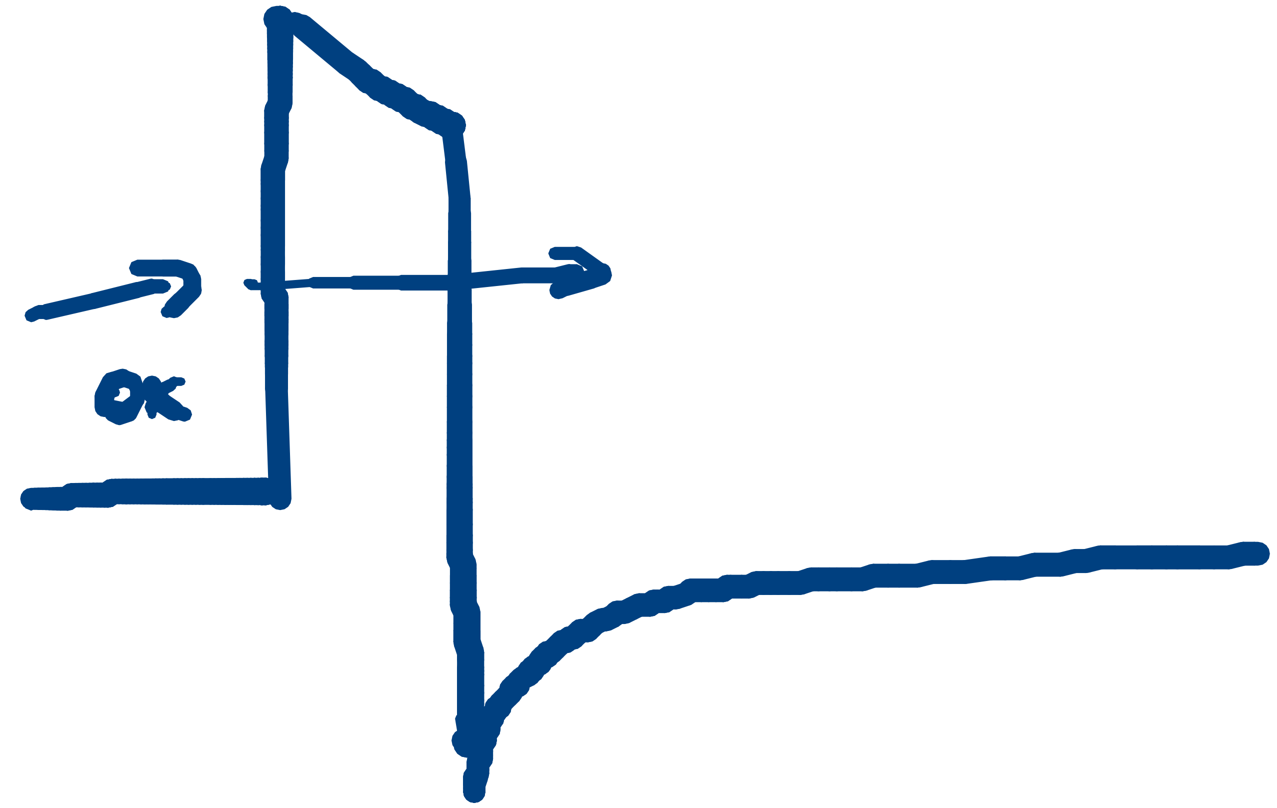
ox