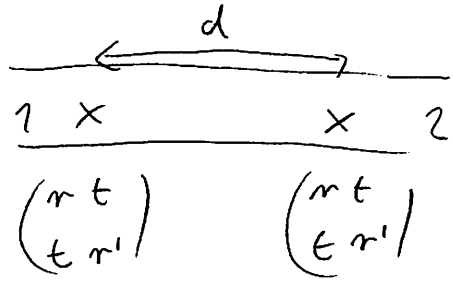
1.a)



označimo še:

$$T = |t_{1\to 2}|^2 \quad ; \quad |r|^2 = |r'|^2 =: R_1 \; , \; |t|^2 =: T_1$$

$$t_{1\to 2} = t\, e^{ikd}\, t + t\, e^{ikd}\, e^{2ikd}\, r r'\, t + \dots =$$

$$= \frac{t^2 e^{ikd}}{1 - r r' e^{2ikd}}$$

$$r = \sqrt{R_1}\, e^{i\ell_1} \qquad r' = \sqrt{R_1}\, e^{i\ell_2}$$

$$r r' = R_1\, e^{i\ell}$$

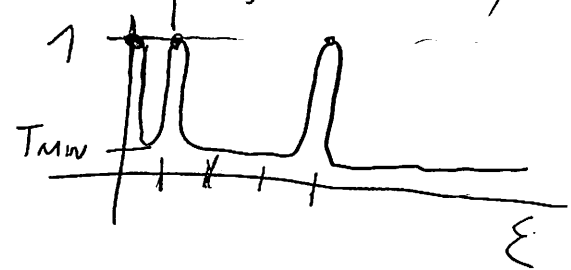
$$t_{1\to 2} = \frac{t^2 e^{ikd}}{1 - R_1 e^{i(\ell + 2kd)}} \Rightarrow$$

$$T = \frac{T_1^2}{1 + R_1^2 - 2R_1 \cos\left(\frac{\ell + 2kd}{2}\right)}$$

$\ell = 0 \dots \pm 2n\pi$ $\quad T_{MAX} = \dfrac{T_1^2}{(1 - R_1)^2} = 1 \qquad (1 - R_1 = T_1)$

$\ell = \pi \pm 2n\pi$

$$T_{MIN} = \frac{T_1^2}{(1 + R_1)^2} \approx \frac{T_1^2}{4} \quad (\text{za majhni } T_1)$$

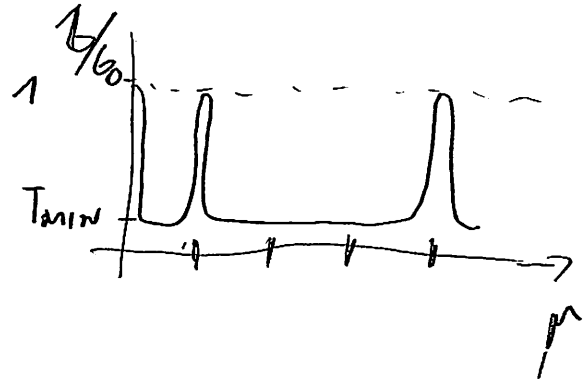


diskretna $\ell = 0$

$$\frac{\hbar^2 k^2}{2m} = \varepsilon \; , \; k \sim \sqrt{\varepsilon}$$

1 b) prevodnost je

$$G = G_0 T(r)$$



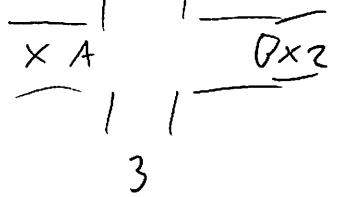
če $\ell \neq 0$, kvantizacija zamaknjena v smeri x

1 c)

$$T = T_1^2 + T_1^2 R_1^2 + \dots$$

$$= \frac{T_1^2}{1 - R_1^2} = \frac{T_1}{1 + R_1}$$

tak $G_0 \frac{T_1}{1+R_1}$ ✓



1 d) $I_2 = \sum G_{23} V_{13}$

$$G_{23} = G_0 \left(|S_{23}|^2 - S_{23} \right)$$

od 0 se razlikuje le naslednji elementi sipalne matrike S

$S_{1\to3} = t \cdot 1 = t$ $\quad S_{3\to4} = r$ $\quad S_{1\to1} = r$

$S_{3\to2} = t$ $\quad S_{4\to3} = r'$ $\quad S_{2\to2} = r'$

$S_{2\to4} = t$ in še faze, oblike e^{ikl},

$S_{4\to1} = t$ ki pa niso važne, ker so interferenčnih členov ni. 21

tok v voltmetru = 0

$$I_3 = G_0\left(|S_{1\to3}|^2 V_1 + |S_{4\to3}|^2 V_4 - V_3\right) = 0$$

$$I_4 = G_0\left(|S_{2\to4}|^2 V_2 + |S_{3\to4}|^2 V_3 - V_4\right) = 0$$

$$(e_1) \quad T_1 V_1 + R_1 V_4 - V_3 = 0$$

$$(e_2) \quad T_1 V_2 + R_1 V_3 - V_4 = 0$$

$$(e_1)\cdot R_1 + (e_2) \quad R_1 T_1 V_1 + R_1^2 V_4 - V_4 + T_1 V_2 = 0$$

$V_1 = V/2 + \mu/e$; izberem $\mu = 0$ (menim $V_1, \dots$ glede na μ/e)

$$V_1 = V/2 \qquad V_2 = -V/2$$

$$V_4 = \frac{R_1 T_1 V/2 - T_1 V/2}{1 - R_1^2} = \frac{V}{2}\frac{T_1(R_1 - 1)}{1 - R_1^2} = \frac{V}{2}\frac{T_1^2}{1 - R_1^2} \cdot (-1)$$

$R_1(e_1) + R_1(e_2)$: $V_3 = \frac{V}{2}\frac{T_1^2}{1 - R_1^2}$

pravilna limita: za $R_1 \to 0$, $T_1 \to 1$; $V_3 \to V/2$, $V_4 \to -V/2$

e) Tok skozi sistem

$$I_2 = G_0\left(|S_{3\to2}|^2 V_3 + \left(|S_{2\to2}|^2 - 1\right) V_2\right) =$$

$$= G_0\left(T_1 V_3 + (R_1 - 1) V_2\right) = G_0\left(T_1 V_3 - T_1 V_2\right)$$

$$= G_0 T_1 (V_3 - V_2) = G_0 T_1 \frac{V}{2}\left(\frac{T_1^2}{1 - R_1^2} + 1\right) = G_0 T_1 \frac{V}{2}\left(\frac{T_1 + 1 + R_1}{1 + R_1}\right)$$

$$= G_0 \frac{T_1}{1 + R_1} V$$; enako kot c)!

2. a) $\left(e^{iHt} N e^{-iHt}\right)^{\cdot} = i[H, N]$

$i\hbar \dot{N} = [N, H]$

$= -2ic + (-E_J)[N, \cos\varphi]$

$[N, \varphi^n] = n\varphi^{n-1}[-2i]$ (i)

$[N, AB] = A[N, B] + [N, A]B$

$[N, \varphi^{n-1}\varphi] = \varphi^{n-1}[N, \varphi] + [N, \varphi^{n-1}]\varphi$

iteriramo in delimo (i)

$[N, e^{i\varphi}] = [N, 1 + i\varphi + \frac{(i)^2\varphi^2}{2!} + \dots]$

$= i(-2i) + \frac{(i^2)(-2i)}{1!}\varphi + \frac{i^3(-2i)}{2!}\varphi^2 + \dots$

$= 2e^{i\varphi}$

podobno: $[N, e^{-i\varphi}] = -2e^{-i\varphi}$

(N deluje kot $\hat{N} = -2i\frac{\partial}{\partial\varphi}$, da velja $[\hat{N}, \hat{\varphi}] = -2i$)

$i\hbar\dot{N} = -2ic - E_J 2\,\frac{e^{i\varphi} - e^{-i\varphi}}{2} =$

$= -2ic - 2E_J i \sin\varphi$

$\dot{N} = -\frac{2c}{\hbar} - \frac{2E_J}{\hbar}\sin\varphi$

b) $e\dot{N} = \dot{Q} = I_{kr} + I_{sc} \Rightarrow$ $\frac{e(-2c)}{\hbar} = I_{kr} \Rightarrow c = \frac{I_{kr}\hbar}{2|e|}$

naboj/čas = tokovni izvir + tok v supeprevodni el.

2a) Krajše:

$$\hat{N} = -2i\frac{\partial}{\partial\varphi}$$

$$[\hat{N}, \cos\varphi] = -2i\left[\frac{\partial}{\partial\varphi}, \cos\varphi\right] = \text{predstavljam si delovanje na } \psi$$

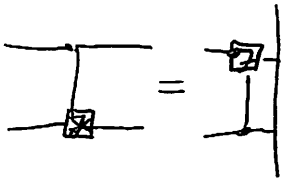
$$= -2i\left\{(-\sin\varphi + \cos\varphi\frac{\partial}{\partial\varphi}) - \cos\varphi\frac{\partial}{\partial\varphi}\right\}$$

$$= 2i\sin\varphi$$

$$i\hbar\dot{\hat{N}} = -2i(\quad - E_J\sin\varphi\,(2i)$$

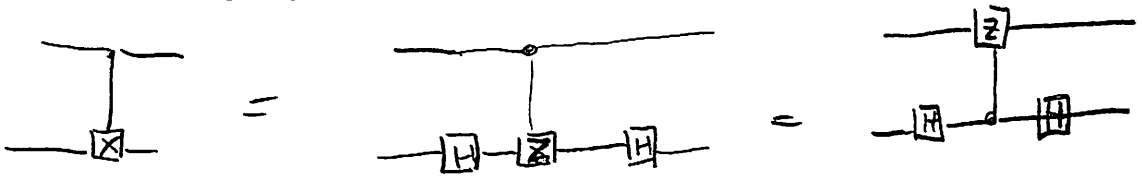
$$\dot{\hat{N}} = -\frac{2c}{\hbar} - \frac{2E_J}{\hbar}\sin\varphi$$

3. a) $c-z_{(1)}|bb'\rangle = (-1)^{b\cdot b'}|bb'\rangle = \begin{pmatrix} 1 & & & \\ & 1 & & \\ & & 1 & \\ & & & -1 \end{pmatrix}$



$= c-z_{(2)}$ (ako operaciji pomnožita z (-1), če ako kubita $|1\rangle$)

b) dve mejitvi



(ekvivalentni po rezultatu iz a)

dokaz: več manj patij, marveč je najhitreje matrično

$$H_{(2)} = \frac{1}{\sqrt{2}}\begin{pmatrix} 1 & 1 & & \\ 1 & -1 & & \\ & & 1 & 1 \\ & & 1 & -1 \end{pmatrix} \qquad c-z = \begin{pmatrix} 1 & & & \\ & 1 & & \\ & & 1 & \\ & & & -1 \end{pmatrix}$$

zgornji blok $^{2\times 2}$ in spodnji se ne mnejita

$$H_{(2)} \cdot c-z \cdot H_{(2)} = \begin{pmatrix} 1 & & & \\ & 1 & & \\ & & 0 & 1 \\ & & 1 & 0 \end{pmatrix}$$

$H = \frac{1}{\sqrt{2}}\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix} \qquad H^{\dagger} = \hat{1}$

$H\,\sigma_z\,H = \sigma_x$