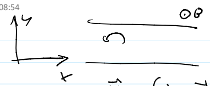
Nanofizika-Kvantni Hallov pojav

petek, 20. marec 2020 08:54



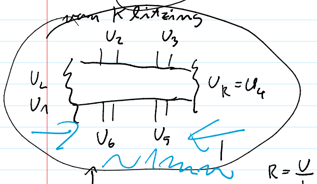
$$\begin{pmatrix} E_x \\ E_y \end{pmatrix} = \underline{\underline{\rho}} \begin{pmatrix} j_x \\ j_y \end{pmatrix}$$

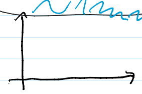
$$\vec{F} = e(\vec{v} \times \vec{B} + \vec{E})$$

$$\underline{\underline{\rho}} = \begin{bmatrix} \rho_{xx} & \rho_{xy} \\ \rho_{yx} & \rho_{yy} \end{bmatrix} =$$

$$\rho_{xx} = \frac{m}{ne^2 \tau} \qquad -\rho_{xy} = \rho_{yx} = \frac{B}{n|e|}$$

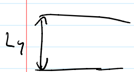
von Klitzing





$R = \frac{U}{I}$

$R_H = \frac{(U_2 - U_6)}{I}$



$I = j_x L_y$

$U = -E_y L_y$

$R_H = U/I = \frac{-E_y \cancel{L_y}}{j_x \cancel{L_y}}$

Klasični napoved $R_H = B/n|e|$

$$R_L = \frac{U_6 - U_5}{I}$$

$$\boxed{R_H = \frac{h}{2e^2 m} \qquad m \in \mathbb{N}}$$

$$\frac{h}{e^2} = 25.8128075(5)$$

$$\frac{e^2}{4\pi\varepsilon_0 \hbar c} = \frac{e^2 \mu_0 c}{4\pi\hbar} = \frac{e^2}{2h}\mu_0 c$$

$$c^2 = \frac{1}{\varepsilon_0 \mu_0}$$

$$1/\varepsilon_0 = \mu_0 c^2$$

anomalni (g-2) mag. moment

Kako pride do kvantizacije?

$$\frac{(\vec{p} - e\vec{A})^2}{2m} \psi = E\psi$$

$$\vec{A} = B(-y, 0, 0) \qquad \vec{B} = \operatorname{rot} \vec{A} = (0, 0, B)$$

$$\frac{1}{2m}\left[\left(-i\hbar\frac{\partial}{\partial x} + eBy\right)^2 - \hbar^2\left(\frac{\partial}{\partial y}\right)^2\right]\psi = E\psi$$

$$\psi(x,y) = e^{ikx}\chi(y)$$

$$\frac{1}{2m}\left[(\hbar k + eBy)^2 - \hbar^2 \frac{\partial^2}{\partial y^2}\right]\chi(y) = E\chi$$

$$\left\{\frac{e^2B^2}{2m}\left[(y - y_k)^2\right] - \frac{\hbar^2}{2m}\frac{\partial^2}{\partial y^2}\right\}\chi = E\chi$$

$$y_k = \frac{-\hbar k}{eB}$$

mag. dolžina $\quad l_B^2 = \frac{\hbar}{|eB|}$

$$m v^2 = \hbar \omega_c$$

$$m \omega_c^2 r^2 = \hbar \omega_c \qquad \omega_c = \frac{|eB|}{m}$$

$$l_B^2 := r^2 = \frac{\hbar \omega_c}{m \omega_c^2} = \frac{\hbar \cancel{m}}{\cancel{m}|eB|}$$

$$\boxed{\frac{\hbar\omega_c}{2}\left[\frac{(y-y_k)^2}{l_B^2} - l_B^2\frac{\partial^2}{\partial y^2}\right]\chi = E\chi}$$

har. oscilator

$$\boxed{\chi_{nk}(y) = \mathcal{H}_n\left(\frac{y-y_k}{l_B}\right) e^{-\frac{(y-y_k)^2}{2l_B^2}}} \qquad \boxed{E = \hbar\omega_c\left(n+\frac{1}{2}\right)}$$

$$\boxed{\psi = \chi_{nk}\, e^{ikx}}$$

$\neq f(k)$ $\qquad l_B^2 = \frac{\hbar}{|eB|}$

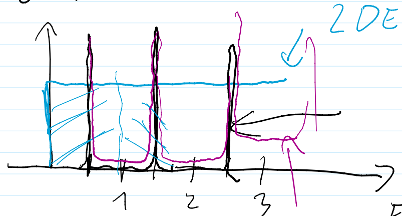
$l_B \sim 10\,nm$ pri $1T$

Landauovi nivoji

$g(\varepsilon)$

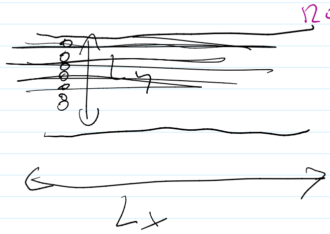
2DEG $\quad \frac{m}{\hbar^2\pi} \quad g(\varepsilon) = \frac{N}{S}$

$\frac{m}{\hbar^2\pi}(\hbar\omega_c)$



$E/\hbar\omega_c$

ZARADI ROBNIH STANJ



e^{ikx}

$\Delta k = \frac{2\pi}{L_x}$

$\Delta y = \frac{\hbar\Delta k}{|eB|}$

$$N = \frac{L_y}{\Delta y} = \frac{L_y|eB|}{\hbar\,\Delta k} = \frac{\overbrace{L_y L_x}^{S}|eB|}{2\pi\hbar} = \frac{m\omega_c}{2\pi\hbar}S = \frac{m(\omega_c\hbar)}{2\pi\hbar^2}S \cdot 2$$

$$N = 2\frac{BSe}{h} = 2\frac{\Phi}{\Phi_0}$$

spin $\qquad$ kvant mag. pretoka

grupna hitrost

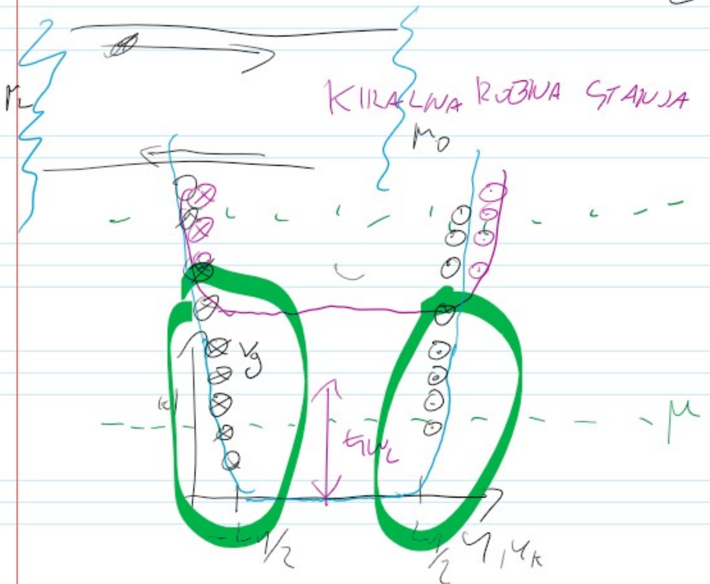
$V = \frac{\partial E}{\partial k} = 0$

potencial zaradi robov

$$E \doteq \hbar\omega_c\left(n+\frac{1}{2}\right) + \langle\psi_{nk}|V(y)|\psi_{nk}\rangle$$

$$\boxed{E \doteq \hbar\omega_c\left(n+\frac{1}{2}\right) + V(y_k)}$$

$$v_g = \frac{1}{\hbar}\frac{\partial E}{\partial k} = \frac{1}{\hbar}\frac{\partial V}{\partial y_k}\frac{\partial y_k}{\partial k} = \boxed{\frac{1}{\hbar}\frac{\partial V}{\partial y_k}\cdot\left(-\frac{\hbar}{eB}\right)}$$



Nielsen – Ninomiya

Sipanje ni mogoče, ker sta $+v_g$ $-v_g$

Imam narazen bulk stanja pa so pri drugi energiji

$$I = 2e\int \frac{dk}{2\pi} v_g (f_L - f_0) = 2e\int \frac{dk}{2\pi}\frac{1}{\hbar}\frac{dE}{dk}(f_L - f_0)$$

$$= 2\frac{e}{h}\int dE\,(f_L - f_0)$$

$T = 1$

$$\boxed{I = \frac{2e^2}{h}(V_L - V_0)\,M}$$

Samo $n=0$ prispeva

M – število zasedenih Landauovih nivojev