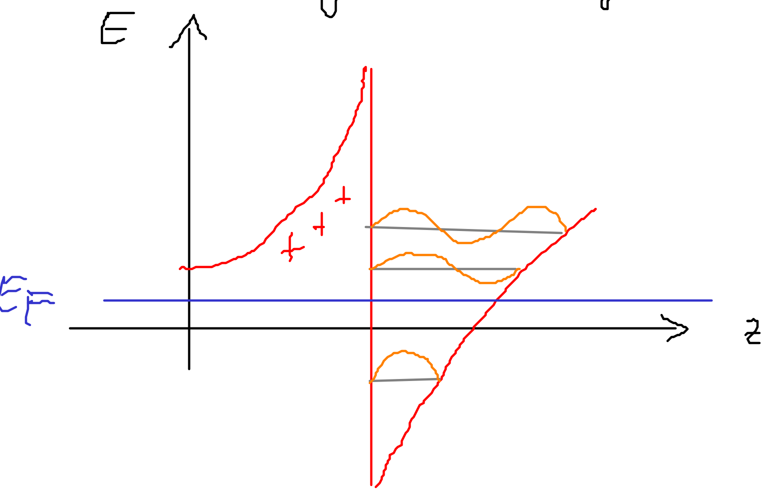
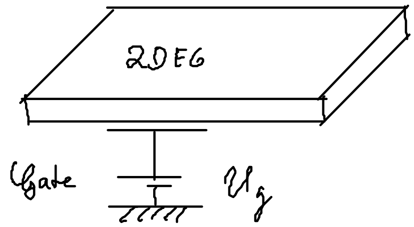
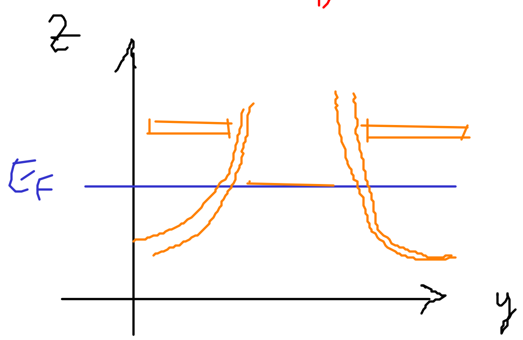
Niederdimensionale Elektronensysteme

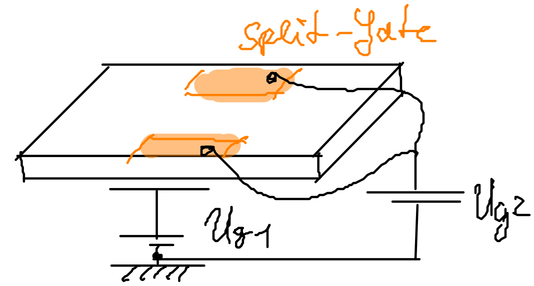
- Beweglichkeit $\mu = \frac{|\bar{v}|}{|\bar{E}|} = \frac{e\tau}{m}$ AlGaAs/GaAs $\mu \sim 10^7 \frac{cm^2}{Vs}$ (T<10K)
- Quantisierung in z-Richtung $L_z \sim \frac{\lambda_F}{2} \sim 10\,nm$





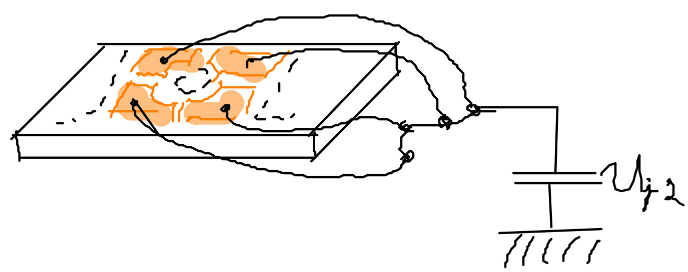


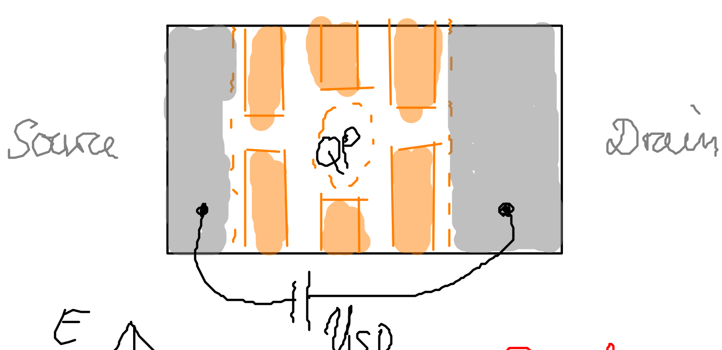
1D

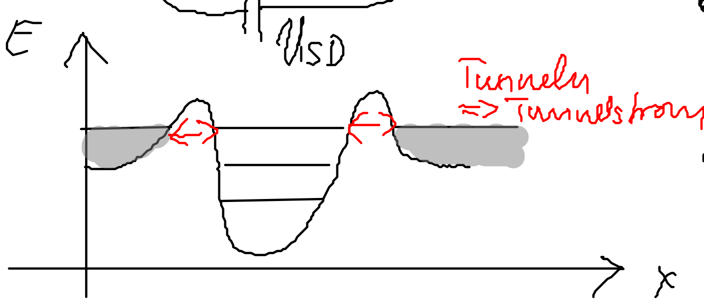


Quantenpunkte

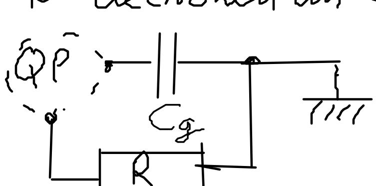
0D







N Elektronen im QP



- Leitwert $G = \frac{I}{U_{SD}}$
- Elektrostatische Energie

$$E(N) = \frac{(Ne)^2}{2C} - \varphi Ne \quad \text{mit } C \approx C_g$$

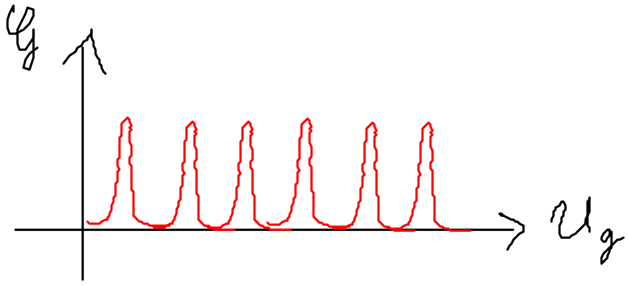
- Tunneln bei der Spannung U_g

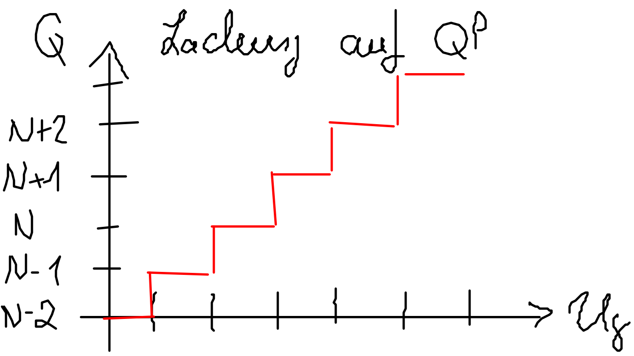
$$E(N+1) = E(N)$$

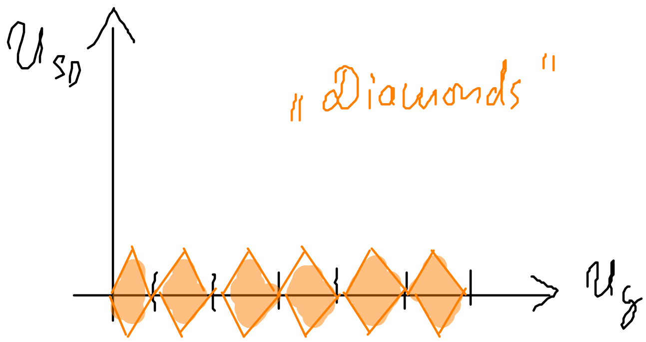
$$(2N+1)e^2 = 2C_g e U_g$$

$$\boxed{U_g = \left(N+\frac{1}{2}\right)\frac{e}{C_g}}$$

Coulomb-Blokade







- Entladung des Kondensators

$\delta t \sim RC$

$$\delta E = \frac{\hbar}{\delta t} \sim \frac{e^2 \hbar}{C\, e^2}\,\frac{1}{R} = \frac{e^2}{C}\,\frac{R_Q}{R}$$

- Quantenwiderstand

$$\boxed{R_Q = \frac{h}{e^2} = 25{,}813\ k\Omega}$$

- Bedingungen für Coulomb-Blockade

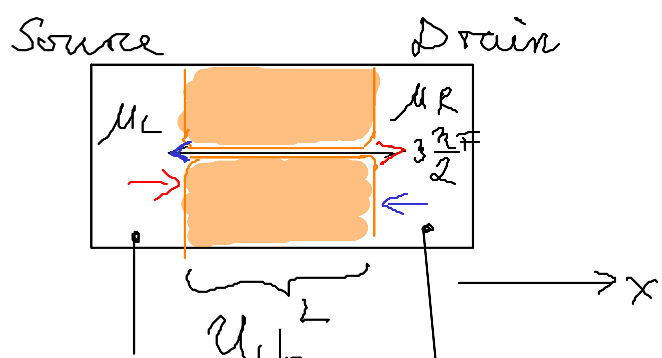
$k_B \ll \frac{e^2}{C}$; $R \gg R_Q = \frac{h}{e^2}$

⇒ einzel Elektron Transistor

single-electron-transistor (SET)
tunneling

1D: Quantendraht /Ballistic quantum wires /Quantum point contacts

- Eindimensionaler Leiter



$$I = n^{1D} e \langle v \rangle \qquad v(k) = \frac{1}{\hbar}\frac{\partial E}{\partial k}$$

$$= \frac{1}{L}\sum_k e\, v_k \qquad \rho_k^{1D} = \frac{2L}{2\pi}$$

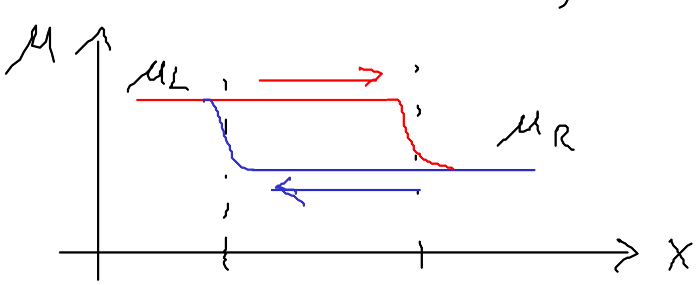
$$= \frac{1}{L}\int dk\, \rho_k^{1D}\, e\, v(k) \left(f\left(E+\frac{eU}{2}\right) - f\left(E-\frac{eU}{2}\right)\right)$$

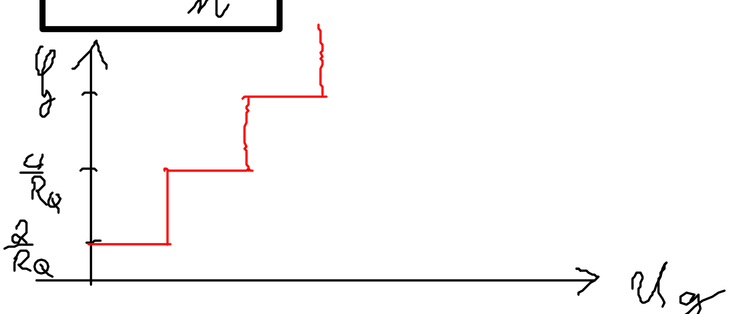
$$= \frac{1}{\pi} e \int dk\, \frac{\partial E}{\partial k}\, eU$$

$$= \frac{2e^2}{h}\, U$$

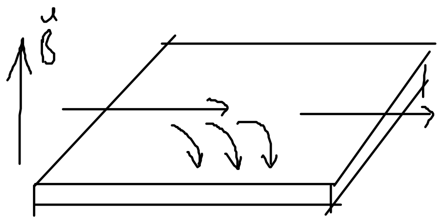
$$\boxed{G = \frac{2e^2}{h}}$$

- elektrochemisches Potential μ





Hall-Effekt



$$m\dot{\vec{v}} = -e(\vec{\mathcal{E}} + \vec{v} \times \vec{B}) - \frac{m\vec{v}}{\tau}$$

$$v_x = -\frac{e\tau}{m}(\mathcal{E}_x + v_y B)$$

$$v_y = -\frac{e\tau}{m}(\mathcal{E}_y - v_x B)$$

mit $j_{x,y} = -env_{x,y}$

$$\begin{pmatrix} \mathcal{E}_x \\ \mathcal{E}_y \end{pmatrix} = \begin{pmatrix} \rho_{xx} & \rho_{xy} \\ \rho_{yx} & \rho_{yy} \end{pmatrix} \begin{pmatrix} j_x \\ j_y \end{pmatrix}$$

- für isotrope Materialien $\rho_{xx} = \rho_{yy} = \frac{m}{ne^2\tau}$ $\quad \rho_{xy} = -\rho_{yx} = \frac{B}{ne}$