Übungen 36-41
Dienstag, 28. November 2023 14:40

37 Bahnen im Magnetfeld

a) Kreisbahn: klassischer Radius

Zentripetalkraft = Lorentzkraft

$$m_e \frac{v^2}{R} = e v B \qquad v = v_F \qquad \text{(Stösse ignoriert)}$$

$$\Rightarrow \boxed{R = \frac{m_e v_F}{e B}}$$

Cu $\quad v_F = \sqrt{\frac{2E_F}{m_e}} = 1.57 \times 10^6 \frac{m}{s}$

$B = 5\,T$

$$R = 1.8 \times 10^{-6}\,m$$

Zyklotronfrequenz $\quad \omega_c = 2\pi \frac{v_F}{2\pi R} = \frac{v_F}{R} = 8.8 \times 10^{11}\,s^{-1}$

$$= v_F \frac{eB}{m_e v_F} = \frac{e}{m_e} B$$

b) Kreisbahn im realen Kristall?

Zeit $\quad$ Periode $T = \frac{2\pi}{\omega_c} < \tau = \frac{l_{imp}}{v_F}$ $\quad$ Stosszeit $\quad$ mittl. freie Weglänge

Messung l_{imp} $\Rightarrow$ el. Widerstand ohne Phononen $(T=0)$

$\Rightarrow$ Restwiderstand

$$\tau^{-1} \sim \rho_0 = \rho(T=0) = \frac{v_F}{l_{imp}} \frac{m_e}{e^2 n_e} = \boxed{5.8 \times 10^{-11}\,\Omega m}$$

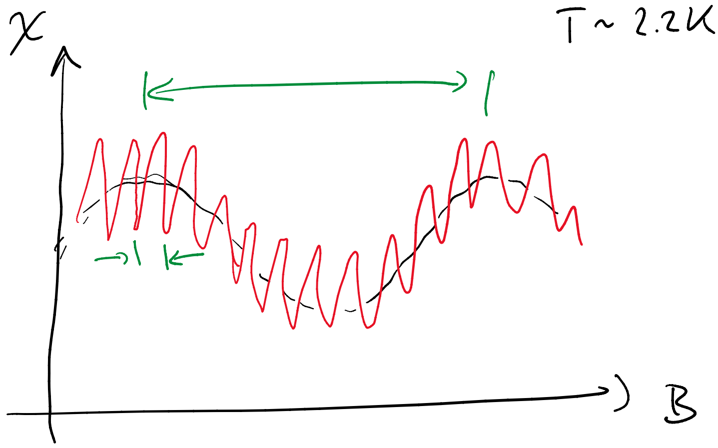
$$l_{imp} \sim 11\,\mu m = 2\pi R$$

typ. $\rho_{Cu} \sim 10^{-8}\,\Omega m$ $\quad \Rightarrow$ sehr reine Kristalle!

typ. $l_{imp} \sim 100\,nm$ bei $T \to 0$

38 $\quad \chi$ $\quad$ $T \sim 2.2\,K$

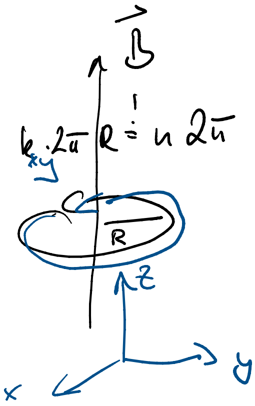
38



e^-: $\Psi_0 = u_k(\vec r) \cdot e^{i\vec k \cdot \vec r}$ Bloch-Zustand.

Kreisbahn mit ω_c $\Rightarrow$ Ψ Phase $\Psi_0 \cdot e^{\boxed{ik \cdot 2\pi R}}$ pro Umlauf

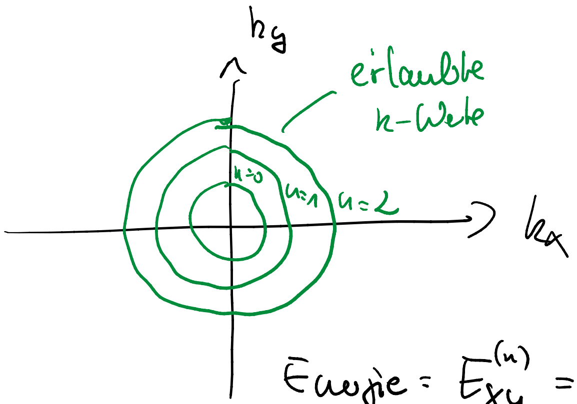
$\overset{!}{=} \Psi_0$

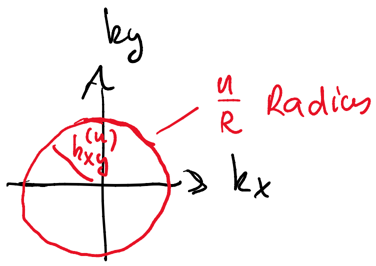


$k_{xy} \cdot 2\pi R \overset{!}{=} n\, 2\pi$

Quantisierungsbedingung $k_{xy}^{(n)} = \frac{n}{R}$

nur diese k-Werte erlaubt!

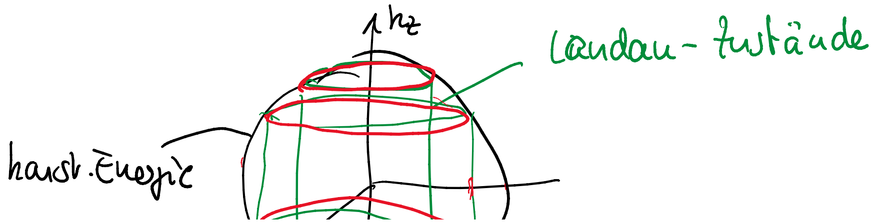


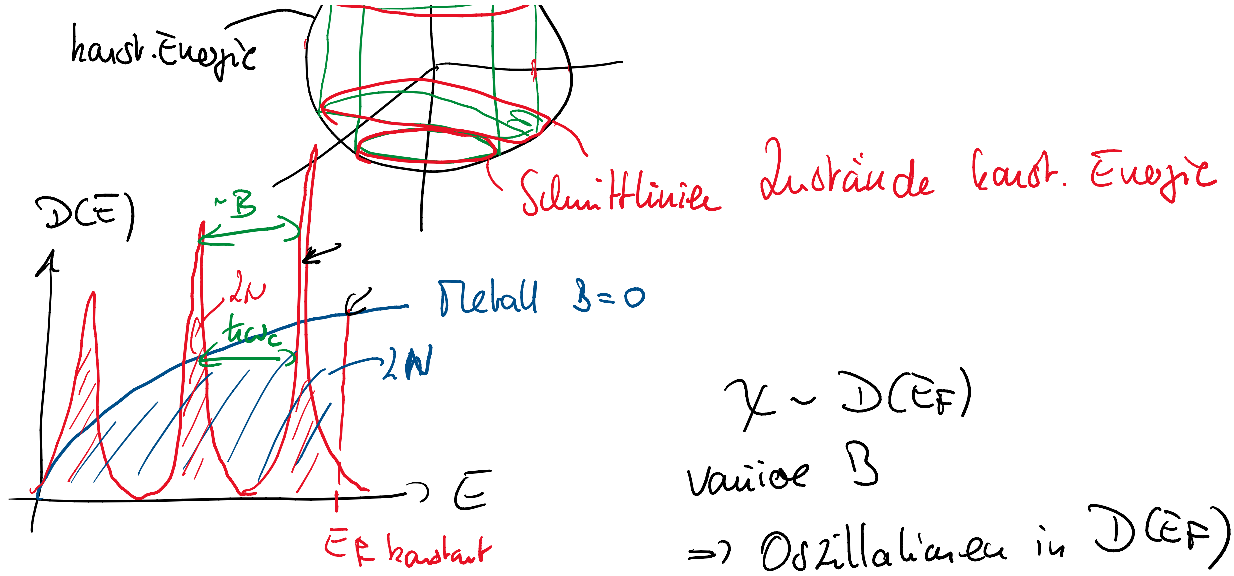


Energie: $E_{xy}^{(n)} = \frac{\hbar^2 k_{xy}^{(n)2}}{2m} = \hbar\omega_c \left(n + \frac{1}{2}\right)$ Nullp.-schw.

$$E(\vec k) = E(\underset{\parallel \vec B}{k_z}, \underset{\perp \vec B}{n}) = \underline{\underline{\frac{\hbar^2 k_z^2}{2m_e}}} + \hbar\omega_c \left(n + \frac{1}{2}\right)$$

Erlaubte Zustände: Schnittlinien Zylinder + Fermi-Kugel





$\chi \sim D(E_F)$

variiere B

$\Rightarrow$ Oszillationen in $D(E_F)$

de Haas-van Alphen-Effekt

$\Rightarrow$ maximales Signal wenn $k_{xy}^{(n)} = k_F \Rightarrow \boxed{E_F} = \frac{\hbar^2 k_F^2}{2m}$

Oszillation periodisch in $\frac{1}{B}$

$$\frac{1}{B^2}\cdot\delta(B) = \delta\left(\frac{1}{B}\right) = \frac{e\hbar}{mE_F} = 2.2\times 10^{-5}\ T^{-1}$$

Periode

$\Rightarrow$ $\underline{E_F = 5.23\ \text{eV}}$ (Lit. 5.51 eV)

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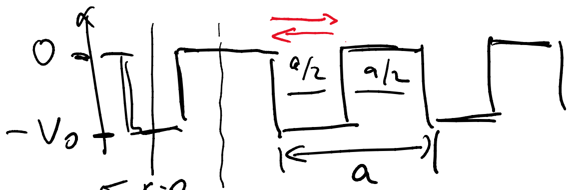
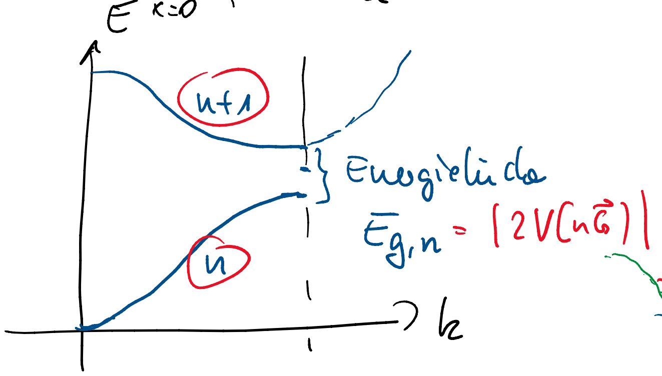
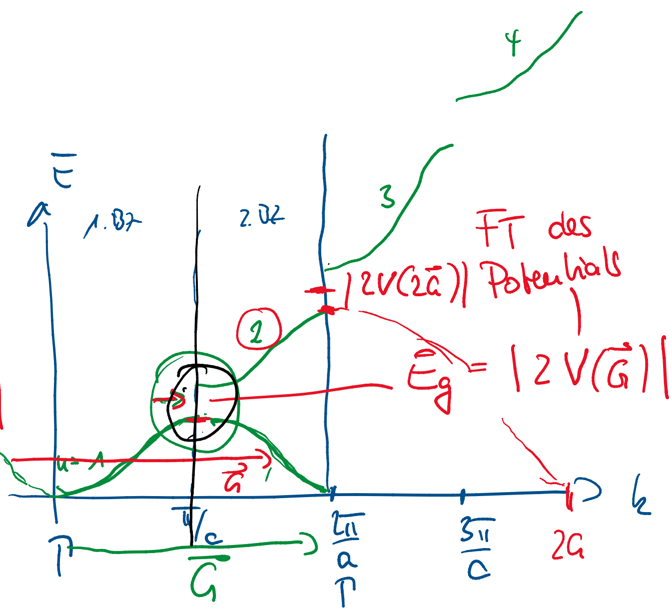
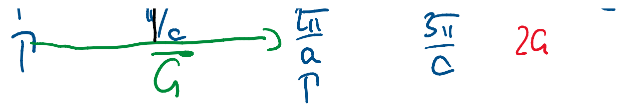
39 Kronig-Penney-Modell — Periodische Kastenpotentiale









$$V(x) = \begin{cases} -V_0 & -a/4 \le x \le +\frac{a}{4} \\ 0 & \text{sonst} \end{cases}$$

$$\Rightarrow \quad V_n = \frac{1}{a} \int_{-a/2}^{a/2} V(x)\, e^{inGx}\, V_n \qquad\qquad G = \frac{2\pi}{a}$$

$$= -\frac{V_0}{a} \frac{1}{inG} \left[e^{inG\frac{a}{4}} - e^{-inG\frac{a}{4}} \right] \qquad\qquad G\frac{a}{4} = \frac{\pi}{2}$$

n gerade $\Rightarrow nG\frac{a}{4} = m\pi \Rightarrow V_{2m} = 0 = V_n$

n ungerade $\Rightarrow e^{in\frac{\pi}{2}} = -e^{-in\frac{\pi}{2}} = \pm i$

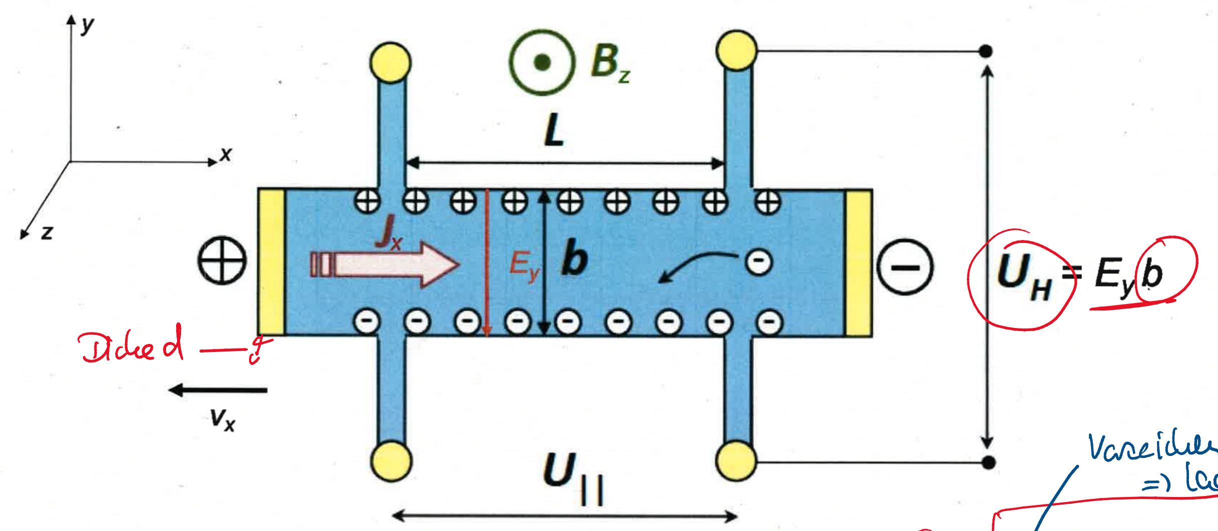
$$\Rightarrow \quad V_n = \mp \frac{V_0}{n\pi} \quad \Big\} \quad E_{gap} = |2V_n| = \begin{cases} \frac{2V_0}{n\pi} & n \text{ ungerade} \\ 0 & n \text{ gerade} \end{cases}$$

40

35 - Hall Effekt

Donnerstag, 30. November 2023 12:49

Hall Effekt im Magnetfeld:



Vorzeichen
=> Ladungsträgerart

$$R_H = \frac{E_y}{j_x B_z} = \boxed{-\frac{1}{|e| n_e} = R_H}$$

$$j_x = \frac{I}{b \cdot d}$$

$$E_y = \frac{U_H}{b}$$ Hall-Feld

B_z bekannt

Cu-Probe

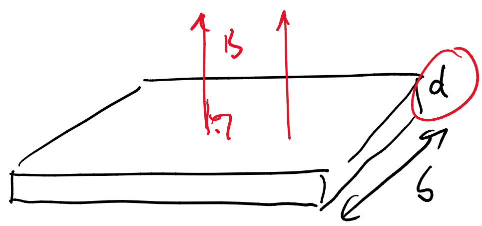
$n_e = 8.47 \times 10^{28}\ cm^{-3}$

$I = 10\,A$ $B_z = 5T$

$b = 1mm$
$d = 0.1\ mm$

$$U_H = E_y \cdot b = \frac{I B \cancel{b}}{e n_e \underbrace{\cancel{b} \cdot d}_{A}}$$

- U_H max wenn d klein ist

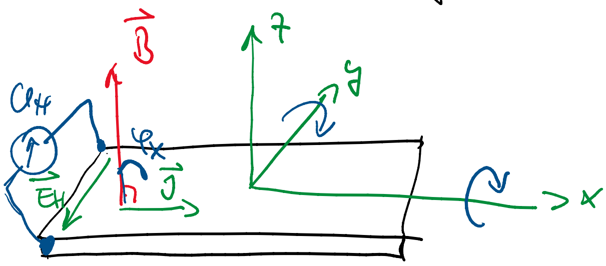


$$U_H = \underline{\underline{37 \mu V}}$$

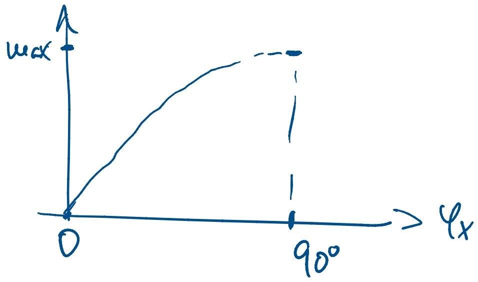
Was passiert wenn Probe gedreht wird? U_H?

$\vec{n}$ z

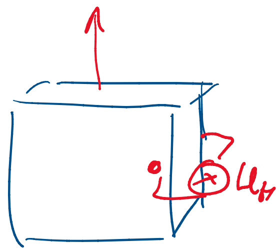
Was passiert wenn Probe gedreht wird! U_H!



Rot um X



$U_H \sim \sin \varphi_x$

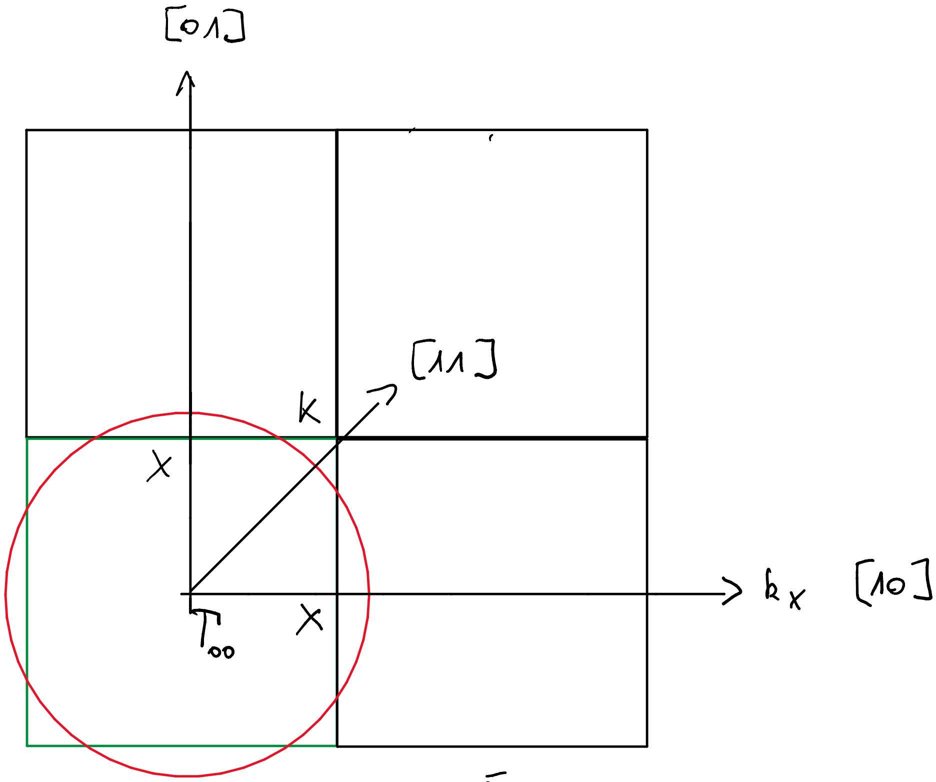


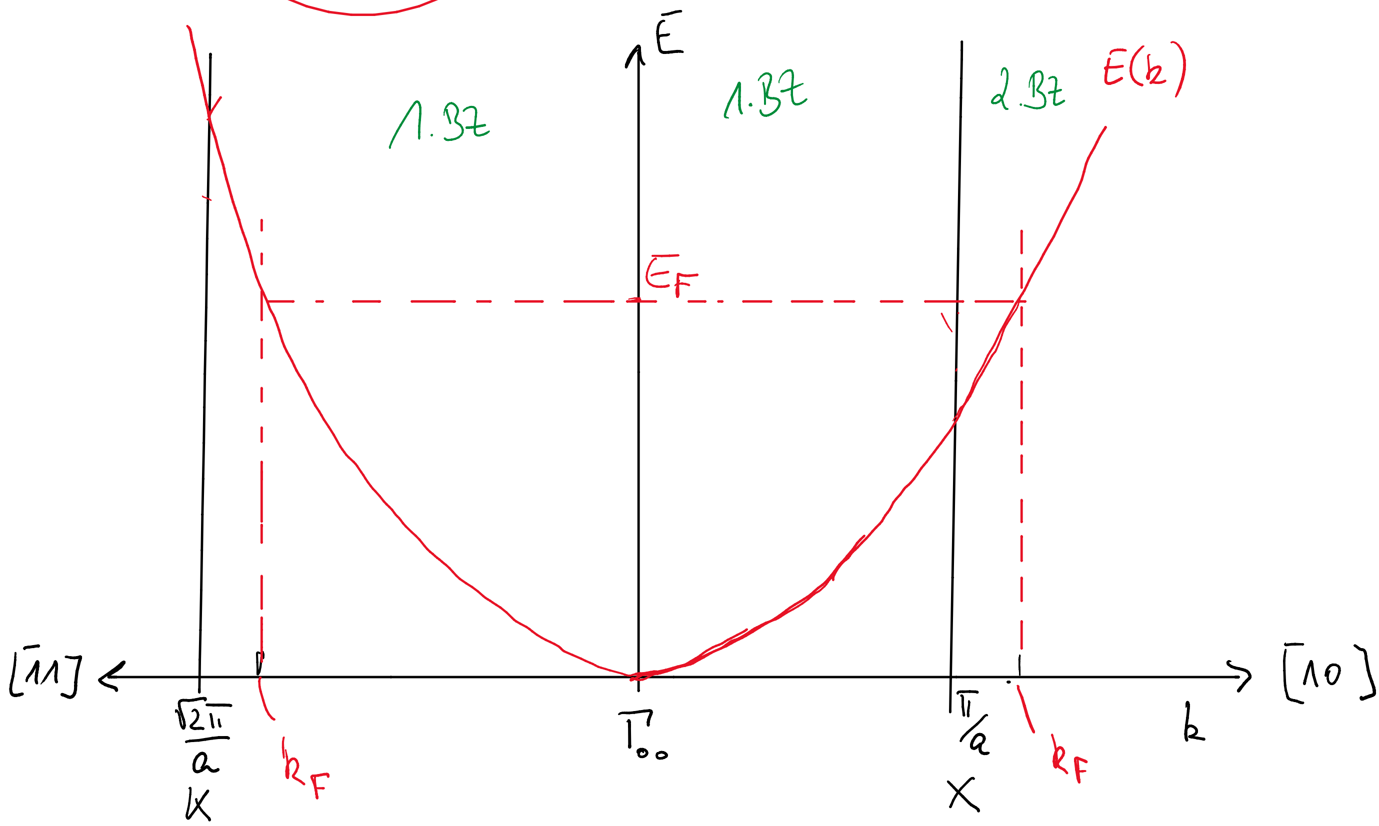
Rot um y 〃 weil $U_H \sim |\vec{v} \times \vec{B}| = |\vec{j} \times \vec{B}|$

Rot um z U_H konstant

40 - without potential

Dienstag, 28. November 2023 14:40





40 - with periodic potential

Dienstag, 28. November 2023 14:40