# Vorlesung 19

Physik II

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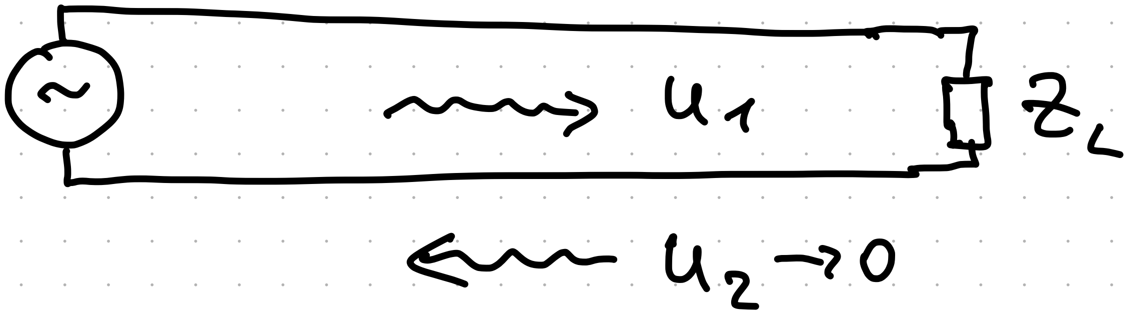
SS 2020

# Impedanzanpassung

$Z_0 = \sqrt{\frac{L_0}{C_0}}$ ; typ. $Z_0 = \underset{\sim}{50\,\Omega}$ oder $75\,\Omega$;

$Z_0 < Z_V = 377\,\Omega$;



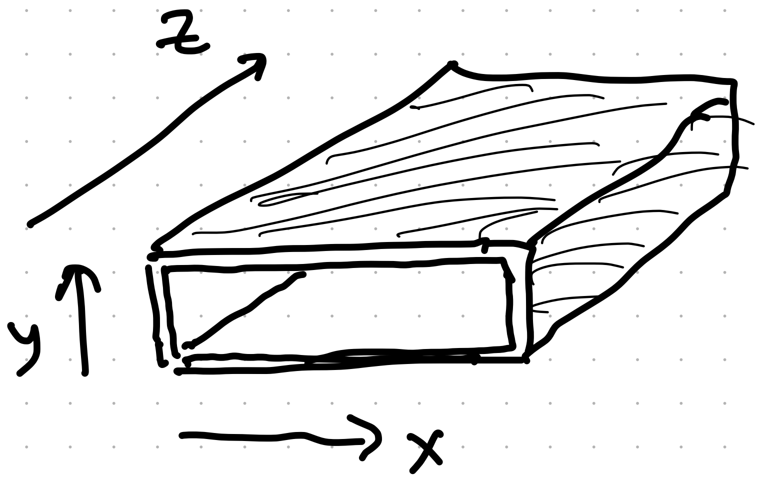

"L" load

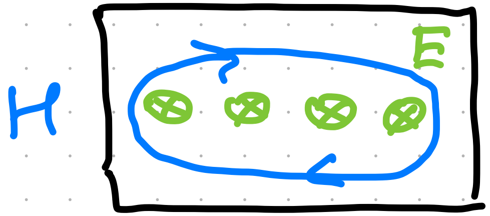
$$\Gamma_{TL} = \frac{Z_L - Z_0}{Z_L + Z_0}$$

Reflexionskoeffizient

Anpassung : $Z_Z = Z_0$ ;

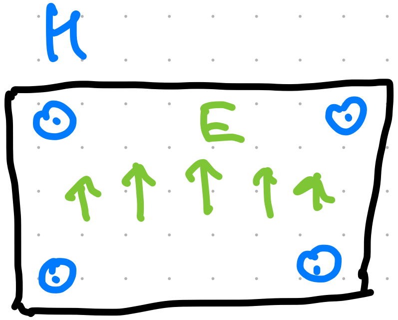
# Wellenleiter (Hohlleiter)




TH oder E-Wellen

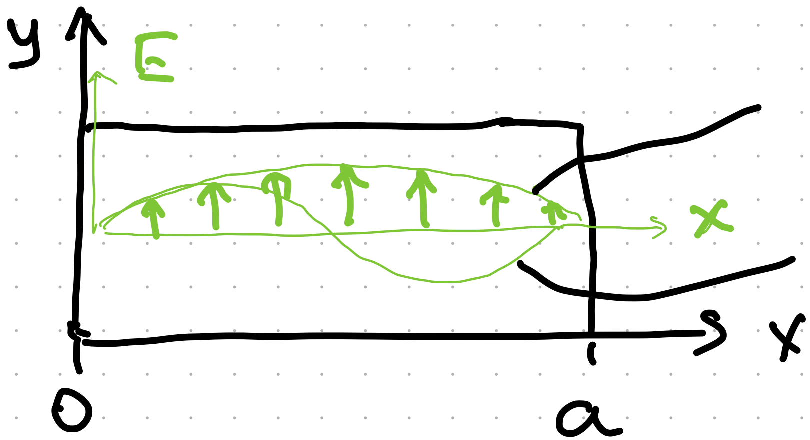
(transvers. $\vec{H}$)




TE oder H-Wellen

(tranv. $\vec{E}$)

Randbedingungen: $E_\tau = 0$; $H_n = 0$;




$H_{20}$

$H_{10}$: $\frac{\lambda}{2}$ entlang $x$;

0 entlang $y$;

$$\frac{\partial^2 E}{\partial t^2} = \frac{c^2}{\underbrace{\varepsilon\mu}_{=1}} \left( \frac{\partial^2 E}{\partial x^2} + \frac{\partial^2 E}{\partial y^2} + \frac{\partial^2 E}{\partial z^2} \right);$$

$$E = E_y = E_0 \sin k_x x \cdot \cos(\omega t - k_z z)$$

$$-\omega^2 \cancel{E_y} = -c^2 (k_x^2 + k_y^2) \cancel{E_y};$$

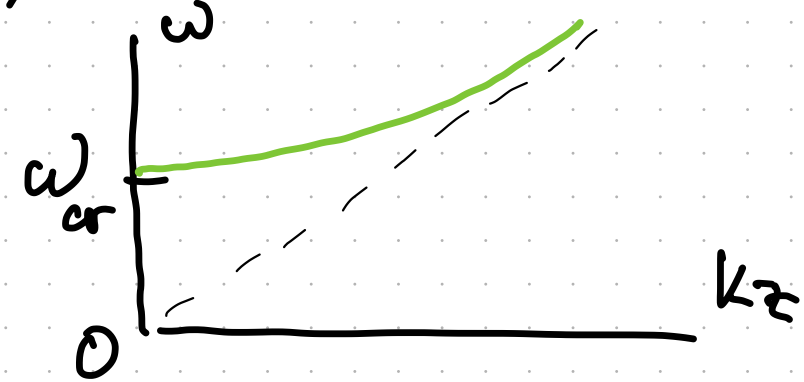
Dispersionsgleichung: $\omega^2 = c^2 (k_x^2 + k_z^2);$

für $H_{10}$, $n = 1$; $\quad k_z = \sqrt{\frac{\omega^2}{c} - \left(\frac{\pi}{a}\right)^2}$

$$= \frac{1}{c}\sqrt{\omega^2 - \omega_{cr}^2};$$

$\omega_{cr} = \frac{\pi c}{a}$; (cut-off)

$$\omega^2 = \omega_{cr}^2 + k_z^2 c^2;$$



# 6. Elektrodynamik der Kontinua

Maxwell-Gleichungen in Materie mit der freien Ladungsdichte $\rho_{el}$ und die Stromdichte $\vec{j}$ :

[SI]
$$\begin{cases} \nabla \cdot \vec{D} = \rho_{el} \; ; \\ \nabla \times \vec{E} = -\dfrac{\partial \vec{B}}{\partial t} \; ; \\ \nabla \cdot \vec{B} = 0 \; ; \\ \nabla \times \vec{B} = \mu\mu_0 \left( \vec{j} + \dfrac{\partial \vec{D}}{\partial t} \right) ; \end{cases}$$

elektrische Suszeptibilität

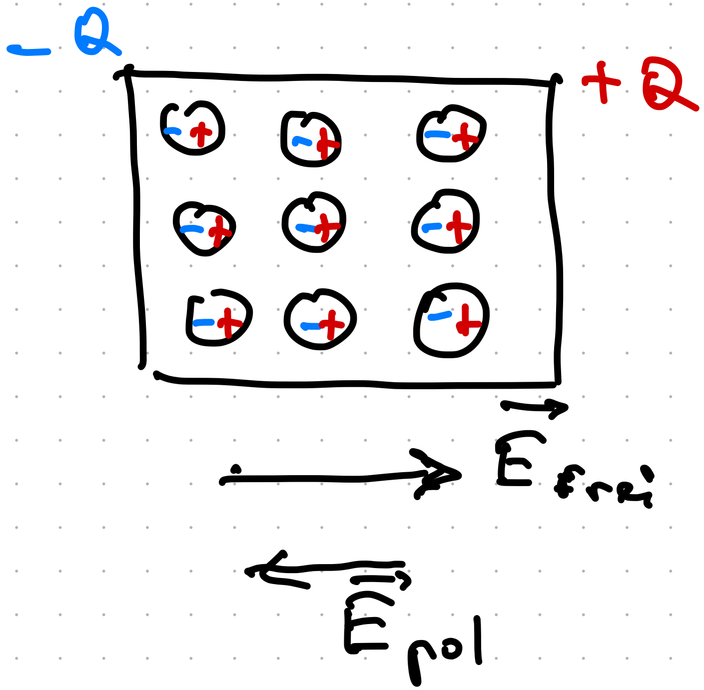
$$\vec{D} = \varepsilon\varepsilon_0 \vec{E} = \varepsilon_0 \vec{E} + \underbrace{\vec{P}}_{\text{Verschiebungspolarisation}} = \varepsilon_0 \overbrace{(1 + \chi_e)}^{\varepsilon} \vec{E} \; ;$$

Im Materie: $\vec{E}_\Sigma = \vec{E}_{frei} + \vec{E}_{pol}$; (Vor. 5)

$\vec{P}_E = \alpha \vec{E} \cdot N$; die Zahl der Dipole pro $m^3$;

Polarisierbarkeit

Polarisationskonstante




Optik: $\mu \approx 1$

Magnetisierung:

$$\vec{B} = \mu_0 (\vec{H} + \underbrace{\vec{M}}) = \mu\mu_0 \vec{H};$$

Magnetische Suszeptibilität

$$\vec{B} = \mu_0 \underbrace{(1 + \chi_m)}_{\mu} \vec{H};$$

$n = \sqrt{\varepsilon\mu}$; $\tilde{c} = \frac{c}{n}$

$\mu = 1$ ; $n \simeq \sqrt{\varepsilon}$ ; frequenzen $\sim 10^{15}$ Hz

$$n^2 = \varepsilon = 1 + \chi_e = 1 + \frac{P}{\varepsilon_0 E} ; \quad P = n_0 e x ;$$

$n_0$ – Atomdichte

$x$ – Verschieb. des Elektr. unter E-feld EM Welle

$$n^2 = 1 + \frac{n_0 e x}{\varepsilon_0 E} ;$$

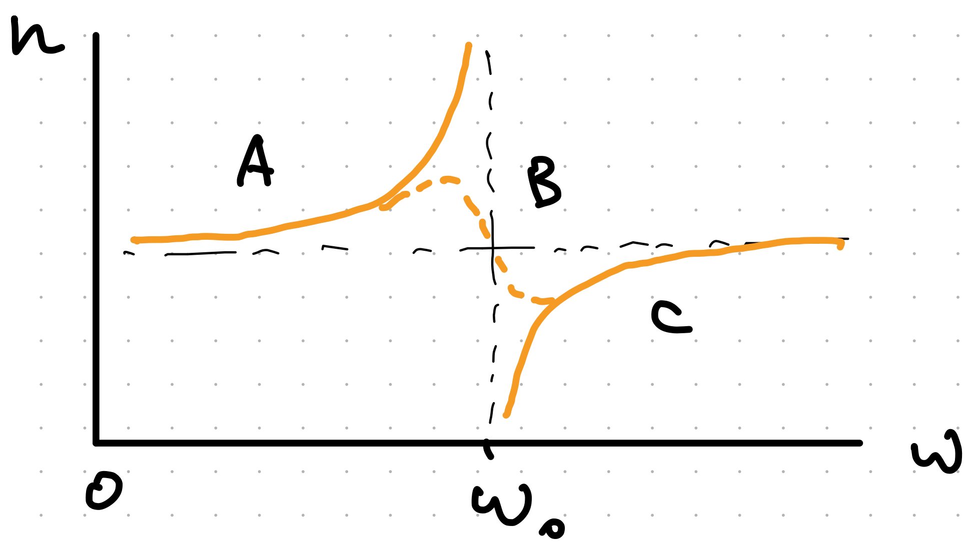
$E = E_0 \cos\omega t$ ; ohne Dämpfung:

$$\ddot{x} + \omega_0^2 x = \frac{F_0}{m} \cos\omega t = \frac{eE}{m} \cos\omega t ;$$

$\omega_0 = \sqrt{\frac{k}{m}}$ ; $m$ – Elektronmasse ;

Ansatz : $x = A \cos\omega t$ ; $A = \frac{eE_0}{m(\omega_0^2 - \omega^2)}$ ;

$$\Rightarrow n^2_{(\omega)} = 1 + \frac{n_0 e^2}{\varepsilon_0 m} \cdot \frac{1}{\omega_0^2 - \omega^2} ;$$




$A, C : \frac{dn}{d\omega} > 0$ ;

normale dispersion

$B : \frac{dn}{\omega} < 0$ ;

anomale dispersion

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Magn. Materialien : Dia-, Para-, Ferro-Magneten

M

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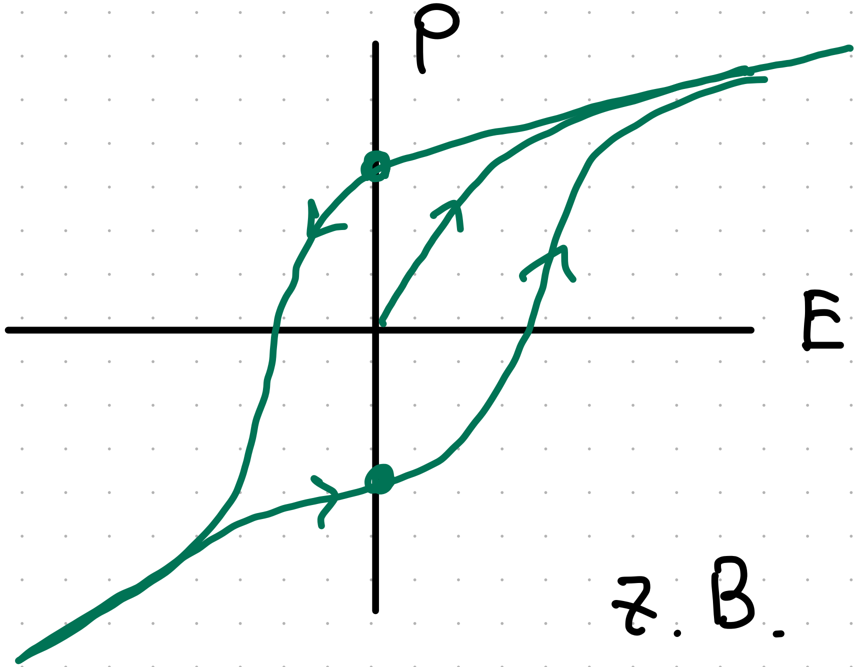
Elektr. Materialien : Verschiebung verschied. Ionen im Kristallgitter ⇒ spontanen Polarisation

⇝ Anlegen einer äußeren Spannung : ungepolt

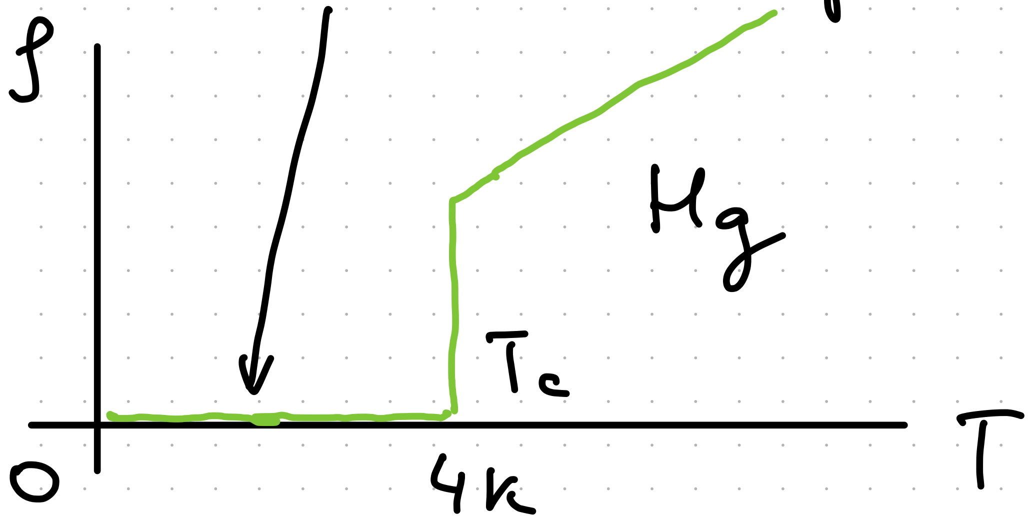



Hysteresekurve zufolge Ferroelektrizität

z.B. $BaTiO_3$ oder $LiNbO_3$

## Supraleitung

1911 Kamerlingh-Ohnes




| | | |
|---|---|---|
| Flussige: | $O_2$ | 90 K |
| | $N_2$ : | 77 K |
| | $H_2$ : | 20 K |
| | $^4He$ : | 4,2 K |

Supraleiter : Pb, Nb, Al, Sn

7 K   9 K   1 K   4 K

$\rho < 10^{-24}\ \Omega\cdot\text{cm}$

$\equiv 0$

1987 : high-$T_c$ superconductor

$YBa_2Cu_3O_{7-\delta} \rightarrow T_c \sim 93\,K$

BiSrCaCuO ...

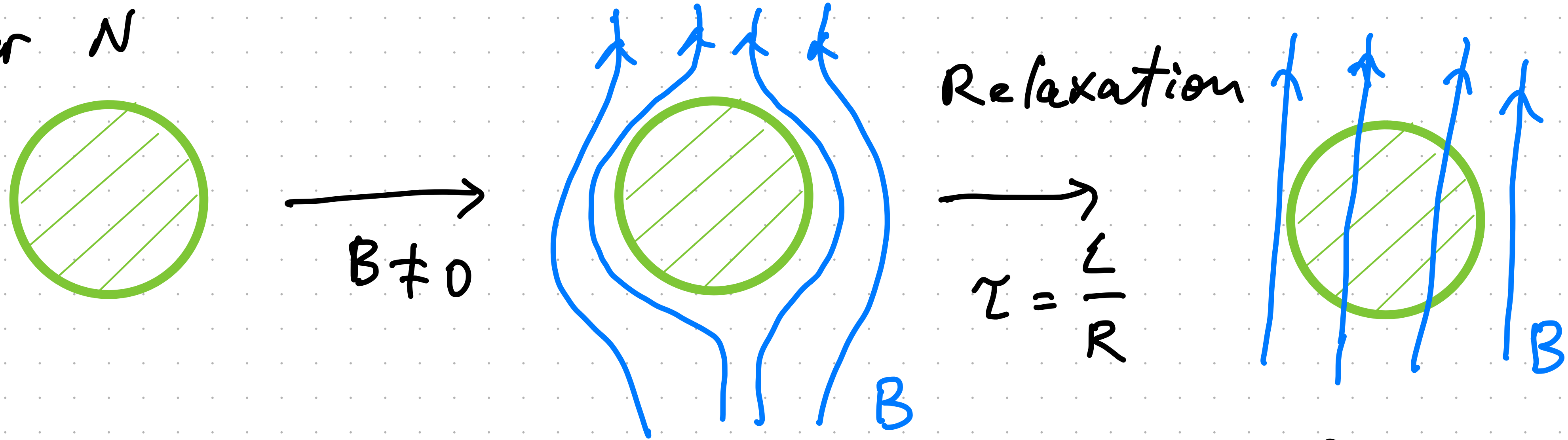
Nicht Supraleiter : Ag, Cu

$\rho \gtrsim 10^{-9}\ \Omega\cdot\text{cm}$

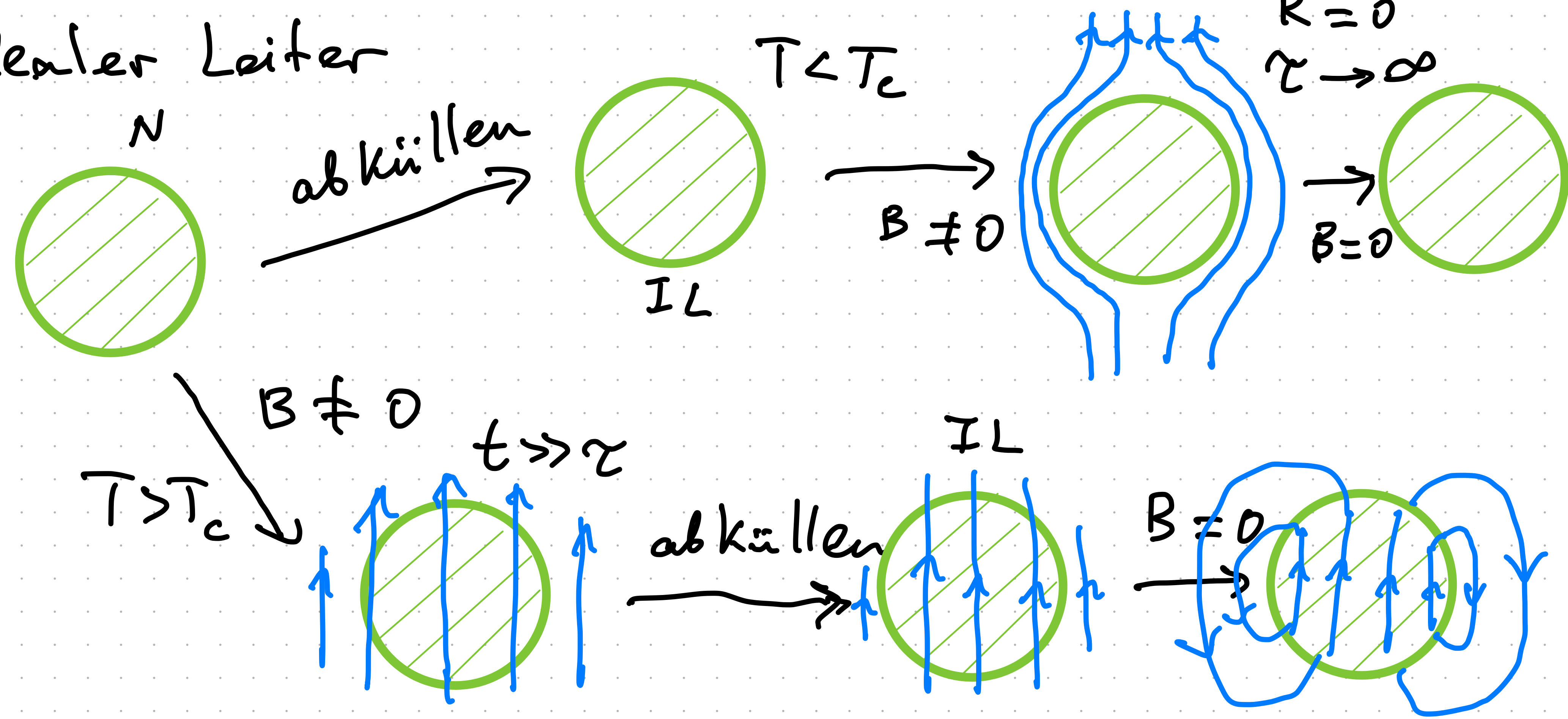
1933 : Meissner, Ochsenfeld

$\rightarrow$ ideale Diamagnetismus

## Leiter N




## Idealer Leiter



Supraleiter: