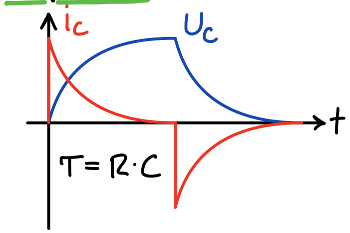
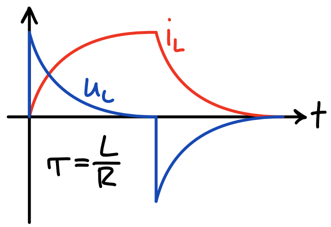
Kapazität

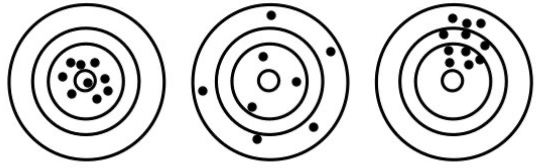


$$u_C = u_C(\infty) + (u_C(0) - u_C(\infty))\, e^{-\frac{t}{\tau}}$$
$$i_C = (u_C(\infty) - u_C(0))\, R^{-1}\, e^{-\frac{t}{\tau}}$$

$$i_L = i_L(\infty) + (i_L(0) - i_L(\infty))\, e^{-\frac{t}{\tau}}$$
$$u_L = (i_L(0) - i_L(\infty))\, R\, e^{-\frac{t}{\tau}}$$

Induktivität





(a) Gute Richtigkeit, gute Präzision, keine Fehler.

(b) Gute Richtigkeit, schlechte Präzision, zufälliger Fehler.

(c) Schlechte Richtigkeit, gute Präzision, systematischer Fehler.

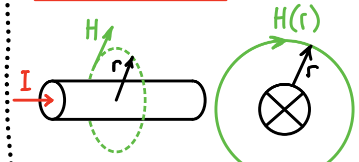
Fehlerausbreitung

$+ \; -$ $\quad |F_{a+b}| \leq |F_a| + |F_b|$

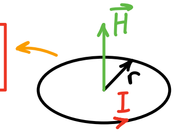
$\bullet \; /$ $\quad |f_{a+b}| = |f_a| + |f_b|$

Gerader Leiter

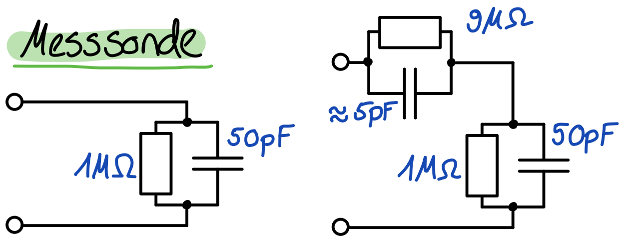
$$H(r) = \frac{I}{2\pi r} \quad \left[\frac{A}{m}\right]$$



$$H = \frac{I}{2r}$$



Messsonde



Messfehler

$$F = A - W$$

$$f = \frac{A-W}{W} \cdot 100\% \approx \frac{F}{A} \cdot 100\% \qquad |F/A| \ll 1$$

$$\tilde{f} = \frac{F}{Msp} \cdot 100\%$$

$$\sigma \sim \frac{1}{\sqrt{k}}$$

F Absoluter Wert $\quad$ f relativer Wert $\quad$ A Messwert

W Wahrer Wert $\quad$ $\tilde{f}$ normierter Fehler $\quad$ σ Streuung

k # Mittelungen $\quad$ Msp Messspanne

Übertragungsfunktion

$$\underline{H} = \frac{\underline{U}_{aus}}{\underline{U}_{ein}} \qquad H_{dB} = 20 \cdot \log_{10}(|\underline{H}|)$$

$$\underline{H} = \underline{H}_1 \cdot \ldots \cdot \underline{H}_n \rightarrow \text{dB \& Phasen addieren sich}$$

$$\varphi = \angle \underline{H}(j\omega) = \arctan\left(\frac{Im(\underline{H}(j\omega))}{Re(\underline{H}(\omega j))}\right)$$

Klirrfaktor k

Nur mit AC-Effektivwerten

$$k = \sqrt{\frac{U_2^2 + U_3^2 + \cdots}{U_1^2 + U_2^2 + U_3^2 + \cdots}} = \frac{\sqrt{U^2 - U_1^2}}{U}$$

$$k_n = \sqrt{\frac{U_n^2}{U_1^2 + U_2^2 + U_3^2 + \cdots}}$$

$k^2 = k_1^2 + k_2^2 + \cdots \quad \rightarrow n \geq 2$

U Effektivwert Gesamtsignal

U_1 Effektivwert Grundschwingung

U_n Effektivwert n-te Oberschwingung

$$\bar{U} = \frac{1}{T} \int_{t_1}^{t_1+T} u(t)\, dt$$

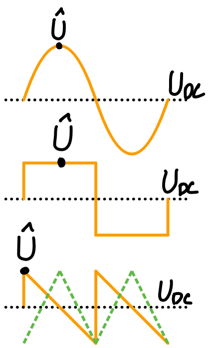
$$|\bar{U}| = \frac{1}{T} \int_{t_1}^{t_1+T} |u(t)|\, dt$$

$$U_q = \underbrace{\frac{1}{\omega_0^2}}\, \frac{d^2 u_C}{dt} + \underbrace{\frac{2\alpha}{\omega_0^2}}\, \frac{du_C}{dt} + u_C$$

$$\left[i_C = C \cdot \frac{du_C}{dt} \; ; \; u_L = L \frac{di}{dt} \right]$$

$$U = U_{rms} = \sqrt{\frac{1}{T} \int_{t_1}^{t_1+T} u(t)^2\, dt}$$

Periodische Signale



Arit. Mittelwert	Gleichrichtwert	Effektivwert
$\bar{U} = U_{DC}$	$\lvert\bar{U}\rvert = \frac{2}{\pi} \hat{U}$	$U_{EFF} = \sqrt{U_{DC}^2 + \frac{\hat{U}^2}{2}}$
$\bar{U} = U_{DC}$	$\lvert\bar{U}\rvert = \frac{2}{\pi} \hat{U}$	$U_{EFF} = \sqrt{U_{DC}^2 + \hat{U}^2}$
$\bar{U} = U_{DC}$	$\lvert\bar{U}\rvert = \frac{\hat{U}}{2}$ * no U_{DC}	$U_{EFF} = \sqrt{U_{DC}^2 + \frac{\hat{U}^2}{3}}$

else → integral

Unterdämpfung $(\alpha^2 - \omega_0^2 < 0)$

$$\left(u_C = e^{-\alpha t} \left(K_1 \cdot \cos(\omega t) + K_2 \cdot \sin(\omega t) \right) + K_3 \right) \quad \left(\omega = \sqrt{\omega_0^2 - \alpha^2} \right)$$

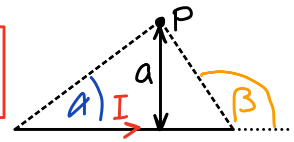
kritische Dämpfung $(\alpha^2 - \omega_0^2 = 0)$

$$\left(u_C(t) = e^{-\alpha t} \left(K_1 + K_2 t \right) + K_3 \right)$$

Überdampfung $(\alpha^2 - \omega_0^2 > 0)$

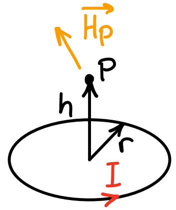
$$\left(u_C(t) = e^{-\alpha t} \left(K_1 e^{\delta t} + K_2 e^{-\delta t} \right) + K_3 \right) \quad \left(\delta = \sqrt{\alpha^2 - \omega_0^2} \right)$$

$$H_P = \frac{I}{4\pi a} (\cos(\alpha) - \cos(\beta))$$



Magnetfeld

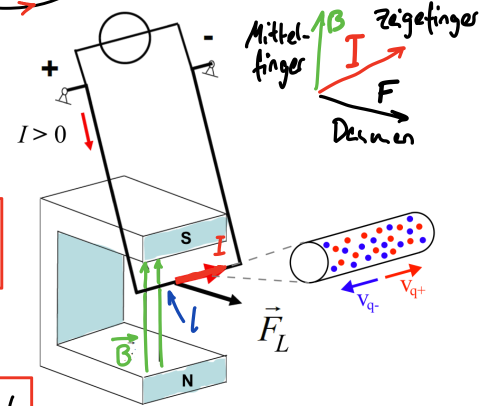
$$|H_p| = \frac{I}{2}\,\frac{r^2}{(r^2+h^2)^{\frac{3}{2}}}$$



Lorentzkraft

$$\vec{F_L} = \underbrace{Q\,(\vec{v}\times\vec{B})}_{\text{magnetisch}} + \underbrace{Q\cdot\vec{E}}_{\text{elektrische}}$$

$$\vec{F_M} = I\,(\vec{l}\times\vec{B}) = \underbrace{I\cdot l\cdot B}_{\text{falls homogen}}$$



Bewegungsinduktion

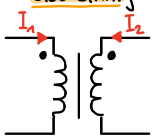
$$U_{AB} = -(\vec{v}\times\vec{B})\cdot\vec{l} = \underbrace{-v\cdot B\cdot l}_{v \perp B \perp l}$$

Trafogleichung

$$u_1 = N_1\frac{d\Phi_1}{dt} \pm N_1\frac{d\Phi_{21}}{dt} = L_1\frac{di_1}{dt} \pm L_{21}\frac{di_2}{dt}$$

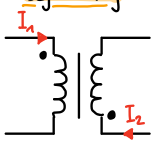
$$u_2 = N_2\frac{d\Phi_{12}}{dt} \pm N_2\frac{d\Phi_2}{dt} = L_2\frac{di_2}{dt} \pm \underbrace{L_{12}\frac{di_1}{dt}}_{=0 \text{ wenn offen}}$$

Gleichsinnig



$+$ Gleichsinnig

Gegensinnig



$-$ Gegensinnig

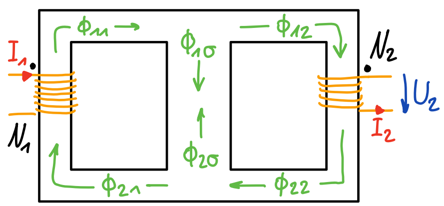
Selbst- und Gegeninduktivität

Ursache $\rightarrow \Phi_{21} \leftarrow$ Wirkung

$$k_{21} = \frac{\Phi_{21}}{\Phi_{22}} \qquad k_{12} = \frac{\Phi_{12}}{\Phi_{11}} \qquad k = \sqrt{k_{12}\cdot k_{21}}$$

$$L_{21} = N_2\frac{\Phi_{21}}{I_2} \qquad L_{12} = N_1\frac{\Phi_{12}}{I_1} \qquad L_{21} = L_{12} = k\sqrt{L_1 L_2}$$

$$L_n = \frac{N_n^2}{R_m} \qquad u_{ind} = -L\frac{di(t)}{dt}$$



Scheinleistung

$$S = U_{EFF}\,I_{EFF} = \sqrt{P^2+Q^2}$$

$$\rightarrow U\,\frac{U^*}{Z^*} = \frac{|U|^2}{Z^*}$$

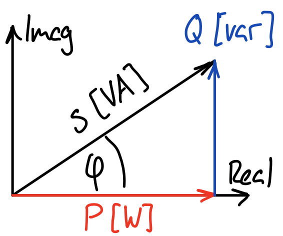
Blindleistung

$$Q = U_{EFF}\,I_{EFF}\,\sin(\varphi)$$

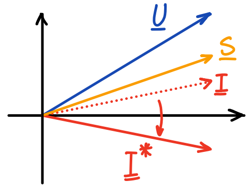
Wirkleistung

$$P = S\cdot\cos(\varphi)$$

$$\underline{S} = P + Qj = \underline{U}\cdot\underline{I}^*$$



Nicht vergessen!



falls Z_V nur ohmisch ($Z_V = R_V$)

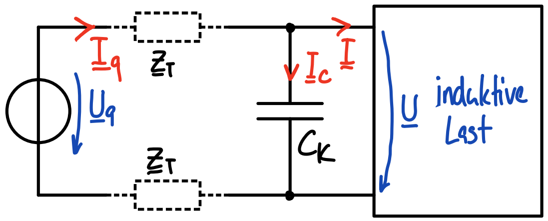
$$Z_V = Z_{iE}^* \qquad R_V = |Z_i| = \sqrt{R_i^2 + X_i^2}$$

$$S_X = \sqrt{var} = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i-\bar{x})^2}$$

Verlustleistung

$$P_V = 2\cdot I_q^2\,R_T$$

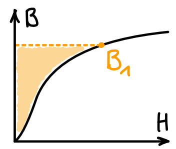
$$\rightarrow Z_T = (R_T + X_T j)$$



Energie im Magnetfeld

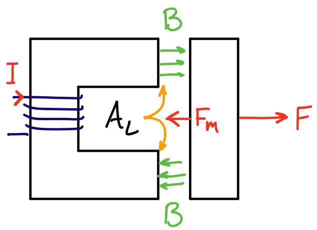
homogenen Raum

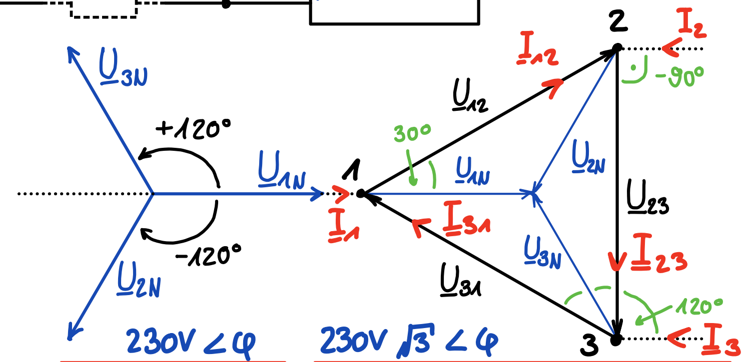
$$W_m = \frac{B^2}{2\mu_0}A_L\cdot l_L$$



Kraft im Magnetfeld

$$F_m = -\frac{dW_m}{dl_L} = -\frac{B^2}{2\mu_0}\cdot A_L$$





230V ∠φ

$$U_{1N} = U_S\angle 0°$$
$$U_{2N} = U_S\angle -120°$$
$$U_{3N} = U_S\angle +120°$$

230V $\sqrt{3}$ ∠φ

$$U_{12} = U_{1N} - U_{2N} = U_S\cdot\sqrt{3}\angle 30°$$
$$U_{23} = U_{2N} - U_{3N} = U_S\cdot\sqrt{3}\angle -90°$$
$$U_{31} = U_{3N} - U_{1N} = \underbrace{U_S\cdot\sqrt{3}}_{U_\Delta}\angle 150°$$

bei Sternschaltung:

$$U_{KN} = \frac{\frac{U_{1N}}{Z_1} + \frac{U_{2N}}{Z_2} + \frac{U_{3N}}{Z_3}}{\frac{1}{Z_1} + \frac{1}{Z_2} + \frac{1}{Z_3} + \frac{1}{Z_N}}.$$

$$\left[I_3 = I_{31} - I_{23}\right]$$

$2 =$
$1 = 12 \quad -31$

$$\left[I_X = \frac{U_X}{Z_X}\right] \qquad X = 12, 23, 31$$