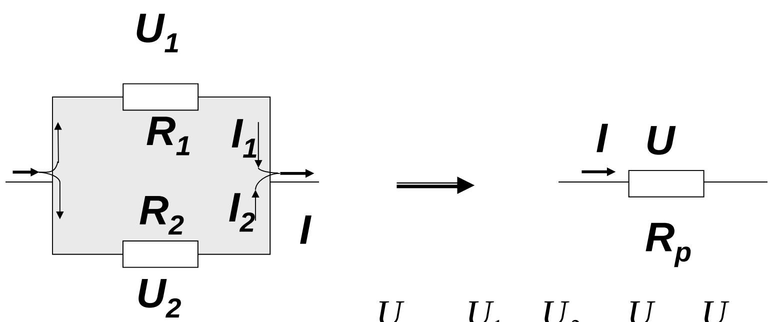
Elektrizitätslehre 3.

Spannung und Stromstärke

Angel Wasserfall
≈1000 m

Niagara Wasserfall
55m

Parallelschaltung von Widerstände

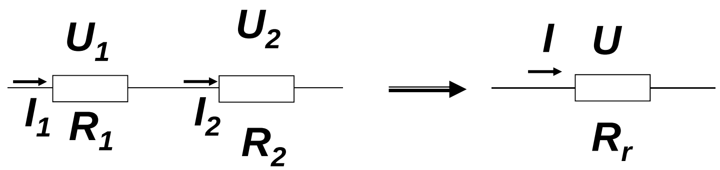


$$U_1 = U_2 = U$$
$$I = I_1 + I_2$$

$$\frac{U}{R_p} = \frac{U_1}{R_1} + \frac{U_2}{R_2} = \frac{U}{R_1} + \frac{U}{R_2}$$

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$$

Reihenschaltung von Widerstände

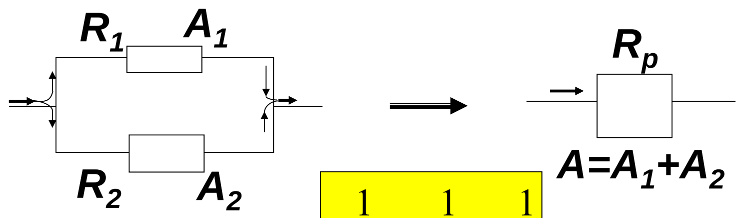


$$I_1 = I_2 = I$$
$$U = U_1 + U_2$$

$$IR_r = I_1R_1 + I_2R_2 = IR_1 + IR_2$$

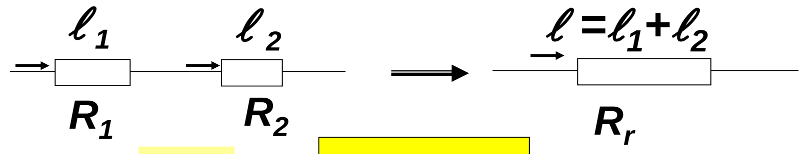
$$R_r = R_1 + R_2$$

Parallel- und Reihenschaltung von Widerstän



$A = A_1 + A_2$

R ~ 1/A   A ~ 1/R ⇨ $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$

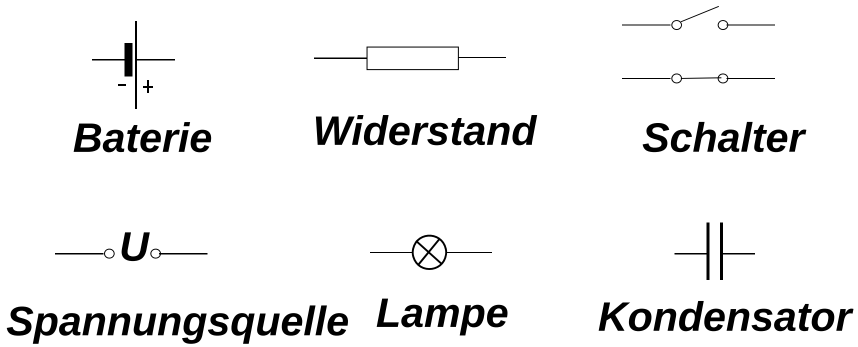


$\ell = \ell_1 + \ell_2$

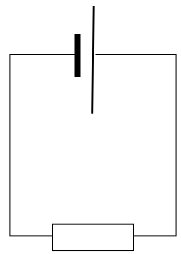
R~ ℓ ⇨ $R_r = R_1 + R_2$

Elektrischer Stromkreis

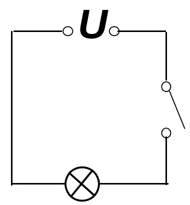
Elektrische Schaltelemente



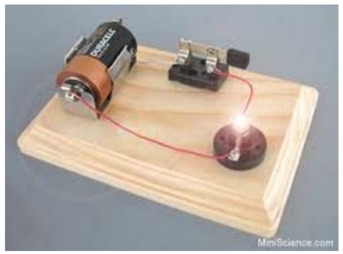
Einfachster Stromkreis



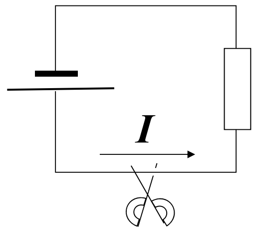
z.B.: Leselampe:

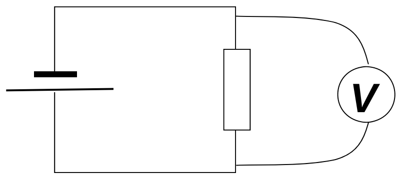


z.B.: Kopflampe:

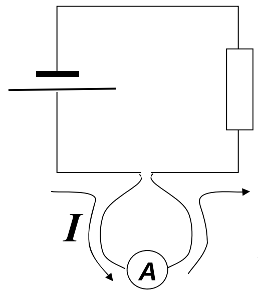


Strom- und Spannungsmessung





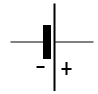
Spannungsmessgerät in Parallelschaltung



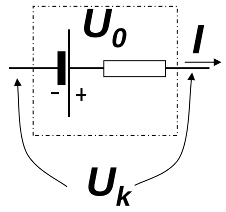
Strommessgerät in Reihenschaltung

Ideale Spannungsquelle:

Spannung ist unabhängig von Stromstärke



Reelle Spannungsquelle: *Innerer Widerstand*

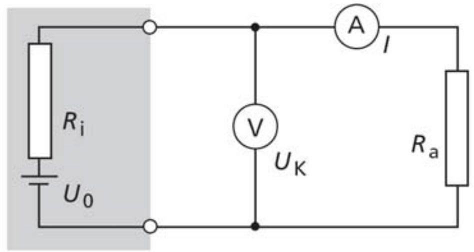


$U_k=U_0-IR_i$

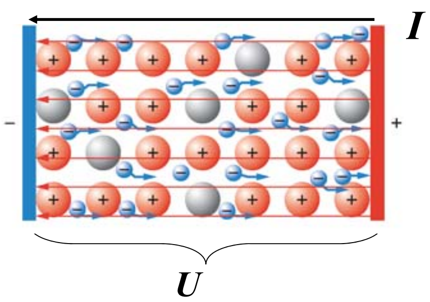
U_0: Leerlaufspannung
Elektromotorische Kraft

U_k: Klemmenspannung der Spannungsq.

$$U_0 \geq U_k \geq 0$$



Joulesche Wärme und Elektrische Leistung



Elektronenbewegung:
Beschleunigung, Zusammenstoß

Energieaufnahme ***Energieabgabe***

Um Q Ladung gegen U Spannung zu transportieren braucht man W=Q·U Energie.

Wenn sich Q Ladung durch das elektrische Feld bewegt, gibt das Feld W=U·Q=U·I·t Energie ab.

Diese Energie wird in Wärme umgewandelt. (Joul‘sche Wärme)

W=U·I·t

Die Elektrische Leistung:

$$P = \frac{W}{t} = \frac{UIt}{t} = UI$$

Einheit: Watt

1W=1V A

5-100 mW

50-100 W

20-40 W

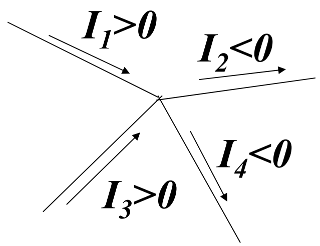
1-2 kW

Zum Vergleich:

~100 W

Kirchoffsche Gesetze

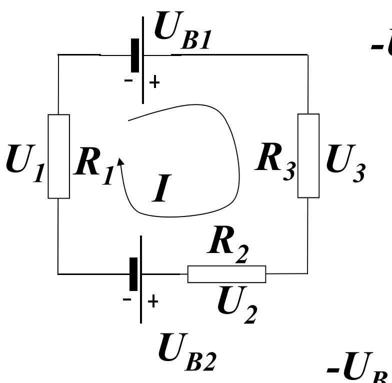
1. Kirchoffsches Gesetz: Knotenregel



$$I_1+I_2+I_3+I_4=0$$

2. Kirchoffsches Gesetz: Maschenregel

Summe der Spannungen in einer Masche ist =0

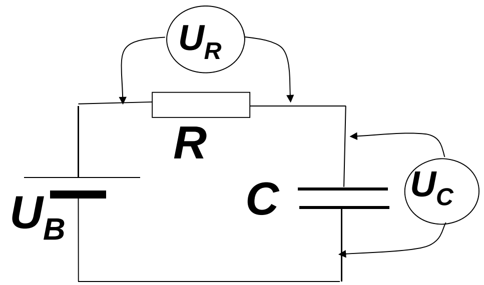


$$-U_{B1}+U_3+U_2+U_{B2}+U_1=0$$

$$-U_{B1}+IR_3+IR_2+U_{B2}+IR_1=0$$

RC Kreis

Kondensator in einem Stromkreis:



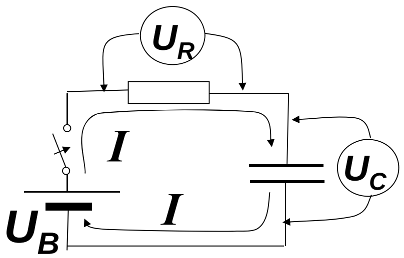
Im Gleichgewichtszustand: Kein Strom $I=0$

(Isolator zwischen den Platten!)

$$\Rightarrow U_R=IR=0 \;\; \Rightarrow U_C=U_B-U_R=U_B$$

Aufladung des RC Kreises

Sei der Kondensator ungeladen vor dem Einschalten des Schalters: $U_C=0$



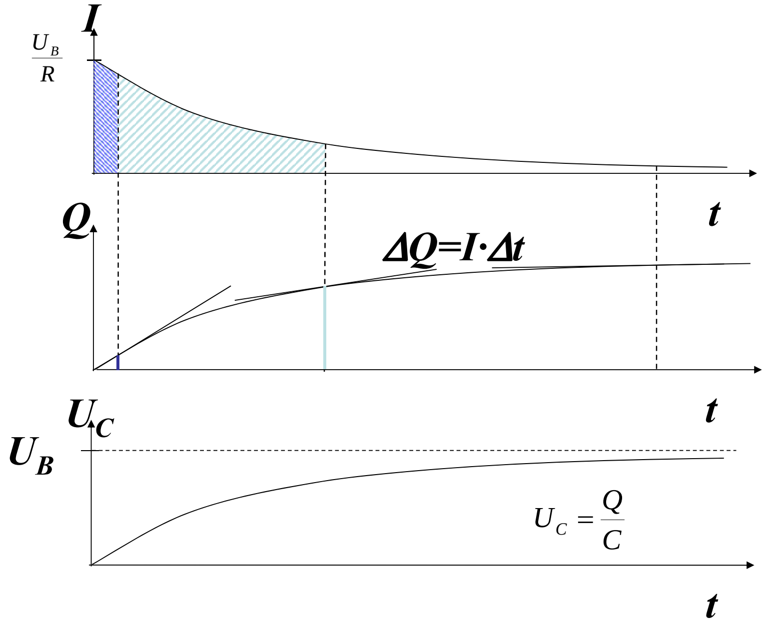
Es gilt zu jedem Zeitpunkt (t):

$$U_R(t)+U_C(t)-U_B=0 \quad (Maschenregel)$$

$$\Rightarrow U_B=U_R+U_C(t)=I(t)\cdot R+U_C(t)$$

Im Moment des Einschaltens:

$$U_B=I(0)R \;\Rightarrow I(0)=\frac{U_B}{R}$$



Die Stromstärke annähert Null asymptotisch.

$U_R=IR$ => U_R annähert Null asymptotisch.

U_C annähert U_B asymptotisch.

$$U_C=U_B\left(1-e^{-\frac{t}{\tau}}\right)$$

$$\tau=RC$$

$$U_R=U_B e^{-\frac{t}{\tau}}$$

Entladung des RC Kreises

Sei der Kondensator vor dem Einschalten des Schalters aufgeladen:

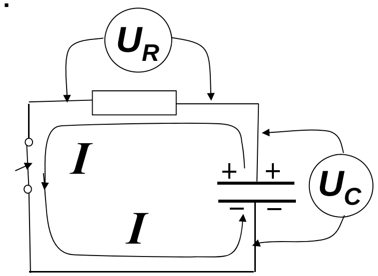
$U_C(0)=U_0$

Maschenregel:

$U_R(t)-U_C(t)=0$

=> $I(t)R=U_C(t)$

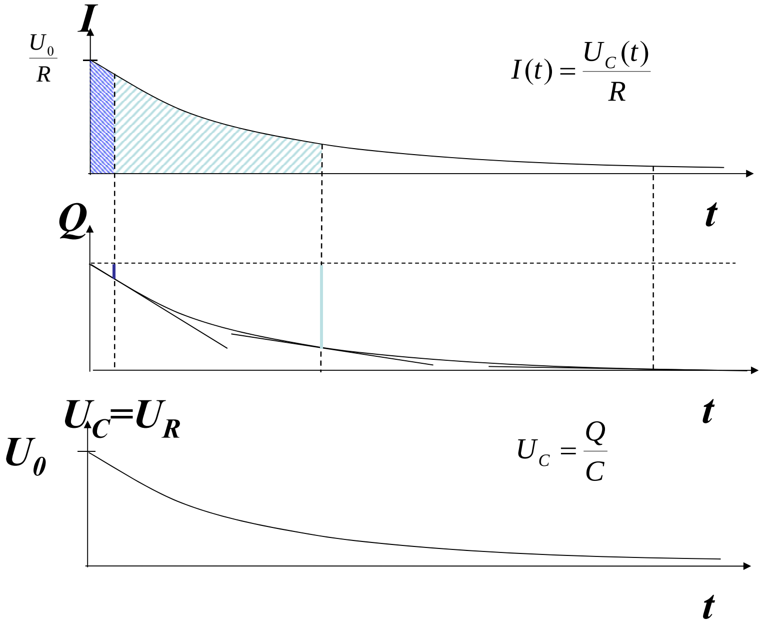
$$I(t)=\frac{U_C(t)}{R}$$



Am Anfang der Entladung: $I(0)R=U_0$ $\quad I(0)=\frac{U_0}{R}$

$$I(t) = \frac{U_C(t)}{R}$$

$$U_C = \frac{Q}{C}$$



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

$$\Delta Q = - I \, \Delta t$$

$$\Delta U_C = \frac{\Delta Q}{C}$$

$$\frac{\Delta U_C}{\Delta t} = -\frac{1}{RC} U_C$$

$$\frac{\Delta U_C}{\Delta t} \sim U_C$$

Änderungsgeschwindigkeit der Spannung (U_C) ist proportional zur U_C .

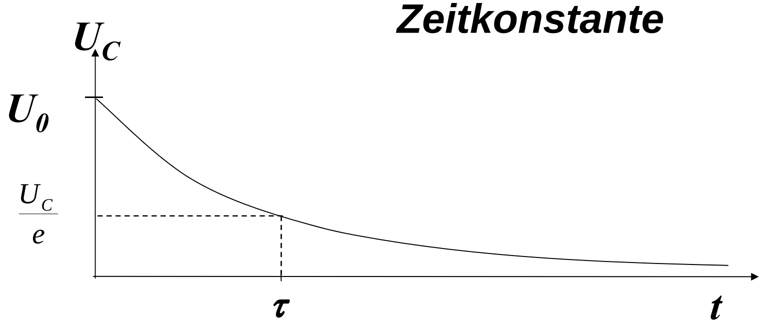
=> **Exponentialfunktion**!

$$U_C = U_0 e^{-\frac{t}{\tau}} \qquad \tau = RC$$

$$U_C = U_0 e^{-\frac{t}{\tau}}$$

$\tau = RC$

Zeitkonstante

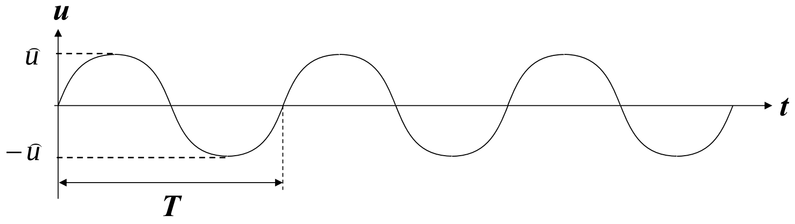


Wechselspannung

Wechselspannung **Scheitelwert**

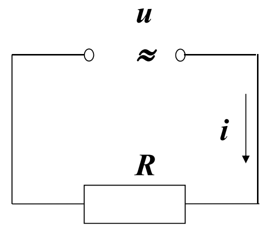
$$u(t) = \hat{u}\sin(\omega t)$$

Kreisfrequenz: $\omega = 2\pi f$



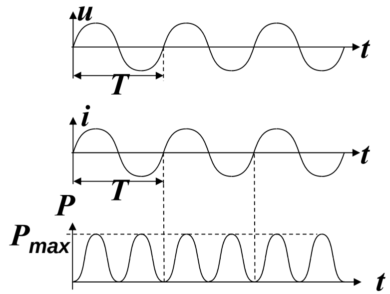
$$T = \frac{1}{f}$$

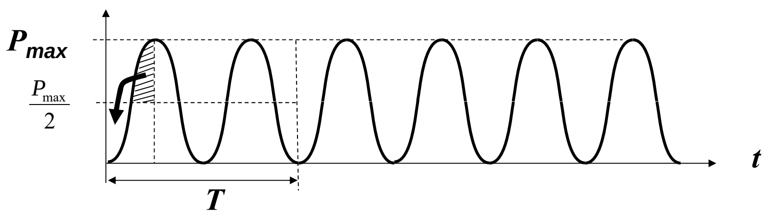
Wechselspannungskreis



$$u(t) = \hat{u}\sin(\omega t)$$

$$i(t) = \hat{i}\sin(\omega t)$$





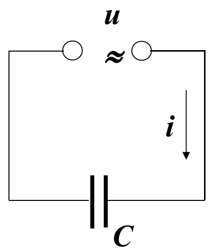
Durchschnittliche Leistung:

$$\overline{P} = \frac{P_{\max}}{2} = \frac{\hat{u}\hat{i}}{2} = \frac{\hat{u}}{\sqrt{2}}\frac{\hat{i}}{\sqrt{2}} = U_{eff} I_{eff}$$

Effektive Spannung: $U_{eff} = \frac{\hat{u}}{\sqrt{2}}$

Effektive Stromstärke: $I_{eff} = \frac{\hat{i}}{\sqrt{2}}$

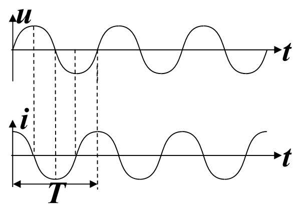
Kondensator im Wechelstromkreis



$$u = U_C = \frac{Q}{C}$$

$$Q = C \cdot u = C \cdot \hat{u}\sin(\omega t)$$

$$i = \frac{\Delta Q}{\Delta t} = C\hat{u}\frac{\Delta \sin(\omega t)}{\Delta t} = \hat{i}\cos(\omega t)$$



$$\frac{\Delta \sin(\omega t)}{\Delta t} = \omega \cos(\omega t)$$

$$\hat{i} = \hat{u} \cdot C \cdot \omega$$

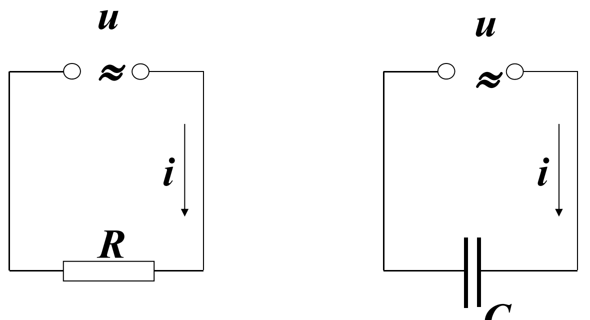
$$\frac{\hat{u}}{\hat{i}} = \frac{1}{\omega C} = X_C$$

Kapazitiver Widerstand

$$X_C = \frac{U_{eff}}{I_{eff}}$$

$$X_C \neq \frac{u}{i}$$

Zusammenfassung:



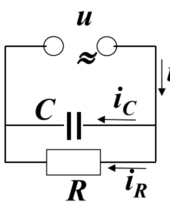
$$R = \frac{u}{i} = \frac{\hat{u}}{\hat{i}} = \frac{U_{eff}}{I_{eff}}$$

$$X_C = \frac{\hat{u}}{\hat{i}} = \frac{U_{eff}}{I_{eff}} \neq \frac{u}{i}$$

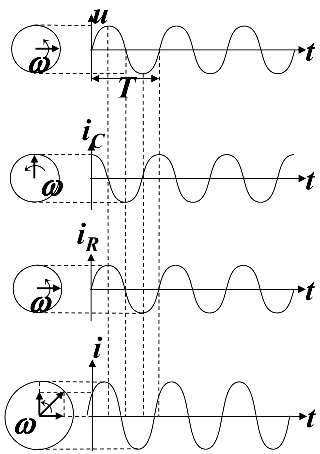
u und i in gleicher Phase

i eilt sich im Vergleich zum u

Wechselstromkreis mit Widerstand und Kondensator in Parallelschaltung



$i = i_C + i_R$



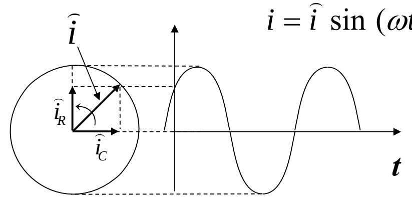
$$\frac{\hat{u}}{X_C} \cos(\omega t)$$

$$\frac{\hat{u}}{R} \sin(\omega t)$$

$$\hat{i} \sin(\omega t + \varphi)$$

$$i = \hat{i} \sin(\omega t + \varphi)$$

$$\hat{i}^2 = \hat{i}_C^2 + \hat{i}_R^2$$



$$\hat{i} = \sqrt{\hat{i}_C^2 + \hat{i}_R^2} = \sqrt{\frac{\hat{u}^2}{X_C^2} + \frac{\hat{u}^2}{R^2}} =$$

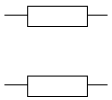
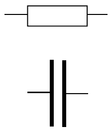
$$= \hat{u}\sqrt{\frac{1}{X_C^2} + \frac{1}{R^2}} = \frac{\hat{u}}{Z}$$

$$\frac{1}{Z} = \sqrt{\frac{1}{X_C^2} + \frac{1}{R^2}}$$

$$Z = \frac{U_{eff}}{I_{eff}}$$

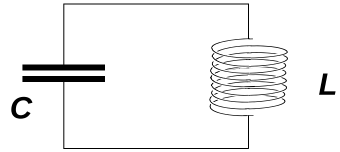
Impedanz

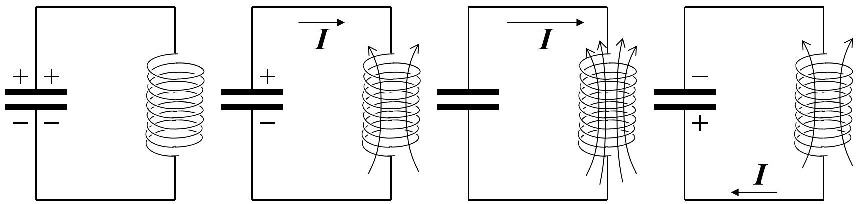
Zusammenfassung

	Reihenschaltung	*Parallelschaltung*
	$R_r = R_1 + R_2$	$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$
	$Z = \sqrt{X_C^2 + R^2}$	$\frac{1}{Z} = \sqrt{\frac{1}{X_C^2} + \frac{1}{R^2}}$

Schwingkreis:

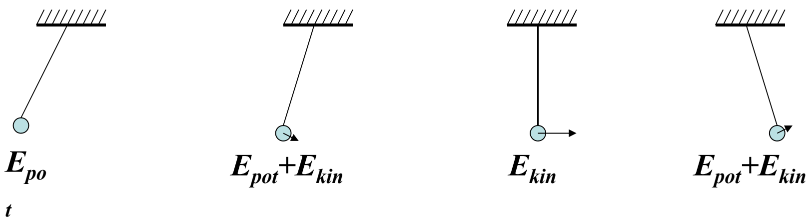
Erzeugung der elektromagnetischen Schwingungen

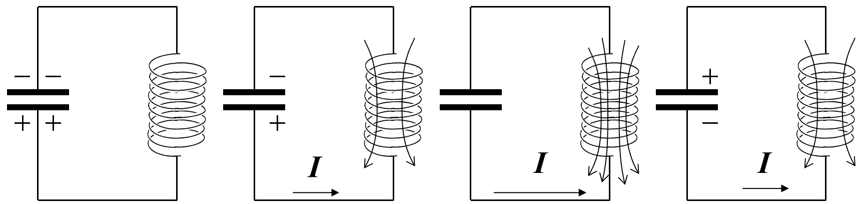




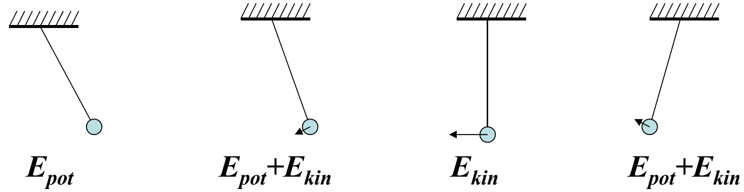
U	***max***	***0***
I	***0***	***max***

Mechanische Analogie: Pendel

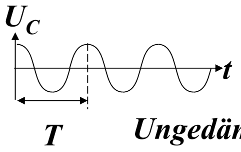


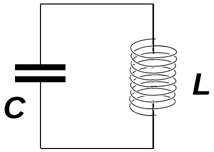


U	***- max***	***0***
I	***0***	***- max***



Idealer Schwingkreis:





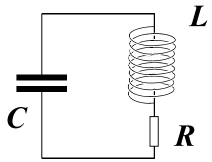
Ungedämpfte Schwingung

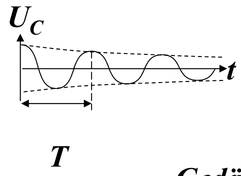
Eigenfrequenz:

$$f = \frac{1}{2\pi\sqrt{LC}}$$

Resonanz!

Reeller Schwingkreis





Gedämpfte Schwingung

Energieverlust am Widerstand