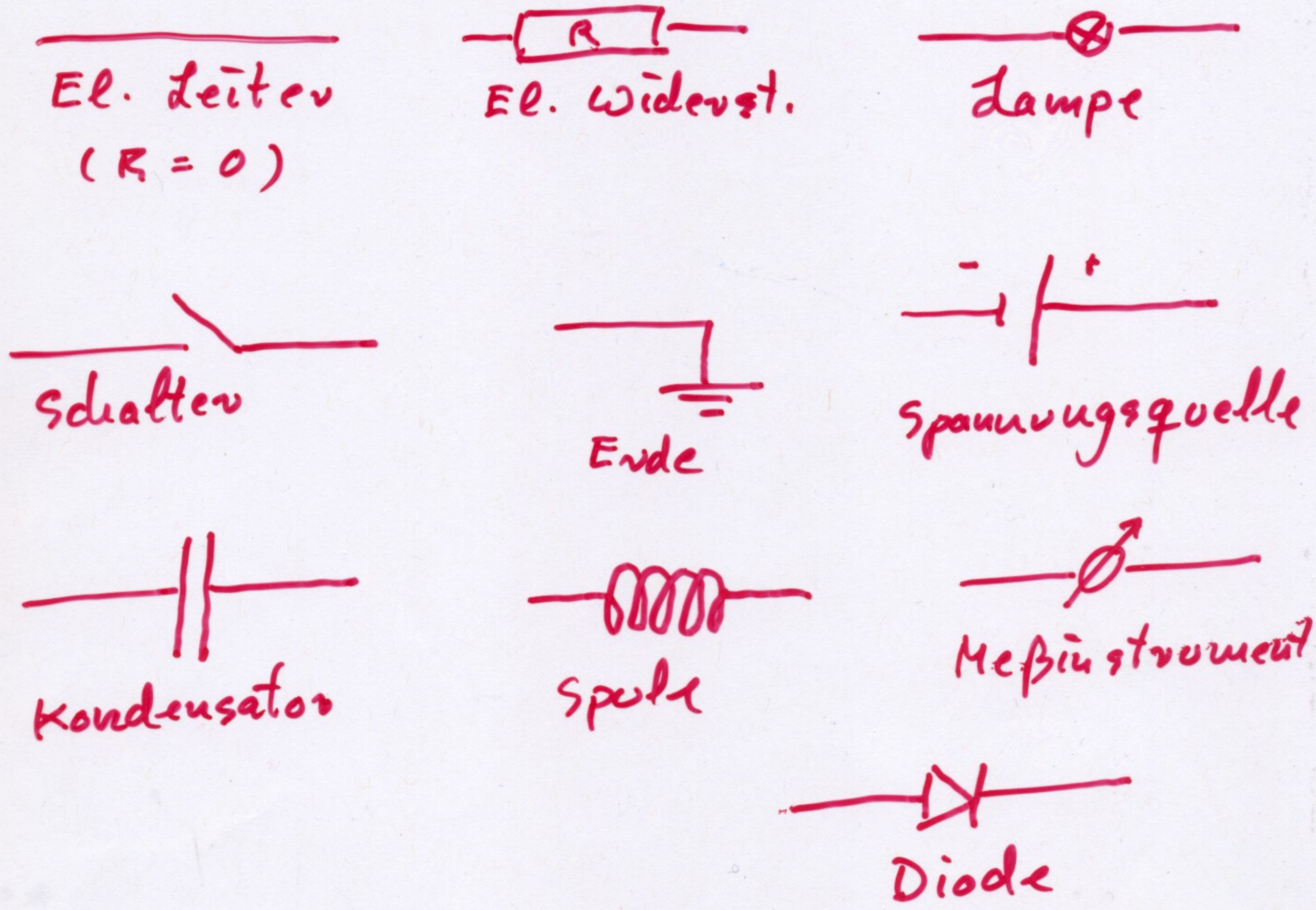
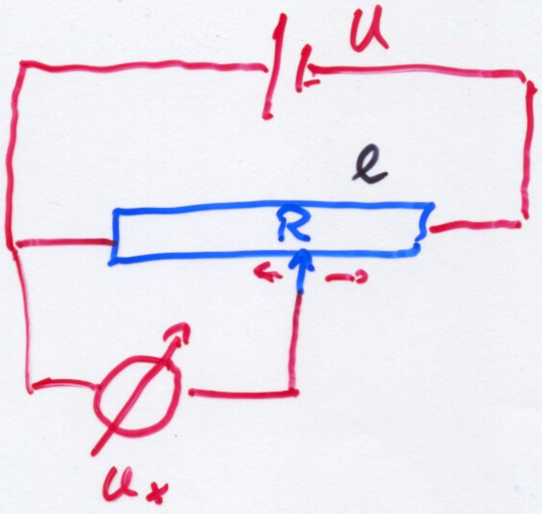
3.2.4 Anwendungen: Schaltungen, Netzwerke

a) Symbole für Leitungselemente



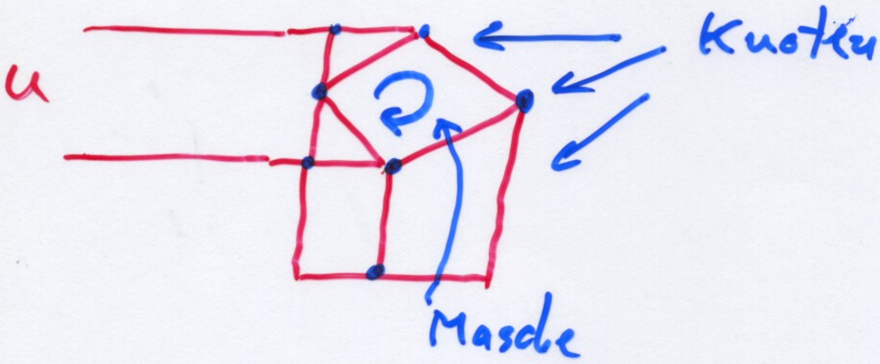
b) Potentiometerschaltung



$$U_x = \frac{x}{l} U$$

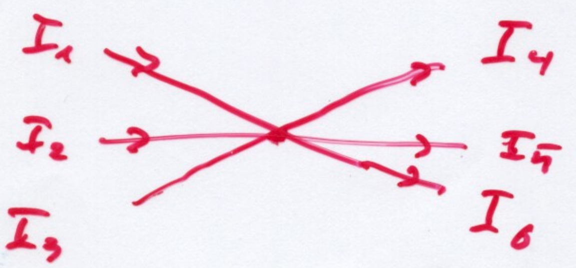
c) Kirchhoffsche Gesetze

Mehrere Leiter el. verbunden ⇒ Netzwerk



1. An jedem Knoten ist $\sum I_i = 0$

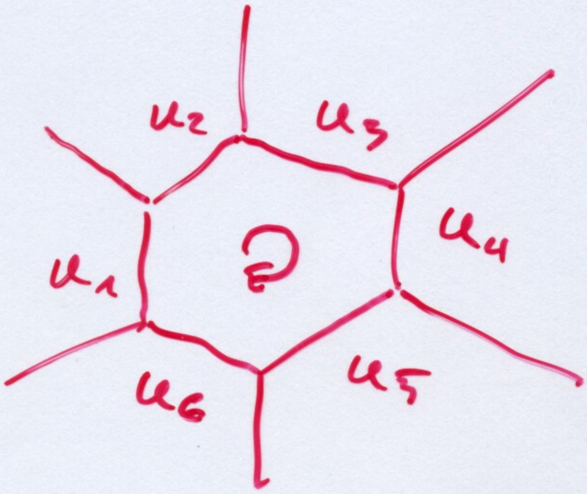
(Kontinuitätsgleichung)



$$\sum I_i = 0$$

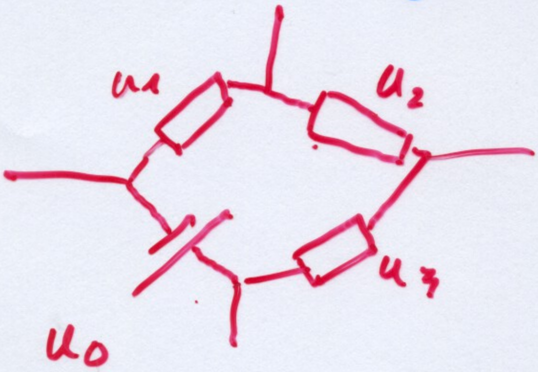
zB: $I_5 = -(I_1 + I_2 + I_3 + I_4 + I_6)$

2: In einer Masche ohne Spannungsquelle gilt $\sum U_i = 0$



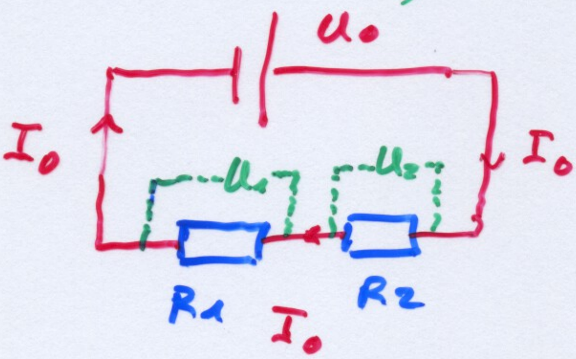
$U = 0$

Mit Spannungsquelle: $\sum U_i = U_0$



Anwendung:

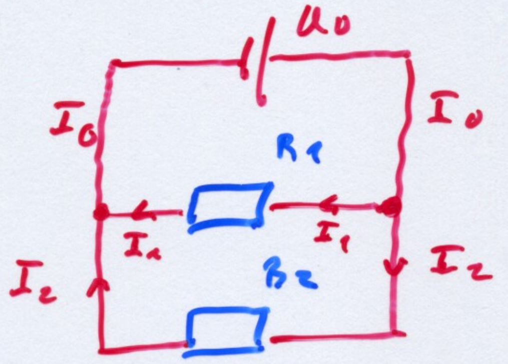
(i) Serienschaltung von Widerständen



K2: $U_1 + U_2 = U_0$

$R_1 \cdot I_0 + R_2 \cdot I_0 = U_0$ $\Big\}$ $U_0 = (R_1 + R_2) I_0$

ii) Parallelschaltung von Widerständen



K1: $I_0 = I_1 + I_2$

K2: $U_0 = R_1 \cdot I_1$

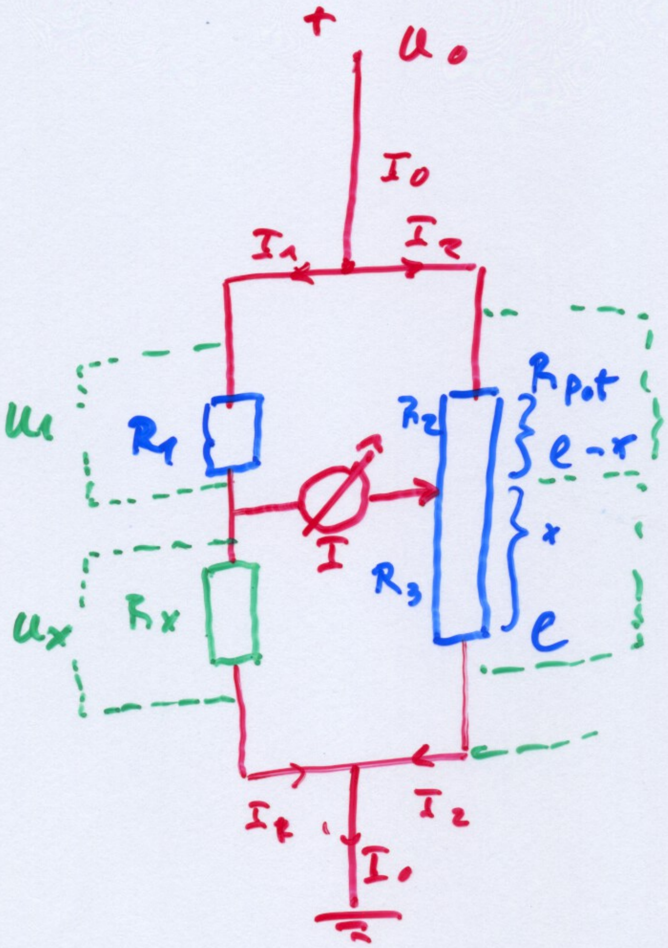
$= R_2 \cdot I_2$

$$\Rightarrow U_0 = \left(\frac{U_0}{R_1} + \frac{U_0}{R_2} \right) \cdot R_x$$

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

Allg.: $\frac{1}{R_1} = \sum_i \frac{1}{R_i}$

(iii) Wheatstonesche Brückenschaltung



Für $I = 0$

$$U_x = I_1 \cdot R_x = I_2 \cdot R_3$$

$$U_0 = I_1 \cdot (R_x + R_1) = I_2 \cdot (R_2 + R_3)$$

$$\Rightarrow \frac{R_x}{R_3} = \frac{R_1 + R_x}{R_2 + R_3} \Rightarrow R_x = \frac{R_1 \cdot R_3}{R_2}$$

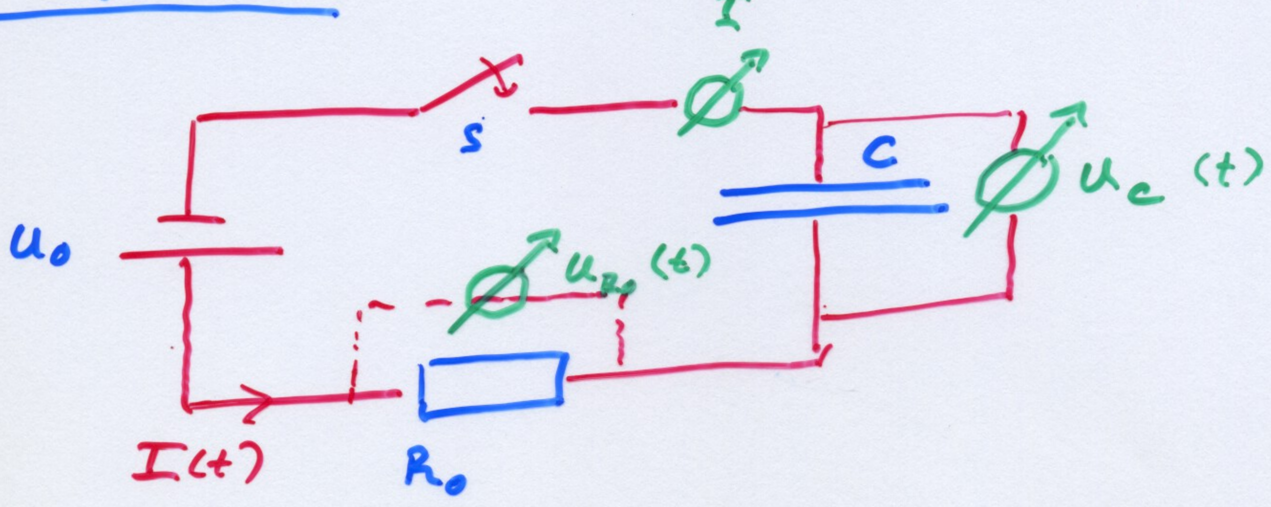
Für $R_3 = \frac{x}{\ell} \cdot R_{pot}$

$R_2 = \frac{\ell - x}{\ell} \cdot R_{pot}$

$$R_x = \frac{x}{\ell - x} \, R_1$$

(iv) Auf- und Entladung eines Kondensators

1. Aufladung



$$U_0 = U_{R_0}(t) + U_C(t)$$

$$= I(t) \cdot R_0 + U_C(t)$$

$$I(t) = \frac{U_0 - U_C(t)}{R_0}$$

$$= \frac{U_0}{R_0} - \frac{Q(t)}{C\, R_0}$$

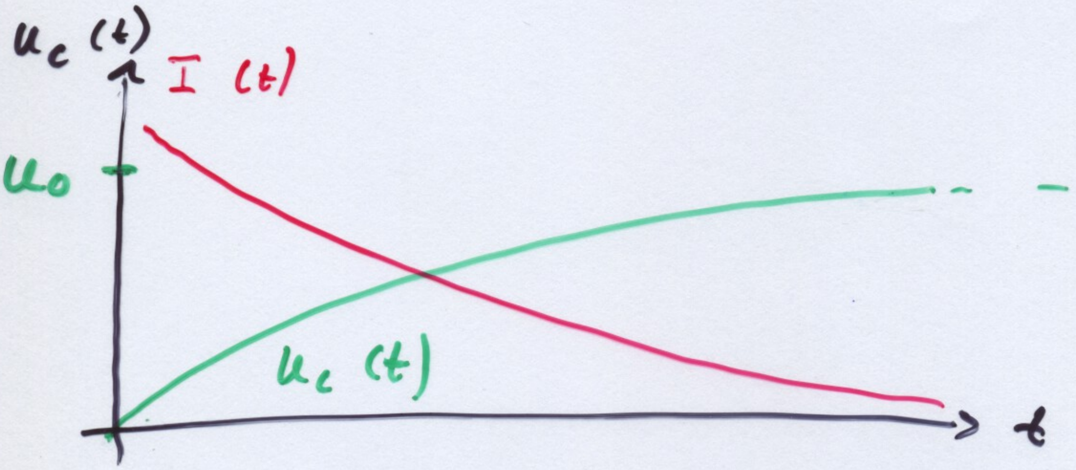
$$\underbrace{\frac{dI}{dt} = -\frac{I(t)}{C \cdot R_0}}_{\text{DGl}}$$

$$\Rightarrow I(t) = I_0 \cdot e^{-t/R_0 C}$$

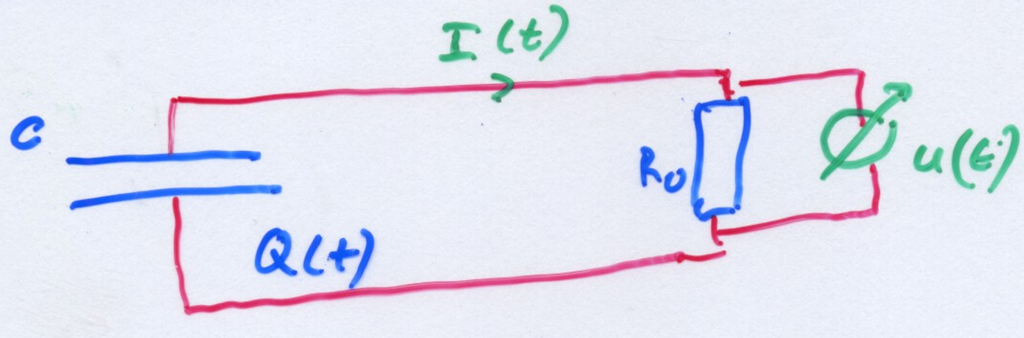
$$U_C(t) = U_0 - I(t) \cdot R_0$$

$$= U_0 - I_0 R_0 \, e^{-t/R_0 C}$$

$$= U_0 \left(1 - e^{-t/\tau}\right) \qquad \tau = R_0 C$$



2. Entladung

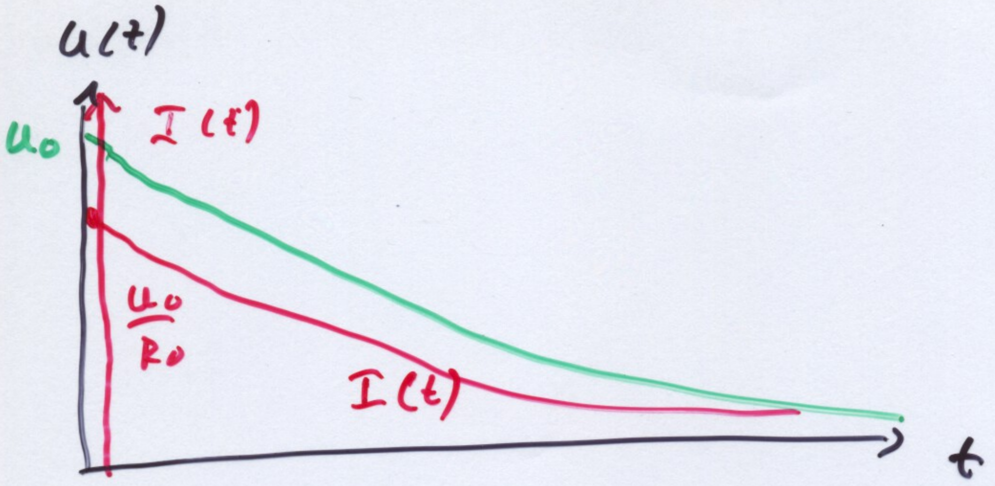


$$U(t) = I(t) \cdot R_0$$

$$= -\frac{dQ}{dt} R_0 \qquad = -\frac{dU}{dt} \cdot R_0 C$$

$$U(t) = U_0 \, e^{-t/R_0 C}$$

$$I(t) = \frac{U_0}{R_0} \, e^{-t/R_0 C}$$



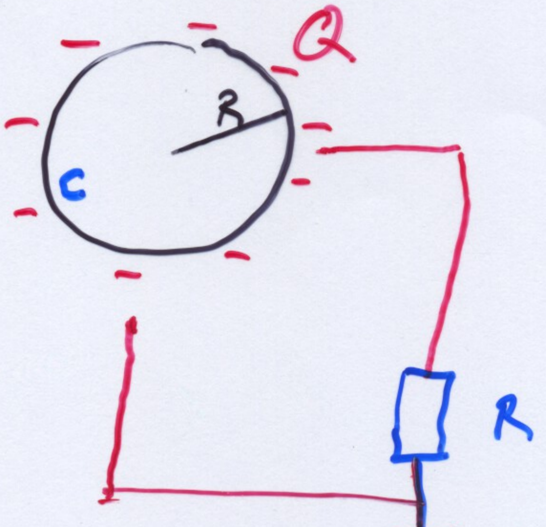
Zeitkonstante:

$\tau = R \cdot C$

Für $C \sim 1\,nF$, $R \sim 1\,M\Omega$ } $\tau = 1\,nF \cdot 1\,M\Omega = 1\,ms$

$C \sim 10\,pF$, $R \sim 10\,k\Omega$ } $\tau = 100\,ns$

Anwendung: Bestimmung eines Kriechwiderstandes



$$C = 4\pi\varepsilon_0 R \quad ; \quad R \approx 0{,}5\,m$$

$$\approx 12 \cdot 10^{-11} \frac{As}{Vm} \cdot 0{,}5\,m$$

$$\approx 6 \cdot 10^{-11} \frac{As}{V} = 60\,pF$$

$$Q = 10^6\,V \cdot C = 60 \cdot 10^{-12} \cdot 10^6\,C$$

$$= 60\,\mu C$$

Zeitkonstante der Entladung:

$$\tau = R \cdot C \, ,$$

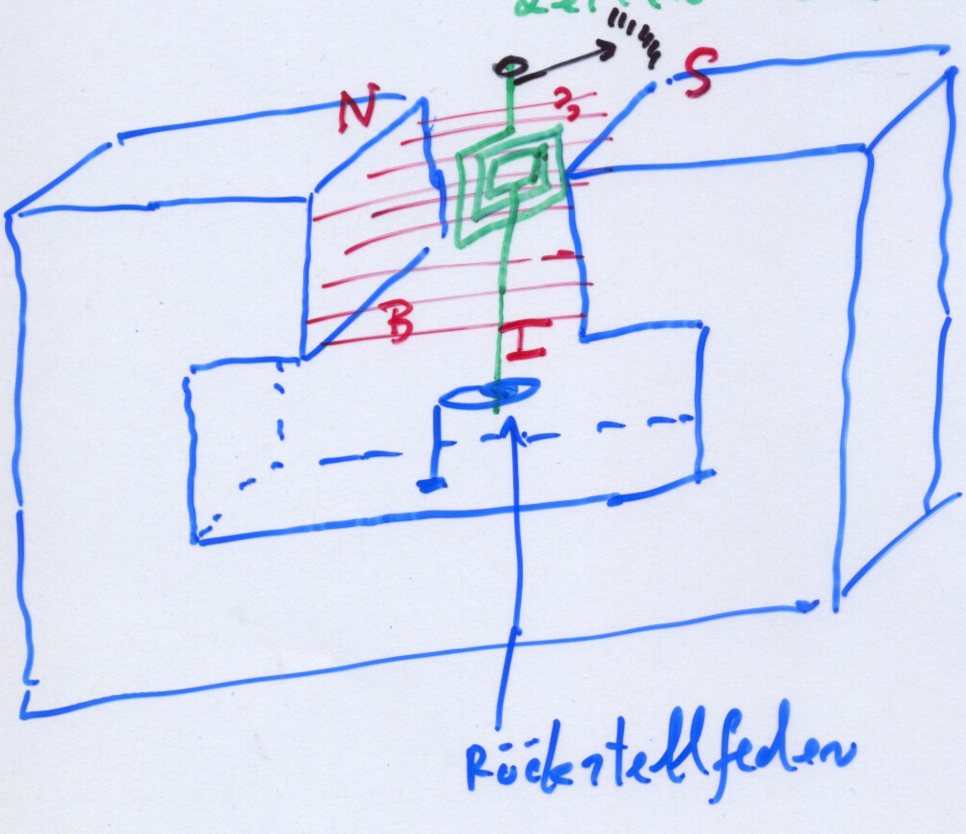
$$R = \frac{\tau}{C} = \frac{15\,s}{60 \cdot 10^{-12}\,\frac{As}{V}} = 2{,}5 \cdot 10^{11}\,\Omega$$

3.2.5 Meßinstrumente

A] Strommessung : Amperemeter

• Galvanometer

Prinzip : Kraft auf stromdurchflossene Leiter im Magnetfeld



Magnetfeld verursacht Drehmoment auf stromdurchflossene Spule.

$D \sim B \cdot I$

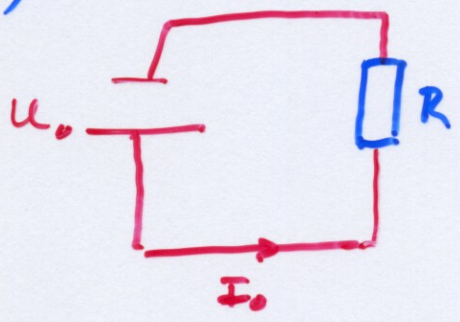
Empfindlichkeit : $\Delta I \sim mA$

• Hitzdraht - Amperemeter :

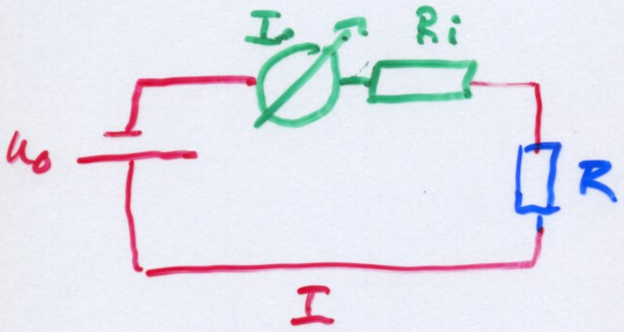
Thermische Ausdehnung von stromdurchflossenem Draht.

Strommessung:

a)



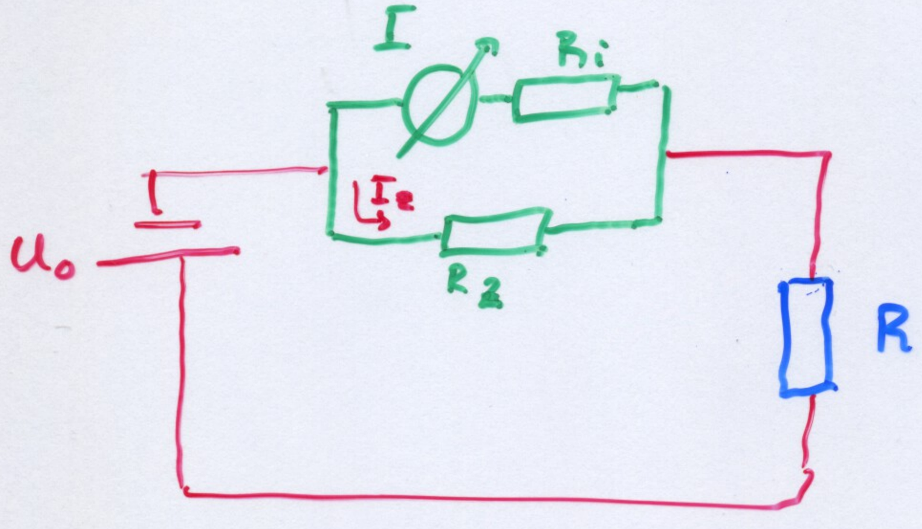
$$I_0 = \frac{U_0}{R}$$



$$I = \frac{U_0}{R + R_i}$$

Innenwiderstand verfälscht Messung; $R_i \overset{!}{\ll} R$

b) Bereichserweiterung:



Mit $I_z \cdot R_z = I_m \cdot R_i$

$$I_0 = I_m \cdot \left(1 + \frac{R_i}{R_z}\right)$$