

Kondensatoren

Zwei Leiterflächen:

$$U = \int_{\textcircled{1}}^{\textcircled{2}} \vec{E} \, d\vec{s} = \phi_1 - \phi_2$$

Kondensator:

Kapazität: $C = \frac{Q}{\phi_1} = \frac{Q}{U}$

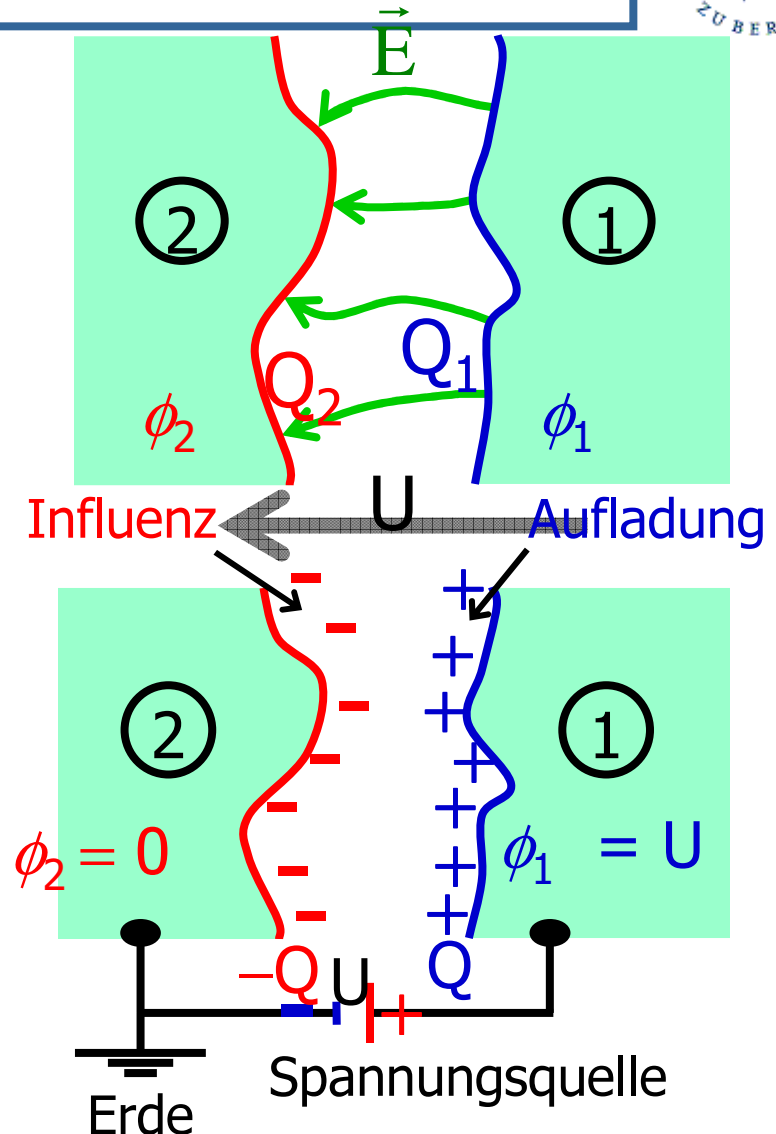
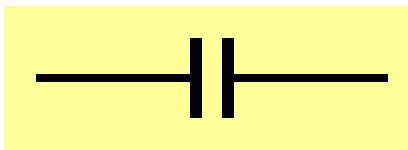
$$\Rightarrow Q = C \cdot U$$

Einheit:

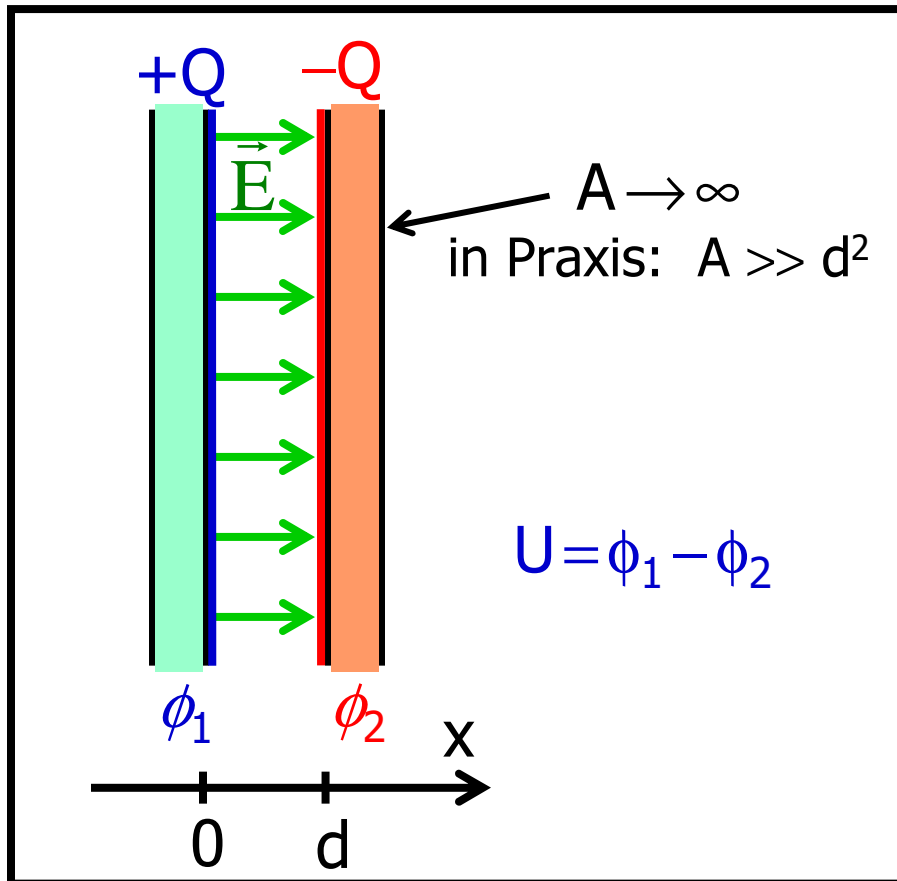
$$[C] = \text{AsV}^{-1} = \text{CV}^{-1} = \text{F} = \text{Farad}$$

(gebräuchlich: pF, nF, μF)

Schaltzeichen:



Der Plattenkondensator



Symmetrie $\Rightarrow \vec{E} \parallel \vec{e}_x, \phi = \phi(x)$

$$\Delta\phi = \frac{\partial^2\phi}{\partial x^2} = 0 \Rightarrow$$

$$\phi(x) = \phi_1 + \frac{\phi_2 - \phi_1}{d} \cdot x = \phi_1 - \frac{U}{d} \cdot x$$

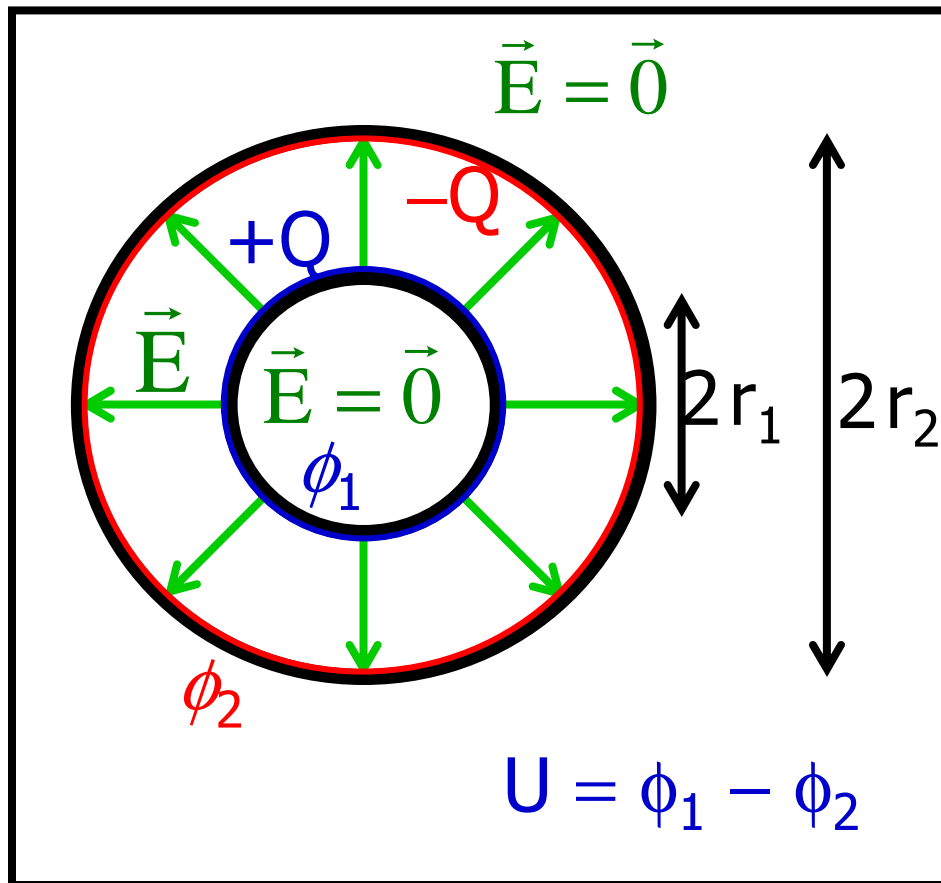
$$\vec{E} = -\vec{\nabla}\phi = -\frac{\partial\phi}{\partial x} \cdot \vec{e}_x = +\frac{U}{d} \cdot \vec{e}_x$$

$$E = \frac{U}{d} \quad \text{homogen}$$

$$\frac{U}{d} = E = \frac{\sigma}{\epsilon_0} = \frac{Q}{\epsilon_0 A} \Rightarrow Q = \epsilon_0 \frac{A}{d} \cdot U \Rightarrow$$

$$C = \epsilon_0 \cdot \frac{A}{d}$$

Der Kugelkondensator

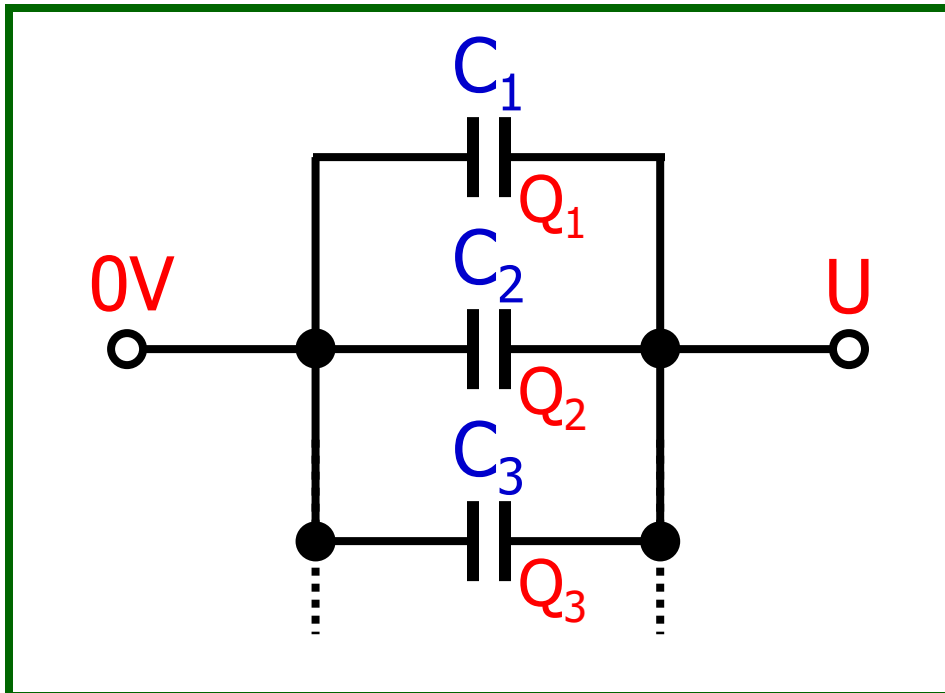


$$\phi_1 = \frac{Q}{4\pi\epsilon_0} \cdot \frac{1}{r_1} \quad \phi_2 = \frac{Q}{4\pi\epsilon_0} \cdot \frac{1}{r_2}$$

$$U = \phi_1 - \phi_2 = \frac{Q}{4\pi\epsilon_0} \cdot \frac{r_2 - r_1}{r_2 r_1}$$

$$C = 4\pi\epsilon_0 \cdot \frac{r_2 r_1}{r_2 - r_1}$$

Parallelschaltung



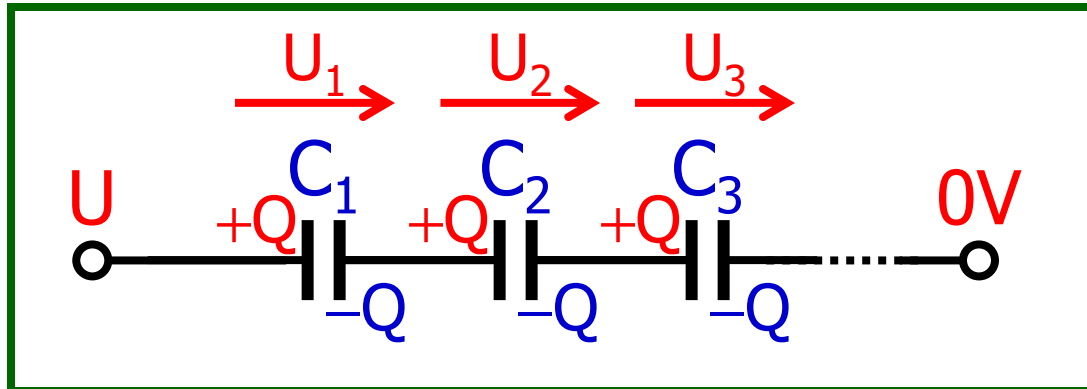
$$U = U_1 = U_2 = U_3 = \dots$$

$$Q = Q_1 + Q_2 + Q_3 + \dots$$

$$C = \frac{Q}{U} = \frac{Q_1}{U} + \frac{Q_2}{U} + \frac{Q_3}{U} + \dots = \frac{Q_1}{U_1} + \frac{Q_2}{U_2} + \frac{Q_3}{U_3} + \dots$$

$$C = C_1 + C_2 + C_3 + \dots$$

Serienschaltung



$$Q = Q_1 = Q_2 = Q_3 = \dots$$

$$U = U_1 + U_2 + U_3 + \dots$$

$$\frac{1}{C} = \frac{U}{Q} = \frac{U_1}{Q} + \frac{U_2}{Q} + \frac{U_3}{Q} + \dots = \frac{U_1}{Q_1} + \frac{U_2}{Q_2} + \frac{U_3}{Q_3} + \dots$$

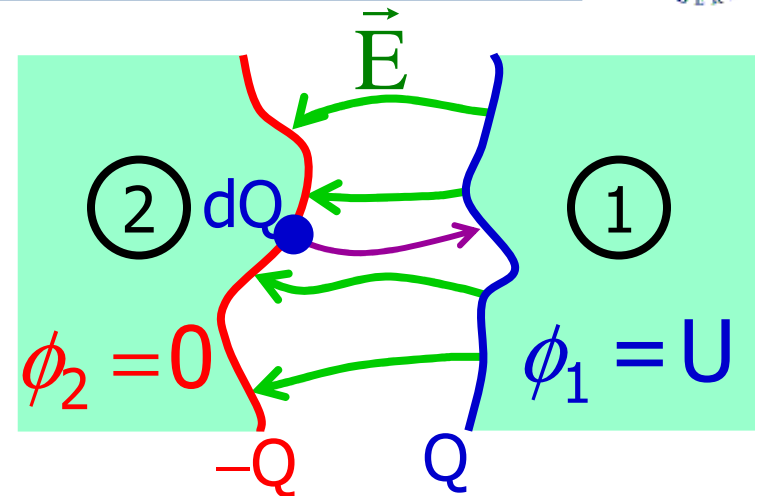
$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \dots$$

1.6. Energie im E-Feld

$$dW_{\text{el}} = - \int \vec{F} d\vec{s} = -dQ \cdot \int \vec{E} d\vec{s}$$

$$= +U \cdot dQ = U \cdot C dU$$

$$W_{\text{el}} = C \cdot \int_0^U \tilde{U} d\tilde{U} = \frac{1}{2} C U^2 = \frac{1}{2} \frac{Q^2}{C}$$



Plattenkondensator:

$$C = \epsilon_0 \frac{A}{d}$$

$$U = E d$$

$$\Rightarrow W_{\text{el}} = \frac{1}{2} \epsilon_0 E^2 A d$$

gilt auch allgemein

Energiedichte: $w_{\text{el}} = \frac{W_{\text{el}}}{A d} \Rightarrow$

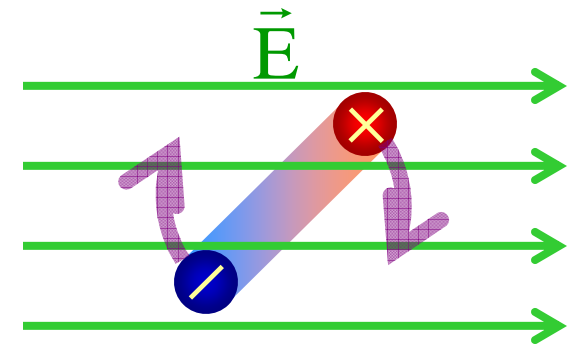
$$w_{\text{el}} = \frac{1}{2} \epsilon_0 E^2$$

1.7. Dielektrika

Problem: Statische elektrische Felder in Materie

- a) polare Dielektrika: z.B. Wasser
permanente molekulare Dipole

Ausrichtung \Rightarrow starkes Gegenfeld



- b) nicht-polare Dielektrika:
induzierte molekulare Dipole: „Polarisation“
 \oplus Atomkerne
 \ominus Elektronenwolke der Atomhüllen

Polarisation \Rightarrow Gegenfeld, oft $\propto E$

