TODO:
- Buy physical copy of Elektrotechnik - Albach

Uebungsgruppe Polybox: https://polybox.ethz.ch/index.php/s/TovEOAu8zo6xh0p

Surface / Volume Integration nudge factors:
Cylindrical coordinate system: r
Spherical coordinate system: $r^2 \sin(\vartheta)$ (where ϑ is the angle from the z axis)

Das Coulomb'sche Gesetz

$$\overrightarrow{F_2} = \frac{Q_1 Q_2 \overrightarrow{e_{12}}}{4\pi\varepsilon_0 |\overrightarrow{r_{12}}|^2}$$

Das elektrostatische Feld

Zum Beispiel: Elektrische, magnetisch
- Distance is from centre of point charge
- A positive test charge of 1C is used to plot electric fields - this means a positive charge has arrows away from it
- Unit vector is always $\frac{\vec{r}_{12}}{|r|} = \vec{e}_{12}$

Feld - die eigenschaften eines Raums, die eine Wirkung auf andere Ladungsstoffen haben
Homogene Feld - Field with the same strength and direction in all points. In reality it exists only when zooming in on a small area. Antonym: *inhomogene / ortsabhaengige Feld.*

$$\vec{E} = \frac{\vec{F}}{Q_2}$$

Um die Kraft in einer gewisse Punkt im Raum zu finden, man muss die Ladung mit dem Feld an diesem Punkt multiplizieren.

Any point in a field always has a unique direction. The electric field at the point exactly between two like charges is 0 as they cancel each other out.

Quantitative - Numbers based
Qualitative - Interpretation based

Das elektrostastische Potential

$$\vec{F} = \vec{E}Q$$

$$W_e = -\int_{P_0}^{P_1} \vec{F} \cdot d\vec{s} = -Q \int_{P_0}^{P_1} \vec{E} \cdot d\vec{s}$$

The work done as a positive charge moves towards another positive is negative, as external energy is needed in order to overcome the repulsive force.

$\oint$ - Closed integral, when a line begins and ends at the same point in space.

Provided the speed as the charge moves through the field tends towards 0 (to minimize the arising electromagnetic field):

$$\oint_C \vec{E} \cdot d\vec{s} = 0$$

Electrostatic potential is the work needed per unit of charge to move it between two points.

$$\varphi = \frac{W_e}{Q}$$

A reference potential (ground) must always be defined, often the Earth's surface / an infinitely far away point is taken as $\varphi_e = 0$. In a circuit, the negative terminal is often used.

Taking r_1 as an infinitely far away point with potential 0, the electrostatic potential in the space surrounding a point charge Q as a scalar is:[1]

$$\varphi(r_2) = \frac{Q}{4\pi\varepsilon_0 r_2}$$

The change in electrostatic potential does not depend on the path taken through the field, only the start and end point.

$$W_e = -Q \int_{P_0}^{P_1} \vec{E} \cdot \vec{s} = Q\left[\varphi_{e(P_1)} - \varphi_{e(P_0)}\right]$$

Voltage (U) - Difference between two potentials with the same reference potential.

$$U_{12} = \varphi(P_1) - \varphi(P_2) = \int_{P_1}^{P_2} \vec{E} \cdot d\vec{s}$$

Elektrische Fluss (Flux)

TODO: Reread Anhang C to understand where the name Fluss comes from

Elektrische Flussdichte (aka elektrische Erregung): How the electric field interacts with a material at a point in space. TODO: Expand after learning about permittivity.

$$\vec{D} = \varepsilon_0 \vec{E} = \vec{e_r} \frac{Q}{4\pi r^2}$$

Elektrische Fluss (Ψ) - Total flux density flowing through a surface. In the case of a charge inside an arbitrary closed surface, it is equal to Q regardless of the charges position / size of the surface.

Electric Flux Density, considering a charge Q inside a sphere with radius r:

$$\begin{aligned}
r &= \text{constant} \\
\Psi &:= \oiint \vec{D} \cdot d\vec{A} \\
&\text{Nudge factor needed for spherical coordinate system} \\
&= \int_0^{2\pi} \int_0^{\pi} r^2 \sin(\vartheta) \varepsilon_0 \overrightarrow{E(r, \vartheta, \varphi)} \cdot d\vartheta d\varphi \\
&= \frac{\varepsilon_0 Q r^2}{4\pi\varepsilon_0 r^2} \int_0^{2\pi} \int_0^{\pi} \sin(\vartheta) \vec{e_r} \cdot d\vartheta d\varphi \\
&\vec{e_r} \cdot d\vartheta d\varphi \text{ is 1, as they are always parallel.} \\
&= \frac{Q}{4\pi} \int_0^{2\pi} (-\cos(\pi)) - (-\cos(0)) d\varphi = \frac{Q}{4\pi} \int_0^{2\pi} 2 d\varphi \\
&= \frac{Q}{4\pi}((4\pi) - (0)) = \frac{4\pi Q}{4\pi} = Q
\end{aligned}$$

[1] Derivation in Elektrotechnik, Albach 1.8.1

Gauss’sche Gesetz

TODO Definition and derivation

Can be used in reverse with infinitely small Gaussian surfaces to calculate the electric field around certain charge distributions.