Vorlesung 1

Physik II

A. Ustinov

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Physik II: Elektrodynamik

1785	Coulomb	$\longrightarrow$	Ladungen
1820	Oerstedt	$\longrightarrow$	Magnetfeld
	Ampere	$\longrightarrow$	Strom
1830	Faraday	$\longrightarrow$	Induktion
1865	Maxwell	$\longrightarrow$	"Axiomen" M. Gleichungen
1887	Hertz	$\longrightarrow$	elektromagnet. Wellen

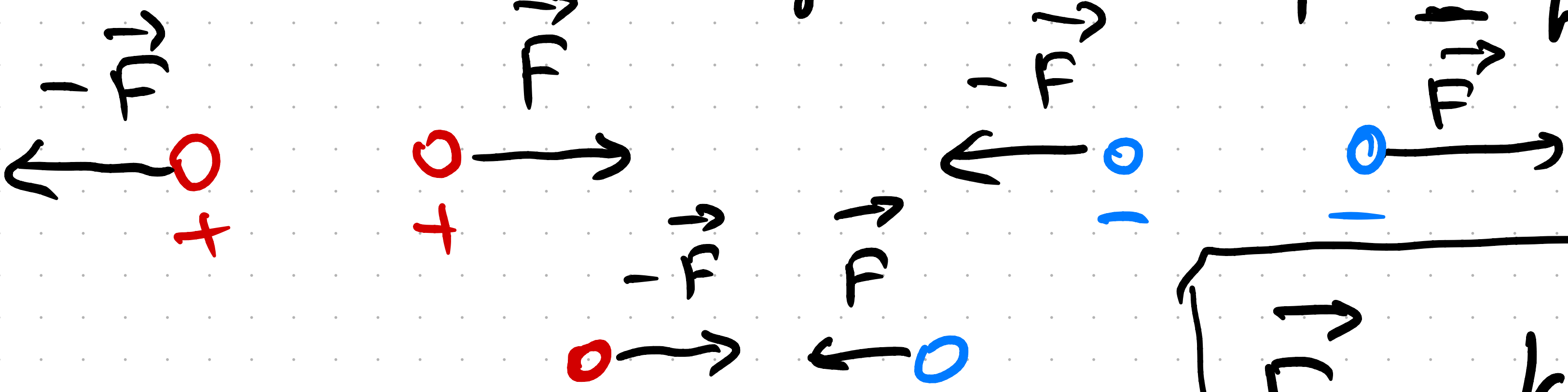
1. Elektrostatik

1.1 Coulombsches Gesetz und elektrische Feld

Coulomb-Kraft

2 Punktladungen

$$F = k \frac{Q q}{r^2};$$



$$\boxed{\vec{F} = k \frac{Q q}{r^3} \vec{r};}$$

Zwei Maßsystemen: cgs und SI

cgs (cm, g, s) : $k = 1$

theoret. Physik

$[Q] = [r] \cdot [F]^{1/2} = 1\,\mathrm{cm} \cdot \mathrm{dyn}^{1/2}$;

elektrostatische Ladungseinheit $\hat{=}$ ESL

$1\,\mathrm{ESL} = 1\,\mathrm{cm} \cdot \sqrt{\mathrm{dyn}}$;

SI (m, kg, s) : $k = \dfrac{1}{4\pi\varepsilon_0}$;

$\varepsilon_0 = 8{,}854 \cdot 10^{-12}\,A^2 s^4\,kg^{-1}\,m^{-3} = \dfrac{1}{4\pi \cdot 9 \cdot 10^9}$;

Dielektrizitätskonstante

$[\varepsilon_0] = 1\, A \cdot s \cdot V^{-1} m^{-1}$;

$[Q] = 1$ Coulomb $\hat{=}\ 1\,C = 1\,A \cdot s$;

mit $Q = q = 1\,C$; $r = 1\,m$;

$$F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{1\,C^2}{1\,m^2} = 9 \cdot 10^9\,N \;;$$

$1\,C \approx 3 \cdot 10^9$ ESL ;

SI cgs

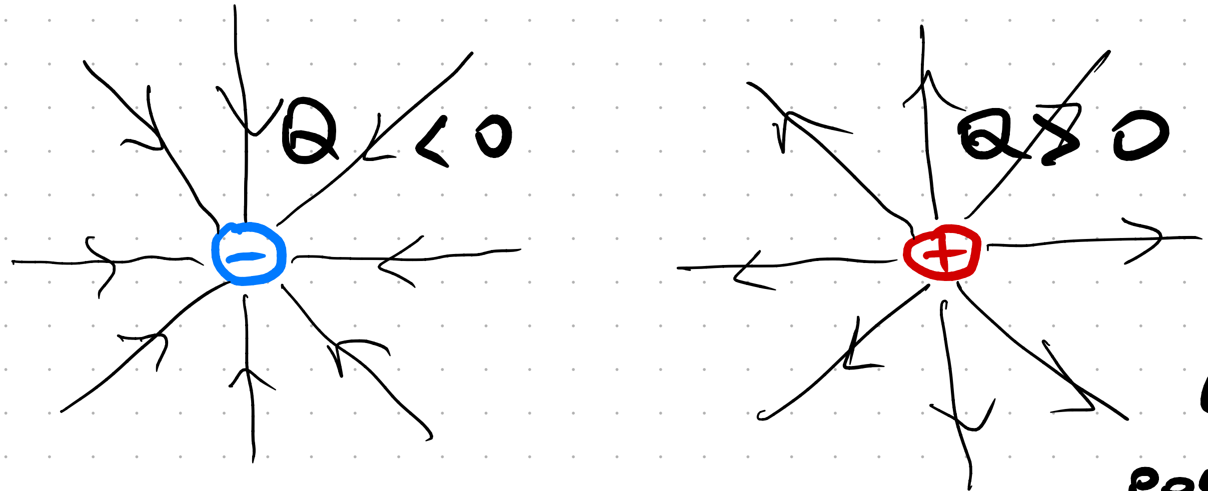
Elementarladung : $e^- = -1{,}60 \cdot 10^{-19}\,C$;

Positron : $e^+ = +|e^-|$;

p^+ Proton ; p^- Antiproton

π^+, π^- Mesonen ; μ^+, μ^- Myonen

Elektrisches Feld : $\vec{E} = \frac{\vec{F}}{q} = \frac{Q}{r^3}\vec{r}$;



Probeladung

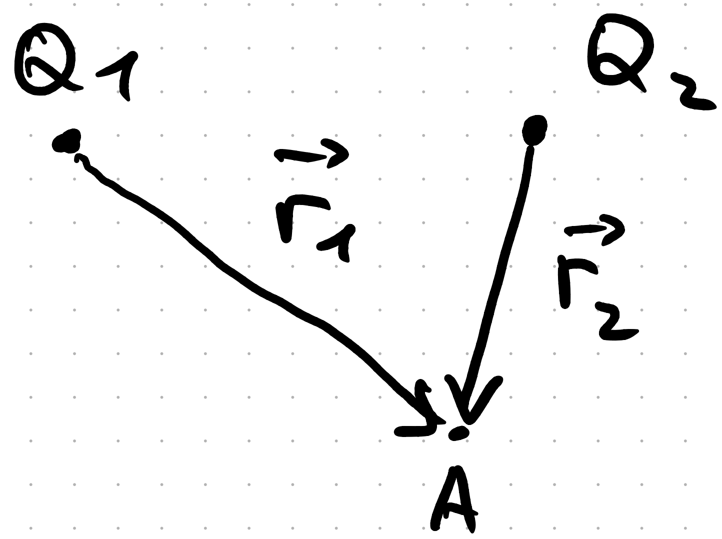
Feldlinien

↳ Bewegungsrichtung positive Probeladung }

$\vec{E} \mathrel{\hat{=}}$ die elektrische Feldstärke der Ladung Q

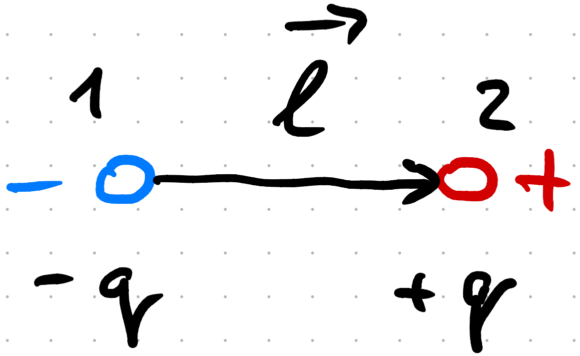
$$[E] = \left[\frac{F}{q}\right] = 1\,N/As = 1\,\frac{V}{m};$$

<u>Superpositionsprinzip</u>: $\vec{E} = \sum_i \vec{E}_i$;



$$\vec{E}_A = \frac{Q_1}{r_1^3}\vec{r}_1 + \frac{Q_2}{r_2^3}\vec{r}_2;$$

1.2 Der elektrische Dipol

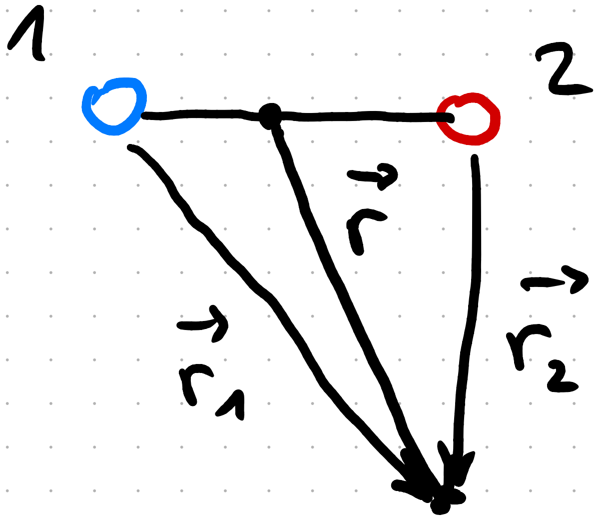


Dipolmoment:

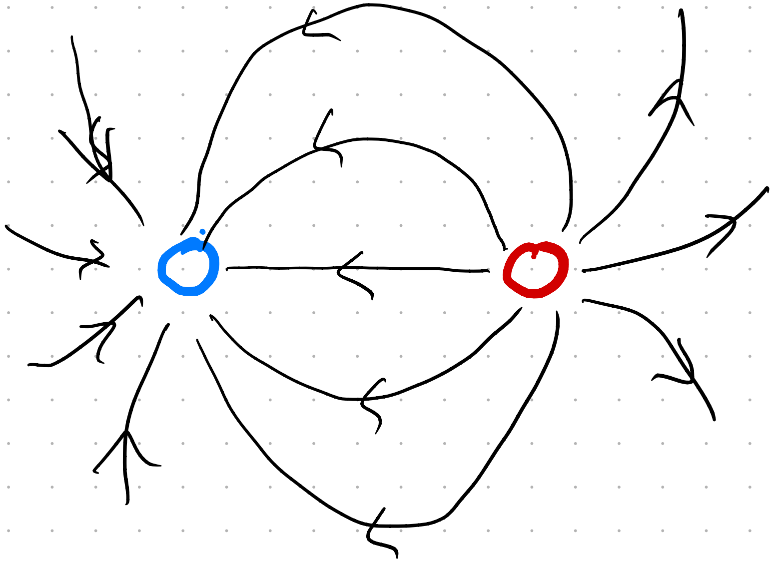
$\vec{p} = q\vec{\ell}$;

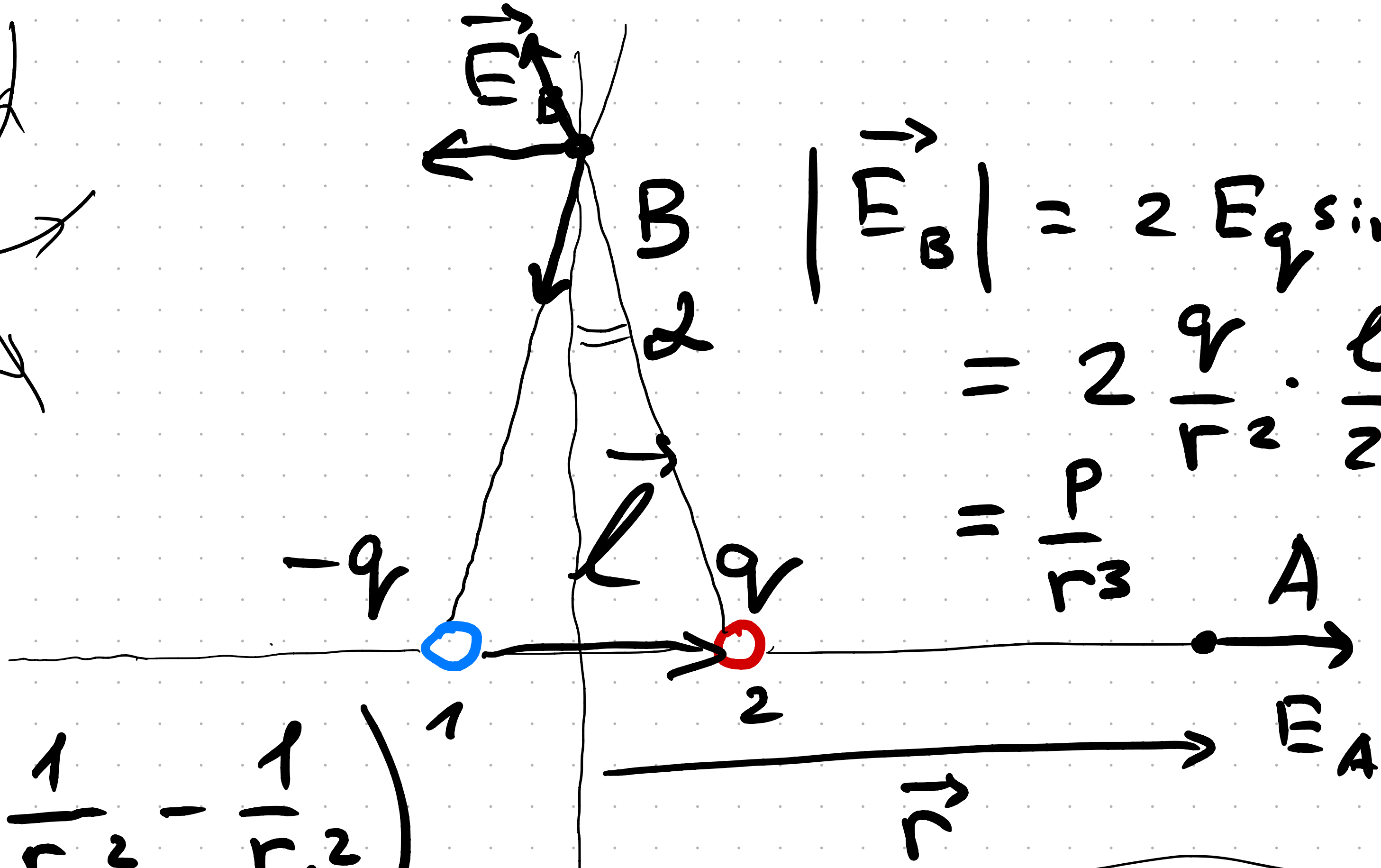
Abstand $|\vec{\ell}|$ ist fest;

"Punktdipol" für $r \gg \ell$;



$r_1 \approx r_2 \approx r$;

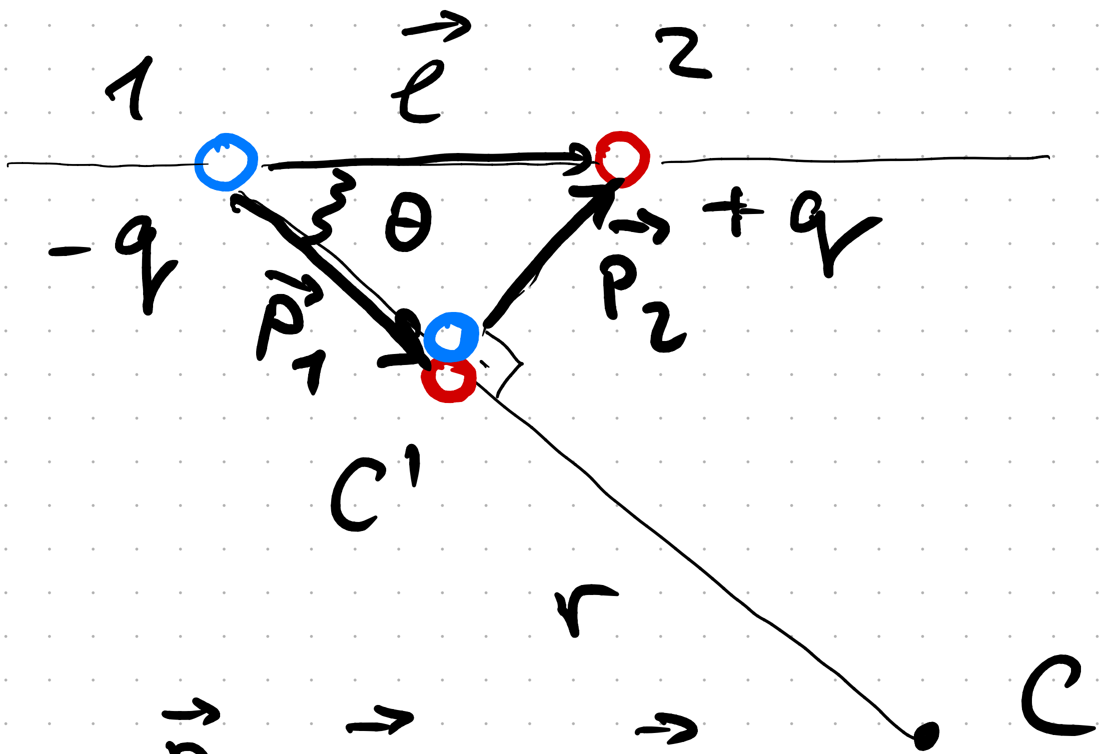




$$|\vec E_B| = 2E_q\sin\alpha$$
$$= 2\frac{q}{r^2}\cdot\frac{l}{2r}$$
$$= \frac{p}{r^3}$$

$$|\vec E_A| = q\left(\frac{1}{r_2^2}-\frac{1}{r_1^2}\right)$$
$$= q\frac{(r_1-r_2)(r_1+r_2)}{r_1^2\, r_2^2}$$
$$= \frac{2ql}{r^3} = \frac{2|\vec p|}{r^3};$$

$$\vec E_B = -\frac{\vec p}{r^3}$$
$$\vec E_A = \frac{2\vec p}{r^3};$$



$$\vec{p}_1 + \vec{p}_2 = \vec{p};$$

$$|\vec{p}_1| = |\vec{p}| \cdot \cos\theta;$$

$$(\vec{p}\cdot\vec{r}) = p \cdot r \cdot \cos\theta$$

$$\vec{E}_c = \frac{1}{r^3}(2\vec{p}_1) - \frac{1}{r^3}\vec{p}_2$$

$$= \frac{2\vec{p}_1}{r^3} - \frac{(\vec{p} - \vec{p}_1)}{r^3}$$

$$= \frac{3\vec{p}_1}{r^3} - \frac{\vec{p}}{r^3};$$

$$\vec{p}_1 = (\vec{p}\cdot\vec{r})\cdot\vec{r}\cdot\frac{1}{r^2};$$

$$\boxed{\vec{E}_c = \frac{3(\vec{p}\cdot\vec{r})\vec{r}}{r^5} - \frac{\vec{p}}{r^3}}$$