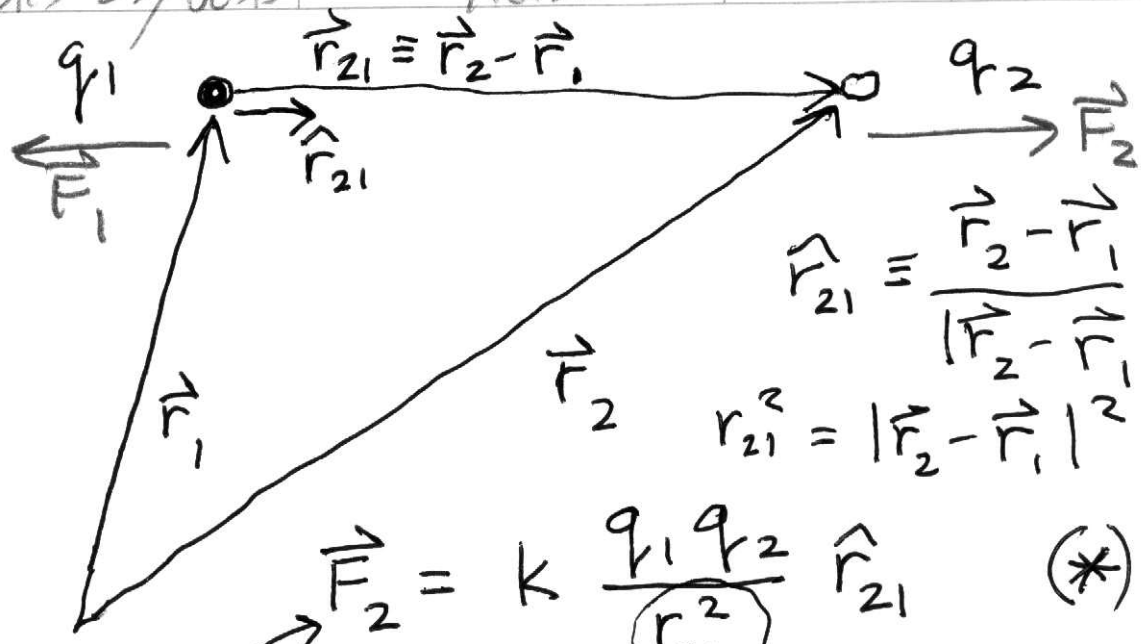



$$\hat{r}_{21} \equiv \frac{\vec{r}_2 - \vec{r}_1}{|\vec{r}_2 - \vec{r}_1|}$$

$$r_{21}^2 = |\vec{r}_2 - \vec{r}_1|^2$$

$$\vec{F}_2 = k \frac{q_1 q_2}{r_{21}^2} \hat{r}_{21} \qquad (*)$$

$$\vec{F}_1 = -\vec{F}_2$$

newtons
or dynes (!) new

meter$^2$
or centimeters$^2$ (!) new

$$\text{newton} \equiv \frac{kg \cdot m}{s^2} \qquad \text{dyne} \equiv \frac{gm \cdot cm}{s^2}$$

$q_1, q_2 \rightarrow$ measured in units of charge can be independent of $*$, so the constant $k$ is introduced to make units turn out OK

"practical units" $\rightarrow$ measure $q$ in "Coulombs" $\rightarrow$ related to batteries, electrolysis

origin not really physics, so $k$ is very important.

$$\text{newtons} = \frac{k \cdot (\text{Coulomb})^2}{(\text{meter})^2}$$

Coulombs used with meters, kg, s "SI"

$$[k] = \frac{m^2}{C^2} \cdot N$$

$$\boxed{k = 9 \cdot 10^9 \ \frac{m^2}{C^2} \cdot N}$$ (from measurement)

History has left k with another name,

$$k \equiv \frac{1}{4\pi \varepsilon_0}$$

$\varepsilon_0 \equiv$ "permittivity of vacuum" ancient concept.

"modern physics units"

⇒ $\boxed{\text{choose } k=1}$ and <u>redefine charge</u>

⇒ kilograms → grams
meters → centimeters
seconds → seconds
Newtons → dynes

why? just a fact.

⇒ q in "electrostatic units" or esu

$$1 \text{ esu} \cong \frac{1}{3} \cdot 10^{-9} \text{ Coulombs}$$

$$1 \text{ Coulomb} = 3 \cdot 10^9 \text{ esu}$$

SI: $$\vec{F}_{21} = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r_{21}^2} \hat{r}_{21}$$

Newtons, Coulombs, meters, kg

Gaussian cgs: $$\vec{F}_{21} = \frac{q_1 q_2}{r_{21}^2} \hat{r}_{21}$$

Dynes, esu, centimeters, grams

In either case, there is a <u>minimum</u> unit of charge that has never been subdivided...

charge on a proton = "e" = $1.6 \cdot 10^{-19}$ C
= $4.8 \cdot 10^{-10}$ esu

The charge on an <u>electron</u> is <u>exactly</u> $-e$, experimentally tested to 1 part in $10^{20}$.

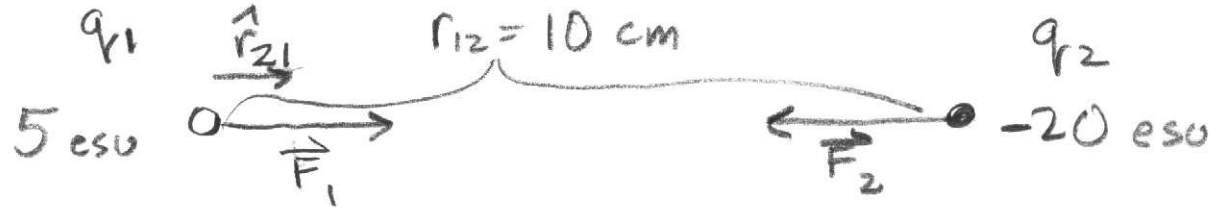
Electrons and protons are otherwise very different. For example, protons have a mass $\simeq 2000\times$ that of electrons, protons have a <u>size</u>, $\simeq 10^{-13}$ cm, but electrons do not!

Also, in a hydrogen atom, the electron moves at $\simeq 10^{-2} \times$ speed of light, proton $\simeq 10^{-5} \times$ speed of light, but nonetheless their charges still cancel...

$$\boxed{\text{Electric charge is independent of velocity}}$$

Charges add up.

Electrostatic Forces add up... presence of a third charge does not influence behavior of first two.




$$\vec{F}_2 = \frac{q_1 q_2}{r_{21}^2}\,\hat{r}_{21} \quad \underline{\text{Gaussian c.g.s.}}$$

$$\boxed{\vec{F}_2 = \frac{5(-20)}{(10^2)^2} = \left(-10^{-2}\text{ dynes}\right)\cdot\hat{r}_{12}}$$

SI: $1 \text{ dyne} = 1\,\frac{\text{gm}\cdot\text{cm}}{s^2} = 1 \cdot 10^{-3} \cdot 10^{-2}\,\frac{\text{kg m}}{s^2}$

$= 10^{-5}$ N

$$\boxed{\vec{F}_2 = \left(-10^{-7}\right)\hat{r}_{21}\text{ N}}$$