Electric Charge pp 1-10 Purcell

Causes static electricity:

① rub balloon on hair, stick to wall/ceiling

② shocks after walking on carpet

these most frequent/effective on cool/cold dry days... when air is a very good insulator, so charge cannot escape through air... escape off your body or the balloon.

The most important use of electricity is the wall socket... "voltage" and all its consequences. To work toward describing that property, start with forces/mechanics of electricity, aka "electrostatics".

charge q_1 q_2

1) q_1, q_2 can be $>, =, < 0$

2) force always directed on a line joining charges, can be either attractive or repulsive

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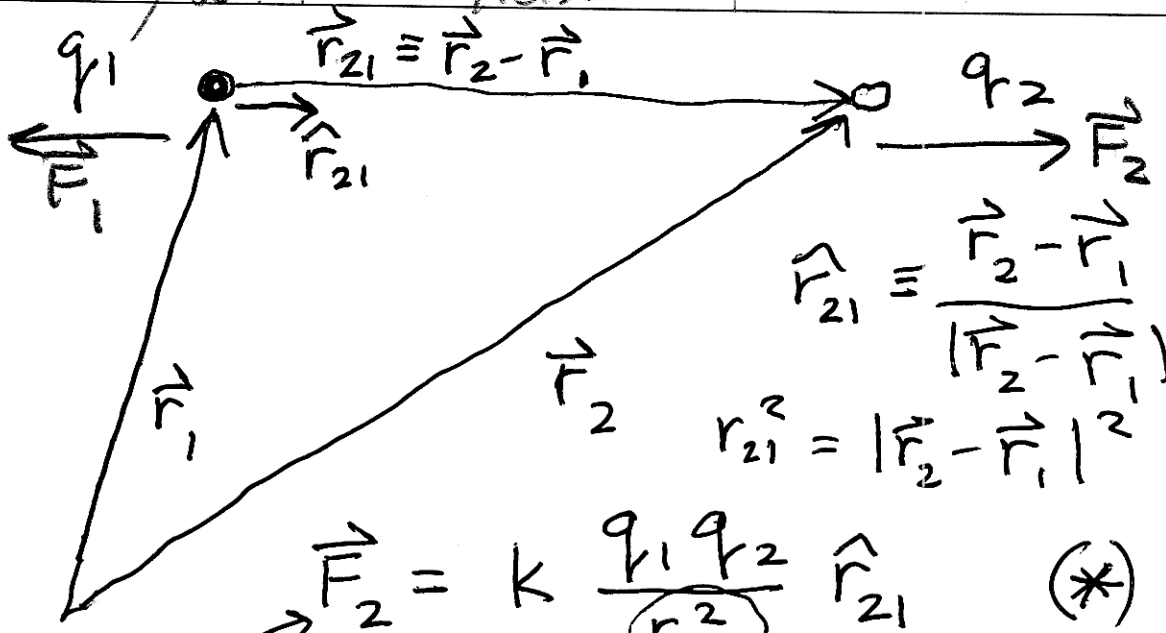
3) NUMERICALLY... charge $\longleftrightarrow$ Newtons



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

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

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

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

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

"practical units" → measure q in "Coulombs" → 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"

$\Rightarrow$ choose $k=1$ and redefine charge

$\Rightarrow$

kilograms	→	grams	} why? just a fact.
meters	→	centimeters	
seconds	→	seconds	
Newtons	→	dynes	

$\Rightarrow$ 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!