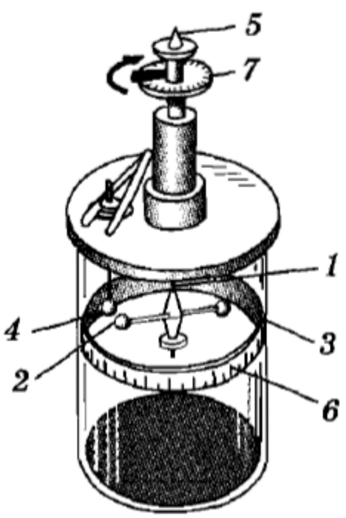
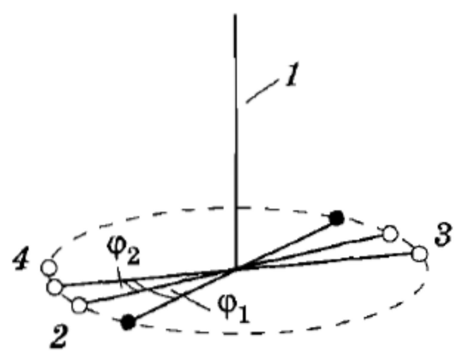
Coulomb Law.

Charles-Augustin de Coulomb . 22 years old in 1785 :
«*Premier Mémoire sur l'Électricité et le Magnétisme.*» :

... Il résulte donc de ces trois essais, que l'action répulsive que les deux balles électrifées de la même nature d'électricité exercent l'une sur l'autre, suit la raison ***inverse du carré des distances.***

Translation: It follows therefore from these three tests, that the repulsive force that the two balls — [which were] electrified with the same kind of electricity — exert on each other, follows the inverse proportion of the square of the distance





Coulomb started with balls 2 and 4 touching each other. Then he charged 4 and the charge was equally distributed between 2 and 4. Now the balls repel and the string is stretched to the angle

$$\varphi_1 = 36^\circ$$

Then Coulomb rotated the knob 7 in the direction shown above. Ball 2 feels more force from the string which is now more twisted and pushes the ball 2 harder to get closer to the ball 4. The angle became

$$\varphi_2 = 18^\circ$$

Scale 7 showed that he rotated rod 5 by

$$\alpha = 126^\circ$$

So the string is now twisted to the angle

$$\beta = \alpha + \varphi_2 = 144°.$$

Which is 4 times greater than the initial angle. The distance between balls was initially

$$r_1 = 2d\sin\frac{\varphi_1}{2}$$

where d is radius of the dashed circle above. Now it became

$$r_2 = 2d\sin\frac{\varphi_2}{2}$$

so

$$\frac{r_1}{r_2} = \frac{\sin 18°}{\sin 9°} \approx 2$$

The angle of the twisting is proportional to the force. So when distance decreases by factor of two, force increases by factor of 4.

Thus

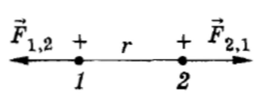
$$F \sim \frac{1}{r^2}$$

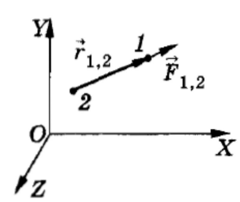
Charges define force. But in our case the force will be used to give ***definition*** of charge:

$$F = k\frac{|q_1||q_2|}{r^2}$$

In vector form

$$\vec{F}_{1,2} = k\frac{q_1 q_2}{r_{1,2}^3}\vec{r}_{1,2}.$$



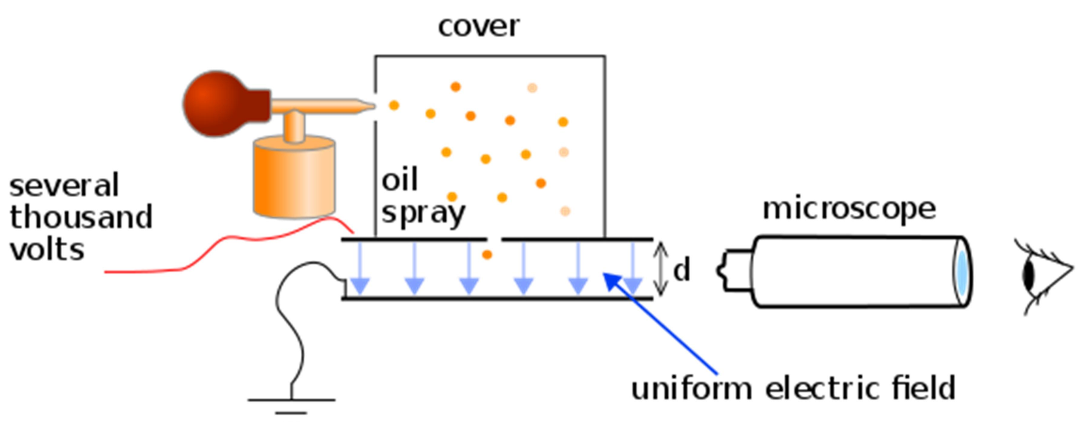


Main properties of electric charge

- Positive or negative. Same sign charges repel and different sign charges attract.
- Total charge of isolated system is not changing.
- Charge quantizes.
- Charge does not depend on velocity.

We discuss these points when we meet in more detail.

Millikan experiment.



Homework problem #1. *Four equal charges q are placed in the corners of a square with side equal to a. What charge one should place in the center of the square to bring the system to equilibrium (that is to make sure the corner charges do not fly apart).*

Homework problem #2. *Watch a short youtube animation about Millikan experiment (use online version of this sheet on SchoolNova's site to copy-paste or to follow link):* [*https://www.youtube.com/watch?v=XMfYHag7Liw*](https://www.youtube.com/watch?v=XMfYHag7Liw)

Units of charge.

Gaussian system:

Unit of charge is such charge which acts on the charge equal to itself and placed 1 cm away from it with a force equal to 1 dyn.

$$F = \frac{q_1 q_2}{R^2}$$

Charge of electron in this system:

$$e = 4.8 \cdot 10^{-10}\ ESU$$

– electrostatic units of charge (also you may meet Fr ,Franklin, StatC, statcoulomb words denoting the same).

SI system

Unit is Coulomb. It is defined as $1C = 1A \cdot 1s$.

$$1C = 3 \cdot 10^{9}\ ESU$$

Two charges $1C$ *, 1km apart from each other, repel with a force slightly below than the Earth gravity's attraction of 1 ton weigh.*

$$F = k\, \frac{q_1 q_2}{R^2}$$

$$k = 9 \cdot 10^{9}\ N \frac{m^2}{C^2}$$

Elementary charge in SI is

$$e = 1.6 \cdot 10^{-19}\ C$$

Homework problem #3. *Using relation between C and ESU prove that I gave you right value of k.*