Coulomb's law and permittivity of medium

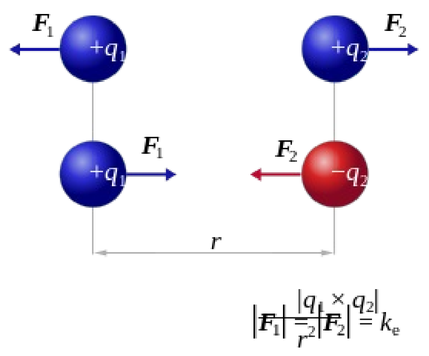
Coulomb's law describes the force F exerted on each other by two point charges Q_1 and Q_2 located at a distance r. This force is repulsive if the charges have the same sign, in the case of charges with different charge signs this force is attractive. Mathematically, Coulomb's law is expressed as follows:

$$F = \frac{1}{4\pi\varepsilon} \cdot \frac{Q_1 Q_2}{r^2}$$

The constant ε is called the **permittivity**. The permittivity of the vacuum is denoted by ε_0 and its size is $8.854 \cdot 10^{-12}\ Fm^{-1}$.

In words, Coulomb's law can be formulated in such a way that the force exerted by two electrically charged particles on each other is directly proportional to the product of their charges and inversely proportional to the square of their distance.

When any substance is placed in an electric field, a force begins to act on the electrically charged particles contained in this substance. If the substance is a **conductor**, i.e. if it contains free charge carriers, these travel to the surface of the body. An electric field appears between the charges on the surface of the body, which acts against the external electric field. In the case of an ideal conductor, the movement of charges stops only when the electric field induced in this way reaches the same magnitude as the external electric field, but with the opposite orientation. In practice, this phenomenon means, among other things, that in a cavity surrounded on all sides by a conductive medium, there will be a zero electric field in a steady state. This arrangement is called a Faraday cage and is used in practice whenever we need to perfectly shield external electric fields.



Mutual effect of charges

If an ideal dielectric, i.e. a substance without free electric charge carriers, is inserted into the external electric field, the situation is somewhat more complicated. Although the dielectric does not contain free charge carriers, its molecules can be polar by their very nature (e.g. a number of organic polymers) or they can be partially polarized by "deformation" of the electron shell due to an external electric field (e.g. noble gases). In both cases, the dielectric particles acquire a dipole moment oriented against the external electric field. Macroscopically, the dipole moments of the individual particles of the dielectric manifest themselves as a vector of dipole polarization ***P***, which in the case of an isotropic[note 1] dielektrika směr opačný směru intenzity vnějšího elektrického pole ***E***. dielectric direction opposite to the direction of the intensity of the external electric field *E*. In the event that the dielectric behaves linearly, which is usually the case for not too large external intensities, the polarization value is a multiple of the electric field intensity. Since polarization is an external manifestation of the existence of dipoles in the dielectric oriented against the external electric field, it actually weakens the external electric field and inside the dielectric the electric field intensity will be lower. Numerically, this change is captured by the change in permittivity of the environment ε. Tabulated is usually the relative permittivity ε_r, from which the permittivity is calculated simply by multiplying by the vacuum permittivity:

$$\varepsilon = \varepsilon_0 \cdot \varepsilon_r$$

The value of relative permittivity is greater than one in all environments, examples of several values are given in the following table:

Substance	ε_r
air	1,00054
paper	3,5
glass	7,6
water	80

The high permittivity value of water is one of the reasons why water is a very good solvent for ionic crystals. In an environment with a relative permittivity of 80, the oppositely charged ions are bound with a force roughly 80× lower than in air, so they leave the crystal more easily.

If the dielectric is placed in an alternating electric field, it behaves significantly more complicated, for example, the permittivity depends on the frequency, and in the mathematical description it is necessary to go to complex numbers. On the other hand, the behavior of the permittivity is determined to a certain extent by the chemical composition of the environment, so from the knowledge of the so-called dielectric spectrum (also the impedance spectrum - depending on the method of measurement) it is possible to infer the chemical composition of the unknown environment. In medicine, such an approach is the theoretical basis of bioimpedance analysis used, for example, in measuring hydration (a more or less experimental procedure) or in estimating the amount of body fat.

Links

Footnotes

1. Isotropic means that it has the same properties in all directions. This seemingly natural property is violated, for example, in crystals. From everyday experience, every road behaves as anisotropic (i.e. non-isotropic), for example, while driving longitudinally is usually possible, in the direction perpendicular to the road axis it is very problematic.

Resources

- KUBATOVA, Senta. *Biofot* [online]. [cit. 2011-01-31]. <https://uloz.to/!CM6zAi6z/biofot-doc>.
- SEDLÁK, Bedřich – ŠTOLL, Ivan. *Elektřina a magnetismus.* 1. edition. Praha : Academia a Karolinum, 1993. ISBN 80-200-0172-7.
- SVOBODA, Emanuel. *Přehled středoškolské fyziky.* 3. edition. Praha : Pometheus, 1996. ISBN 80-7196-116-7.

External links

- Czech translation of the course *Elektřina a magnetizmus* z MIT: [1] (https://www.aldebaran.cz/elmg/)