Electrostatic field

An electrostatic field is a special case of an electric field. An electric field exists in the vicinity of every electrically charged (electrified) body, or electrically charged particles, and its manifestation is the mutual force action of these electric charges.

The simplest case is the state when the field is caused by a charge that is constant (its size does not change) and is at rest (does not move) with respect to the chosen frame of reference. We then refer to this field as electrostatic. Electrostatic fields are therefore classified as stationary electric fields (i.e. time-invariant) - the opposite is non-stationary electric fields (time-varying).

The physical nature of the electrostatic field

An electrostatic field (like, for example, a gravitational field) is a form of matter and its essence is material – its source is particles carrying an electric charge.

An electrostatic field can only exist in a non-conductive medium (dielectric), because in a conductive medium the charges would move (and thus create a direct current - then it would be another form of stationary electric field). Therefore, no electric current can exist in an electrostatic field (electrical charges do not move).

Basic properties

To create an electric field, the presence of an electric charge is necessary, which is always bound to a material object. Each charge that occurs in nature is a multiple of the elementary charge, i.e. the charge of one electron e = $1{,}602 \times 10^{-19}$ C (quarks with a third electrical charge do not occur freely in nature, only in combinations); this rule is also referred to as the charge quantization law. By agreement, there are positive charges and negative charges (a positive elementary charge has a proton, a negative electron).

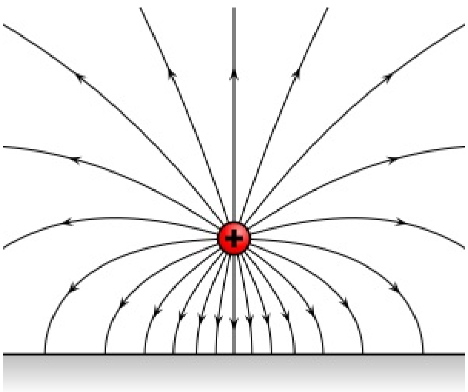
The law of conservation of electric charge applies – in an electrically isolated system of bodies, the total electric charge is constant; electric charge cannot be created or destroyed, it can only be moved (within one body or from one body to another).

According to the principle of superposition of electric fields, the intensity of the field (see below) formed by a system of N charges is equal to the vector sum of the intensities of the fields created by each of them individually.

For point electric charges, Coulomb's law applies, the law of the force of charges, describing the magnitude of the force that these two point charges exert on each other.

Field lines are used to represent the electric field, which are imaginary lines characterizing the force action of the field at different points in space (they start from positive electric charges and go towards negative electric charges), and equipotential levels.

Quantities characterizing the electrostatic field



- The basic quantity describing the source of electric force action is electric charge (**Q**), a scalar quantity whose unit in the SI system is the *coulomb* (**C**).

The most important quantities characterizing the electrostatic field are the vector electric intensity and the scalar electric potential.

- **The intensity of the electrostatic field** (electric intensity; **E**) is a vector quantity expressing the magnitude and direction of the electric field. It is defined as the quotient of the electric force $\mathbf{F_e}$, which acts on the positive point charge at that location (or would act) and the magnitude of this charge **q** ($E = F_e / q$). It is possible to substitute the relation for calculating the electric force from Coulomb's law into this relation– then the magnitude of the intensity at a given point is directly proportional to the size of the charge and inversely proportional to the square of the distance of this point from the charge, and at the same time depends on the environment. If the charge is positive, both the electric intensity and the electric force have the same direction; if the charge is negative, they have the opposite direction. The tangent of the field line at each of its points determines the direction of the electric field intensity. The unit in the SI system is the *volt per meter* ($\mathbf{V.m^{-1}}$), another unit used is the *newton per coulomb* ($\mathbf{N.C^{-1}}$).

- **The electric potential** (**φ**) is a scalar quantity that we define as the ratio of the electric potential energy $\mathbf{E_p}$ of a positive point charge **q** and this charge ($\varphi = E_p / q$). It is therefore the amount of work required to transfer a unit electric charge from a reference point to which a zero potential is assigned to a given location. Points with the same potential form a potential surface (equipotential surface). The unit of electric potential is the *volt* (**V**).

- **Electric voltage** (**U**) characterizes the field's ability to do work. It is equal to the difference of the electric potentials of two points A and B of the electric field ($U = \varphi_A - \varphi_B$), i.e. the work done by the electric field when transferring a unit charge from place A to place B ($U = W_{AB} / q$). It does not depend on the shape of the trajectory, but only on the initial and final location. Its unit is the same as that of electric potential, i.e. the *volt* (**V**).

- **Electric polarization** (**P**) is a vector quantity related to the polarization of the dielectric – it describes the electric field created in the dielectric by its polarization (see below), it expresses the effect of the external electric field on the dielectric. The unit is *coulomb per square meter* (**C/m^2**).

- **Electric induction** (**D**) is a vector quantity (caution – do not confuse with the phenomenon of electrostatic induction (see below) or with the term electromagnetic induction) which is equal to the induced charge that falls on the unit area of a conductor placed in an electrostatic field ($D = Q / S$) . It describes the electric field in any environment as a result of the action of only free charges (it does not take into account the influence of bound electric charges). The unit is *coulomb per square meter* (**C/m^2**).

- **Electrical capacity** (**C**) expresses the ability of a conductor (system of conductors) to hold a certain charge Q at a given potential value φ (it is defined by the relation $C = Q / \varphi = Q / U$). The capacity of a single conductor is small, therefore capacitors are used (a system of two conductors (most often plates), a dielectric between them, which increases the capacity ε_r-times). The unit in the SI system is the *farad* (**F**).

Conductor and insulator in an electrostatic field

Conductor

If we bring an electrically charged body close to an insulated conductor, an electrostatic field will also be created in it, which will cause free electrons to move. Free electrons carrying a negative charge move to one side of the conductor, which becomes negatively charged (at the point where the field lines enter the conductor). On the other hand, a lack of electrons induces a positive charge. The phenomenon is called electrostatic induction, and electrically induced charges are *induced charges*(there are two, equal in size and non-uniformly induced). The action continues until the field of induced charges disturbs the external field in the entire volume of the body and the field intensity everywhere inside the conductor is zero. We can separate the induced charges in the conductor from each other - by dividing the conductor into two parts (thereby obtaining one body positively charged and the other negatively charged). If we do not separate the conductor and move the charged body further away, the phenomenon disappears.

Insulator

An insulator (dielectric) does not contain free electrons in its structure, but nuclei and electrons are not tightly bound and can move in atoms. The atoms of the insulator, which is not located in an electrostatic field, are symmetrically arranged. However, due to the action of an external electrostatic field, the movement of nuclei and electrons occurs. The positive nucleus of an atom in an electric field moves in the direction of intensity, while the negative shell moves in the opposite direction. A particle with two electric poles, called *an electric dipole*, is created (these induced charges are completely bound to the dipoles and cannot be dissipated or separated). Therefore, if we put an insulator in an electric field, the **dielectric becomes polarized**, that is that dipoles are formed (electrical charges opposite to each other are created on the sides of the insulator) and the resulting electric field has the opposite intensity to the original field. Therefore, the force action of the external electric field is weakened by polarization (the intensity of the field weakens ε r -times compared to the vacuum environment, where ε_r is the relative permittivity of the dielectric).

Links

References

- LEPIL, Oldřich – ŠEDIVÝ, Přemysl. *Fyzika pro gymnázia - Elektřina a magnetismus.* 5. edition. Praha : Prometheus, 2008. ISBN 978-80-7196-202-1.

- JAVORSKIJ, Boris Michajlovič – BRDIČKA, Miroslav. *Přehled elementární fyziky.* 1. edition. 1989. ISBN 80-03-00184-6.

- REICHL, Jaroslav. *Elektrický náboj a elektrické pole* [online]. [cit. 2013-11-23]. <http://fyzika.jreichl.com/main.article/view/218-elektricky-naboj-a-elektricke-pole>.