

PHYSICAL MEANING OF CONCEPTS “ELECTRICAL CHARGE”  
AND “ELECTRIC FIELD”

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**Abstract:** In physics, as in other sciences, scientific results are often presented formally, without appropriate disclosure of their physical meaning. For example, in the discussion about interacting charged bodies the meaning of charge is not discussed. It is shown that the term “electric charge” in science is conditional and has an auxiliary symbolic meaning. In reality there is a “positive” and “negative” substance in nature. There is no any charge isolated apart from the substance. In fact, in nature there are a proton and an electron as a matter. The substance of the electron and the proton substance are different by their nature. Therefore, it is logical to assume the substance as a “positive” or “negative” charge itself. It is shown that substances of electrons and protons should emit some unknown particles, that cause the interaction between “charged” bodies. The space distribution of interacted particles forms an electric field.

**Key words:** charges, charged bodies, the electron, proton, matter, electric field.

**Introduction.** In electrical engineering and radio engineering, the concepts of electric charge and electric field are commonly used. We use term “electric charge” as something traditional, understandable, and non-explanatory. Here is an example of the charge in the modern textbook: “The electric charge characterizes the property of the body to a certain interaction ... From the experience the fundamental property of an electric charge is that it exists in two types, conventionally called positive and negative charges. Charges of the same sign are repel each other, and the opposite signs are attract each other respectively” [1, p. 11]. That is, the charge exists as something obvious that does not require proof and even an explanation. So, charge is the property of the body to interact. But the fundamental property of this property is the existence of electric charge in two forms. In a high school situation is similar. For example, I. Savelyev, in a well-known textbook “Electricity and Magnetism”, wrote about the charge: “All bodies in nature are able to electricity, that is, to acquire an electric charge. The charged body interacts with other charged bodies. There are two types of electricity, conventionally called positive and negative charges. Charges with the

same signs repel each other and those with opposite signs attract” [2, p. 9]. Similarly, the charge is explained in the foreign literature as follows: “The charge of an electron or proton is an intrinsic property of the particle” [3]. Again, the nature of an electric charge remains unknown. These questions cannot be answered until the nature of the electric charge is identified [4]. “Electric charge is an intrinsic characteristic of the fundamental particles making up those objects; that is, it is a characteristic that automatically accompanies those particles wherever they exist” [5]. As we can see, here the charge is considered as an internal property, although in reality it has the property of external interaction. Thus, the issue of the physical content of the concept of charge remains relevant today. It is possible to agree entirely with the author [6] that “there is no clear explanation for the electric charge.”

**Problem formulation.** From this we can conclude that in nature there is something such as “charges” and they interact. A well-known law of the interaction of point “charges” is Coulomb's law. But the charges have one extraordinary feature — they do not exist separately, but always with substance. We know about it with certainty. Nobody could separate the charge from a substance. In addition, the mechanism of the interaction of the electric charges, their mutual attraction or repelling is incomprehensible. These traditional questions of physics need to be explained in more detail.

**Discussion of the problem.** Even in ancient times it was noticed that when two bodies are rubbed, they interact with each other – are attracted or repelled. This interaction was explained by the appearance of positive or negative “electric charges” on bodies. It could be different amount of electric charges. It can move from one body to another. Now we know that the smallest negative charge is in the electron as the smallest particle of matter. The substance of the electron can be conventionally called “electronic substance”. The smallest positive charge is in the proton which also known as the smallest particle of the “proton substance”. In our time, we know that electronic and proton substances are quite different substances. And they are different not only because they have different charges –

positive and negative, but also because of the difference of the internal structure of electron and proton matter. The electron is known to be an elementary particle and until now it has not been divided yet into some constituents. Proton is also considered to be an elementary particle, although it is known that it consists of quarks. Therefore, we must pay attention to the special circumstance: electrons and protons have different substances, but they are said to have different charges! Negative charges always coupled with electrons, and positive ones coupled with protons. At the time of Coulomb, such particles as electrons and protons were not known.

Therefore, the concept of positive and negative charges corresponds to the concepts of proton and electron matter. It is just the double terminology for the same phenomenon. As proton substance has a positive charge, this substance can be conditionally called “positive”. Correspondingly, a negative charge is the electron substance which can be called “negative”. It is known that the atoms of matter consist of protons (nuclei) and electrons around them. The number of protons is equal to the number of electrons and the atom is electroneutral as a whole. But it is possible to detach an electron from the atom, that is, to ionize the atom. In this case, the body is charged – it contains ionized atoms. Consequently, the “charge” of a body means the predominance of “positive” or “negative” substance in it. Thus, the name “charge” is a conditional name, because in fact it is the electron or proton substance. By the way, well-known theoretical physicist Feynman under the notion of “charge” understood specific real particles – positive protons and negative electrons: “The substance is a mixture of positive protons and negative electrons, which are attracted and repelled with incredible force ... The same types of substance are repulsed, and different types are attracted” [6, p. 9].

It becomes clear that in reality the term “charge” is a conditional name. It is quite possible to do without it. The problem is only in traditional representations and habits. For example, Coulomb's law is traditionally formulated using the concept of electric charges. But it can be formulated without the notion of “charge”. In this case its interpretation becomes even clearer: “The force of interaction between two point bodies with an electron or proton substance is proportional to the amount of these substances and is inversely proportional to the square of the distance between the bodies”.

Of course, ideas are often changing with the development of science and there is a need for changing the terminology as well. So, in the seventeenth century, caloric theory was suggested to explain the nature of hot and cold bodies: if one body is warmer, it possesses

more caloric, and its caloric flows to other colder bodies during the contact. Later the true cause of heating of the bodies was determined as the chaotic motion of the molecules, its energy, intensity, and the notion of “caloric” was abandoned.

However, there is no need to abandon the term “electric charge”. This name has become traditional and may remain. This notion should not be treated as something abstract, but as specific content: “electric charge” is the amount of electron or proton substance that participates in the interaction. But in the educational literature the explanation of the true meaning of the concept of “charge” should be given. The main peculiarity of “charges” is that they interact at a distance. However, the mechanism of interaction traditionally comes without explanation. It should be investigated in more detail.

**Interaction of charged bodies.** It is very important to understand why charged bodies interact with each other and the nature of this interaction. We traditionally assume that “electric charges” create electric fields around themselves, through which they interact. This is all correct, but it is not known what kind of “field” it is. We use abstract language for the explanation. Therefore, it turns out that one unknown concept is explained by the means of another one. There is “something” called “electric charge”, which creates around itself another and different “something” – the “field”. So, what is a field?

In mathematics, the word “field” is synonymous with the word “distribution”. For example, it is quite clear that the “field of vectors” means the distribution of vectors in space or on a plane. In this case, the electron or proton substance also creates a “field” around itself, through which interaction occurs. But this “field” is something quite real. This can be a “field” (distribution) of real particles which is emitted by electron or proton substance. Moreover, positive charged bodies radiate particles of the same type, and negatively charged ones – of another type. By the way, this is precisely how the interaction between particles is explained by well-known theoretical physicist Stephen Hawking: “In quantum mechanics, it is assumed that all interaction forces between particles of a substance are carried by particles with an integer spin equal to 0, 1, or 2. A particle of matter, such as an electron or quark, emits a particle that is a carrier of interaction. As a result of the impact, the particle velocity of the substance changes. Then the particle – carrier collides with another particle of the substance and is absorbed by it. This collision changes the velocity of the second particle, as if the force acts between these two particles of matter” [7, p. 38].

Or: "... the electric force of mutual repelling between two electrons arises from the exchange of virtual photons, which can not be directly registered" [7, p. 38].

Gravitational attraction between bodies is explained by the exchange of particles called gravitons in [8, p. 39]: "The gravitational interaction between the Sun and the Earth is explained by the fact that the particles from which the Earth and the Sun are composed are exchanged by gravitons. Despite the fact that only virtual particles participate in the exchange, the effect they create is definitely measurable, because this is the effect of rotation of the Earth around the Sun! Real gravitons are distributed in the form of waves, which in classical physics are called gravitational, but they are very weak, and they are so difficult to register that it has not been possible for anyone to do so".

Thus, to explain the real interaction, we need to use subject or at least hypothetical representations instead of abstract reasoning about the existence of some "ether" or "field" created by the conditional "electric charge". The presence of the hypothesis stimulates the search. At the very least, students will know the boundary where our understanding of the essence of the phenomenon ends. Therefore, it is reasonable to consider the mechanism of interaction of bodies in more detail.

**Mechanism of interaction of bodies.** It is important to explain how two bodies (two particles) can interact at a distance. In physics, two methods of physical interaction are known: interaction through the medium that divides them and through the exchange of bodies (particles).

For example, there are two boats on the water. If one boat starts to shake and disturb water (environment), then the perturbation is transferred to another boat. This interaction is through the environment. It is also possible to interact in another way – through the exchange of bodies (particles). For example, it is possible to throw bags with sand from one boat to another and the boats will diverge, since with such an exchange the amount of movement is transmitted (Fig. 1).

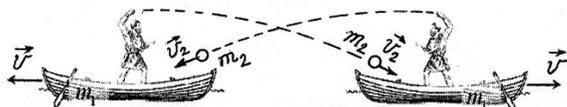


Fig. 1. If some bodies are thrown from one boat to another, the boats will diverge.

This raises the question how electrons and protons interact with each other during mutual repelling or during the attraction. It can be assumed that they interact through some medium (some kind of "ether"). It can be also possible that the exchange is realized by the means

of still unknown particles. These questions are not rhetorical, but substantive to all experimental and theoretical physicists, teachers and students. Of course, the answer can be abstract – the interaction occurs through "electric fields". But this interaction is not abstract, it is real. Therefore, it is necessary to find the substantive answer and determine through what fields it occurs, taking into account that the scientific term "field" stands for the spatial distribution of "something".

Let us assume that the body  $m_1$  emits "particles of interaction" in all directions (Fig. 2). The lines in the drawing depict the distribution ("field") of these particles in space. Obviously, when the body  $m_2$  is closer to the body  $m_1$ , more "interaction particles" (Fig. 2) are found on it, than in the case when the body  $m_2$  appears farther (Fig. 3). Therefore, the closer the distance of such particles (the density of the field lines is greater), the greater the interaction will be. This means that the "tension" or "potential" of the "field" of "interaction particles" at a shorter distance is greater than that of the longer one.

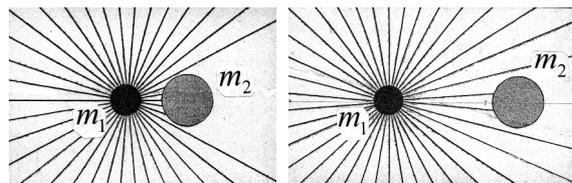


Fig. 2.

Fig. 3.

By analogy with above mentioned we can come to the conclusion that the electron and proton also radiate some particles, which are the medium of interaction.

If the distribution of some particles, even unknown, is considered, then they are quite real. It is only essential to know what kind of particles they are. Therefore, this issue needs to form a hypothesis. If the interaction occurs through the exchange of particles, it turns out that the electrons and protons, in which various substances, even themselves eliminate the particles, and different (conditionally positive and negative). And it is through this that you can explain repelling or attraction. But here we touch a completely different problem – the problem of the structure of the electron and the proton. After all, to ensure interaction, which undoubtedly exists, they must eliminate something, which means they have a complex structure. The fact that the proton is composed of quarks is known. But there is no any facts even hypothetically about the fission of the electron particle. And the electron is perceived as a stable elementary particle. It is possible that the electron is a complex and very high-energy structure. There is also no explanation for the physical (non-abstract) mechanism of attraction. If the repelling through the exchange of particles is

understandable – there is a transfer of the amount of motion, it is not clear then why the bodies are attracted, or what is the mechanism of attraction. These are questions that need to be studied. We can assume that this mechanism is similar to gravitational attraction [5, 7]. Of course, it is possible to think in an abstract way: positive and negative charges deform the space (some “ether”), and, deform in different ways – compressing or thinning - which causes an attraction or repelling. The deformation of space explains the gravitational attraction in the theory of relativity (in the case of large masses the space is “distorted”). However, in the theory of relativity the notion of ether is rejected. So, the explanation of the mechanism of attraction or repelling of electrical “charges” is not given by modern physics, and it is unlikely that such studies are being conducted, because it is believed that this is a question of “classical” physics of bygone times. But it becomes clear that these are not only problems of yesterday or of the last century, but current and tomorrow's problems faced by high school teachers and researchers and so they are very relevant. As we have already seen (Fig. 1), the usual exchange of particles ( $m_2$ ) between two bodies (boats  $m_1$ ) only causes repelling of bodies. Therefore, if we consider, for example, the interaction of two cosmic bodies  $M_1$  and  $M_2$  that have a mass, then they, seemingly, should emit and absorb particles from each other (Fig. 4). We observe an attraction.

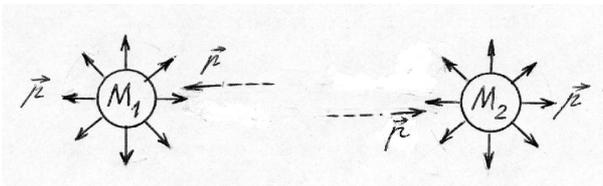


Fig. 4.

Considering the mechanisms of interaction of bodies, the masses of emitted particles, their velocities, impulses, and the law of conservation of momentum are detected. However, in this case, one important circumstance remains out of sight, namely, for the account of which particles that are removed by bodies receive impulses. The radiation of particles (gravitons), which influence the attraction effect, is logically linked to the transition of one state of matter to another – from the state of matter in the field and vice versa, in accordance with the known ratio:  $W = c^2 m$ . In this case, the situation is radically changing. Protivating graviton, the body loses a part of the mass ( $\Delta W = c^2 \Delta m$ ), which goes to the formation of a graviton and giving it a pulse. However, in the space between the bodies (Fig. 2), not only the radiation and absorption of gravitons occurs (which should lead to a difference in bodies), but also

there is a recovery of body weight from absorbed gravitons. ( $\Delta W = c^2 \Delta m$ ) and, consequently, the momentum arises in the opposite direction (that is, towards the second body). No such recovery occurs on the opposite sides of the interacting bodies. Thus, the effect of the difference in bodies is compensated and the radiation of gravitons in the external opposite directions causes the convergence of the bodies.

**Conclusions.** The matter from which the universe is composed exists in the form of substance and field. Two types of substance are known, namely, electronic (electron) and proton (proton), which have completely different structures. The electronic substance is traditionally associated with a “negative charge” and the proton with “positive charge” .

There is interaction between the particles of matter - particles of different substances (proton and electron) are attracted to each other and form an electroneutral substance. In the formed bodies, the amount of positive and negative matter may not coincide – then we assume that the body is “charged” .

The traditional physical notion of “electric charge” characterizes the amount of uncompensated electron or proton substance, which is accordingly called “negative” or “positive” electric charge. However, there is interest in the mechanism of attraction and repelling between electrons and protons, which is obviously realized through unknown emitted particles.

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## **ФІЗИЧНИЙ ЗМІСТ ПОНЯТЬ “ЕЛЕКТРИЧНИЙ ЗАРЯД” ТА “ЕЛЕКТРИЧНЕ ПОЛЕ”**

Богдан Сусь

Автор стверджує, що термін електричний “заряд” умовний і в науці має допоміжне символічне значення. Окремо від речовини заряд не існує. Реально в природі існують протон і електрон як речовина. Речовини електрона і речовина протона за природою різні, тому логічно саму речовину вважати “позитивним” чи “негативним” зарядом. Обґрунтовано, що речовини електронів і протонів вилучають якесь ще не відомі частинки, завдяки чому й відбувається взаємодія між “зарядженими” тілами. Розподіл частинок взаємодії в просторі і являє собою електричне поле.



**Bohdan Sus** was born in Kyiv, Ukraine in 1976. He graduated from the department of Radiophysics of the Taras Shevchenko National University of Kyiv with a master degree in 2000. He defended his Ph. D. thesis and received a Ph. D. degree in Physics and Mathematics, specializing in Physics of Semiconductors and Dielectrics in 2006. Since graduation, his research interests include Experimental research and modelling of Functional materials and structures, Semiconductor physics and Electronics. He was the scientific researcher, Head of scientific sector, conducted complex investigations of the phenomena caused by the anisotropic properties of semiconductors, which occur under conditions of various kinds of influences on the properties of crystals – strong pressures, irradiation with particles of high energies, annealing, etc. Now he is associated professor of the Department of Nanophysics of Condensed Matter. He is also member of IT Ukraine association, author of 4 books and more than 80 articles.