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Gyroscopic Model of Electron Charge

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Abstract

This paper, within the framework of classical physics, offers a gyroscopic model of the electron charge based on possible processes in the early stage of atomic formation in the Big Bang. It allows us to explain the relative stability of atoms and also the situations occurring in electromagnetic processes when the object moves perpendicularly to the forces of action. The proposed electron charge model not only does not contradict the empirical Maxwell equations but complements their explanations by analysing a number of electromagnetic processes in their research and practical application, including the duality of defining the current unit.

Keywords: electron charge, gyroscope, electric current, atomic model, electric field, magnetic field, Big Bang

1. Introduction

The most essential properties of the bodies of various substances and their elementary particles are rightly recognised as their mass and electric charge. There is a belief that, because of the forces of electrical interaction, atoms of chemical elements can be formed, and they, in turn, can combine into molecules and form substances. Therefore, the electric charge should be considered as a property of a particle of matter, not less essential but perhaps even more important than mass? The electric charge demonstrates its "superiority" in the dynamics of the particle's movement because in the theory of relativity, when dealing with high speeds of movement of bodies, it is concluded that the body's mass loses its meaning in general, both as a measure of inertia and as a measure of gravitational interaction because the acceleration of the body caused by force may not be parallel to this force in the general case. Consequently, mass can no longer be defined by the force-acceleration ratio. Similarly, it also happens with a gravitational interaction. Therefore, strictly speaking, the law of mass conservation cannot be defended, whereas, in the case of electric charge, no processes have been observed in nature in which the change of charge value can be detected.

It should be added here that there can be no question of mass disappearing because mass can exist without a charge (neutron), but a charge has never been detected without a particle with its mass. In addition, it has been possible to find out the mass structure of the particles of matter in subatomic sizes. In the periodic table of chemical elements, the mass of each atom has been determined, and the number of "shells" in electron "clouds" and the number of electrons in each shell have been determined. However, there is no interest in causal relationships of the properties of the electric charge. One can feel satisfaction in the mathematical description of the empirical measurements. This is partly due to the fact that researchers dealt with electrical phenomena before the atomic structure of matter was clarified.

Let us approach the causes of confusion, noting the concepts that have been clarified so far.

2. Electric Charge

Classical physics defines the electric charge as a fundamental property of various elementary particles (Valters et al., 1992, p. 212). However, this concept is very capacious as it includes several features (rather than only one):

a) charges are a source of the electromagnetic field;

b) the interaction of different charges takes place in an electric field;

c) all electromagnetic phenomena are expressions of the existence, movement, and interaction of electric charges;

d) stationary electric charges create an electrostatic field around them;

e) the charge size is independent of the particle velocity and is invariant in all reference systems.

The set of all these properties, as well as the physical quantity used for their quantitative characterisation, is denoted by one unified concept – charge – while not explaining the origin of its numerous properties. Such an interpretation of charge indicates the use of a heterogeneous physical quantity because homogeneous physical quantities are usually defined as those that characterise the same property of matter but can differ only in numerical values.

It can be inferred from what has been said that such a set of properties cannot be expected for a passive particle of matter. It rather seems that such a concept of charge helps to use a compact model for a more complex dynamic process, thus achieving a simpler explanation of many electromagnetic processes found in nature and technology.

To form an idea of the possible model of the charge itself, let us continue to focus on observations.

2.1 Elementary Charge

Experimentally, it has been found that all electrically charged elementary particles have the same charge, the modulus of which is: $e \approx 1.6 \cdot 10^{-19}$ C. For an electron, it was determined by Robert Millikan already in 1910. Currently, the value of this constant is estimated to be $1.602\ 176\ 487\ \cdot 10^{-19}$ C, regardless of the mass of the elementary particle. It can differ only by sign. For a proton with m/m_e=1 836.1 the charge is + e, but for an electron with m/m_e=1 the charge is $-e$. For particles that are significantly heavier than a proton, the charge modulus is also e.

2.2 Electric Charge of Macroscopic Bodies

It has been found that substances consist of molecules and atoms, which, in turn: of protons (+ e), electrons (-e) and neutrons (without charge). Generally, the number of protons and electrons per volume unit is equal, and the body is electrically neutral. If, due to some external circumstances, the total charge of one sign for the body is greater than the total charge of the opposite sign, then the body is electrically charged. Electrons can be detached from the atoms of some bodies and transferred to another body. Thus, a positively charged body has an electron deficiency, but a negatively charged body has an electron abundance. In such a case, the body charge q is determined by the number of uncompensated elementary particles N:

$$q = N \cdot e, \tag{1}$$

where N is an integer, therefore, the body charge is also a discrete quantity. Since the charge quantum e is very small, it can be approximately assumed that the total electric charge of macroscopic objects can change smoothly and continuously.

It has been found that in the process of electrification of bodies by friction and under other conditions of atomic ionisation, equal charges with the opposite sign can be obtained. Also, in the case of recombination, there is no surplus, the object becomes electrically neutral. Therefore, it is reasonable to assume that in an electrically isolated system, the sum of the electric charges is a constant value (electric charge conservation law).

2.3 Interaction of Electric Charges

It would probably be more correct to say the interaction of electrically charged bodies instead of electric charges since the charge is already defined as a property of elementary particles. To shorten the text, the word "body" is omitted, but by "charge" it is often meant a charged body that has a detectable property to interact with other electrically charged bodies. A qualitative description of the interaction was provided already in 1733 by S. Dife, who found that charges of the same signs repel and charges of the opposite signs attract each other. Moreover, in the case of point-type charges (if the charged bodies are small compared to the distance between them), the force of interaction acts on the line connecting the charges (Valters et al., 1992, p. 215).

The charge interaction was quantified by Coulomb in 1785: the interaction force F is directly proportional to $1/r^2$, q_1 and q_2:

$$F = k \cdot q_1 \cdot q_2 / r^2, \tag{2}$$

where k - coefficient, which represents the requirements of the units used and the electrical properties of the experimental environment. In a vacuum environment $k = 9 \cdot 10^9\ \mathrm{N} \cdot m^2/\mathrm{C}^2$.

The Coulomb law does not explain the cause of the remote interaction of charges. Therefore, it is assumed that one charge creates a special environmental condition in its surroundings – an electric field – where another charge experiences a mechanical force. Since the concept of an electric field is used to explain the interaction of charges, one of the main characteristics of this field is the force with which the field would act on a positive point charge of one unit (coulomb) if it were in this field. This force is called the strength of the electric field and is denoted by *E*. The force *F*, exerted by the point charge (q_1) on the second charge (q_2), is orientated in the direction of the line *r* connecting the charges. If the signs of charges are the same, then it is a repulsive force. The intensity of an electric field, like a force, is a vector quantity. The unit of intensity, according to the definition, is N/C (newton per coulomb). Since the force can be derived from energy (work) divided by distance, then 1 N = 1 W s/m = 1 V ·A s/m. Since 1 C = 1 A s, then 1 N/C = 1 V/m. Thus, the unit of electric field strength *E* is V/m (volts per metre).

The electric field has also been characterised by a scalar size - potential φ. The potential φ at a point in the field is defined as the work the field forces need to do to move a unit positive point charge from the point under consideration to the point where the potential is assumed to be zero (outside the limits of field *E*). Absolute potential values are rarely used in practice. The difference between the potentials of two points, called the voltage between these points, is more useful and easier to determine. The voltage is denoted by the letter U and two indices, the sequence of which indicates the measuring or evaluation points. For example, $U_{ab} = \varphi_a - \varphi_b$, but $U_{ba} = \varphi_b - \varphi_a$. The voltage between two points does not depend on the choice of zero potential. Potential and voltage are measured in volts, V.

3. Nature of Electric Charges

From the above definitions follows:

- A charge is not a particle of a substance, but only a set of its properties. A charge does not exist without particles.
- For most particles a charge cannot be detected, so the charge is a property that a particle can obtain!

In the process of charging bodies, for example, by means of friction, electrically neutral atoms can lose electrons. The symbol of electric charge (±) is used following the historical designation that the glass rod acquires a positive (+) ionic charge when rubbed with a silk cloth, and an ebonite rod is charged with negative (-) electrons when rubbed with a woollen cloth. Nowadays it has been clarified that only an atom or a molecule with an electron deficiency – an ion has the properties of a positive charge, and only an electron detached from the atom or a molecule with an excess electron has the properties of a negative charge. An interaction between these ions is observed, and this force is named the Coulomb force. But, with due respect to Coulomb's achievements, may this force between ions of opposite signs also be called the force of ion tendency to unite? However, in Coulomb's time, the understanding of the structure of an atom was not yet developed, and there was no idea that the interaction between large amounts of atomic ions was being studied. What do electrons and ions do before the ionisation of the atom? Why is there such an interaction? Do not rush with the answer about charges because it will only be a questionable description of the observation, not an explanation. Public lectures with demonstrations of electric power were very popular at the beginning because the process of ion recombination and their formation into neutral atoms is accompanied by an efficient rapid release of the energy invested in ionisation: spark, lightning, and the smell of ozone. Why is this happening?

The first atomic model was proposed by J. J. Thomson in 1903. According to Thomson's model, the positive charge of an atom is evenly distributed over its entire volume together with negatively charged electrons that neutralise the positive charges by acting on them. From 1906 to 1911, by studying the scattering of radiated isotope α-particles as they passed through a gold foil, E. Rutherford developed a planetary atom model in which the dimensions of the atomic nucleus are estimated in the order of 10^{-1} to 10^{-15} m, but the sphere of the rotating electron shell is about 10^{-10} m (atomic dimension). Such a model with a fixed electrically positive nucleus and negative electrons rotating around it caused difficulties in justifying the stability of the atom and its line spectra. Therefore, in 1913, N. Bohr supplemented the planetary model with his assumptions (Bohr's postulates). The model systematised the calculations of the arrangement of electron orbits and the changes in the energy of the electrons in them. In this model the structure of the atom is still based on the Coulomb electric field forces between the nucleus and the electrons, with concern about the ability of classical physics to provide stability of electron orbits, that is, there is a possibility that the electron can still reach the atomic nucleus under the influence of Coulomb's forces. As is well known, to enter orbit around a source of centring forces, a certain speed and direction of motion must be provided, which does not coincide with the direction of application of the Coulomb forces (the line connecting the charges). In this case, many electrons would be able to reach the atomic nucleus, and the positive atomic ion of a substance could have a different number of orbital electrons (but such a case is not detected). It is difficult to accept an atomic model in which electrons travel only passively in the atomic carousel when remaining within classical physics (Feynman et al., 2006, Volume II, p. 5-3).

By analysing different geometric shapes of the electron and the spatial arrangement of the charge, and using calculation possibilities of electrodynamics and quantum mechanics for fixed and moving electrons, no reliable theory of the origin of the electron mass was found. Attempts to improve Maxwell's equations or to increase the size of the electron (non-point charge) have also failed physics (Feynman et al., 2006, Volume II, p. 1-12 and chapter 28).

3.1 Electron Beam Experiments

Thomson's experiments with cathode rays (Thornton & Rex, 2006, p. 86) showed that a cathode ray beam, like charged particles, interacts with both electric and magnetic fields in its motion. The beam approaching (+) electrode in the E-field (Figure 1) indicates that the cathode rays are an electron flux. By subjecting the charge beam to a magnetic field, where the induction B is perpendicular to both the electric field and the initial trajectory of the charge, the motion of the charge conforms to Lorentz law (3), which describes the effect of electric and magnetic forces on a positive unit charge (Feynman et al., 2006, Volume II, p. 15-14):

$$\vec{F} = q\vec{E} + q(\vec{v} \times \vec{B}) \tag{3}$$

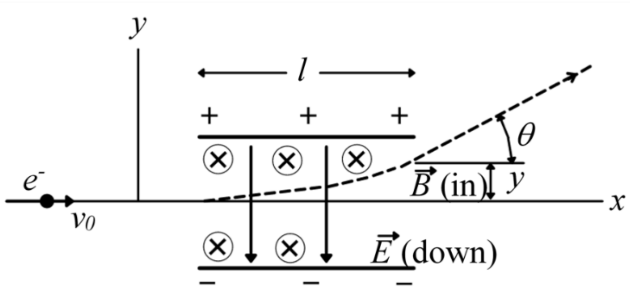

Figure 1. Schematic diagram of cathode rays under the influence of field E

For negative electron charges passing through the field vector area (Figure 1), the electric force $\overrightarrow{F_E} = q\vec{E}$ is directed in the direction of the y-axis, while the magnetic force $\overrightarrow{F_B} = q(\vec{v} \times \vec{B})$ - in the opposite direction. By changing the flux B, the proportion $\frac{E}{B}$ can be reached when $\frac{E}{B} = v_x$, and the effect of the E field on the charge movement disappears ($\vec{F} = 0$). It allows to express $\vec{E} = -\vec{v} \times \vec{B}$ from formula (3) and then calculate $v_x = E/B$. Without a magnetic field, the tangent to the angle of the electron trajectory (Figure 1) is equal to:

$$tg\theta = \frac{v_y}{v_x} = \frac{a_y t}{v_x} = \frac{qEl}{mv_x^2}. \tag{4}$$

From (4) follows the charge-to-mass ratio:

$$\frac{q}{m} = \frac{v_x^2 tg\theta}{El} = \frac{Etg\theta}{B^2 l}. \tag{5}$$

The numerical value to be specified later: $q\ /\ m = 1.76\times 10^{11}$ C/kg. The result shows that there is both a relatively small electron mass and a relatively large electron charge. By analysing the course of the electron beam experiment, it can be concluded:

- even for a particle as light as an electron, the charge is inseparable from the mass;
- a magnetic field is formed around a moving electron or its charge, and it interacts with the external magnetic field;
- the magnetic field is the result of the either overt or covert motion of the particles.

3.2 Magnetic Force of an Electron in a Magnetic Field

If there is no electric field, $E = 0$, then it follows from (3) that the direction of the magnetic force $\overrightarrow{F_B} = q(\vec{v} \times \vec{B})$ in a homogeneous field is perpendicular to both the direction of particle motion $\vec{v}$ and the direction of the external magnetic field induction $\vec{B}$ (Figure 2).

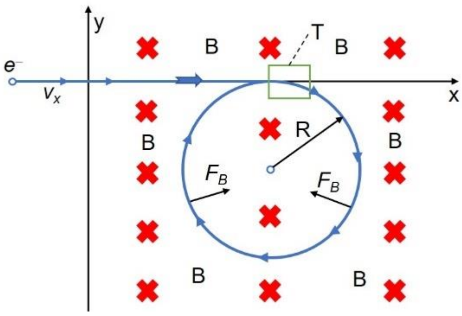

Figure 2. Influence of the magnetic field on a charge in motion

e^- – negative charge; v_x – vector of charge velocity;

B – magnetic induction; F_B – magnetic component of Lorentz force;

T – zone of J. J. Thomson's experiment.

This force does not change the velocity of the electron, but it changes its direction, forming a circular trajectory of the electron (Valters et al., 1992, p. 533; Feynman et al., 2006, Volume II, p. 29-1). The radius of the particle trajectory can be calculated by equating the centripetal force mv^2/R to the magnetic force $q \cdot v \cdot B$, then

$$R = \frac{m \cdot v}{q \cdot B} \ . \tag{6}$$

This relation allows us to calculate the velocity v of electrons:

$$v = \frac{q}{m} B \cdot R, \tag{7}$$

as well as the momentum L per charge unit:

$$\frac{L}{q} = \frac{mvR}{q} = B \cdot R^2. \tag{8}$$

It should be noted that to determine the radius of the electron trajectory, it is necessary to provide a homogeneous magnetic field throughout the trajectory zone. Thomson's experiment used only the initial stage T of the electron trajectory (Figure 2). Thus, an electron charge represents both its mass and its momentum. The dualism of electron charge properties in Thomson's experiment is visible but not emphasised or analysed.

4. Charges and Current in Metals

Undoubtedly, the movement of charged particles is affected by environmental properties. Under normal conditions, metals, except for mercury, are solid polycrystalline substances in which the interaction of atoms manifests itself in the form of very different types of bonds discussed (described) in an inorganic chemistry course (Ahmetovs, 1978).

4.1 Ion Interaction Bonds

Different cases of ionic interaction are encountered and analysed in inorganic chemistry because ionic bonds are responsible for the stability and properties of various molecules and substances formed by atoms. An electrostatic theory of chemical bonding is used. Let us examine whether supplementing an electrostatic theory with its electrodynamic origin can improve it or, conversely, there are insurmountable contradictions in the explanations.

It has been shown that chemical elements form simple ions with opposite signs, and thus a chemical bond is created between these elements. These properties have been shown to depend on the electron composition of the atoms: there are groups of chemical elements whose atoms have relatively lower ionisation energy and there are groups of elements that have a distinct tendency to gain electrons.

4.2 Metallic Ionic Bonds

Metals can be considered to be highly compacted positive ionic structures held together by collective electrons. It can be concluded that to compensate for the angular momentum of the metal atom nucleus, one electron in the atomic shell is almost redundant (poorly attached). For example, by getting rid of one electron, the radius of silver (Ag) and copper (Cu) ions decreases because this electron moves in the outer orbit of atoms. This makes it possible to form a denser ion crystal structure, in which the released electrons simultaneously interact with several atomic ions to form binding molecular orbitals. The observed regularities are systematised by atomic energy band theory, in which the increased electrical conductivity of metals is explained by the overlap of the electron energy valence band and the conductivity band. But nowhere will you find a fixed electron without its orbital motion. Studies show that among metals, (Al) is a paramagnetic, (Cu) and (Ag) atoms have diamagnetism, but the presence of free electrons ensures that paramagnetic properties dominate in all metals (Valters et al., 1992, p. 354; Ahmetovs, 1978, p. 64 and p. 170). This means that free electrons provide a dominant magnetic moment in metals, which may exist even outside the magnetic field but in its presence is orientated in the direction of the external field and supplements it. As a result, the relative magnetic permeability is $\mu > 1$. For ferromagnetic metals, $\mu \gg 1$ due to unfilled electron shells of atoms. In all cases, it can be seen that the magnetic properties of an electron are related to its movement along a closed trajectory.

4.3 Ampere's Force

For the practical application of electrical processes, electrons can be removed from atoms in various ways but with the common goal of using electricity (electrons) to do the job. For all types of direct current sources, two external conductor connection points are created: a negative (-) terminal with high electron concentration and a positive (+) terminal with high electron deficiency. The task of this source is to supply the output terminals with a sufficiently high concentration of charges (ions) of both signs to produce the desired potential difference $(\varphi_+ - \varphi_-)$, which is defined as the voltage *U* (the work to be performed by a positive charge unit in route from point (-) to point (+)). By connecting both terminals with a metal wire having a lot of "free" electrons, under the influence of the Coulomb force, the electrons will rush to neutralise positive ions in the voltage source (+), but the shortage of electrons in the conductor will be supplemented by electrons from the source (-). A large number of electrons cross the conductor rapidly, and this number and the total charge are very difficult to estimate. Therefore, the intensity of the charge flow is estimated by current *I*, but the total charge *q* is determined by:

$$q = I \cdot t, \tag{9}$$

where *q* – total charge flowing through the conductor cross-section, *I* - current, *t* - time. An electric charge is assumed to be one coulomb [C] large, if it flows through the cross-section of the conductive medium in one second [s] at a constant current of one ampere [A], so 1C = 1A · 1s.

When studying the effect of a magnetic field on such a current line, it was subjected to an external homogeneous perpendicular magnetic field with induction *B*, and the effect of mechanical force was detected (Valters et al., 1992, p. 326]. It had to be concluded that the direction of the Ampere's force *F* (Figure 3) coincides neither with the direction of the current (charge movement), nor with the direction of induction *B* of the external field, but it is perpendicular to them and can be described by a vector product:

$$\overrightarrow{F_A} = \vec{I}l \times \vec{B}, \tag{10}$$

where $\overrightarrow{F_A}$ is the force exerted on the power line, $\vec{I}$ is the current in the line, *l* is the length of the wire line segment, $\vec{B}$ is the induction of the magnetic field. The experimentally determined impact direction and an empirically obtained formula (11) for the mechanical force (Ampere force) acting on the power line in the external magnetic field have gained wide practical application in the development of electric motors.

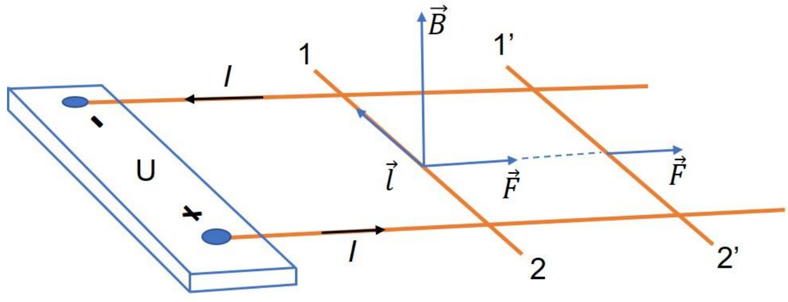

Figure 3. Illustration of the effect of the Ampere force $\vec{F}$ on a straight-line segment $\vec{l}$ of a conductor carrying a current in a homogeneous magnetic field $\vec{B}$

We can be very satisfied with the practical usefulness of the formula; however, there is no explanation: Why is the ***F*** direction perpendicular to the directions of ***I*** and ***B***? To increase understanding of it, the scale of the experiment can be changed and the motion of a single positive charge in a magnetic field chosen instead of the current (charge flow), and as a result, we get the formula for the magnetic component of the Lorentz force (3): $\overrightarrow{F_B} = q\vec{v} \times \vec{B}$.

Unlike Thomson's experiment where electron movement in a vacuum is not restricted, in an Ampere force experiment, electrons are trapped in a current line, the mounting assemblies of which are subjected to a force (support reaction) and prevent free movement in space, although each electron in this conducting line must follow a circular path (Figure 2). Thus, all that remains is to study and explain the causes of changes in electron motion under the influence of a magnetic field.

4.4 Definition of a Current

When the current ***I*** is expressed from formula (9), *I* = *q*/*t*, it is not good to describe it as follows: The current in a conductor is the flow of charges per time unit. Somehow awkward: a property (see chapter 2.1) flowing through a wire cross-section? Oh well, it was a shortened text. This will be more correct: The current is the flow of electrified particles (ions), with mass *m* and charge q_e, through a cross-section of the wire per time unit. The definition of charge still retains a dual character. Now the current 1 ampere is defined in the SI system by the magnetic interaction force $F = 2 \cdot 10^{-7} N$ between two infinitely long and infinitely thin wires at a distance of 1 m per meter of wire length (Figure 4):

$$\frac{dF_{21}}{dl} = \mu_0 \frac{I_1 I_2}{2\pi a}, \tag{11}$$

where F_{21}- interaction force of the second wire under the influence of the magnetic induction B_{21} of the first wire; $\mu_0 = 4\pi \cdot 10^{-7}$ – vacuum magnetic permeability; I_1 and I_2- current in wires 1 and 2, but *a* - distance between the wires. In Figure 4, $B_{21} = \mu_0 \cdot H_{21} = \mu_0 \cdot \frac{I_1}{(2\pi a)}$. This definition of the current 1 A is highly theoretical because it is not practically feasible, and so it is replaced by weighing the interaction of two solenoids.

On the other hand, until 1960, the MKS system was used, in which the current was 1 A that while flowing through a solution of silver nitrate in water, would deposit 0.001 118 00 g of silver in 1 second. Here, the dependence of the current on the rate of ion mass transfer is directly visible. But the SI unit system allows us to include electron mass and acceleration (F_{21}) in (11) as a result of the interaction of the magnetic fields of currents, where $I = I_1 = I_2$.

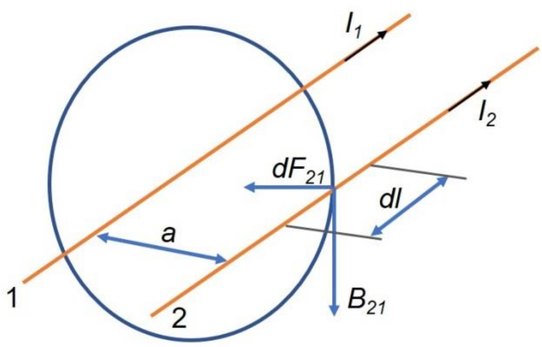

Figure 4. Scheme for defining the SI unit of current using formula (11),

where B_{21}- magnetic induction in the second wire caused by the current in the first wire,

dF_{21}- force caused by the power line section *dl*.

The vector directions (Figure 4) are postulated, but the direction of the force $dF_{21}$is not explained. In view of the duality of current characteristics and the versatility of electron charge properties, we look for a physical model suitable for electron charge.

5. Electron Motion in an Atom

Modern physics claims that electrons in an atom are not bound by nuclear forces but are scattered under the influence of nuclear electromagnetic forces (Thornton & Rex, 2006, p. 428). However, several facts suggest the opposite. Atomic nuclei of chemical elements and their electron shells form relatively stable systems. To date, it has been shown that the atomic nucleus of a substance is formed by protons, the number of which coincides with the number of electrons in the "electron shell" of the atom, and by neutrons, the number of which in the nucleus depends on the isotope type of the chemical element. The atomic nucleus can also absorb and radiate energy in the form of electromagnetic radiation (Thornton & Rex, 2006, p. 466). The phenomenon of nuclear magnetic resonance indicates a dynamic process in the nucleus itself. The content of the atomic nucleus is now being studied by impressive high-budget institutes of quantum physics. But there are still problems to be solved within classical physics (Feynman et al., 2006, Volume II, p. 8-1).

Since electromagnetic processes are explained by the presence of free electrons, let us look at them on an atomic scale. This orbital motion of electrons around the atomic nucleus (Figure 5) is usually characterised by two values: orbital angular momentum $\overrightarrow{L_e}$ and magnetic moment $\overrightarrow{p_m}$:

$$\overrightarrow{L_e} = me \cdot \vec{v}_e \cdot r_e, \tag{12}$$

$$\overrightarrow{p_m} = q_e \cdot \vec{v}_e \cdot r/2, \tag{13}$$

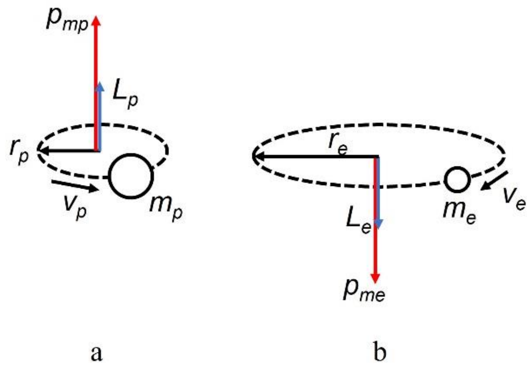

Figure 5. Orbital parameters of the positive and negative ions

From (13) the area *S* enclosed by the current loop *I* can be calculated: $|\overrightarrow{p_m}| = I \cdot S$. The direction of current and motion is defined for a particle with a positive charge (Figure 5a), but for an electron, they are opposite (Figure 5b).

Here, a single model combines two values characterising the properties of an electron: mechanical (material) L_e (12), and magnetic (nonmaterial) p_m (13). The latter seemingly ignores the mass of the electron, but as it includes the ambiguously defined scalar charge q_e, it nevertheless indicates the presence of a mass, since the charge, as a property, does not exist without particles. Thus, the definition of charge (9) is incomplete in terms of physics, because it includes current I, the unit of measurement of which has a dual magnet-mechanical nature (see chapter 4.4). To approach the physical interpretation of the charge, it is necessary to start from the beginning.

5.1 The Big Bang

The Big Bang hypothesis is not new in the evolution of the universe (Thornton & Rex, 2006, p. 566), however, it was only in 2015 that with a powerful telescope, an explosion of dark matter could be partially captured.

If the ‘black hole’ Big Bang model of dark matter is adopted, then at the beginning of the process, due to the high density of matter, the linear motion of the particles (away from the epicentre) should have been difficult. Due to the lack of space, the elementary particles could have been able to transform the received energy into a rotational motion. At first in self-rotation, but with decreasing density – in other types of rotational movement: electron rotation around the atomic nucleus (during its formation), as well as changes in the position of the orbital plane and the axis of rotation of the electron itself (rolling). In nature, energy-minimising processes can be observed at different speeds. Therefore, the existence of all of the discovered and yet undiscovered chemical elements and molecules may be related to very different combinations of groupings of elementary particle motions, which has made it possible to carry out rapid external minimisation of energy while retaining its internal kinetic energy. There is reason to believe that today all moving particles have retained their angular momentum and energy of motion generated by the Big Bang. This is evidenced by energy release experiments. It seems that only such an ambitious hypothesis can justify identical properties for all groups of elementary particles in the structure of the universe. Let us try to use this assumption to justify several electrical and magnetic processes. Yet there will be no attempt to normalise physics equations with respect to the origin point of the universe due to the accelerative expansion of galaxies (Feynman et al., 2006, Volume I, p. 12-10). There will also be no attempt to modify Maxwell's equations.

5.2 Possibilities of Minimising Volume Energy in an Atom

Since the nucleus-induced radiation of an atom has been detected and used in practice, the movement of the protons forming the nucleus must also exist. The particularities of proton and neutron interactions and uncertainties of dynamic processes in classical physics are discussed in (Feynman et al., 2006, Volume II, p. 8-6). It is safe to conclude that the nucleus can also have a dynamic rotating structure in which protons retain the angular momentum once gained, but still, fail to fully compensate for it within the nucleus. In this case, nuclear protons can use collective or even individual interactions of the electrons (the number of electrons in the shell corresponds to the number of protons in the nucleus). It can be argued that the juxtaposition of the proton angular momentum $\overrightarrow{L_p}$ to the angular momentum $\overrightarrow{L_e}$ (14) of the rotating electron in the electron shell, takes place in an atom and allows to compensate for the angular momentum of these two elementary particles $(\overrightarrow{L_p} + \overrightarrow{L_e} = 0)$. At the same time, it allows to store (accumulate) the energy (W = m$\cdot v^2/2$) of the individual rotational motion of each particle in the volume of a single atom.

$$\overrightarrow{L_p} = -\overrightarrow{L_e} = m_e \cdot \vec{v}_e \cdot r_e, \tag{14}$$

where $\overrightarrow{L_e}$ - electron orbital momentum, m_e - electron mass, $\overrightarrow{v_e}$- tangential velocity, r_e- orbital radius. Since the mass of a proton is significantly larger than the mass of an electron (m_p, / m_e =1 836.1), the electron rotates with a significantly larger radius, which was also observed in E. Rutherford's experiments. This leads to the conclusion that the orbital stability of the atomic electron shell is closely related to the stability of the nucleus, and any necessity for electrons to get too close to the nucleus disappears because then the orbital radius r_e decreases, but the increase in $\vec{v}_e$ (14) is limited by the speed of light. Thus, such an association of atomic nuclei and their electron shells can be considered to be a sufficiently stable model because the separation of electrons from the atom requires considerable ionisation energy. It is even more difficult to release the energy stored in the whole atom. When the momentum conservation law is applied to elementary particles, the electron in its orbital motion, together with the other electrons of the "shell", is able to compensate and thus keeps the total kinetic energy in the minimum possible volume (volume of the neutral atom). Therefore, the atomic ion will recover to a neutral atom as soon as possible, incorporating a free electron into its electron shell (ion-electron recombination). Thus, in contrast to the formal nature of the attraction of charged particles, an energetic explanation can be given for it: it is a local concentration of kinetic energy that could have taken place at a very early stage in the development of the universe.

Let us try to justify this explanation using several considerations about possible processes in the micro-world.

• The statement that the charge is a fundamental property of several elementary particles seems incomplete. It is just a concealed avoiding of a functional explanation.

• All the properties postulated for electric charges are observed only after different elementary particles have abandoned their natural dynamic coexistence.

• The ionisation of an atom by removing one electron disrupts the existing angular momentum balance. The part of the energy of the atom carried away by an electron is as large as that an ionised atom lacks. It is no longer surprising that for all elementary particles, the modulus of elementary charge is equal to e; it differs only by the sign, despite very large mass differences.

• The angular momentum conservation law can explain the fact that electrostatic energy conservation is occurring. Electrostatic energy conservation is discussed philosophically in (Feynman et al., 2006, Volume II, p. 8-10) and the principle of local conservation of energy is defined, however, without explaining its mechanism but referring only to the commonality of energy and mass location.

From the point of view of the proposed angular moment compensation model, it must be stated that not all element atoms in their electron shell are able to balance the proton momentum (14). Atoms in one group have an increased angular momentum, whereas atoms in another group have a slightly decreased angular momentum in the opposite direction. If such atoms with opposite properties contact, a new molecule can be created with a more balanced total angular momentum. Due to the very high electron affinity, when one electron is added to an oxygen, sulphur, or carbon atom, energy release is observed (Ahmetovs, 1978, p. 32). There is no reason to attract one more electron. This confirms the role of the electron shell in reducing the energy of the atom.

Because the field of ionic interaction forces propagates evenly in all directions, the ionic bond has spatial isotropy and unsaturation, that is, the ability to interact with other ions in various directions. In the electrostatic field, an atom with high electron affinity attracts many ions of the opposite sign; however, their approach will be stopped by the repulsive forces of the same sign charges. In nature, the stability of compounds is determined by the ratio of the ionic radii of the atoms of the compound elements. If the ratio is 0.41 to 0.73, the ions form a three-dimensional octahedral crystal structure. If the ratio is 0.73 to 1.37, then the ion interaction forms a cubic crystal structure. In these cases, the whole crystal is considered to be a single molecule with the energy of the most densely packed ions.

If an atom is deprived of an electron (ionisation), then, according to the conservation law of angular momentum L_e of an electron, as r_e increases, the tangential velocity $\vec{v}_e$ must decrease. Thus, the atom will be fully ionized if $r_e \to \infty$ and $\vec{v}_e \to 0$ (the parameters of the free electron) (Vonsovskij, 1971, p. 176). Since the radius of electron motion in the orbit of an atom is of the order of 10^{-10} m, but in a synchrotron, it is measured at least in centimetres, it can then be said with some certainty that an electron, being free, is able to retain its angular momentum without changing the mass but changing the radius of motion according to the speed of movement.

6. Charge and Current Modelling

When studying the movements and vector directions observed in the experiments described above, it is very difficult to avoid the conclusion that current-generating electrons must have gyroscopic properties, that is, the free electrons must be able to maintain their angular momentum L_e and, under the external impact, move in a direction perpendicular to the impact direction (Figure 2). Induction B of the external magnetic field acts on the magnetic moments $\overrightarrow{p_m}$ (14) of free electrons of an arbitrary direction with a torque $\vec{M} = \overrightarrow{p_m} \times \vec{B}$ (Valters et al., 1992, p. 315), which orients the magnetic moments of all electrons in the direction of B, and thus many individual atoms follow a uniform trajectory (Figure 2). For a classical electron orbit (Figure 5b), the magneto-mechanical ratio can be calculated:

$$\gamma = \frac{p_m}{L_e} = g \cdot \frac{e}{2m_e}, \tag{15}$$

where previously specified $e = |q_e|$ = 1.602· 10^{-19} C and m_e = 9.1 ·10^{-31} kg, but g is a factor (g-factor) to indicate deviations of the measured or material properties from the theoretical data (for orbital motion, g = 1 (Grēve, 2015a; Grēve, 2015b; Grēve, 2016)). It follows from formula (15) that the magnetic moment of the electron orbit is directly proportional to its angular momentum:

$$p_m = \frac{e}{2m} \cdot L_e = 0{,}8 \cdot 10^{-12}\ L_e, [\mathrm{A \cdot m^2}], \tag{16}$$

because both L_e (12) and p_m (13) have $\vec{v}_e$ and r_e in common. Formula (16) shows the dual properties of the angular momentum of an electron: mechanical, gyroscopic movement of the mass in combination with a magnetic moment. This calls for an examination of the possibility of using L_e in electric charge and current modelling because the duality of current is already discussed (see chapter 4.4).

A neutral atom acquires the name of an ion only when one electron is separated from its electron shell, and two electric charges with opposite signs are formed at the same time, where the electron had its own angular momentum L_e. As there are many free electrons in metals when they interact, they may change the original direction of the $\overrightarrow{L_e}$ vector but not a module $|\overrightarrow{L_e}| = me \cdot v_e \cdot r_e$, which may take part in the characterisation of the electron charge because it includes the mass of the particle and requirements of the law of conservation of charge. To adapt the proposed charge model to the existing system of measurement units, we dare assume that the charge of an electron is proportional to its angular momentum:

$$|q_e| = k_L \cdot |\overrightarrow{L_e}|, \tag{17}$$

where k_L is a factor that meets the requirements of the units used: $[\frac{C \cdot s}{kg \cdot m^2}]$, or $[\frac{A \cdot s^2}{kg \cdot m^2}]$.

Formula (17) also combines the law of conservation of angular momentum with the fact of conservation of charge.

Without much doubt, magnetic phenomena (16) can also be described using the characteristics of the mechanical motion of elementary gyroscopes. This may be used to justify the following:

- the gyroscopic movement of elementary particles is the root cause of all electromagnetic phenomena;
- in the orbital motion of an electron, the angular momentum L_e (12), magnetic moment p_m (16) and charge q_e (17) are constant values.
- a kinetic-magnetic bond dominates between the nucleus of the atom and the electrons surrounding it, which ensures external neutrality of the atom and conservation of energy in the minimum possible volume;
- electric field $\boldsymbol{E}$ is formed in the ionisation process of the atom when the induction $\boldsymbol{B}$ of the magnetic field of the bond changes similarly to the Maxwell equation for macroscopic objects: $rot\boldsymbol{E} = \frac{-\partial \boldsymbol{B}}{\partial t}$;
- the electric field is essentially a potential field of mechanical forces acting between ions (charges);
- ions (charges) of opposite signs attract one another to combine in a neutral atom, retaining their kinetic energy.

6.1 Electron Dynamics in a Current Line

Given the dual explanation of the current unit (see chapter 4.4), it is clear that dualism must also appear in the definition of charge (17). So far, we have considered the dualism of closed motion of a free electron: mechanical and magnetic. Therefore, we need to test the suitability of the gyroscopic model of charge for the characterisation of the current (the charge flow).

First, let us try to synthesise the dynamics of an electron motion in a current conductor by analysing the experimentally determined magnetic fields H_1 and H_2 for a single current line. In the macroscopic view, the following relation for an infinitely long wire (Valters et al., 1992, p. 318) is obtained: $H = I/(2\pi x)$, where x is the perpendicular distance from the wire with current *I*. Thus, the lines of magnetic field intensity H around the current conductor form concentric circles, such as H_1 and H_2 (Figure 6).

Let us try to synthesise the external magnetic field of the current conductor using microcurrents generated by the movement of free electrons. There are several reasons that electron trajectories are closed loops:

1) Free electrons are not completely free, but very weakly bound to their atoms; therefore, when attracted by the forces of the E field, they move easily from one atom to another until they reach the positive pole of the voltage source. Let us say pseudo-free electrons.
2) An electron released from the atom cannot suddenly lose its angular momentum of motion $|\vec{L}|$=m· $v \cdot r$ and the magnetic moment $p_m = I \cdot S = q_e \cdot v \cdot r/2$ related to it. Both v and r can be varied, but their product is constant (according to the law of conservation of the angular momentum). In both cases, a moving (in the direction of the E field) closed microcurrent circuit with its own magnetic field is formed.
3) In thermal chaotic motion, electrons create a chaotic magnetic field for each other, which causes electrons to move along closed or curved trajectories.

Such a set of chaotic disordered microcurrent circuits can be systematised by the potential field E, which is maintained in the direction of the power line by a voltage source U. This is governed by the Coulomb force discussed above, and the electrons rush to the positive ions to recombine them into complete neutral atoms. This is not enough to form the experimentally determined external fields H_1 and H_2 (Figure 6), but a special arrangement of magnetic moments $\overrightarrow{p_m}$ caused by electron motion is required. For illustrative purposes, it is shown enlarged as eight projections of elementary orbits (green stripes in Figure 6).

For much larger number of $\overrightarrow{p_m}$ their magnetic fields could add up and orient in the direction of H_1 and H_2. However, the proposed model is not fully satisfactory: we cannot deny the possibility of an alternative way of $\overrightarrow{p_m}$ grouping in the opposite direction. The directions of H_1 and H_2 should then also change, although no such cases have been observed in practice. Let us try to find out what forces $\vec{F}$ act on electrons in their orbits – in both cases. Following the recommendation mentioned by Feynman et al. (2006, Volume I, p. 1-3), determine the force directions for positive charges using an electrodynamically proven formula (3), which can be used in this case because for physical quantities $\vec{B}$ and $\overrightarrow{p_m}$ the directions are the same. According to the vector multiplication rule, in the situation of Figure 6, the magnetic component of the force is directed toward the outer wall of the wire, because the direction of charge velocity $\vec{v}$ is perpendicular to $\overrightarrow{p_m}$ and points away from the viewer.

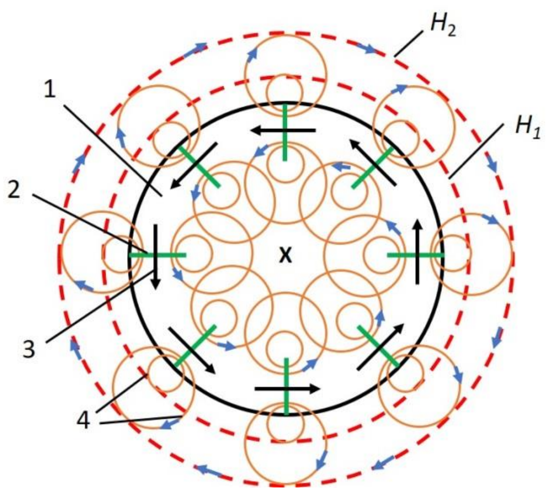

Figure 6. Schematic illustration of the participation of microcurrents in the generation of external magnetic fields (red) H_1 and H_2 of a current conductor:

1 – cross-section of the current wire; 2 – microcurrent contour projection (green);

3 – magnetic moment p_m; 4 – magnetic field lines (orange).

The charge density is expected to increase closer to the conductor surface. If for all $\overrightarrow{p_m}$ in Figure 6 we change directions to the opposite, the charges are subjected to the force of the opposite direction to the centre of the wire. There is no reason for this situation to occur because there are no free positive ions in the centre. Charges are placed on the wire surface in such a way that the surface becomes equipotential (Feynman et al., 2006, Volume II, p. 6-8), and, moreover, the external magnetic components of the current conductor H_1 and H_2 (Figure 6) would then have the opposite direction, which is not observed in practice.

It can be considered that the characterisation of the motion of electrons in a single power line with their angular momentum constant has succeeded because the maximum electron density in the vicinity of the conductor surface has also been found experimentally.

6.2 The Role of the Electron in Energy Transfer

The role of electric charges in energy transfer can be characterised quantitatively if we multiply both sides of equation (9) by the voltage U, which is applied to the ends of the current conductor and maintains a constant current I:

$$U \cdot q = U \cdot I \cdot t. \quad (18)$$

The right-hand side of the equation clearly shows the energy W transferred by the charge, so we can obtain the characteristics of the charge in energy transfer:

$$q = W/U. \quad (19)$$

So, the following relationship of units of measurement [C] = [watt ·s] / [V] is also valid, which characterises a charge with energy transfer capability in a conductor if the potential difference U = 1[V].

We have obtained quantitative relationships, but we lack satisfaction because classical physics does not explain by what means elementary particles are able to transfer energy without losing charge. Let us try to trace the energy transfer process.

First, the voltage source. It can be created by using the ionisation of various substances with various techniques (chemical, photoelectric, piezoelectric, and thermoelectric), both magneto-mechanically achieving the separation of electrons and positive ions in metals. In all variants, isolated terminals with opposite polarity (+/-) are created. So (Figure 3): $U = \varphi_+ - \varphi_-$, and the concentration of positive ions has been achieved at the terminal (+), and the concentration of electrons at the (-) terminal. The natural tendency of ions of opposite signs to recombine, forming neutral atoms with minimised external energy, allows this process to be subordinated to a very wide range of technologies to accomplish targeted work. Since the motion and states of elementary particles are analysed here, we must use the concepts of mechanical energy (Valters et al., 1992, p. 52). To do the work, an energy change must occur: $A = \Delta W = W_2 - W_1$. On the other hand, the full energy of the mechanical system is manifested in the kinetic form (W_k), which is related to the movement of material points of the body, and in a potential form (W_p) related to the dependence on the position in the potential field: $W = W_k + W_p$. For an orbiting electron v=ω·r, therefore:

$$W_k = \frac{mv^2}{2} = \frac{\omega L}{2}. \quad (20)$$

The concept of potential is used to characterise the electrostatic field at a point (Valters et al., 1992, p. 236):

$$\varphi = W_p \ / \ q_z, \quad (21)$$

which numerically indicates the potential energy obtained by a one-unit positive point probe charge q_z placed at this point. Therefore, the potential energy for a set of charges q can be calculated:

$$W_p = \varphi \cdot q. \quad (22)$$

Regarding the kinetic energy of the electron, it follows from the above that it is an invariant property of the charge of the electron and therefore does not directly participate in the transfer of energy from one point to another; however, precisely the removal of an electron, with its kinetic energy, from an atom creates an electric field in which Coulomb forces are manifested, which are useful for doing work. A current source can do work through the translational motion of charges in a potential field $A = \Delta W_p = \Delta\varphi \cdot q = U \cdot q$. For this purpose, an external electrical circuit with high electrical conductivity (two wires with a lot of free electrons) is adapted to the current source. It provides negligible voltage drop, so most of the source voltage and energy are offered for a suitable load, for performing work. Electrical engineering and energy industries are successful in dealing with these tasks.

This work considered the motion of electrons in static and direct current examples only. In the case of alternating current, the charges in the conductors must change direction, but in this case, the tiny mass of electrons and the associated angular momentum allow electron charges to track even very rapid changes in the electromagnetic potential – electrical signals.

The ability of electrical signals to propagate at the speed of light shows that this does not occur in substances by the slow diffusion of elementary charges (see chapter 4). A process in which electrically charged particles do not have to move at a distance, but only influence the behaviour of "neighbours" to form a wave, can be faster. Electromagnetic waves in metals are caused by the interaction of electron charge movements under conditions of changing electric field potential. After careful studies of M. Faraday's extensive experimental research, already in 1861 James Clark Maxwell succeeded in mathematically describing electromagnetic phenomena both in a vacuum and in various environments with a system of the differential equation. Later, only symbols and unit constants have been changed in the equations, which are now analysed in the electrodynamics course (Šilters et al., 1986). J. Maxwell has succeeded in showing that the vector fields E and B are mutually perpendicular, that the origins of the electric and magnetic fields are based on the same causes, and that they can be combined in a single theory. J. Maxwell himself admitted that the analysis of the possible movements of "ether particles" in the space of macroscopic dimensions helped to write the equations. It is known that "ether particles" have not been detected in a vacuum, but electromagnetic waves propagate successfully. However, it can be safely asserted that the most efficient way to propagate waves is by a suitable emitter – an antenna, which is usually made of an electrically conductive material containing an infinite number of electrons, the movement of which directly creates an electromagnetic wave, whose periodic copies in space help radiate energy, and thus cool the antenna. Synthesising the "choreography" of electron movement in an electromagnetic wave cannot be an easy task because it is mentioned (Šilters et al., 1986, p. 36) that on the surface of a metal ball (with a radius of 1 cm and a charge of 1 nC) with a thickness of one atom per square centimetre there are approximately 10^{10} free electrons, but you have to calculate that next to each free electron there are 10^6 atoms.

7. Conclusions

The gyroscopic model relates the charge of the electron proportionally to the angular momentum of the mass of the electron. It cannot claim to specify the numerical value of the charge because Heisenberg's proven uncertainty principle applies to such a light and fast-moving particle. It does not allow one to simultaneously improve the measurement accuracy of the particle's velocity and its position (radius). However, the proposed charge model helps to qualitatively explain the observations of a series of electromagnetic processes, following Faraday's call to supplement each mathematical formula with a physical explanation of the process. Such an explanation is especially useful in cases where the observed object's movement occurs even perpendicular to the direction of the applied forces and is formally characterised by a vector product. The electron charge is not visible, but its gyroscopic properties are manifested in various demonstration experiments related to the movement of free electrons. There is reason to believe that such a charge model can also be used successfully in the explanations of other three-dimensional processes that have not been considered before.

It is hoped that the accuracy of determining the orbital angular momentum of the electron will gradually improve, and it will be possible to include it numerically in the definition of the electron's charge.

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