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An Alternative Path to a New SI

(Part 2. On the Necessity of Changing the Set of Base Quantities)

Abstract. This article considers M.Planck's idea to create a natural system of units for all times and all civilizations. The necessary and sufficient number of natural base quantities for the implementation of this idea is considered. These quantities include energy and rotation angle. The article grounds the following statement: mass and electric charge can be included into the set of base quantities only conventionally. Kilogram is shown to be a measure of gravitation only, while the so-called "inert mass" stands for linear inertia in rectilinear movement, which has another unit. The classification of charges of the physical field is given; their dimensions and units are defined. It is pointed out that the potential of physical field, the potential of the system, and the difference of potentials of the system are fundamentally different, and therefore their dimensions and units are revised. The dimensions and units of intensities of different forms of physical field are also revised.

1. Natural and Conventional Base Quantities and Units

1.1. The Distinctive Feature of the Natural Base Quantities and Base Units

The idea to create systems of units based solely on the fundamental physical constants (FPC) and not depending on measurement standards (artifacts) emerged as far back as in the XIX century. The history of this idea is described in detail in the article [1]; it says that the existence of the FPC "*creates possibility of changeover from the conventional measures to the absolute measures of the Nature, i.e. the measures that have their own absolute precision*". The first two "universal systems of units" were suggested by James Maxwell in 1870 and 1873, while the first natural system of units based solely on the FPC was suggested in 1874 by George Stoney. Currently, "*the development of metrology can be described as transition from measuring the fundamental constants to measuring with the fundamental constants*" [1].

The M. Planck's natural system of units, suggested in 1897, was the most popular in the XX century. It was based on the Planck's constant h, the electrodynamic constant c, the gravitational constant G, and the Boltzmann's constant k. The constants h and k were introduced by M. Planck himself. There were other systems as well: **the Hartree's system of atomic units**, in which the base units are the units of electric charge, mass, and angular momentum of electrons, and **the system of relativistic units**, in which the velocity of light is used instead of the unit of electric charge.

The purpose of creating natural systems of units was very clearly stated by M. Planck himself [2]: they were created for the natural units "*to preserve their value for every epoch and every culture, including extraterrestrial and inhuman ones*".

Currently the metrological community aims to redefine the base units of the SI on the basis of the FPC. But the units of the FPC are pegged to the base units of the SI, which were defined on the Earth, including the conventional base units. This contradicts the goal declared by M. Planck.

The author of [1, section 3.4.12] concludes that "*it's better to record the single natural system of units as* (c, $\hbar$, E_0, e, k)*, where E_0 – a certain fundamental scale of energy*." Table 3.4.1 of the same paper lists 4 variants of that *fundamental scale of energy*. All of them are listed by the paper's author in the column "The Unit of Mass," since the unit of electron mass was a base unit in every natural system of units created by now.

This corroborates the suggestion set forth in this article — creation of a **natural system of quantities**, in which energy will be a natural base quantity, while mass as a derived quantity will remain in the set of the base quantities as a "conventionally chosen" one.

1.2. How the Planck's Idea Is Influenced by the Difference between Dimensions and Units

The main drawback of the existing natural systems of units is the fact that the gravitational constant G is not a FPC, but rather a dimension factor in the Newton's law of universal gravitation. The true dimension factor in this law is not G, but $\gamma_0 = 4\pi G$ (see Section 3.5). The constant used for calculating the Planck quantities is not the Planck constant h, but the reduced Planck constant $\hbar = h/2\pi$, which became popular in physics thanks to the use of the mathematical method of vector diagrams. Besides, the paper [3] clarifies, why the unit of h should equal J s quantum^{-1}, and not J s. Therefore the existing natural systems of units are still pegged to our times and the earthly science.

Even if in the future the base units will be based not only on atoms, but also on elementary particles, as it is suggested in the paper [4], it will still be an earthly approach, since any "extraterrestrial" civilization can base their system on other atoms and other elementary particles.

Dimensions, on the contrary, don't need measurement standards, even if those standards are the dimensions of the FPC. This is the crucial advantage of dimensions over the units, and the dimensions' raison d'être. Surely, the symbols of dimensions of the natural base quantities, which are chosen on the Earth, won't coincide with the symbols of the "extraterrestrial" base quantities, but the set of natural base quantities should be the same, as well as the quantity equations. This is why the M. Planck's idea concerning the creation of a system of "extraterrestrial" units should be substituted with the idea of creating a system of "extraterrestrial" quantities, since it's the units that are pegged to the dimensions of quantities, and not vice versa.

At the same time, we should remember that neither dimensions nor units reflect physical content of the quantities, though such statements can still be found in many places. The physical content of a quantity is defined only by its quantity equation, which can also include dimensionless quantities, numbers, logarithmic and trigonometric functions, operations of addition and subtraction. That's why the dimension analysis, which is widely used in practice, is necessary but far from sufficient correction criterion of the quantity equation. Every attempt to compare quantities based on their dimensions should be considered as groundless. For instance, when M. Planck introduced a dimensionless factor – the difference between an exponential function and number 1 – into the Rayleigh–Jeans radiance law, it made the law correspond to the experimental data, and saved physics from the "ultraviolet catastrophe."

The insufficient attention to the discipline of metrology while teaching physicists and engineers also plays a negative role. Many specialists, even high-level ones, don't recognize the difference in the essence of the two concepts – dimension and unit.

1.3. On the Necessary and Sufficient Number of the Natural Base Quantities

The article [5, section 6] suggests to discern between natural and conventional base quantities; here we briefly present the content of that section. The article sets forth a variant of structure of a **system of quantities** with 5 natural base quantities and one conventionally chosen base quantity. The diagram of this variant is shown on Fig. 1.

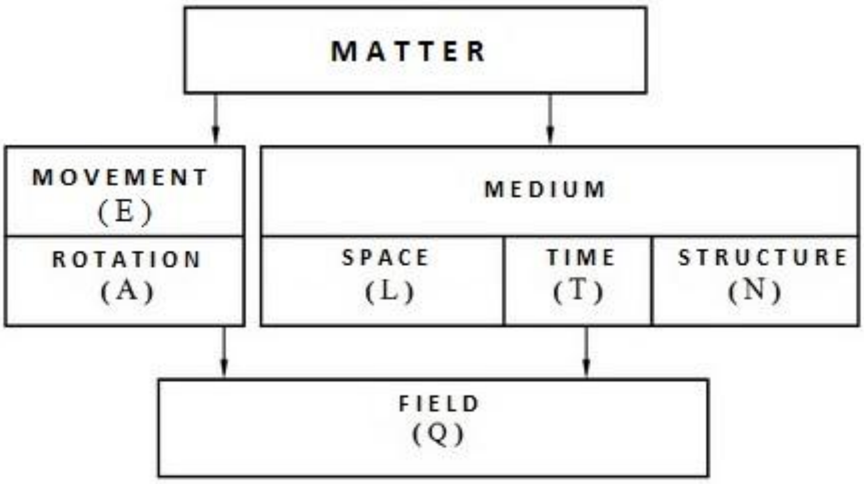

Fig. 1. Diagram of a Natural System of Quantities

The natural base quantities should describe categories included in the 'matter' concept: the **movement** of matter, the movement type (**rotation**), the **space**, in which the matter moves, the **time**, which defines the pace of the movement, and the **structure** of the space, in which the matter moves. All of them are reflected in the diagram. In the parentheses there are suggested symbols of dimensions of the natural base quantities.

The diagram on Fig. 1 also includes another category: physical **field**. It is described by **charge** – a derived quantity, <u>conventionally</u> chosen as a base one. The main reason of conventional introduction of the dimension of the charge Q into the system of quantities is the desire to avoid fractional powers in the exponents of dimensions and units. Mass, which has been accepted as a base quantity for almost two centuries, is in fact <u>a particular case of charge</u> in the gravitational field.

Movement is <u>the main feature of matter</u>; based on the definition of the 'quantity' concept [6, section 1.1] and also being aware of the necessity of taking into account the vector nature of quantities [7] we can draw a conclusion that **movement** is a vector physical quantity. Quantitatively, movement as a physical quantity is defined by its module, that is, **energy**. This is why the letter E was chosen as a symbol of the movement dimension (and therefore the energy dimension, too).

Intrinsically, the movement of matter is **rotation**, which is described by the rotation angle, for the dimension of which the letter A was suggested [3]. Spinning rotation of a separate material entity and the direction of rotation is described by its <u>angular momentum</u>.

Rectilinear movement is a particular case of the object's movement along a curvilinear orbit, when the radius of the trajectory goes to infinity [3]. In this case movement is described by linear **displacement**, the dimension symbol of which is the letter L, while the movement direction is described by the <u>momentum</u>.

The pace of movement is defined by **time**, the dimension symbol of which is the letter T.

The movement can take place only in a **medium**, which consists of the structural elements of this medium; the letter N is suggested for the dimension of their number [3].

All the quantities that include the dimension of the charge of the physical field Q (the mass or the electric charge) in the first order are **quantities of the first order**. According the Newton's law of universal gravitation and the Coulomb's law, all the natural base quantities are **quantities of the second order**. If the charge of the physical field is not introduced into the system of quantities as a conventional quantity, all the dimensions of the quantities of the second order will have fractional exponents with number 2 in denominator of their dimensions (see Section 3.5). This is why in the CGS system of units all the electromagnetic units had fractional exponents of dimensions. Some scientists even called the fractional exponents unnatural, but this is not so. They are inconvenient, but fully natural.

The suggested set of natural base quantities can already solve several problems existing in metrology [8]. First, it would eliminate the equality of the units of energy and the torque moment, which is so annoying for metrologists [9, section 4.6]: the dimension of torque moment would be EA^{-1} with the unit J rev^{-1}, which is different from the unit of energy, joule. Second, the units of electromagnetic quantities would correspond to their dimensions, i.e. stop being delusive [10] (see Section 2.3). It becomes clear that the delusion is caused not by the fact that dimensions and units of the electromagnetic quantities of the current SI don't correspond to each other visually, but by the absence of dimension and units of energy and electric charge in the ISQ.

When it comes to the base ISQ quantities of thermodynamic temperature, amount of matter, and luminous intensity, they are typical conventional base quantities; mass will be discussed separately and in more detail in Section 2.

1.4. What Are the Prospects of Changing the Set of Base Quantities?

The hopes of introduction of energy as a natural base quantity and substitution of electric current with electric charge as a base quantity in the course of the upcoming redefinition of the base SI units are rather unlikely to come true in the nearest future.

The article by the architects of the redefinition of units [9, Section 1.2] says the following: "*…the overall structure of the current SI—that is, the present SI base quantities and their units—should remain unchanged. The reason is that these quantities and units are deemed to meet the current and future needs of both the metrological and scientific communities and are well recognized and understood by the vast majority of the users of the SI throughout the world. Clearly, this assumption precludes consideration of a major restructuring of the SI, for example, replacing mass by energy as a base quantity and making mass a derived quantity, which would lead to the joule becoming a base unit and the kilogram a derived unit, or replacing electric current by charge as a base quantity and making electric current a derived quantity, which would lead to the coulomb becoming a base unit and the ampere a derived unit.*" This point of view was corroborated in the resolution [11].

As we see, the most important obstacle to migration to an updated SI, in the opinion of the authors of the quote, is a psychological one. Everyone got used to the kilogram unit, but not to the joule unit as a base unit. But kilogram is not suggested to be substituted as a base unit; rather, it is suggested to be interpreted in a different way. And the main reason is even not the fact of being accustomed to kilogram as a unit of mass. "The vast majority of the users of the SI throughout the world" has still not got accustomed to newton as the unit of force; they don't know about the newton unit, and commonly use a unit of weight, kilogram-force, omitting the word 'force' and at the same time having no idea that kilogram is the unit of mass. This majority will not even notice the redefinition of units.

Interestingly, the metrological community, as it is shown in Section 2.3, prefers to use in electromagnetism not the units of quantities corresponding to the dimensions of the current SI, but the units that correspond to dimensions given that energy is introduced as a base quantity. To say nothing of the fact that, according to opinions of both physicists and metrologists, substituting the electric charge with the electric current as a conventional base quantity is contrary to the causality principle.

There is no difficulty in defining the unit of energy, joule. It can be defined in the same way as they now suggest to redefine kilogram, that is, "by fixing the numerical value of the Planck constant to be equal to exactly $6.6260693 \times 10^{-34}$ when it is expressed in the SI unit J s."

We can also express doubts concerning the statement that the SI units meet the current needs of both the metrological and scientific communities, let alone the future ones. For a genuinely New SI we need exactly the "major restructuring of the SI" which is spoken of in the aforementioned quote from the article [9]. Meanwhile, if we keep the status quo, a number of problems described in the papers [8,12] will remain unsolved. This means we would have to come back to solving them in the nearest future.

2. What Is Mass?

This question has been being asked for several centuries, but there is still no single reply that would satisfy at least the majority of physicists and metrologists – regardless of the two fundamental papers by M. Jammer [13] and L. Okun [14], the reading of which seems to leave no uncertainty on this subject, except the historical aspect of its development [15]. However, a paper [16] recently published by V.Etkin has presented the subject in a new way.

We will consider the metrological aspect of this problem with regard to the upcoming redefinition of the unit of mass, kilogram [11].

2.1. The Terminology Used in Regard to Mass

The term "mass" is used in physics with a number of additional words: inert mass, gravitational mass, active and passive mass, relativistic mass, longitudinal and transverse mass, rest mass, electromagnetic mass. But as a rule the term doesn’t mean the different kinds of mass, but rather one and the same physical quantity; it was I.Newton who called it the amount of matter.

From the metrological point of view it is very important to make things clear about the terms ‘inert mass’ and ‘gravitational mass’. The article by J. Roche [15] says that "Einstein gave currency to the terms ‘inertial mass’ and ‘gravitational mass’ from 1907". At that time physics was starting the process of transition from the Newtonian mechanics and the Galilean principle of relativity (where the velocity of bodies $v << c$) to the relativistic mechanics (where $v \to c$). But L. Okun [14] explains, that "*the mass of a body in the Newtonian mechanics and the mass of the same body in the relativistic mechanics is one and the same quantity*". The terms "inert mass" and "gravitational mass" are used in his article only in quotation marks.

In this article we will discuss the mass that is present in the Newton’s law of universal gravitation and is marked by the letter m. At the same time, we should find out what defines the body’s inertia in rectilinear movement and is often called ‘inert mass’. This is exactly what still influences the definition of the dimension and the unit of mass.

2.2. What Is Meant by ‘Inert Mass’?

The term "inert mass" of the body usually stands for the so called "linear inertia" of the body [15] in rectilinear movement.

The concept of "system inertia" can be explained with the use of the automatic control theory. According to this theory, the **equation of transition process** from one equilibrium state of the system to another is expressed as a linear differential equation of the second order with constant coefficients. This equation connects the input signal $x(t)$ (influence on the system) with output signal $y(t)$ (reaction of the system). Let us write this equation as follows:

$$D\,\Delta\mathbf{q} + R\,\mathrm{d}(\Delta\mathbf{q})/\mathrm{d}t + I\,\mathrm{d}^2(\Delta\mathbf{q})/\mathrm{d}t^2 = -\,\Delta\mathbf{P}\,. \qquad (2.1)$$

In the equation (2.1) $\Delta\mathbf{P}(t)$ is an input signal, **difference of potentials** between the system and its environment; $\Delta\mathbf{q}(t)$ – output signal expressed as the difference of coordinates of the state of the system and its environment; D, R, and I – constant coefficients (parameters of the system). In physics an equation of the type (2.1) is used as an equation for forced damped oscillations, though the system parameters in that case are of other kind, have other content, and other names.

The term "potential" has a lot of different meanings. Here the **potential of the system** for the i-th form of movement is understood as a scalar quantity defined in thermodynamics with the equation

$$P_i = \partial U/\partial q_i\,. \qquad (2.2)$$

The content of the potential of the system is defined as internal energy change of the system ∂U divided by the change of the coordinate of state of the i-th form of movement of the system ∂q_i (given its invariance regarding other forms of movement). The potential of the system P is a function of state of the system. Its physical content is different from that of the **potential of the field** $\varphi(\mathbf{r})$ described in Section 4.1.

Unlike the potential P, the **difference of potential** $\Delta\mathbf{P}(t)$ is a function of the process of change of the system's state during its interaction with the environment. The difference of potentials $\Delta\mathbf{P}(t)$ and the difference of the coordinates of state $\Delta\mathbf{q}(t)$ are vector quantities, since they are defined by the direction of movement of energy carriers during the energy exchange: from the environment to the system, or in the opposite direction.

The system parameters from the equation (2.1) have the following names: D – the **rigidity** of the system (the inverse quantity $C = 1/D$ – **capacity** or **elasticity** of the system); R – the dissipative resistance of the system (**resistivity**); I – the system **inertia**. All the quantities of the equation (2.1) are different for rectilinear and rotational forms of movements, in which the difference of potentials can assume the form of force or torque moment. Therefore the system inertia I can be either **linear** or **rotational**.

Since the graphs of $\Delta\mathbf{q}(t)$ and $\mathbf{q}(t)$ on the coordinate plane (q, t) differ from each other only in position against to the origin of coordinates, $\mathrm{d}(\Delta\mathbf{q})/\mathrm{d}t = \mathrm{d}\mathbf{q}/\mathrm{d}t$ and $\mathrm{d}^2(\Delta\mathbf{q})/\mathrm{d}t^2 = \mathrm{d}^2\mathbf{q}/\mathrm{d}t^2$. That is why the equation (2.1) can be also recorded as

$$D\,\Delta\mathbf{q} + R\,\mathrm{d}\mathbf{q}/\mathrm{d}t + I\,\mathrm{d}^2\mathbf{q}/\mathrm{d}t^2 = -\,\Delta\mathbf{P}\,, \qquad (2.3)$$

For rectilinear movement of the body, in which $\Delta\mathbf{q}$ corresponds to the linear displacement $\mathbf{x}$, the equation (2.3) will be recorded as:

$$D\mathbf{x} + R\mathbf{v} + I\mathbf{a} = \mathbf{F}_D + \mathbf{F}_R + \mathbf{F}_I = -\,\mathbf{F}\,, \qquad (2.4)$$

where $\mathbf{F}$ – the difference of the force influencing the body and the total of the reaction forces of the body. The parameter D defines the body's resistance to deformation, the parameter R – external friction resistance while moving with the velocity $\mathbf{v} = \mathrm{d}\mathbf{x}/\mathrm{d}t$, and the parameter I defines the **linear inertia** of the body if the acceleration is $\mathbf{a} = \mathrm{d}^2\mathbf{x}/\mathrm{d}t^2$.

The linear inertia I is usually called "inert mass" [15].

The linear inertia I in the current SI has the dimension of mass M and the unit kilogram. After update of the set of base quantities of the SI, the linear inertia will have – based on the analysis of the equation (2.4) – the dimension $\mathrm{EL^{-2}T^2}$ and the unit $\mathrm{J\ m^{-2}\ s^2}$.

The force $\mathbf{F}$ influencing the body, according to (2.4), is numerically equal to the sum of the three forces: the force of elastic resistance $\mathbf{F}_D = D\mathbf{x}$, the friction force $\mathbf{F}_R = R\mathbf{v}$, and the inertia force $\mathbf{F}_I = I\mathbf{a}$.

Let us add some important remarks from the paper [14]: "*If we try to define 'inert mass' as a ratio of force to acceleration, this quantity in the relativity theory depends on how the force and velocity are directed against each other, therefore it cannot be defined in unequivocal way... The mass of a relativistically moving body is not a measure of its inertia. Moreover, there is no single measure of inertia for relativistically moving bodies, since the resistance of the body to the accelerating force depends on the angle between the force and the velocity.*"

In the second Newton's law, $\mathrm{d}\mathbf{p}/\mathrm{d}t = \mathbf{F}$**,** there is momentum $\mathbf{p}$. However, the mass m in the equation $\mathbf{p} = m\mathbf{v}$ should not be identified with linear inertia I from the equation (2.4), since the linear inertia I is defined in the equation (2.4) by the formula

$$I = F_I/a\,. \qquad (2.5)$$

The module of the inertia force $F_I \neq F$, since the inertia force $\mathbf{F}_I$ should be considered with due regard to the two other reaction forces ($\mathbf{F}_D$ and $\mathbf{F}_R$).

Currently the equality of dimensions of the units of mass m and linear inertia I is based on the *principle of equivalence of gravitational and inert mass*. This principle is based on the assumption that the kilogram unit describes both kinds of masses. But, firstly, the principle of equivalence of masses does not work on velocities v → c. Secondly, equivalence does not mean equality. In the paper [15], for instance, it is said about equality of ratios of 'inert masses' and 'gravitational masses' of two bodies, and not of them as such.

Let's look at the opinions of several physicists who deny the principle of equivalence of masses. In the monograph [17] it is said that "*in every experiments conducted on the Earth to check the principle of equivalence, all the external influences are carefully eliminated on purpose.*" The paper [18] considers a situation when the principle of equivalence of masses conflicts the energy conservation law. It is shown that the ratio of photon's gravitational mass m to its inert mass m_{in} equals $k_m = m/m_{in} = 2\sin\varphi$, where φ – the angle between the direction of the force of gravitational interaction and its projection to the plane perpendicular to the lines of force of the gravitational field. Macroscopic bodies are anisotropic. Therefore, the numerical value of k_m equals almost 1 for them. That is why the calculations of planet trajectories according to the Kepler's laws are confirmed, and the results of the experiments proving the validity of the principle of equivalence are valid, <u>but only in the macro world</u>.

The monograph [19] shows direct analogy between linear inertia in the equation of oscillations in mechanics and inductance in the equation for oscillations in electrodynamics. But this gives no one grounds to think that there is a principle of equivalence of electric charge (an analog of mass m as a charge of gravitational field) and inductance of the electric circuit (an analog of linear inertia I).

This proves the opinion that the "inert mass" concept is different in content from the "linear inertia" concept. The elimination of the "inert mass" concept from physics would make the discussions concerning the equality of the "inert mass" and the "gravitational mass" useless; moreover, the very 'gravitational mass' concept will become unnecessary. Besides, L.Okun [14] emphasizes that "*the concept of the gravitational mass is inapplicable for a relativistic body*", since the value of mass depends on how the vectors of the force and the velocity of a relativistic particle are located against each other. This is why for a relativistic body the linear inertia has two components: along the movement direction and perpendicular to it.

If the "inert mass" concept is excluded from physics, it will become obvious that the experiments conducted to prove the equality of the 'gravitational mass' and the 'inert mass' in the conditions of the Earth, when the velocity of bodies $v << c$, were needless, since they only proved that one and the same quantity, the mass m, equals itself in the macro world. As for the experimental error of these experiments, which was reduced to 10^{-13}, this is the error of the experimental set-up.

2.3. Dimensions and Units of Parameters of the Equation of Transition Process

Let's come back to the quantity equation of the potential of the system (2.2). In the current SI its dimensions are: dim P_i = L^2T^{-2} with the unit $m^2\,s^{-2}$ in gravidynamics, and dim P_i = $L^2MT^{-3}I^{-1}$ with the unit $m^2\,kg\,s^{-3}\,A^{-1}$ in electrodynamics. In updated SI <u>this dimension would look simpler</u>: dim P_i = EQ^{-1}, which would correspond the unit $J\,kg^{-1}$ in gravidynamics and the unit $J\,C^{-1}$ in electrodynamics. The dimension of the difference of potentials $\Delta\mathbf{P}$ is equal to dimension of the potential P_i itself, that is, dim $\Delta\mathbf{P}$ = dim P_i.

2.3.1. Analysis of dimensions of the first summand in the left part of the equation (2.3) in the current SI leads to dimension of the dynamic rigidity of the body D in the theory of oscillations, which is equal to MT^{-2} , which corresponds to the unit $kg\,s^{-2}$. In updated SI this would correspond to the dimension EL^{-2} with the unit $J\,m^{-2}$, <u>which is equal to the unit N m^{-1} that is used for this case in practice</u>.

In electrodynamics instead of rigidity D they use an inverse quality, which is called electric capacity C. In the current SI the dimension of the electric capacity is equal to $L^{-2}M^{-1}T^4I^2$

that corresponds to the unit m^{-2} kg^{-1} s^{4} A^{2}, which is very different from the currently used farad unit that is equal to 1 F = 1 C V^{-1}. In practice, the electric capacity is defined by the ratio of the charge of the capacitor plate to the difference of the field potentials between the plates, $C = Q/\Delta\varphi$, which leads to the unit C V^{-1}. In updated SI the unit of the electric capacity would correspond to dimension E^{-1}Q^{2} with the unit J^{-1} C^{2}, which is easily transformed into C V^{-1}, since 1 J = 1 C V.

There is another option in the theory of the electric field: capacity can be defined with the equation $C = 4\pi R\varepsilon_0$, according to which the dimension of capacity C becomes equal to L, which corresponds to the meter unit. This unit was used for capacity earlier, in the CGSE. But in this case the dynamic rigidity D in the CGSE should be equal to L^{-1} with the invalid unit m^{-1} (inverse meter). Such a situation in this case is prevented if we take into account that the charge of the body Q consists of a certain number N_Q of elementary charges q_e, that is, $Q = N_Q\, q_e$. Then the equation $C = 4\pi R\varepsilon_0$ should be substituted with the equation $C = 4\pi R\varepsilon_0/N_Q$. If the dimension of N_Q is N, the dimension of capacity C becomes equal to LN^{-1} with the unit m quantum^{-1} (meters per quantum), and the dimension of rigidity D will be equal to L^{-1}N with the unit quantum m^{-1} (quanta per meter), where quantum means one elementary charge. Such units have the following physical content: the electric capacity C shows the length of a charged body surface, on which a certain number of elementary charges are situated, while the dynamic rigidity D shows the number of elementary charges per unit of length of the surface of a charged body.

2.3.2. Dimension analysis of the second summand in the left part of the equation (2.3) in the current SI for the mechanical rectilinear from of movement results in the dimension of the resistance of external friction R, which is equal to MT^{-1} with the unit kg s^{-1}. In practice, the unit N m^{-1} s is used. In updated SI this would correspond to dimension EL^{-2}T with the unit J m^{-2} s, which is exactly equal to N m^{-1} s.

In electrodynamics the dimension analysis of the second summand results in the dimension of active electrical resistance that is equal to L^{2}MT^{-3}I^{-2}, which corresponds to the unit m^{2} kg s^{-3} A^{-2}. Such a unit is very inconvenient, and in the SI the unit ohm is chosen as a unit of active resistance. But it is equal to the unit V A^{-1} (volts per ampere), derived from another quantity equation (from the Ohm's law, written as $R = U/I$). Earlier, the use of the Ohm's law in the CGSE system resulted in the dimension equal to L^{-1}T with the unit m^{-1} s. In updated SI the active electrical resistance would have dimension ETQ^{-2} with the unit J s C^{-2}, which is easily transformed into the unit V A^{-1}.

2.3.3. The third summand in the left part of the equation (2.3) (inertia I) in mechanics was already discussed in Section 2.2. Section 2.4 is devoted to it.

In electrodynamics inertia I is called **inductance**, and noted by the symbol L. The dimension of inductance L in the SI is equal to L^{2}MT^{-2}I^{-2}, which corresponds to the inconvenient unit m^{2} kg s^{-4} A^{-2}. In metrology the unit H (henry) is used, which is equal to Wb A^{-1} (webers per ampere). But in the current SI inductance is defined by the quantity equation $L = \Psi/i$, where Ψ – magnetic flux linkage (the sum of the magnetic fluxes of the current loops). The use of this quantity equation earlier in the CGSE system of units resulted in the dimension that is equal to L^{-1}T^{2} with the unit m^{-1} s^{2}.

In updated SI induction would have dimension ET^{2}Q^{-2} with the unit J s^{2} C^{-2}, which is also equal to the unit V s^{2} C^{-1}. This unit is already free from the unit of mass kg, which is unnecessary for electrodynamics.

Therefore, the dimension analysis of the equation (2.3) shows that practitioner metrologists do not wish to use in electromagnetism the units following from dimensions of the current SI; instead, they prefer to use the units of the SI that should be taken for the update. In the dimensions of electromagnetic quantities they need the dimension of the electric charge, and not the dimension of mass.

2.4. What Is the Quantity Equation of Linear Inertia?

The reply for this question is given in the article by V.Etkin [16]. The author draws attention to the fact that according to the theory of irreversible processes, the relation between force and velocity should include non-linear "phenomenological" proportionality factor, which is defined experimentally. In particular, Newton's second law should include the factor $R_a(\mathbf{v})$, and therefore it should look as follows:

$$R_a\, d\mathbf{p}/dt = \mathbf{F}_a. \qquad (2.6)$$

Let's note that the accelerating force $\mathbf{F}_a$ (a term and symbol by the author) is equal in module and opposite in sign to the force of inertia $\mathbf{F}_I$ from the equation (2.5). Having substituted the force of inertia $\mathbf{F}_I = I\mathbf{a}$ from the equation (2.5) instead of $\mathbf{F}_a$ in the equation (2.6), and having rewritten $d\mathbf{p}/dt$ as $m\mathbf{a}$, we get the equation

$$I = R_a\, m\ . \qquad (2.7)$$

Having analyzed the equation (2.6), V. Etkin finds that in that equation "*the measurement units of physical quantities are chosen in such a way that the factor R_a equals one, and can be omitted if it is constant*" and "*the mass m, which in the equation* $\mathbf{p} = m\mathbf{v}$ *acts as a measure of the amount of matter, has nothing to do with the factor R_a as a measure of its inertia.*" The mass m is a function of state, while the factor R_a is a function of process (a function of the velocity $\mathbf{v}$).

In V.Etkin's opinion, the relation $R_a = f(\mathbf{v})$ is not known yet, and the factor $R_a(\mathbf{v})$ is different from the Lorentz factor $\gamma = (1 - v^2/c^2)^{-½}$, which is used in the relativistic mechanics.

If $v \to c$, no force can cause growth of acceleration, that is why the increment of momentum $d\mathbf{p}/dt \to 0$, and R_a goes to infinity. "*This is exactly what is observed in elementary particle accelerators, and is mistakenly explained in* STR *with the growth of mass*" [16] .

Such an explanation of linear inertia I has important consequences for metrology. Since in the current SI there is no difference between the dimension of mass m and linear inertia I, the factor $R_a = I/m$ has dimension 1. But in updated SI linear inertia I should have a dimension different from that of mass m, therefore the factor R_a should have its own dimension different from 1. And R_a should also keep this dimension if $v << c$, when its numeric value is as close as desired to 1.

The dimension of the factor R_a after dimension analysis of the equation (2.7) becomes equal to $EL^{-2}T^2Q^{-1}$ with the unit J m^{-2} s^2 kg^{-1}.

2.5. The Unit of What Is Kilogram?

In metrology the measurement standard of mass is still a mass prototype or a measurement device, in which mass is measured by weighing. The unit of mass – kilogram – was first introduced in 1799 as the unit of weight. Metrologists measure the mass of body at the point of the terrestrial gravitational field where the kilogram prototype or the current balance (watt balance) is located. This shows that currently kilogram is a measure of gravitation only. Linear inertia I has in the current SI the unit J s^2 m^{-2}, which does not correspond to the kilogram unit as a measure of gravitation.

In the current SI the unit kilogram was established arbitrarily. The dimension of force $\mathbf{F}$ that equals LMT^{-2}, and the unit of force 1 newton = 1 kg m s^{-2} are determined based on dimension analysis of the equation (2.5) $\mathbf{a} = \mathbf{F}_I/I$ without taking into account the fact that the equality of linear inertia I and mass m is not proven.

The mass is only a measure of gravitation. Consequently, it follows from the law of universal gravitation that the unit of mass depends on the unit of force of interaction of masses (gravitational force) and the unit of distance between the interacting masses. Therefore kilogram, the unit of mass, is a derived unit. But it can be accepted as a base unit conventionally.

Concerning the definition of kilogram, there are two points of view, which can be called ‘electric kilogram’ and ‘atom kilogram’ for convenience [20]. The former is based on the Planck constant, and the latter based on the Avogadro constant. Advocates of the ‘atom kilogram’ reprimand advocates of the ‘electric kilogram’, claiming that the Planck constant is complicated for understanding at school. But the Avogadro constant is not much simpler, and also has to be substituted with the Avogadro number [3]. In our opinion, the main reason is not the teaching methodology, but the cost of the measurement process (with silicon spheres or with watt balance).

2.6. On the Relation between Mass and Energy

In the XX century, thanks to the established importance of the ‘mass defect’ concept, the opinion that "*mass can be seen as a measure of the consumed or released energy*" became widespread [13]. The same paper suggests to consider a quantity named ‘massergy.’ However, as early as in 1905 A.Einstein [21] made the following conclusion: "*Mass of a body is a measure of energy contained in it*". L.Okun [14] specifies what exact kind of energy is meant here: "*...mass of a particle is a measure of energy ‘dormant’ in the particle at rest, a measure of rest energy.*"

But in this case there is a question: can’t we consider the particles’ rest energy E_0, not their mass m, as their main characteristic? Can’t we consider mass m as merely a factor between E_0 and c^2 in the famous formula $E_0 = mc^2$? Because we know that in the relativistic mechanics the mass of elementary particle is measured with a unit of energy – electron-volt – not a unit of mass – kilogram. The unit of electron mass m_e is a factor of the unit of energy in the main types of atomic natural systems of units [1, section 3.4.10]. This is why from this point of view as a natural base quantity should be energy.

Surely, creation of a measurement standard of energy is a very complicated task; but if the unit of energy will be defined with the help of the Planck constant, it won’t be necessary.

2.7. Dimensions and Units of Impulse of Force and Momentum of the Body

These quantities have equal dimensions in the current SI**,** but their units are different, since they are defined by different quantity equations.

Impulse of force S is a particular case of impulse of the difference of potentials Δ**P** (see Section 2.2) in rectilinear form of movement, when the force **F** substitutes Δ**P**. It is defined with the quantity equation $\mathbf{S} = \int \mathbf{F} dt$. In the current SI the dimension of **S** is equal to LMT^{-1}, but the unit is equal to N s, which means the unit of the impulse of force does not correspond to its dimension. In updated SI the dimension of **S** will be $\mathrm{EL}^{-1}\mathrm{T}$ with the unit J m^{-1} s, fully corresponding to its dimension.

Momentum of a body has quantity equation $\mathbf{p} = m\mathbf{v}$. In the current SI the dimension of **p** is the same as that of **S** – it is equal to LMT^{-1}, but in this case the unit of momentum of a body in the SI corresponds to its dimension; it is equal to kg m s^{-1}. In updated SI the dimension of **p** will be equal to LQT^{-1}, which coincides with the unit kg m s^{-1}. As a result, the impulse of force and momentum of a body will have different dimensions, which corresponds to the difference of their content.

Not only do the impulse of force and momentum of a body have different quantity equations, dimensions, and units — they can have different values, too. Indeed, every moving body has momentum **p**, even if the body is moving under its own inertia. But the ‘impulse of force’ concept cannot be used for such a body, since there is no force **F** when the body is moving under its own inertia. The impulse of force **S** appears only if a force is applied to the body. In this case the increment of the impulse of force d**S** is transformed into the increment of momentum of the body d**p**, which has the same value. This is true only if the body is not deformable, and there is no dissipation of energy caused by external friction.

When two moving inelastic bodies collide, the change of momentum of one of the bodies $d\mathbf{p}_1$ is transformed into the impulse of force d**S**, which causes the change of momentum of another body d$\mathbf{p}_2$. The impulse of force **S** can appear and disappear, while the momentum of the body **p** is a constantly existing characteristic of a moving body.

Amount of movement ($m\mathbf{v}$), according to the definition by I. Newton, contains mass m, which plays the role of a *measure of the amount of matter* – in modern terms, the role of the 'gravitational mass'. No wonder this term is considered as a synonym of the momentum of a body.

3. On Dimensions and Units of Charges of the Physical Field

3.1. Charge of a Body: a Physical Object or a Physical Quantity?

Since there is a lively discussion concerning redefinition of the units of electric charge and electric current, it is necessary to clarify the very concepts of "charge" and "current of charges."

We have not found any commonly accepted concept of the charge of a body. For instance, there is the following definition: "*Charge is a physical quantity, which is the source of the field, through which the particles that possess this characteristic interact*", which defines charge both as a quantity and an object (the source of the field). But a physical quantity is a property of a physical object; therefore the concept of physical quantity is subordinate to a physical object. To remove this ambiguity, the source of the field should be called a **charged system** or a **charged body**, while the **charge of the body** should be considered as a physical quantity. Hereinafter, when using the word 'charge' we will mean 'the charge of a body', not 'a charged body'. In electrodynamics, instead of the term "electric charge" we can find the outdated term "quantity of electricity," which is not advisable for use.

The charge of a body should be defined as a sum of **elementary charges**. The word 'elementary' in the expression 'elementary charge' should be understood not as an infinitessimal, but the indivisible, irreducible charge, which cannot be divided into parts without losing its physical content. For instance, the elementary charges of the electromagnetic field are electrons and positrons, while in the gravitational field they are atoms, molecules, and other similar physical objects, of which macro world bodies consist. The more correct wording of the term "elementary charge" would be "unit charge"; however, it is not rational to substitute the term "electric charge", since it is highly popular.

Therefore, the **charge of a body** is equal to the product of the elementary charge and the number of elementary charges, which has dimension of the number of entities [3], therefore the charge of a body and the elementary charge should have different dimensions and units, which will be shown in Section 3.5. In the current SI there is no difference between the unit of the charge of a body and the unit of the elementary charge, since the number of entities still has no unit.

3.2. Adjusted Terminology of Charges of a Physical Field

In modern physics the terminology of charges of the physical field is not regulated. This is the reason why defining their dimensions and units is somewhat difficult. Let us present the terminology to which we will adhere. It will describe the charges of both the electromagnetic and the gravitational field.

If the value of one of the two charges of interactive bodies is considerably higher than another, we will refer to the former as the **field-generating charge**, and the latter as the **field charge**. They are equivalent from the point of view of interaction. We will denote the field-generating charge with the symbol Q, and the field charge as q.

In modern physics, if the field charge is conventionally concentrated in one point, it is called a **point charge** – in other words, the charge of a material point. The point charge that conventionally doesn't distort the field is called a **test charge**. These terms reflect mathematical abstractions, and this is why we do not use them.

The charge of a body, which creates central field, can be logically referred to a **static charge**. The static charge of the field is a scalar quantity.

Elementary charges moving together with a charged body or moving inside a conductive motionless body relative to it create two other types of charges, which create vortex field. These two types of charges can be logically called as **dynamic charges** and are noted by the symbols **Q** or **q**, since they are vector quantities.

One of the types of dynamic charges (the elementary charges are motionless relative to a moving charged body) is referred to in electrodynamics as **moving charge**; it is noted as ($Q\mathbf{v}$) or ($q\mathbf{v}$), where **v** – the velocity of movement of the charged body. Another type of dynamic charge (the elementary charges are moving through a motionless conductor body) will be referred to as **current charge**. This is a new concept, so it should be explained.

The quantity equation for the electric current is currently written in electrodynamics as $i = \mathrm{d}q/\mathrm{d}t$, where d$q$ – the quantity of electricity carried through a conductor section over the time dt. The expression ($\mathrm{d}q/\mathrm{d}t$) is suitable for a charged body, in which the total number of elementary electric charges q is changing; it describes the speed of changing the number of charges in the body, but not the movement of elementary charges through a conductor. When the elementary charges are moving in the conductor, the number of charges entering the conductor is equal to the number of charges leaving it, therefore the number of elementary charges in the conductor q is not changing, which means that in the conductor $\mathrm{d}q/\mathrm{d}t = 0$.

In a conductor we should consider the number of charges q_{fl} flowing through it. The vector quantity $\mathbf{q}_{fl} = (q_{fl}\,\mathbf{v})$ is a moving charge. The **linear density** of this moving charge is $\mathbf{q}_{fl}/l$, where l – length of a straight-line portion of the conductor; it is marked as $\mathbf{i}_{fl}$, and is a **current of charges**. In electrodynamics $\mathbf{i}_{fl}$ corresponds to the electric current **i**, from which we can conclude that electric current is a vector quantity and is not equal to the scalar expression ($\mathrm{d}q/\mathrm{d}t$). Current charge in electrodynamics can be defined with formulas $\mathbf{Q} = (\mathbf{I}l)$ or $\mathbf{q} = (\mathbf{i}l)$.

In the Biot–Savart law written as $\mathrm{d}\mathbf{B} = k\, i\, [\mathrm{d}\mathbf{l}\ \mathbf{r}] / r^3$ the elementary current charge ($\mathbf{i}\mathrm{d}l$) is present in the formula implicitly and not parenthesized. The vector nature of magnetic induction d**B** is defined with the vector product of the elementary length d**l** and the radius vector **r**. But the elementary length d**l** is not a vector quantity; rather, it resembles a fixed road sign on the highway, along which cars move. Therefore the following representation of Biot–Savart law is correct: $\mathrm{d}\mathbf{B} = k\,[(\mathbf{i}\mathrm{d}l)\ \mathbf{r}] / r^3$.

In a similar way, when the Ampère's law is written as $\mathrm{d}\mathbf{F} = i\,[\mathrm{d}\mathbf{l}\ \mathbf{B}]$, the vector nature of the force of interaction d**F** is defined by the vector product of the elementary length d**l** and the vector of magnetic induction **B**. The correct representation of the Ampère's law is $\mathrm{d}\mathbf{F} = [(\mathbf{i}\mathrm{d}l)\ \mathbf{B}]$.

The moving charge ($q\mathbf{v}$) and current charge ($\mathbf{i}l$) have different physical content while sharing the same dimension. Both types of the dynamic charge create vortex field, but the moving charge moves together with the central field created by the charged body, while the motionless conductor inside of which a current of charges is moving, does not create a central field. In updated SI the dimensions of the moving charge and current charge are the same and equal to $\mathrm{LT^{-1}Q}$ with the unit m s^{-1} kg in the gravitational field and m s^{-1} C in the electromagnetic field. Both the moving charge ($q\mathbf{v}$) and the current charge ($\mathbf{i}l$) are separate physical quantities, therefore it is not possible to factor out any of their factors without loosing the physical content of these quantities. We can mention the physical quantity of amount of movement ($m\mathbf{v}$) as an example.

Current charge is a synonym of the concept 'magnetic charge'. Let us provide a clarification in order not to confuse those who think that magnetic charges do not exist: current charges exist only in closed current circuits, where the current charge of one sign in one of the branches of the circuit is counterpoised with the current charge of another sign in the opposite circuit branch. Therefore, the total current charge of a closed circuit (the magnet charge of the circuit) is always equal to zero. This is true for the total charge, but not for the elementary charge.

3.3. Charge of a Field Is a Derived Quantity

The laws defining the forces of interaction of charged bodies by the values of their charges are considered as experimental laws. Therefore, in order to equalize dimensions, the quantity equations should include **dimensional factors**. In electrodynamics they are the electric constant ε_0 and the magnetic constant μ_0, in gravidynamics – the gravitational constant G (sometimes written as γ). These 'constants' have only metrological content and are actually not FPC, though they are sometimes represented as such.

Earlier, when the CGS system of units was used, the charges of bodies were defined by the force of their interaction, that is, opposite to the way they do it now. But the problem of the CGS was the presence of fractional numbers in the exponents of dimensions and units of the electric and magnetic quantities. In the SI they got rid of fractional exponents by means of introducing electric current as a conventional base quantity. In this sense nothing will change after redefinition of units if electric current as a conventional base quantity will be substituted with electric charge.

Energy of the field surrounding a charged body depends on the value of the charge of the body. The value of the charge of the body depends on the energy contained in the elementary charges. Therefore the charge of the field is a quantity the dimension of which should include the dimensions of energy and the number of elementary charges. Therefore *the charge is a derived quantity*.

Charge of the field should be included into ISQ as a conventional base quantity with dimension Q (see Section 1.3). But in updated system of units it can have two different base units (kilogram and coulomb), which are chosen arbitrarily. Their definition is subject to discussion, and their relation is shown in Section 3.5.

3.4. On Dimensional Factors in Electromagnetism

In order for the dimensions and units of electromagnetic quantities not to have fractional exponents, the quantity equations include dimension factors, which are incorrectly referred to as constants.

As far back as in 1785 there appeared a proportionality factor k in the Coulomb's law, which depended on the ether's properties and the system of units chosen; it became known as the **dimensional factor**. Another dimensional factor appeared in 1820 in the Biot–Savart law. These two factors, which were later noted as ε_0 and μ_0, became known as the **dielectric** and the **magnetic permeability** of a substance and considered as the physical constants. James Maxwell in 1860-1865 found that their product is connected with the phase velocity of electromagnetic wave c by the equation $c = 1/\sqrt{(\varepsilon_0 \mu_0)}$.

In 1870-1881 physicists used two systems, the CGSE and the CGSM, created separately for the electric quantities (when $\varepsilon_0 = 1$) and magnet quantities (when $\mu_0 = 1$). Later, they were united into a mixed system of units, the CGS (supposing that $\varepsilon_0 = \mu_0 = 1$), in which the Maxwell's equation was not observed. Therefore coincidences of the dimensions of heterogeneous quantities were frequent in the CGS. This was a serious drawback of the CGS, and one of the reasons why the CGS was substituted.

After Heavyside's rationalization of units in the first half of the XX century the MKSA system appeared, in which $1/\varepsilon_0$ and μ_0 were multiplied by $(1/4\pi)$, and the dimensional factors became equal to $(1/4\pi\varepsilon_0)$ and $(\mu_0 /4\pi)$. In the second half of the XX century the MKSA was brought into the SI with the same dimensional factors.

The Gauss' law requires that the dimension of the flux of intensity vector of the electrostatic field should be equal to the dimension of the static charge. This requirement corresponds to $\varepsilon_0 = 1$ with the dimension 1. Any other dimensions of ε_0 don't result in complying with this requirement. Then, according to the Maxwell's equation, $\mu_0 = 1/c^2$ and its dimension is $L^{-2}T^2$. Such values of ε_0 and μ_0 were used earlier in the CGSE. In updated SI we should come back to them.

In the current SI ε_0 is defined by μ_0, which is set numerically, but such an order contradicts the causality principle. The dimension of ε_0 in the current SI is equal to $L^{-3}M^{-1}T^4I^2$, which corresponds to the unit m^{-3} kg^{-1} s^4 A^2, and the dimension μ_0 is equal to $L^2MT^{-2}I^2$, which corresponds to the unit m^2 kg s^{-2} A^2. No wonder that instead of these units, which are inconvenient and not understandable in electromagnetism, the SI has the unit F m^{-1} for ε_0, and H m^{-1} for μ_0.

The factor ($1/4\pi$) introduced by O. Heavyside, in our opinion, is necessary not for rationalization of recording the quantity dimensions, but because it reflects the inverse proportionality of the intensity of the field to the area of the equipotential surface $4\pi r^2$, and not the inverse proportionality to the squared radius r^2. For the same reason, the expression ($\mathbf{r}/r^3$) that is often used in the Newton's and Coulomb's laws undoubtedly needs to be substituted with an equal expression ($\mathbf{e}_r/r^2$), where $\mathbf{e}_r$ is a unit vector of the radius vector connecting the centers of the interacting charged bodies. Instead of the concept of 'the inverse-square law' we should use the concept of 'the inverse-surface law.'

3.5. Dimensions and Units of the Charge of a Body and Elementary Charge

The dimensions and units of the charge of a body and elementary charge in updated SI should be defined by the Newton's law of universal gravitation or the Coulomb's law.

Let's write the generalized equation for defining the force of interaction of static charges Q and q in the central field $\mathbf{F}_f$ as

$$\mathbf{F}_f = k_f\, Q\, q\, \mathbf{e}_r / S_f = k_f\, N_Q\, N_q\, q_e^2\, \mathbf{e}_r / S_f\,, \qquad (3.1)$$

where k_f – the dimensional factor of the central field (which corresponds to $1/\varepsilon_0$ in electrodynamics); S_f – the area of equipotential surface of the central field; q_e – elementary charge; N_Q and N_q – the numbers of elementary charges in the field-generating charged body and the field charged body; $Q = N_Q\, q_e$ – the charge of the field-generating body; $q = N_q q_e$ – the charge of a body in the field.

The equation for defining the force of interaction between moving charged bodies $\mathbf{F}_c$ with the moving charges ($Q\mathbf{v}_Q$) and ($q\mathbf{v}_q$), which generate vortex field, will be written as

$$\mathbf{F}_c = k_c\, [(Q\mathbf{v}_Q)\ (q\mathbf{v}_q)] / S_c = k_c\, N_Q\, N_q\, q_e^2\, [\mathbf{v}_Q\, \mathbf{v}_q] / S_c\,, \qquad (3.2)$$

where k_c – the dimensional factor of the vortex field (which corresponds to μ_0 in electrodynamics); $\mathbf{v}_Q$ and $\mathbf{v}_q$ – the velocities of the moving charges; S_c – the area of the equipotential surface of the vortex field.

In modern physics the relation k_f/S_f from the equation (3.1) is written in electrodynamics not as $(1/\varepsilon_0)(1/4\pi r^2)$, but as $(1/4\pi\varepsilon_0)(1/r^2)$, which means that k_f is written as $(1/4\pi\varepsilon_0)$ instead of $(1/\varepsilon_0)$. This permutation of factors is acceptable from the mathematical point of view; however, it leads to incorrect interpretation of the physical content of the Coulomb's law. In the same way, the ratio k_c/S_c from the eqution (3.2) is written not as $\mu_0(1/4\pi r^2)$, but as $(\mu_0/4\pi)(1/r^2)$, which means k_c is written as $(\mu_0/4\pi)$ instead of μ_0. This leads to incorrect interpretation of the physical content of the Coulomb's law for magnet masses in electrical engineering, and of the Ampère's law.

In gravidynamics the things are even worse. In the Newton's law of universal gravitation there is no factor 4π in the denominator, therefore one cannot guess about the existence of the equipotential surface of the gravitational central field if it is not explicitly mentioned while teaching. In order to make the physical content of the equation (3.1) understandable in gravidynamics, we should introduce the dimension factor $k_f = (1/\gamma_0)$, which is similar to the factor $(1/\varepsilon_0)$ in the electric field. This factor is $\gamma_0 = 1/(4\pi G)$, from where $G = 1/(4\pi\gamma_0)$. The introduction of the factor 4π into the numeric value of G can result in reconsideration of the numeric values of the Planck's constants. As for the gravidynamic vortex field, there should appear a dimensional factor corresponding to μ_0 in electrodynamics.

In the current SI the dimension of the charge of a body is equal to TI. Dimension analysis of the equation (3.1) with taking into account the new symbols for dimensions (E and N), and the dimension of force $\mathbf{F}_f$, which is equal to EL^{-1}, and $\varepsilon_0 = 1$ results in the **dimension of charge of a body** dim $q = E^{1/2}L^{1/2} = Q$ and the **dimension of elementary charge** dim $q_e = E^{1/2}L^{1/2}N^{-1} = QN^{-1}$ in updated SI. Dimension analysis of the equation (3.2) for $\mu_0 = (1/c^2)$ leads to the same conclusion.

The dimension of a elementary charge $E^{1/2}L^{1/2}N^{-1}$ will correspond to the unit $J^{½}\,m^{½}\,pcs^{-1}$, where pcs (piece) is a unit of the number of entities, in this case – the number of elementary charges. And the dimension QN^{-1} corresponds to the unit C pcs^{-1} or kg pcs^{-1}.

The paper [22] provides detailed grounding of the necessity of introduction of a conventional base quantity into the New SI – the electric charge with definition "Coulomb is an electric charge, which is equal to the precise number $1/(1{,}60217653\times10^{-19})$ of elementary charges, and which interacts in vacuum with an equal charge situated at a distance of 1 meter with the force of $(299792458)^2 \times 10^{-7}$ N". But in the suggested definition of coulomb the unit newton should be written as J m^{-1}, to emphasize the connection of the unit of the electric charge with the units of energy and length.

The relation between the values of the units of charge of the gravitational and the electric fields (kilogram and coulomb) can be calculated for the macro world. For instance, in the paper [23], based on the fact that mass and linear inertia are considered as the same quantity in the macro world, the attracting force and the inertial force are considered as equal. It follows from this assumption that mass has the unit $m^3\,s^{-2}$, and that 1 kg = $8{,}385539\cdot10^{-10}\,m^3\,s^{-2}$. The same unit ($m^3\,s^{-2}$) is ascribed to the electric charge, and, according to the Ampère's law, it is calculated that 1 C = 9,73175(4) m^3/s^2. This leads to the following equality for the macro world: 1 kg = $8{,}61641199\cdot10^{-11}$ C.

3.6. Dimensions and Units of Dipoles and Dipole Moments

Dipole can be translated from the Greek language as **double-pole**, which corresponds to the system with a positive and a negative charge in electromagnetism. Therefore a dipole is a 'double-charge' rather than a double-pole. First, let us consider the diagram of dipoles in electrodynamics, which is shown on Fig. 3.1. Dipoles are considered as charged systems consisting of two elementary charges (**monopoles**); the distance between their centers is called the **dipole distance**, and is noted by the symbol **d**. The notation **d** was chosen for a reason: when a dipole rotates around its center, the module **d** is the diameter of the circle along which the monopoles move.

The dipole distance should not be called as it is conventionally called now – **arm of a dipole l** that is present in the quantity equation for the electric moment of a dipole $\mathbf{p}_e = q\mathbf{l}$, which is used in electrodynamics. In reality, when an extraneous field influences a dipole, it is influenced by a couple of forces; by definition, "arm of a couple of forces is a shortest distance between the lines of action of the forces that constitute the couple of forces". In other words, **l** is the distance vector between the lines of action of the forces that constitute the couple of forces; therefore this is a quantity of which changes when the dipole rotates. Meanwhile, the distance **d** between the charges of the so-called 'rigid' dipole is a constant quantity. Moreover, the couple of forces appear only if the dipole is influenced by an extraneous field; if there is no influence, there is no reason to speak of the couple of forces.

The electric monopoles of different signs are **electrons** and **positrons**. The directions of their orbital movement around the atomic nucleus relative to the directions of their spinning movement are opposite, and this is what shows the difference in the signs of monopoles.

The constructive parameters of dipoles are the **dipole moments** with quantity equations listed in Fig 3.1 (the **electric moment** $\mathbf{p}_e = q\mathbf{d}$ and the **magnetic moment** $\mathbf{p}_m = [\mathbf{q}\ \mathbf{d}]$).

The Fig. 3.1 shows moving charge **q** = (q**v**) as a dynamic charge. In electromagnetism they often consider current charge **q** = (**i**l) in the current circuit. But this does not change the reduced quantity equation for the magnetic moment $\mathbf{p}_m$ = [**q d**]. In physics they use another quantity equation for the magnetic moment $\mathbf{p}_m = iS\mathbf{n}$, where S is the area of section of the current circuit; **n** is the unit normal vector of the section of this circuit. But the only thing that makes this equation different from $\mathbf{p}_m = [(\mathbf{i}l)\ \mathbf{d}]$ is notation; both quantity equations are easily transformable into each other.

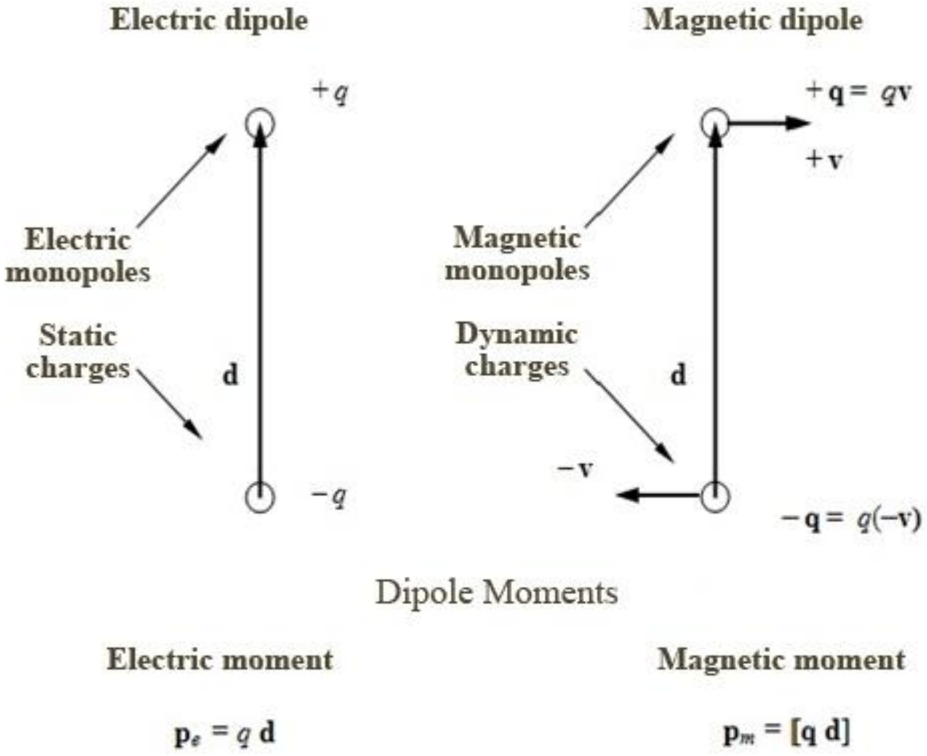

Fig. 3.1 Diagram of Dipoles and Dipole Moments in Electrodynamics

The Fig. 3.2 shows a diagram of dipoles in gravidynamics. If two massive bodies have opposite direction ns of orbital movements along their trajectories relative to their spinning movement (like an electron and a positron), then a positive and a negative sign can be ascribed to such **gravistatic monopoles**. Such a couple of gravistatic charges constitute a **gravistatic dipole**. **Gravistatic charges** of the same sign are attracted to each other; for instance, the planets are attracted to the Sun, massive bodies are attracted to the Earth and to each other. But usually it is not mentioned which of the gravitational charges is a positive, and which is a negative one.

Massive bodies on a rotating planet are gravistatic charges of the same sign, since they move together with the planet during its spinning movement. The rotation of each massive body around the planet's axis happens along a gravitation current circuit. Therefore each massive body located on the surface of the planet and moving together with it is a **gravidynamic monopole**. Two monopoles located in the two hemispheres of the planet, which are opposite relative to the prime meridian, constitute a **gravidynamic dipole**, since they are moving in the opposite directions.

Let's consider gravitational interaction between two gravidynamic monopoles (two massive bodies) that are placed near and move parallel to each other. If the radius of the planet is big enough, the massive bodies can be seen as two **gravitational current charges** of the same sign, which move parallel to each other and are attracted to each other according to the law that is similar to the Ampère's law for the two parallel conductors with electric current charges of the same sign. This explains both the mutual attraction of massive bodies and their attraction to the surface of the planet. A similar explanation can be given to the mutual attraction of the planets of the Solar System when the direction of their rotation relative to the Sun is the same.

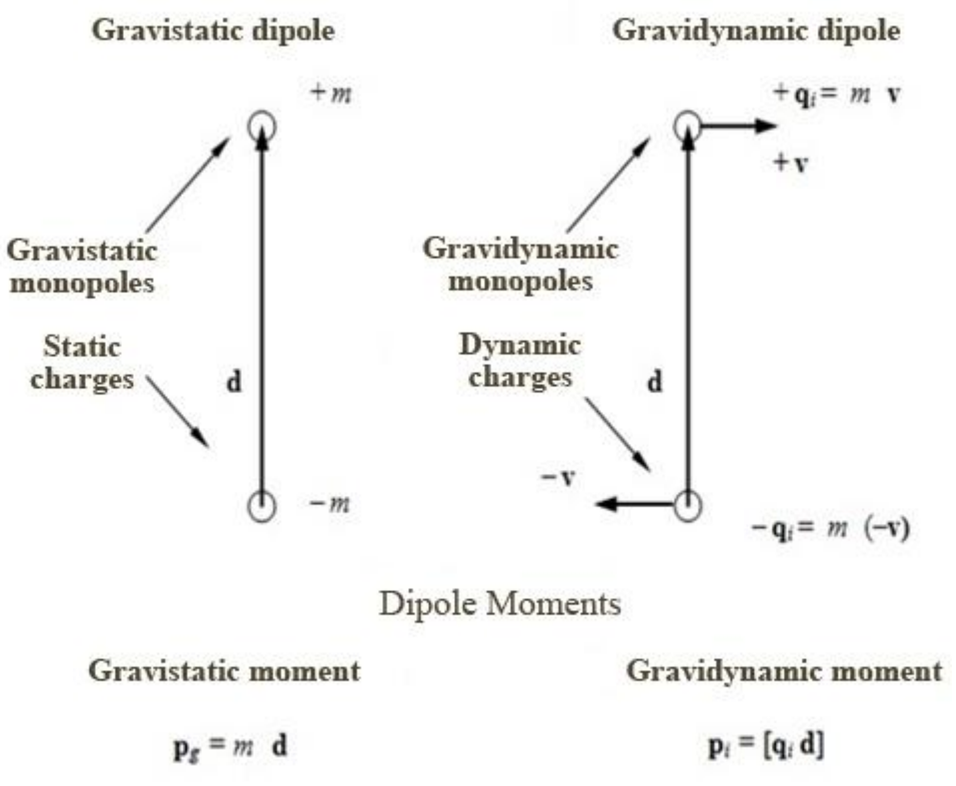

Fig. 3.2 Diagram of Dipoles and Dipole Moments in Gravidynamics

The dimensions of dipole moments are equal to QL, therefore their units should be equal to C m in electrodynamics, and kg m in gravidynamics. In the SI the dimension of magnetic moment is equal to L^2I, and the unit is A m^2, which is, in essence, the same as C m.

But the SI also considers the magnetic moment of the magnetic dipole with the dimension $L^3MT^{-2}I^{-1}$ and the unit Wb m.

4. In updated SI the Dimensions and Units of Field Quantities Should Be Changed

4.1. Dimensions and Units of Potentials of the Physical Field

The modern definition of scalar potential φ in a particular point of a field, which is used to define its dimension and unit, is derived from the formula $\varphi = W_p/q$, where W_p – the potential energy of interaction of the test charge q, which is situated in that point, with the field. But the potential of the field φ describes the intense state of the filed medium in a given point, regardless of presence of any charge in that point. This is why the formula $\varphi = W_p/q$ does not follow the causality principle. Besides, it does not take into account the value of the field-generating charge Q and the distance r from the field-generating charge to a given point.

In the vector calculus [24] the **scalar potential of field** $\varphi(\mathbf{r})$ does not have a defining equation and is the argument of the vector function of the intensity of field $\mathbf{E}(\mathbf{r})$, defined as $\mathbf{E}(\mathbf{r}) = -\,\mathrm{grad}\,\varphi(\mathbf{r})$. The intensity of field $\mathbf{E}(\mathbf{r})$ is defined in physics by the value of the field-generating charge Q. Therefore, the quantity equation of the potential φ will not coincide with the aforementioned equation $\varphi = W_p/q$.

At the same time, let us mention that the potential of field φ is a physical quantity different fom the potential of system P that was discussed in Section 2.2.

4.1.1. The potential of the central field generated by the charge Q and equally distributed on the spherical equipotential surface with the area $S = 4\pi r^2$ will be equal to [25, p. 185]:

$$\varphi = k_f Qr / S = k_f Q/4\pi r \,. \qquad (4.1)$$

In the New SI the dimensional factor k_f should be equal to 1 (see Section 3.4). According to the equation (4.1), the potential of the central field depends only on the values of Q and r. The dimension of the potential φ according to the equation (4.1) will be equal to $L^{-1}Q$, which corresponds to the unit C m^{-1} in electrodynamics or kg m^{-1} in gravidynamics. The equipotential surface can be different from spherical; this will not influence the dimension of the potential of field.

In the current SI the dimension of the electric potential is equal to $L^2MT^{-3}I^{-1}$, which corresponds to the unit m^2 kg s^{-3} A^{-1}; nevertheless, very different units are used (J C^{-1} and V). The unit J C^{-1} follows from the equation $\varphi = W_p /q$, which was mentioned above as not following the causality principle, therefore the unit J C^{-1} should not be used. The unit V (volt) follows from the equation $U = P/I$, where U – voltage drop on a section of circuit, I – electric current, P – power. But I and P have no relation to potential of field. Therefore the volt unit also should not be used for potential of field. Thus, the units of the current SI used for the potential of electric field don't correspond to its physical content. The only unit that can be left for use is C m^{-1}.

4.1.2. The potential of vortex field (**vector potential**) is noted by the symbol **A**. In the vector calculus [24] the **vector potential A** also does not have a defining equation and is the argument of the vector function of the intensity of vortex field (in electrodynamics – the magnetic induction) **B**, defined as **B** = rot **A**.

Let us write the equation for vector potential similar to (4.1). For the vortex field generated by the current charge **Q** = (**I***l*) (see Section 3.2), the equipotential surface is not a sphere, but a cylinder with the area of side surface $S = 2\pi bl$, where b – the radius of the cylinder, and l – the length of the cylinder. Therefore we can write an equation

$$\mathbf{A} = k_c\, \mathbf{Q}b/S \;= k_c\, \mathbf{Q}/2\pi l \,, \qquad (4.2)$$

In the magnetic field $k_c = \mu_0$. Therefore the equation (4.2) is transformed into the equation

$$\mathbf{A} = \mu_0\, (\mathbf{I}l)\, /2\pi l \,. \qquad (4.3)$$

According to the equation (4.3) the dimension of **A** in the current SI should be equal to $LMT^{-2}I^{-1}$, which corresponds to the unit kg m s^{-2} A^{-1}. But the unit kg is foreign for electrodynamics, therefore the unit Wb m^{-1} = T m is used for the vector potential. We have to conclude that the introduction of the units Wb (weber) and T (tesla) is caused not by the physical content of the vector potential, but by the convenience of writing. In updated SI the dimension of **A** should be equal to $L^{-2}TQ$, which in electrodynamics corresponds to the unit C m^{-2} s, and in gravidynamics – the unit kg m^{-2} s.

4.2. Dimensions and Units of Intensities in the Physical Field

While studying dimensions and units of intensities of field in the current SI for different forms of physical field we cannot find any conformity. This is explained by these units' historical development: they were constantly changed with transition from one system of units to another. The base units were chosen so that they were convenient for measurements and creation of measurement standards.

The dimension formulas of intensities of the field in the SI are based on the set of dimensions MLTI. Let us show that in the New SI it will be possible to achieve the same goal with the set of dimensions ELT, or, if we desire to avoid fractional numbers in the exponents of dimensions, the set of dimensions LTQ, taking into account that dim Q = $E^{1/2}L^{1/2}$. Let's take a look at the corresponding table (dash means the absence of the necessary symbol, dimension, and unit for a given quantity in the SI).

Table of Dimensions and Units of Intensities of the Physical Field

Physical Field	Medium	Intensity	Dimension and Unit in the SI		Dimension and Unit in updated SI	
Gravistatic	physical vacuum	**G**	LT^{-2}	m s^{-2}	$L^{-2}Q$	kg m^{-2}
Gravistatic	inside substance	-	-	-	$L^{-2}Q$	kg m^{-2}
Electric	without regard to medium	$\varepsilon_0\mathbf{E}$	$L^{-2}TI$	C m^{-2}	$L^{-2}Q$	C m^{-2}
Electric	physical vacuum	**E**	$LMT^{-3}I^{-1}$	N C^{-1} V m^{-1}	$L^{-2}Q$	C m^{-2}
Electric	inside substance	**P**	$L^{-2}TI$	C m^{-2}	$L^{-2}Q$	C m^{-2}
Electric	with regard to substance	**D**	$L^{-2}TI$	C m^{-2}	$L^{-2}Q$	C m^{-2}
Gravidynamic	physical vacuum	-	-	-	$L^{-3}TQ$	kg s m^{-3}
Gravidynamic	inside substance	-	-	-	$L^{-1}T^{-1}Q$	kg m^{-1} s^{-1}
Magnetic	without regard to medium	$\mathbf{B}/\mu_0$	$L^{-1}I$	A m^{-1}	$L^{-1}T^{-1}Q$	C m^{-1} s^{-1}
Magnetic	physical vacuum	**B**	$MT^{-2}I^{-1}$	T	$L^{-3}TQ$	C s m^{-3}
Magnetic	inside substance	**M**	$L^{-1}I$	A m^{-1}	$L^{-1}T^{-1}Q$	C m^{-1} s^{-1}
Magnetic	with regard to substance	**H**	$L^{-1}I$	A m^{-1}	$L^{-1}T^{-1}Q$	C m^{-1} s^{-1}

4.3. Conclusions Drawn from the Table of Intensities

1. In updated SI, dimension Q will be present in all the dimensions of intensities. Therefore a unit of charge will be present in every unit of intensity. The sum of exponents of the dimensions L and T will be always the same, and will be equal to (−2).

In the current SI the equality of the sum of exponents of the dimensions L and T to the number (−2) is observed only in part. It doesn't apply to intensities in the physical vacuum, therefore the latter have their own units (m s^{-2}, N C^{-1}, V m^{-1}, T, Wb), which makes an impression of chaos, especially in electromagnetism. This is caused by the wrong choice of the dimensional factors (the electric and magnetic constants, see Section 3.4). The dimensions and units of intensities of electromagnetic field in the physical vacuum are currently misrepresenting the objective physical content of this quantity.

2. By defining the dimension and unit of intensity **G** of gravistatic (gravitational central) field based on the equation for free fall acceleration $\mathbf{g} = \mathbf{F}/m$, and not the Newton's universal law of gravity, we arrive at the unit of free fall acceleration **g** , which is equal to m s^{-2} , as the unit of intensity G. But the unit of energy joule is not present in such a unit, though any force field has energy. The unit of intensity of gravidynamic field (gravitational vortex field) after some calculations according to this method is s^{-1}, in which even the unit of length is not present.

However, the unit of linear inertia I and the unit of mass m should not be seen as equal (see Section 2). This leads to the two important consequences. Firstly, the unit of intensity of the gravistatic field ceases to be equal to the acceleration m s^{-2}. Secondly, the so-called kinematic LT-system of dimensions, which is liked by many physicists and is based on seeing the units of linear inertia I and mass m as equal, loses its scientific ground.

3. While considering intensities of fields in substance (polarization **P** and magnetization **M**) and with regard to substance properties (electric displacement **D** and magnetic field intensity **H**) we can see that the fields of the fixed and foreign charges are described with intensities <u>without regard to the properties of the medium</u> (physical vacuum). Not much attention is paid to this in physics, and the concept of **"pure intensity"** ($\varepsilon_0\mathbf{E}$ or $\mathbf{B}/\mu_0$) is almost never used. This gives a faulty impression that electric displacement **D** and intensity of the magnetic field **H** can be used for fields in physical vacuum even if there is no hint of the presence of substance.

4. In the electric field the dimensions of **D** and $\varepsilon_0\mathbf{E}$ coincide, just as the dimensions of **H** and $\mathbf{B}/\mu_0$ in the magnetic field. But intensity of the magnetic field **H** is the intensity of magnetic field with regard to substance properties and without regard to the properties of physical vacuum. If there is no substance in the magnetic field (for instance, there is no core in the inductor), then magnetic induction **B** should be used instead of **H**. Accordingly, in the quantity equation of the Poynting vector there should be **B**, and not **H**, as it was in Feynman's lectures on Physics [26].

5. The New SI should naturally include the dimensions and units of intensities of the gravidynamic field, which are currently not present in the SI.

6. In order to relieve the psychological difficulties caused by transition to the new dimensions and units of intensities while teaching physics and electrical engineering, it is possible to provide both the SI and the New SI dimensions and units of the intensities of field, just like they are doing now in textbooks on physics with the intensities of field, the units of which are given both in the SI and the CGS.

4.4. Dimensions and Units of Capacity and Rigidity

Let's come back to the generalized equation of the system's transition process (2.2) for some form of movement:

$$D\,\Delta\mathbf{q} + R\,\mathrm{d}\mathbf{q}/\mathrm{d}t + I\,\mathrm{d}^2\mathbf{q}/\mathrm{d}t^2 = -\,\Delta\mathbf{P}.$$

For this form of movement the equation of condition is $\Delta U\mathrm{d}q = \mathrm{d}W$, or, after substitution of the equation (2.2),

$$[[D\Delta\mathbf{q} + R\,(\mathrm{d}\mathbf{q}/\mathrm{d}t) + I\,(\mathrm{d}^2\mathbf{q}/\mathrm{d}t^2)]\,\mathrm{d}\mathbf{q} = \mathrm{d}W\,. \qquad (4.5)$$

The summands of the equation (4.5), in order of appearance, are: change of the potential energy of deformation, change of the energy of dissipation, and change of the kinetic energy.

Change of the **potential energy** $\mathrm{d}W_p = D\Delta\mathbf{q}\mathrm{d}\mathbf{q} = \Delta\mathbf{q}\mathrm{d}\mathbf{q}/C$ after integration on the whole time span of the transition process, leads to the equation

$$\Delta W_p = D(\Delta\mathbf{q})^2/2 = (\Delta\mathbf{q})^2/2C\,, \qquad (4.6)$$

The dimension analysis of (4.6) in the SI leads to the dimension of rigidity of the body D, which is equal to $L^2M^{-1}T^{-2}$ with the unit $m^2\,kg^{-1}\,s^{-2}$, and to the dimension of elasticity (a quantity that is inverse to rigidity), which is equal to $L^{-2}MT^2$ with the unit $m^{-2}\,kg\,s^2$.

In the electrodynamics instead of elasticity they use electric capacity C, which is equal to the ratio of charge increment to potential increment, $C = \Delta Q/\Delta\varphi$, which corresponds to unit C V^{-1}

that is called farad (F). But the dimension of capacity in the SI is equal to $L^{-2}M^{-1}T^4I^2$, which corresponds to the unit m^{-2} kg^{-1} s^4 A^2. It looks very different from C V^{-1}.

There is another option. After substitution of $C = \Delta Q/\Delta\varphi$ to the equation (4.1) they get the equation $C = 4\pi R/ k_{f0}$, according to which the dimension of capacity C becomes equal to L, which corresponds to the unit m (meter). This unit was used for capacity earlier, in the CGSE.

Rigidity D is a quantity inverse to the capacity C, which means its dimension in the CGSE should be equal to L^{-1} with the invalid unit m^{-1} (inverse meter). Such a situation is prevented if we take into account that the charge of the body Q consists of a certain number N_Q of elementary charges q_e, that is, $Q = N_Q\ q_e$. Then the equation $C = 4\pi R/ k_{f0}$ should be substituted with the equation $C = 4\pi R/k_{f0}N_Q$. If the dimension of N_Q is N, the dimension of capacity C becomes equal to LN^{-1} with the unit m $quantum^{-1}$ (meters per quantum), and the dimension of rigidity D will be equal to $L^{-1}N$ with the unit quantum m^{-1} (quanta per meter). These units reflect the physical content in the following way: capacity C shows the length of a charged surface, on which a certain number of elementary charges are situated, while rigidity D shows the number of elementary charges per unit of length of the surface of a charged body.

4.5. Dimensions and Units of Dissipative Resistance

Measuring the **dissipation energy** ΔW_R, the second summand of the equation (4.5), after integration on the whole time span of the transition process, leads to the equation

$$\Delta W_R = R\,(\mathrm{d}\mathbf{q}/\mathrm{d}t)^2\Delta t, \qquad (4.7)$$

In an electric conductor there is no increment of the conductor charge dq, we consider only the elementary amount of energy carriers d$\mathbf{q}$, the velocity of which corresponds to the electric current $\mathbf{i} = \mathrm{d}\mathbf{q}/\mathrm{d}t$. This is why the equation (4.7) in electrodynamics can be written as:

$$\Delta W_R = R\,\mathbf{i}^2\Delta t. \qquad (4.8)$$

The dimension of dissipative resistance R in the SI, according to the equation (4.8), is equal to $L^2MT^{-3}I^{-2}$, which corresponds to the units m^2 kg s^{-3} A^{-2} or m^2 kg s C^{-2}, which are substituted with unit ohm in electrodynamics. Deciphering the unit of mass – kg – in the aforementioned units by using the unit of energy makes ohm equal to J s^{-3} C^{-2}.

All of these units are inconvenient, that is why in the SI the unit ohm is chosen as a unit of dissipative resistance. But it is equal to another unit, V A^{-1} (volts per ampere), derived from another quantity equation (from the Ohm's law, written as $R = U/I$). The use of the Ohm's law in the CGSE system led to the dimension, which is equal to $L^{-1}T$ with the unit m^{-1} s.

4.6. Dimensions and Units of Inertia

The third summand in the equation (4.5) after integration leads to the equation for increment of the kinetic energy:

$$\Delta W_k = I\,\Delta[(\mathrm{d}^2\mathbf{q}/\mathrm{d}t^2)^2]/2, \qquad (4.9)$$

which can be simplified to

$$\Delta W_k = I\,\Delta(\mathbf{i}^2)/2, \qquad (4.10)$$

where I – the system's inertia. In the modern mechanics this quantity equation is recorded as $W_k = m\mathbf{v}^2/2$. Such a recording is acceptable only in the Newtoniam mechanics. Taking into account the clarifications provided in Section 1.3, we should use the equation $W_k = I\mathbf{v}^2/2$, where I is linear inertia.

In electrodynamics inertia I is called **inductance**, and noted by the symbol L. The dimension of inductance L in the SI is equal to $L^2MT^{-2}I^{-2}$, which corresponds to the inconvenient unit m^2 kg s^{-4} A^{-2}. Deciphering the unit of mass through the unit of energy will lead to the dimension ET^2Q^{-2} and a simpler unit J s^2 C^{-2}.

But in the SI inductance is defined by another quantity equation, $L = \Psi/i$, where Ψ – magnetic flux linkage, that is, the sum of the magnetic fluxes Φ of the current loops; the unit H (henry) is used, which is equal to Wb A^{-1} (webers per ampere). The use of this quantity equation in the CGSE system of units led to the dimension that is equal to $L^{-1}T^2$ with the unit m^{-1} s^2.

5. Overall Conclusions

Let us make the overall conclusions based on both the Part 1 [3] and this Part 2.

1. The introduction of the quantities of energy and rotation angle into the set of base units is suggested. Mass users are unlikely to reject the concept of „energy," since the concept of energy grows more and more popular with all layers of society with each coming year. Meanwhile, rotation angle has long been expecting an established position in metrological documents.

2. No new or unfamiliar base units are being suggested, except for the unit of the quantity 'number of entities'; this quantity is already being officially recognized as a base qunantity [6], though there is no general consensus conserning the dimension and the name of the unit of this quantity.

3. Reconsideration of status of base quantities is being suggested. It is suggested to consider energy, rotation angle, length, time, and number of entities as natural base quantities. Mass is suggested to be considered as a conventional base quantity, while its unit is suggested to be considered as the unit of charge of the gravitational field. Electric current as a conventional base quantity is suggested to be substituted with electric charge.

4. The suggested introduction of the new symbols for the dimensions of energy, rotation angle, and number of entities, as well as sequence of symbols in the dimension formulas should be discussed. Though the sequence of writing dimension symbols does not make considerable difference from the metrological point of view, it is important from the point of view of physics and philosophy.

5. We suggest introduction of new dimensions of the new base quantities, but not the change of the units that these quantities already have. The vast majority of the SI users will not even notice these changes, since they either have no idea of the 'dimension' concept, or do not discern between the concepts of 'dimension' and 'unit'; therefore no one will feel any discomfort.

6. The use of the new dimensions and units of rigidity, capacity, resistance, and inductance in updated SI will result in the units that are used in practice even now, instead of the units that follow from the dimensions of the current SI.

7. The suggestion to substitutue the radian measure of angle with the degree measure can be disapproved by physicists, but in practice metrologists use only the degree measure. Physicists can continue using the radian measure when it is more comfortable.

8. The introduction of a unit of rotation angle as a base unit will remove two units that are devoid of physical sense: the inverse second and the inverse meter [3, Section 4]. The return to the definition of mole based on the Avogadro number instead of the Avogadro constant will remove another unit that is devoid of physical sense – the inverse mole [3, Section 3].

9. The definition of the unit of energy, joule, based on the Planck constant will require certain updates in the school curricula. In particular, it will be necessary to explain the difference between continuity and quantizability of changes of physical quantities. But it is not more complicated for a school student's psychology than transition from arythmetics to algebra, or learning trigonometric functions and logarithms in high school. It is not necessary to learn the basics of the relativity theory to get acquainted with the Planck constant: this constant was introduced by M. Planck earlier than A. Einstein's relativity theory emerged.

10. In some cases we use terms that are either not used or rarely used in modern physics (e.g., current charge, gravistatic and gravidynamic field, pure intensity). But metrologists have to take care of the correspondence between the names of physical concepts and their physical content.

11. The change of units of derived units in electrodynamics and gravidynamics should be discussed. As a variant of possible improvement of naming, symbols, quantity equations, dimensions and units in these branches of physics we suggest to consider the Table of Quantities of the Physical Field (in the current SI) [27] and a similar table for the suggested updated SI [28] and compare them.

12. It is possible that some of these suggestions are slightly untimely. But in our world of rapid updates of science and technology we should be ready for these suggestions to be on the agenda in the neares future.

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