# ON THE PHYSICAL MEANING OF THE GRAVITATIONAL CONSTANT AND MASS

N.I.Pozdnyakov

E-mail npozdniak@rambler.ru

Popular science article

Everybody may well remember their first acquaintance with Newton's laws. At least I felt unforgettable surprise when at a lesson of physics my teacher wrote the following formula on the board, essentially without any proof:

$$F = m \cdot a \qquad (1),$$

and said that it was Newton's second law.

Then many examples had to be reviewed and quite a number of problems solved using this law before the notion of force somehow started getting more or less clear, besides, the force is easily felt by hand, whereas the meaning of mass was virtually impossible to understand.

The explanation of mass as a measure of inertia of a physical body hardly clarified anything because of a sneaking suspicion that this is just a modified wording of the same Newton's second law. Gradually I got used to simply treating the mass as a factor in the formula (1).

And now the time has come to study the law of gravity the formula of which takes the following form:

$$F = G \frac{m_1 m_2}{r^2} \qquad (2).$$

As the proof the teacher informed us that this law was supported with numerous observations and calculations, and that it governed planetary and spacecraft motion.

I imagined how very upset my teacher of geometry would have got and that she would have probably kicked me out of the classroom if, as a proof of the Pythagorean theorem, I had referred to the fact that since the equality $3^2 + 4^2 = 5^2$ was always fulfilled, as confirmed by numerous experiments with building right triangles, therefore it followed that the Pythagorean theorem $a^2 + b^2 = c^2$ was proved.

The Pythagorean theorem states that the property of space not less fundamental than the law of gravity. And what a big difference in substantiation and proving of these regularities at that! It is seen that there is certain incompleteness in foundations of physics as compared to geometry.

That is why questions came up. Why is it impossible to convert all formulas and laws of physics into theorems leaving a minimum number of axioms as in geometry? Why does all physics consist of only laws, postulates, principles, exclusions, effects and definitions? The answer is obvious. Geometry attained its full growth and became a completely axiomatized theory whereas physics is an experimental science. And many are satisfied with this state of affairs. However, one would like to see at least the classical physics, the most established and complete branch of it, as an axiomatized theory.

I finally accepted the absence of elementary physical quantities of which force and mass might be formed. I thought that such simple notions like those in geometry were non-existent in physics at all.

However, the gravitational constant would not leave me in peace. It spoiled the whole picture altogether. I did not understand why the law of gravity could not be written without it.

On the one hand, the popular science literature attached a certain specific fundamental meaning to it while all textbooks repeatedly stated the same thing:

**"The physical meaning of the gravitational constant:**

*the gravitational constant is numerically equal to the modulus of the gravitational force acting between two point bodies having a mass of 1 kg each and spaced 1 m apart.*

It follows from this statement that the gravitational constant is simply a unit conversion factor. However, if units are established conventionally, by way of arbitrary conventions, what is the deep fundamental meaning of the constant?

If the dimension of the gravitational constant is analyzed, interesting singularities may be found. The formula of dimension of the gravitational constant takes the following form:

$$G = \left[ \frac{L^3}{T^2 M} \right] \qquad (3)$$

A known yet curious fact catches the eye. The expression $L^3/T^2$ - is Kepler's third law: "The square of the orbital period of a planet is directly proportional to the cube of the semi-major axis of its orbit". Mathematically it may be written as follows: $L^3/T^2 = \text{const}$. What is the real reason of such a constancy of all planets of the Solar system? The Sun is responsible for that. The Sun is one for all planets, with its mass being constant for each planet: $M_c = \text{const}$.

Since the mass of the Sun $M_c$ may be considered constant, it appears reasonable that the value $L^3/T^2$ will be constant for any planet of the Solar System. Therefore, there exists proportional relationship between the inert mass of the Sun and the ratio $L^3/T^2$.

However, Kepler's third law is true not only for the Sun and the planets but also for the planets and their satellites, and, consequently, for any material body and its physical space. From which it follows that mass can vary while the ratio (3) remains constant for any mass in the vacuum.

If the expression $L^3/T^2$ is assumed to be the characteristic of the gravitational field, then the invariability of the gravitational constant suggests that any material body is capable of generating around itself a gravitational field proportional to its mass.

What conclusion can be drawn from the quoted analysis? Here is the conclusion: the gravitational constant is not only an invariable value adjusting dimensions of the left and right side of the law of gravity equation, but also an expression of the fundamental capability of an inert mass to generate a gravitational field around itself which is proportional to the same inert mass in terms of quantity.

Then what field does the inert mass generate around itself?

The value in the numerator takes the exotic form $L^3/T^2$. If not a kilogram but some other mass is taken as the basic unit of mass, that would make the gravitational constant equal to 1, and if it is assumed to be dimensionless, then the expression (3) can be put to be as follows:

$$m = \frac{L^3}{T^2} \qquad (4)$$

It is readily seen that the force will then take the form $F = L^4/T^4$, energy $E = L^5/T^4$, mass flow $I = L^3/T^3$ etc. In his work [1] R.O. Bartini developed a table of physical dimensions in LT system where many of the physical dimensions are derived with stunning simplicity. For some reasons R.O.Bartini was not understood by the official science. However, all these relations in LT system are interesting in making the unified approach to building a system of physical quantities thereby indicating that the idea of how to axiomatize the classical physics is somewhere around.

It follows from the formula (4) that expression $L^3/T^2$ can be assimilated, or attributed the physical meaning of a certain special mass which may be called a gravitational mass, and the expression (4) can be re-written as follows:

$$m_\Gamma = \frac{L_\Gamma^3}{T_\Gamma^2}, \qquad (5)$$

where $L_Г$ - normal length, inferior index “г” states conditional association with gravity;

$T_Г$ - normal time, where inferior index “г” also states conditional association with gravity;

Then the expression (3) for the gravitational constant will take the form

$$G = \frac{m_Г}{m_И} \qquad (6)$$

And now is the critical moment. What can be said about the expression (6). It is not worthwhile recalling only the equivalence of inert and gravitational masses. It is another beaten track while we are going in a different direction - towards the fundamentals of physics. Our problem is outlined as follows: it is necessary to find the simplest – elementary unified physical quantities that could be used to express the inert mass. If, however, the expression for the gravitational mass is the expression (5), then, our dear reader, you may have already understood what the form of the formula for the inert mass should be - right, it should be **similar to** the formula of the gravitational mass.

For that it is necessary to make a mental leap to think that if the gravitational to inert mass ratio for any physical body is a fundamental constant, these masses must then be **similar**. Or, in other words, the expression for the inert mass must **have the structure similar to that** of the expression (5). Therefore, we must select a substitution for mass in the formula (3) similar to the expression $L^3/T^2$.

Let us try to introduce certain “inertial length” $L_И$ similar to length $L_Г$, and “inertial time” $T_И$ similar to time $T_Г$. Is it not clear yet what physical meaning $L_И$ and $T_И$ have? This is for later, but since the formula of the gravitational mass takes the form of $m_Г = L_Г^3/T_Г^2$, then the **structurally similar** formula for the inert mass must provisionally take the form of:

$$m_И = \frac{L_И^3}{T_И^2}. \qquad (7)$$

Now, that’s EUREKA indeed!!!

And there is no need to talk about Occam’s razor. Well, if, for example, we need to take integral at an exam, we shall indeed be prepared to use any ideas, and often try to find a suitable substitution by way of changing of variables, or guesswork for simplicity, that is to say, we often introduce new entities to resolve our problems.

In search of the physical meaning of the gravitational constant we used **the similarity principle** and found by mere guesswork what form the formula of the inert mass must take. As a result we derived a nice formula for the inert mass (7).

Therefore, the physical meaning of the gravitational constant is that it is a ratio of similar physical quantities characterizing any physical body – a ratio of the gravitational mass to the inert mass.

These ideas served as the basis of the study [2] written by the author and published at his own expense. In the study the formula for the inert mass in its final version takes the following form:

$$m_{И} = \frac{\pm i\ L_{И}^{3}}{T_{И}^{2}}, \qquad (8)$$

where i is an imaginary unit $i = \pm\sqrt{-1}$.

The study [2] outlines the solution of the classical physics axiomatization problem, or that of Hilbert's sixth problem.

To solve the problem of the classical physics axiomatization, the study used ideas of: duality, self-organization, similarity, geometrization and unification of physical objects and their physical quantities.

We shall call the entire physical reality consisting of self-organizing physical systems as Universum.

The study 2 introduces four kinds of basic subsystems of Universum.

1) Geometric space (ГП) consisting of physical elements – continuous multi-dimensional cavities $D_{ГП}^{\pm\alpha}$ which are comparable to the space of the classical physics and constitute a spatial component of the gravitational and photonic (electromagnetic) field.

Multi-dimensional cavities $D_{ГП}^{\pm\alpha}$ may have dimensions α equal to: 1, 2, 3, 4, or 5 and have an appropriate unified physical quantity $L_{Г}^{\pm\alpha}$.

A unified physical quantity of a physical element as well as that of a physical complex formed by interaction of physical elements will be called a frame.

2) Material substance (BC) consisting of physical elements – discrete multi-dimensional granules $D_{BC}^{\pm\delta}$ which are located in ГП cavities and constitute a component of inert and electrical matter (electricity) filling ГП cavities.

Multi-dimensional granules $D_{BC}^{\pm\delta}$ may have dimension δ equal to: 1, 2, 3, 4, or 5, and corresponding frame $\pm i L_{И}^{\pm\delta}$.

3) Astronomical time (AB) consisting of physical elements – continuous multi-dimensional intervals $D_{AB}^{\pm\beta}$ which are comparable to the classical physics time and constitute a time component of the gravitational field and electrical matter.

Multi-dimensional intervals may have dimensions β equal to: 1, 2, 3, 4, or 5, and corresponding frame $T_{\Gamma}^{\pm\beta}$.

4) Chronal ether (ХЭ) consisting of physical elements – discrete multi-dimensional pulses $D_{AB}^{\pm\beta}$ which occur (originate, continue and end) in AB intervals and constitute a component of the photonic field and inert matter occurring in AB intervals.

Multi-dimensional pulses $D_{AB}^{\pm\beta}$ may have dimensions γ equal to: 1, 2, 3, 4, or 5 and have an appropriate frame $\pm i T_{И}^{\pm\gamma}$.

The notion of a physical complex is introduced.

*A physical complex is an object formed as a result of the system integration of physical elements of various kinds.*

Four types of physical complexes are the formed as a result of system orthogonal integration of physical elements of basic subsystems:

1) $D_{ГП}^{\pm\alpha} \otimes D_{AB}^{\pm\beta} = D_{ГР}^{\pm\alpha,\pm\beta}$ – gravitons of the gravitational field;

2) $D_{ГП}^{\pm\alpha} \otimes D_{ХЭ}^{\pm\gamma} = D_{ФТ}^{\pm\alpha,\pm\gamma}$ – photons of the photonic field;

3) $D_{BC}^{\pm\delta} \otimes D_{AB}^{\pm\beta} = D_{ЭЛ}^{\pm\delta,\pm\beta}$ – electrions of the electrical matter;

4) $D_{BC}^{\pm\delta} \otimes D_{ХЭ}^{\pm\gamma} = D_{ИН}^{\pm\delta,\pm\gamma}$ – inertions of the inert matter.

Two axioms are introduced.

Axiom №1

The ratio $\lambda^{\alpha} = L_{\Gamma}^{\alpha} / i L_{И}^{\alpha}$ is a fundamental system constant.

Axiom №2

The ratio $\tau^{\beta} = T_{\Gamma}^{\beta} / i T_{И}^{\beta}$ is a fundamental system constant.

Then the gravitational constant will take the form: $G = \lambda^3 / \tau^2$.

The electric constant will take the form: $\varepsilon_0 = 1 / \lambda^3 \tau^2$.

It follows from the formula (8) that the physical meaning of mass is that it constitutes a frame of the physical complex of the inertion $D_{ИН}^{+3,-2}$ consisting of interacting physical elements: a material substance three-dimensional granule and a chronal ether two-dimensional reverse pulse.

In the study the physical reality is treated as a unified self-organizing system formed by interaction of multi-dimensional basic subsystems of: geometric space, astronomical time, material substance and chronal ether. Interaction of these subsystems results in the gravitational and electromagnetic fields, electric and inert matters.

A system of unified physical quantities – frames has been developed. It allowed for all physical quantities to be arranged in combinatorial matrices which, in its turn, made it possible to reveal the physics of known quantities and laws, and to formulate new laws.

The study, in particular, provides the proof of the formula of charge and mass interaction based on postulates and axioms of the system physics, just as it is done in geometry, which takes the following form:

$$F = \sqrt{\frac{G}{4\pi\varepsilon_0}}\frac{q\,m}{r^2}. \qquad (9)$$

Well, it is Pozdnykov's theorem, as it were.

This theory carries a lot of interesting applications and corollaries.

For example, the physics teaching methodology may change altogether.

We may succeed in finding new regularities in the mass spectrum of elementary particles.

Probably, the physical meaning of the fine structure constant will be theoretically substantiated, and it will be understood why the constant is so important.

It would be interesting to confirm by experiment the possibility of generation of gravitational waves mentioned in the study.

And, naturally, it would be very important to verify by experiment the charge and mass interaction formula (9).

List of references:

1. Robert Oros di Bartini. Relations between physical quantities. Collection of articles: Problems of the theory of gravitation and elementary particles. Atomizdat, Moscow, 1966.

2. N.I.Pozdnyakov. System physics – the solution of Hilbert's sixth problem. Nizhny Novgorod: Volgo-Vyatskaya Academy of Public Administration Publishers, 2008.
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