Gravitational cells and gravitational strings.

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Article

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Abstract.

In this work, such concepts as gravitational cells and gravitational strings were successfully built into the theory of the gravitational field. This innovation made it possible to move from general ideas about gravitational interaction to a deeper and more detailed understanding of this physical process and to obtain significant scientific results. These results include: obtaining the formula for the gravitational constant, the mass of an electron and the mass of a hydrogen atom through fundamental physical constants; determining the energy of a graviton, obtaining the length and frequency of gravitational waves; obtaining the distance of action of gravitational forces; obtaining a relativistic formula for the speed of a body in a gravitational field, and etc.

In this work, Planck's constant was successfully applied to the theory of gravitational cells and strings. As a result, the formula for the minimum distance of gravitational interaction, the formula for the mass of an electron, and the formula for the mass of a hydrogen atom were obtained.

Through the synthesis of the theory of gravitational cells and the relativistic formula of Einstein's total energy, the relativistic formula for the velocity of a body in a gravitational field was obtained.

The results obtained by the new formulas completely coincided with the known scientific and experimental data. A distinctive feature of this study is the fact that only fundamental physical constants are present in the new formulas.

Keywords. Black hole, gravitational cell, gravitational string, gravitational quantum, graviton, gravitational wave length and frequency, gravitational constant formula, electron mass formula, hydrogen atom mass formula, elementary charge, Schwarzschild radius formula, Planck's constant, vibrational velocity of gravitational string, minimum distance actions of gravitational forces, Casimir force, electromagnetic string, relativistic formula for velocity in a gravitational field, maximum limit of gravitational forces.

Introduction.

In this research, physical concepts such as gravitational cells and gravitational strings were built into the concept of the gravitational field. This made it possible to move from general ideas about the gravitational interaction of bodies in space to a more detailed understanding of this physical process and to obtain real scientific results confirmed by observations.

Methods.

The gravitational field of any body cannot be considered separately without taking into account the interaction of this body with another body in space. In this case, the magnitude of the gravitational field depends not only on the amount of matter (mass), but also on the structure of the interacting bodies. This structure includes gravitational cells. These cells have a charge equal to two elementary charges $\boldsymbol{2q}$ and a mass $\boldsymbol{m}$. Each gravitational cell m forms around itself in space a set of point gravitational fields $\boldsymbol{g_n}$, the intensity of which depends on the distance $\boldsymbol{r_n}$ to this point, that is, $\boldsymbol{g_n = \frac{2q}{r_n^2}}$**.** These numerous point fields are up to a certain point latent potential fields and can manifest themselves only upon contact with the gravitational cells of other bodies. Therefore, when another body of mass $\boldsymbol{M_1}$ (also consisting of a plurality of gravitational cells with a charge of $\boldsymbol{2q}$) hits this area of space, a real gravitational field now appears at the point of contact of two cells: $\boldsymbol{g} = \frac{\boldsymbol{k\,2q \cdot k\,2q}}{\boldsymbol{r^2}} = \frac{\boldsymbol{k^2 4q^{\,2}}}{\boldsymbol{r^2}}$. As a result, the field $\boldsymbol{g}$ imparts the acceleration $\boldsymbol{g} = \frac{\boldsymbol{k^2 4q^{\,2}}}{\boldsymbol{r^2}}$ to the gravitational cell of the body $\boldsymbol{M_1}$. Due to the fact that the body $\boldsymbol{M_1}$ consists of a huge number of such cells with a charge of $\boldsymbol{2q}$, and the dimensions of the body are much less than the distance $\boldsymbol{r}$ between $\boldsymbol{M}$ and $\boldsymbol{M_1}$, then the whole body $\boldsymbol{M_1}$ will experience an acceleration in this area of space equal to the magnitude of the acceleration of one gravitational cell, that is, $\boldsymbol{g} = \frac{\boldsymbol{k^2 4q^{\,2}}}{\boldsymbol{r^2}}$. (This situation can be compared with the same accelerated motion of many absolutely identical charged particles in an electric field of a large electric charge).

Now let's move on to the basic formulas. A body of mass $\boldsymbol{M}$ consists of a huge number of $\boldsymbol{n}$ gravitational cells of mass $\boldsymbol{m}$, where $\boldsymbol{n} = \frac{\boldsymbol{M}}{\boldsymbol{m}}$. These cells together form a common gravitational field $\boldsymbol{E} = \boldsymbol{g} \cdot \boldsymbol{n}$. As a result of all of the above, the formula for the gravitational field of a body with mass $\boldsymbol{M}$ when it interacts with another mass $\boldsymbol{M_1}$ looks like this:

$$\boldsymbol{E} = \boldsymbol{g} \cdot \boldsymbol{n} = \boldsymbol{k_{conv.}} \frac{\boldsymbol{e}}{\boldsymbol{r^2}} \, \frac{\boldsymbol{M}}{\boldsymbol{m}} \qquad \textbf{(1-1)}$$

where $\boldsymbol{E}$ is the gravitational field of the body $\boldsymbol{M}$, m/s^2.

$\boldsymbol{g}$ is the value of the field of one gravitational cell of the body $\boldsymbol{M}$, m/s^2.

$\boldsymbol{n}$ is the number of gravity cells in the mass $\boldsymbol{M}$.

$\boldsymbol{e}$ is the energy of the gravitational string. The field interaction of two gravitational cells in space can be considered as an extended force string. The energy of such a gravitational string is equal to $\boldsymbol{e} = \boldsymbol{k}^2 \boldsymbol{4q}^{\ 2}$J. Where $\boldsymbol{k}$ is the coefficient of energy output from the charges of the gravitational cell (or the coefficient of proportionality), J/Cl.

$\boldsymbol{m}$ is the mass of the gravitational cell of the body $\boldsymbol{M}$, kg.

$\boldsymbol{q}$ is the value of elementary charges, where $\boldsymbol{q} = \mathbf{1{,}60217733 \cdot 10^{-19}}$ Cl.

$\boldsymbol{k_{conv.}}$ – unit conversion factor, where $\boldsymbol{k_{conv.}}$ = 1 m/kg (This coefficient is entered into the formula so that the units of measurement are not violated).

(Note that if in the formula (1-1) the expression $\frac{\boldsymbol{e}}{\boldsymbol{m}}$ is denoted as $\boldsymbol{G}$, then taking into account the fact that $\boldsymbol{k_{conv.}}$ =1 m/kg, we obtain the classical formula of the gravitational field: $\boldsymbol{E} = \boldsymbol{G}\ \frac{\boldsymbol{M}}{\boldsymbol{r}^2}$).

To clearly understand the physics of the process, it is necessary first to consider the case of the gravitational interaction of two superdense masses, called black holes. So, we have two superdense masses $\boldsymbol{M_0}$ and $\boldsymbol{M_{01}}$, located at a distance r from each other. These two masses are a homogeneous substance, consisting of many superdense cells with mass $\boldsymbol{m_0}$ and a charge equal to the value of two elementary charges - $\mathbf{2}\ \boldsymbol{q}$. Such gravitational cells were formed after an extremely dense compression of matter, as a result of which molecules and atoms turned into identical gravitational cells, consisting of two opposite charges. (The mass of such a cell should be less than the total mass of a free proton and a free electron by $\Delta\ \boldsymbol{m}$ due to the release of energy during the compression of matter, where $\Delta\ \boldsymbol{m} =$

$\boldsymbol{E}/\mathrm{c}^{2}$). The formula of the gravitational field $\boldsymbol{E}$ of a superdense body with mass $\boldsymbol{M_0}$ in its interaction with another superdense body $\boldsymbol{M_{01}}$ looks like formula (1-1):

$$\boldsymbol{E} = \boldsymbol{k_{conv.}} \frac{\boldsymbol{e_0}}{\boldsymbol{r^2}} \frac{\boldsymbol{M_0}}{\boldsymbol{m_0}} \quad \textbf{(1-2)}$$

$\boldsymbol{e_0}$ is the energy of the gravitational string between two cells, $\boldsymbol{e_0} = \boldsymbol{k_0^2}\, \boldsymbol{4q}^{\,\boldsymbol{2}} = \boldsymbol{1{,}026789 \cdot 10^{-37}}$ J. Where $\boldsymbol{k_0}$ is the coefficient of energy output from the charges of the gravitational cell (or proportionality factor), where $\boldsymbol{k_0} = \boldsymbol{1}$, J/C.

$\boldsymbol{m_0}$ is the mass of the gravitational cell, kg.

$\boldsymbol{q}$ – elementary charge, $\boldsymbol{1{,}60217733 \cdot 10^{-19}}$ Cl.

In the superdense state of matter, the coefficient of energy output from the charges of the gravitational cell is $\boldsymbol{k_0} = \boldsymbol{1}$. (For comparison: at interaction of electric charges in vacuum $\boldsymbol{K} = \boldsymbol{9 \cdot 10^9}$). The reason for such a large discrepancy is that the matter of the black hole is so strongly compressed that almost all the force lines of elementary charges are closed inside the gravitational cells. And only an extremely small part of the lines of force goes outside, creating a gravitational field in the outer space. Due to this circumstance, the coefficient $\boldsymbol{k_0}$ outside the gravitational cell decreases to its minimum threshold, i.e. exactly to 1. In this case, the main field, with the coefficient of proportionality $\boldsymbol{K} = \boldsymbol{9 \cdot 10^9}$, remains closed between the elementary charges inside the gravitational cell and therefore does not manifest itself in any way.

In formula (1-2) $\frac{\boldsymbol{e_0}}{\boldsymbol{m_0}}$ shows the value of the gravitational constant, where $\boldsymbol{G_0} = \frac{\boldsymbol{e_0}}{\boldsymbol{m_0}}$**.** Therefore, if we accept the condition that the gravitational constant in the region of the black hole $\boldsymbol{G_0}$ is equal to the classical value $\boldsymbol{G = 6,6743 \cdot\ 10^{-11}}$, then we get:

$$\boldsymbol{m_0} = \frac{\boldsymbol{e_0}}{\boldsymbol{G_0}} = \frac{\mathbf{1{,}026789 \cdot 10^{-37}}}{\mathbf{6{,}6743 \cdot 10^{-11}}} = \mathbf{1,538422 \cdot 10^{-27}}\ \text{kg} \quad \textbf{(1-3)}$$

But such a result $\boldsymbol{m_0}$ cannot be considered final, because the gravitational constant $\boldsymbol{G_0}$ under extreme conditions of a black hole may have a different value. Therefore, for the sake of purity of the study, the obtained value $\boldsymbol{m_0} = \mathbf{1,538422 \cdot 10^{-27}}$ kg should be checked through another formula associated with the concept of "black hole". Such a test formula is the Schwarzschild radius formula.

$$\boldsymbol{R} = \frac{\boldsymbol{2G_0}}{\boldsymbol{c^2}} \cdot \boldsymbol{M}$$

where $\boldsymbol{R}$ is the gravitational radius of a black hole, m, $\boldsymbol{G_0}$ is the gravitational constant in the field of a black hole, $\boldsymbol{M}$ is the mass of a black hole, kg, $\boldsymbol{c}$ is the speed of light, m/s.

In this formula, the expression $\frac{\boldsymbol{2G_0}}{\boldsymbol{c^2}}$ is of particular interest. This expression is equal to $\frac{\boldsymbol{R}}{\boldsymbol{M}}$, measured in **"m / kg"** and is a specific indicator of "length" and "mass". When multiplying $\frac{\boldsymbol{2G_0}}{\boldsymbol{c^2}}$ by the mass of the body $\boldsymbol{M}$, the gravitational radius of the black hole is determined. But in the one-dimensional space of a black hole, such a physical quantity as length does not exist, therefore the $\frac{\boldsymbol{R}}{\boldsymbol{M}}$ index in **"m / kg"** should be perceived as the minimum structural unit of the black hole substance, that is, the mass of the gravitational cell $\boldsymbol{m_0}$. It follows that $\boldsymbol{m_0} = \frac{\boldsymbol{2G_0}}{\boldsymbol{c^2}}$. Taking into account the fact that according to f. (1-5) $\boldsymbol{m_0} = \frac{\boldsymbol{e_0}}{\boldsymbol{G_0}}$, we get the following equation:

$\frac{2\boldsymbol{G_0}}{\boldsymbol{c^2}} = \frac{\boldsymbol{e_0}}{\boldsymbol{G_0}}$.

Let's solve this equation and get:

$$\boldsymbol{G_0 = \sqrt{2}\, q\, c = 6,7927 \cdot 10^{-11}} \quad \textbf{(1-4)}$$

$$\boldsymbol{m_0 = \frac{\sqrt{8\,q}}{c} = 1,511593 \cdot 10^{-27}} \text{ kg} \quad \textbf{(1-5)}$$

As you can see, the mass of the gravitational cell of the black hole is $\boldsymbol{m_0 = 1,511593 \cdot 10^{-27}}$ kg, and not $\boldsymbol{,538422 \cdot 10^{-27}}$ kg, as calculated above. But at the same time, these very close results, which were obtained in different ways, indicate the correctness of the hypothesis of gravitational cells. When choosing between two values of $\boldsymbol{m_0}$, it will be more correct to dwell on the value obtained using the Schwarzschild formula, that is, $\boldsymbol{m_0 = 1,511593 \cdot 10^{-27}}$ kg. (This will be confirmed by calculations in this article when determining the mass of a hydrogen atom).

The discrepancy between $\boldsymbol{G_0 = 6,7927 \cdot 10^{-11}}$ and $\boldsymbol{G = 6,6743 \cdot 10^{-11}}$ is only $\boldsymbol{1,7\%}$**.** This slight difference is due to structural changes in superdense gravity cells.

Now let us consider the gravitational interaction of an "ordinary" body of mass $\boldsymbol{M}$ with another "ordinary" mass $\boldsymbol{M_1}$. The formula of the gravitational field $\boldsymbol{E}$ of the body $\boldsymbol{M}$ according to the basic formula (1-2) looks like this:

$$\boldsymbol{E = k_{conv.} \frac{e}{r^2} \frac{M}{m}} \quad \textbf{(1-6)}$$

$\boldsymbol{e}$ is the energy of the gravitational string between the cells, $\boldsymbol{e} = \boldsymbol{k}^2 \boldsymbol{4q}^{\ \boldsymbol{2}} = \boldsymbol{1,108293 \cdot 10^{-37}}$ J. Where $\boldsymbol{k}$ is the coefficient of energy output from the charges of the gravitational cell (or the coefficient of proportionality), where $\boldsymbol{k} = \boldsymbol{1,038931}$ J/C.

$\boldsymbol{m}$ – mass of the "ordinary" gravitational cell, where $\boldsymbol{m} = \boldsymbol{1{,}660539 \cdot 10^{-27}}$ kg.

$\boldsymbol{k_{conv.}}$ – coefficient for converting units of measurement, where $\boldsymbol{k_{conv.}} = \boldsymbol{1}$ m/kg.

Taking into account the fact that $\boldsymbol{k_{conv.}} = \boldsymbol{1}$, from formula (1-6) we obtain the classical formula of the gravitational field:

$$\boldsymbol{E} = \boldsymbol{G}\,\frac{\boldsymbol{M}}{\boldsymbol{r^2}}\text{, where } \boldsymbol{G} = \frac{e}{m} = \boldsymbol{6,6743 \cdot\ 10^{-11}} \quad \textbf{(1-7)}$$

Let us now explain the quantities $\boldsymbol{k}$ and $\boldsymbol{m}$. To do this, imagine that ordinary matter was formed from the superdense matter of a black hole. In this case, each superdense gravitational cell, due to the influx of energy $\boldsymbol{E}$, will increase its mass $\boldsymbol{m_0}$ to mass $\boldsymbol{m}$ by the amount $\Delta\ \boldsymbol{m}$ (where $\Delta\ \boldsymbol{m} = \boldsymbol{E}/\mathrm{c}^{\boldsymbol{2}}$). As a result, a plasma is formed from a superdense substance, from which gaseous, liquid and solid substances can then be formed. All four states of matter are neutral, that is, they have a total electric charge equal to zero. As a result of this circumstance, any "ordinary" substance can be represented as a huge set of gravitational cells. All four states of matter are neutral, that is, they have a total electric charge equal to zero. As a result of this circumstance, any "ordinary" substance can be represented as a huge set of gravitational cells. These cells consist of a proton and an electron with a total charge of $\boldsymbol{2\ q}$, as well as of neutrons, which are also a pair of a proton and an electron with a total charge of $\boldsymbol{2\ q}$. Thus, the mass of the gravitational cell

$\boldsymbol{m}$ of any substance (plasma, gas, liquid or solid) with a high degree of accuracy will be equal to $\mathbf{1}$ Da or $\boldsymbol{m} = \mathbf{1{,}660539 \cdot 10^{-27}}$ kg.

Under the conditions of the standard density of the substance, $\boldsymbol{k} = \mathbf{1,038931}$, that is, $\boldsymbol{k} > \boldsymbol{k_0} = \mathbf{1}$. This very small difference between $\boldsymbol{k}$ and $\boldsymbol{k_0}$ can be explained by the fact that, in contrast to the gravitational cell of a black hole, where elementary charges are absolutely tightly adjacent to each other, in an ordinary cell there is some ultramicroscopic distance between two elementary charges. As a result of this circumstance, slightly more lines of force emerge from the ordinary cell than from the superdense cell, as a result of which $\boldsymbol{k} > \boldsymbol{k_0}$.

The gravitational interaction of an "ordinary" body of mass $\boldsymbol{M}$ and a superdense body of mass $\boldsymbol{M_0}$ is determined by the total value $\boldsymbol{e_1} = \boldsymbol{k}\, \boldsymbol{k_0}\, \mathbf{4}\boldsymbol{q}^{\mathbf{2}} = \mathbf{1,066763 \cdot 10^{-37}}$ J and different masses of gravitational cells $\boldsymbol{m} = \mathbf{1{,}660539 \cdot 10^{-27}}$kg and $\boldsymbol{m_0} = \mathbf{1,511593 \cdot 10^{-27}}$ kg.

Hence, we obtain the following formulas for the gravitational field:

The gravitational field of an "ordinary" body $\boldsymbol{M}$:

$$\boldsymbol{E} = \boldsymbol{k_{conv.}} \frac{\boldsymbol{e_1}}{\boldsymbol{r^2}} \frac{\boldsymbol{M}}{\boldsymbol{m}} \text{ or } \boldsymbol{E} = \boldsymbol{G} \frac{\boldsymbol{M}}{\boldsymbol{r^2}}, \text{ where } \boldsymbol{G} = \mathbf{6,4242 \cdot 10^{-11}}$$

The gravitational field of a superdense body $\boldsymbol{M_0}$:

$$\boldsymbol{E} = \boldsymbol{k_{conv.}} \frac{\boldsymbol{e_1}}{\boldsymbol{r^2}} \frac{\boldsymbol{M_0}}{\boldsymbol{m_0}} \text{ or } \boldsymbol{E} = \boldsymbol{G} \frac{\boldsymbol{M_0}}{\boldsymbol{r^2}}, \text{ where } \boldsymbol{G} = \mathbf{7{,}0572 \cdot 10^{-11}}$$

The inclusion of gravitational cells and gravitational strings in the concept of the gravitational field has made it possible to obtain other significant results. Such results are the derivation of the formula for the electron mass and the formula for the mass of the hydrogen atom solely on the basis of fundamental physical constants.

In the conditions of a black hole, when the matter is maximally compressed, the gravitational field between two superdense gravitational cells is reduced so much that it turns into a point gravitational string, that is, into a vibrating energy point. In this situation, the gravitational field formula no longer works, and Planck's formula works instead:

$$\boldsymbol{e_0} = \boldsymbol{h\,\gamma} \quad \textbf{(1-8)}$$

where $\boldsymbol{e_0}$ is the energy of the point gravitational string of the black hole, $\boldsymbol{e_0} = \mathbf{1,026789 \cdot 10^{-37}}$ J. (see f.1-2)

$\boldsymbol{h}$ is Planck's constant, $\mathbf{6,62607 \cdot 10^{-34}}$ J · s.

$\boldsymbol{\gamma}$ - frequency, where $\boldsymbol{\gamma} = \frac{\boldsymbol{e_0}}{\boldsymbol{h}} = \mathbf{1,549620 \cdot 10^{-4}}$ s^{-1} ($\boldsymbol{\gamma}$ is constant and does not depend on the SI or CGSE measurement system).

The frequency $\boldsymbol{\gamma}$ is related to the ratio of negative and positive charges in a gravitational point string by the following formula:

$$\boldsymbol{\gamma} = \frac{1}{4}\,\frac{2\,\boldsymbol{e_-}}{2\,\boldsymbol{e_+}} = \frac{1}{4}\,\frac{\boldsymbol{e_-}}{\boldsymbol{e_+}}\;\boldsymbol{k_{conv.}} \quad \textbf{(1-9)}$$

$\boldsymbol{e_-}$ is the energy value of the negative charge mass inside the cell, J.

$\boldsymbol{e_+}$ - the energy value of the positive charge mass inside the cell, J.

$\boldsymbol{k_{conv.}}$ – conditional conversion factor of units of measurements, $\boldsymbol{k_{conv.}} = 1$ s^{-1}.

(Due to the fact that $\boldsymbol{k_{conv.}}$ =1, this coefficient will not be indicated further, so as not to complicate the formulas).

The above definitions: “the energy value of the negative charge mass inside the cell and the energy value of the a positive charge mass inside the cell” are introduced because electrons and protons inside gravitational cells are not independent particles.

Now, based on f. (1-9) we obtain from f. (1-8) the expanded formula for the energy of a point gravitational string:

$$\boldsymbol{e_0 = h\,\gamma = h\,\frac{1}{4}\,\frac{e_-}{e_+}} \quad \textbf{(1-10)}$$

The fraction **1/4** is explained by the fact that **4** charges are involved in the formation of a point gravitational string (or a static gravitational quantum). For comparison: in the formation of a quantum of an electromagnetic field, only **1** charge is involved in the form of an electron. That is, the difference is exactly **4** times. The correctness of formula 1-10 (and, accordingly, this statement) will be confirmed by the coincidence of the calculations made using this formula with the experimental data given below.

Based on formula (1-10) and taking into account that the total energy of the gravitational cell of a black hole is $\boldsymbol{m_0 c^2 = e_+ + e_-}$, we will get the formula for the mass energy of the negative charge inside this cell:

$$\boldsymbol{e_- = \frac{4e_0\, m_0 c^2}{h + 4e_0}} \quad \textbf{(1-11)}$$

Taking into account that $\boldsymbol{m_0 = \frac{\sqrt{8}\,q}{c}}$ (f. 1-5) and $\boldsymbol{e_0 = 4\,q^2}$, we obtain the value $\boldsymbol{e_-}$ through the formula with **three fundamental constants:**

$$\boldsymbol{e_- = \frac{32\sqrt{2}\,q^3\,c}{(h + 16q^2)} = 8{,}415740\ \cdot 10^{-14}}\ \text{J} \quad \textbf{(1-12)}$$

As you can see, $\boldsymbol{e_-}$ almost coincided with the value of the mass-energy of a free electron, where $\boldsymbol{e = 8{,}187110 \cdot 10^{-14}}$ J. The discrepancy is $\boldsymbol{2{,}7\%.}$ It should be noted that there should not be a complete coincidence here, because the negative charge inside the gravitational cell and the free electron are different physical quantities.

The energy of the mass of a positive charge in a black hole cell will be:

$$\boldsymbol{e_+ = m_0\, c^2 - e_- = 1,511593 \cdot 10^{-27} \cdot c^2 - \ 8,415740 \ \cdot 10^{-14} = 13,577104 \cdot 10^{-11}} \text{ J}$$

The body of a black hole consists of a huge number of such densely packed superdense cells. Now consider the process of formation of hydrogen atoms from these gravitational cells. To do this, external energy must enter each cell. As a result of the flow of energy into the cell, the energy of the mass of the positive charge $\boldsymbol{e_+ = 13,577\,104 \cdot 10^{-11}}$J increases by the value of $\Delta\, \boldsymbol{e_+ = 1,455\,672 \cdot 10^{-11}}$ J exactly to the energy of the mass of the proton ($\boldsymbol{e_p = \ m_p c^2 = 1,6726219 \cdot 10^{-27} \cdot c^2 = \ 15,032776 \cdot 10^{-11}}$J):

$$\boldsymbol{e_p = e_+ + \Delta e_+ = \ 15,032776 \cdot 10^{-11}}\text{J}$$

More than this value, the energy of the positive charge mass in the gravitational cell cannot increase. Thus, the energy of the gravitational cell increases and becomes equal to:

$$\boldsymbol{e = \ e_- + e_p = \ 8,415740 \ \cdot 10^{-14} + 15,032776 \cdot 10^{-11} = 15,041191 \cdot 10^{-11}}\text{J}$$

As you can see, the obtained value $\boldsymbol{e} = \mathbf{15,041191 \cdot 10^{-11}}$J practically does not differ from the value of the mass-energy of the hydrogen atom, where $\boldsymbol{e}_{\boldsymbol{h}} = \mathbf{1{,}6735575 \cdot 10^{-27}}$kg $\cdot$ $\boldsymbol{c^2} = \mathbf{15{,}041185 \cdot 10^{-11}}$J. The ultramicroscopic difference between them $\Delta\boldsymbol{e} = \boldsymbol{e} - \boldsymbol{e}_{\boldsymbol{h}} = \mathbf{6 \cdot 10^{-17}}$J ($\mathbf{374,49}$ eV) is explained by the fact that when a proton is formed, a neutrino beam is emitted from the gravitational cell with a total energy of $\sum \boldsymbol{e}_{\nu} = \mathbf{374{,}49}$ eV. (To put it figuratively, the formed proton "pushes out" the energy of **374,49** eV from the cell in the form of a neutrino). As a result of all of the above, the superdense cell turns into a hydrogen atom. In the form of a formula, this process looks like this:

$$\boldsymbol{e}_{\boldsymbol{h}} = \boldsymbol{e}_{-} + \boldsymbol{e}_{\boldsymbol{p}} - \sum \boldsymbol{e}_{\nu} \quad \textbf{(1-13)}$$

where $\boldsymbol{e}_{\boldsymbol{h}}$ is the energy of the formed hydrogen atom, $\mathbf{15{,}041185 \cdot 10^{-11}}$ J.

$\boldsymbol{e}_{-}$ – the value of the energy of the mass of the negative charge in the cell, $\mathbf{8,415740 \cdot 10^{-14}}$ J (f.1-12)

$\boldsymbol{e}_{\boldsymbol{p}}$ is the energy of the generated proton, where $\boldsymbol{e}_{\boldsymbol{p}} = \boldsymbol{e}_{+} + \Delta\boldsymbol{e}_{+} = \mathbf{15,032776 \cdot 10^{-11}}$ J, ($\boldsymbol{e}_{\boldsymbol{p}} = \boldsymbol{m}_{\boldsymbol{p}}\boldsymbol{c}^{\mathbf{2}}$)

$\sum \boldsymbol{e}_{\nu}$ is the total energy of emitted neutrinos, $\sum \boldsymbol{e}_{\nu} = \mathbf{6 \cdot 10^{-17}}$J (374.49 eV)**.**

Note that the discrepancy between the energy value e and the energy value of the hydrogen atom $\boldsymbol{e}_{\boldsymbol{h}}$ (where $\boldsymbol{e} > \boldsymbol{e}_{\boldsymbol{h}}$ by **374.49** eV) agrees with the Big Bang theory with amazing accuracy. Because if $\boldsymbol{e} \le \boldsymbol{e}_{\boldsymbol{h}}$, then during the formation of hydrogen atoms there would be no release of energy from the gravitational cell and, accordingly, relict neutrinos would not exist. Thus, we can conclude that the ultramicroscopic discrepancy between $\boldsymbol{e}$ and $\boldsymbol{e}_{\boldsymbol{h}}$ (0.00004%) is not the result of the allowable measurement error of the physical constants $\boldsymbol{q}, \boldsymbol{h}, \boldsymbol{c}$, used in formula (1-12), but a physical pattern.

Taking into account the negligibly small value $\sum \boldsymbol{e}_{\nu}$ in the formula (1-13), we apply the formula $\boldsymbol{E} = \boldsymbol{m}\,\boldsymbol{c}^{2}$ to it and obtain the formula for the mass of the hydrogen atom $\boldsymbol{m}_{\boldsymbol{h}}$, which is based on **4 fundamental physical constants:**

$$\boldsymbol{m}_{\boldsymbol{h}} \approx \frac{32\sqrt{2}\,q^{3}}{c\,(h+16q^{2})} + \boldsymbol{m}_{\boldsymbol{p}} \quad \textbf{(1-14)}$$

where $\boldsymbol{q}, \boldsymbol{h}, \boldsymbol{c}, \boldsymbol{m}_{\boldsymbol{p}}$ are physical constants.

Let's make sure once again of a negligibly small (but necessary from the point of view of physics!) difference between the mass obtained by formula (1-14) and the experimental mass of the hydrogen atom. So, when calculating by the formula $\boldsymbol{m}_{\boldsymbol{h}} = \mathbf{1,6735582 \cdot 10^{-27}}$ kg, and the experimental mass $\boldsymbol{m}_{\boldsymbol{h}} =$ **1,6735575** $\cdot\, \mathbf{10^{-27}}$ kg . The difference between them is $\mathbf{7 \cdot 10^{-34}}$ kg, that is, the discrepancy is only 0,00004%.

The results obtained by formula (1-13) confirm the correctness of the original formula (1-10), as well as the previously obtained value of the mass of the gravitational cell of a black hole, where $\boldsymbol{m}_{\mathbf{0}} = \frac{\sqrt{8\,q}}{c} = \mathbf{1,511593 \cdot 10^{-27}}$ **kg (f. 1-5). Also (and this is the main thing) the obtained results confirm the existence of gravitational cells and gravitational strings.**

Let us give one more proof of the existence of gravitational cells and strings. To do this, consider the interaction of two mirror-polished plates located at a very close distance d from each other (such an experiment was carried out when studying the Casimir effect). In this case, gravitational cells (atoms) of opposite bodies will interact with each other through gravitational strings. Let's write on the basis of formulas (1-6) and (1-7) the formula of the gravitational field for the case when two gravitational cells m are opposite each other:

$$\boldsymbol{E = G\,\frac{m}{d^2}} \text{ or } \boldsymbol{E = k_{conv.}\frac{e}{d^2}} \quad \textbf{(1-15)}$$

where $\boldsymbol{E}$ is the strength of the gravitational field, m/s^2.

$\boldsymbol{e}$ – energy of the gravitational string, $\mathbf{1,108293 \cdot 10^{-37}}$ J. (see f.1-6)

$\boldsymbol{m}$ is the mass of the gravitational cell, $\mathbf{1{,}660539 \cdot 10^{-27}}$ kg. (see f.1-6)

$\boldsymbol{d}$ is the distance between two gravitational cells, m.

$\boldsymbol{k_{conv.}}$ – coefficient for converting units of measurement, where $\boldsymbol{k_{conv.}} = \mathbf{1}$ m/kg.

Just as in the previous one, we apply the Planck formula to the gravitational string between cells:

$$\boldsymbol{e = h\,\gamma} \quad \textbf{(1-16)}$$

where $\boldsymbol{h}$ is Planck's constant.

$\boldsymbol{\gamma}$ – string frequency, where $\boldsymbol{\gamma = \frac{e}{h} = \frac{1{,}108293 \cdot 10^{-37}}{6{,}62607 \cdot 10^{-34}}} = \mathbf{1{,}672\,466 \cdot 10^{-4}}$ s^{-1}

The frequency of the gravitational string $\boldsymbol{\gamma}$ is a constant value, but it itself consists of two variables $\boldsymbol{v}$ and $\boldsymbol{d}$:

$$\boldsymbol{\gamma = k_{conv.}\, v\, d^2} \quad \textbf{(1-17)}$$

where $\boldsymbol{v}$ is the vibrational speed of the gravitational string, m/s.

$\boldsymbol{k_{conv.}}$ – coefficient for conversion of units of measurements, where $\boldsymbol{k_{conv.}}$ =**1** m^3

It follows that $\boldsymbol{v = \gamma/d^2}$ and $\boldsymbol{d = \sqrt{\gamma/v}}$ **(1-18)**

Thus, the oscillation speed $\boldsymbol{v}$ of a gravitational string is inversely proportional to the square of its length $\boldsymbol{d}$. The vibrational speed of the string v has an upper limit, which is equal to the speed of light in vacuum, that is, $\boldsymbol{v_{max} = c}$. It follows from this that there must be a minimum distance $\boldsymbol{d_{min}}$ at which the gravitational string «breaks». Let's define this distance:

$$\boldsymbol{d_{min}} = \sqrt{\frac{\boldsymbol{e}}{\boldsymbol{h\ c}}} = \sqrt{\boldsymbol{\gamma/c}} = \mathbf{0{,}747}\ \mu\text{m} \quad \mathbf{(1\text{-}19)}$$

It is from this distance $\boldsymbol{d_{min}} = \mathbf{0{,}747}$ µm that the gravitational interaction between cells (atoms) stops and passes into direct interaction of elementary charges. At the same time, the main force lines of elementary charges, which were previously enclosed inside gravitational cells (atoms), are now released. As a result, a new strong interaction arises, called the Casimir force. We will not dwell on its physical nature, because this is not included in the research task. **Now it is important to emphasize the important circumstance that the distance of the "break" of the gravitational string $\boldsymbol{d_{min}} = \mathbf{0{,}747}$ µm exactly coincided with the appearance of the Casimir force.**

This ultramicroscopic boundary of the transition of the gravitational interaction into another interaction is confirmed by experiments to study the Casimir effect: it is from a distance less than a micrometer between two mirror-polished metal plates that a noticeable manifestation of the Casimir force begins. Taking into account the large orders of quantities used in formula (1-19) ($\mathbf{10^{-37}}$, $\mathbf{10^{-34}}$, $\mathbf{10^{8}}$), an accidental coincidence between the calculated by the formula and the experimental result is excluded.

It follows from this that the formula (1-19) on the basis of which the result $\boldsymbol{d_{min}} = \mathbf{0{,}747}$ μm was obtained is correct. Therefore, formulas (1-15), (1-16), (1-17), on the basis of which this formula was obtained, are also correct. **This, in turn, confirms the existence of gravitational cells and strings.**

The existence of 2 types of gravitational strings with a fixed energy $\boldsymbol{e} = \mathbf{1,108293 \cdot 10^{-37}}$ J (or much less often $\boldsymbol{e_0} = \mathbf{1,026789\ \cdot 10^{-37}}$ J) suggests the existence of gravitational quanta or gravitons. Their birth can take place during extremely fast movement of gravitational cells relative to each other. As a result, the gravitational string between cells breaks off and turns into a free moving quantum with an energy value equal to $\boldsymbol{e}$ or $\boldsymbol{e_0}$. As in the previous case, we again apply the Planck formula:

$$\boldsymbol{e} = \boldsymbol{h\,\gamma}$$

1. $\boldsymbol{e} = \mathbf{1,108293 \cdot 10^{-37}}$ J, $\boldsymbol{\gamma} = \mathbf{1{,}672\,466 \cdot 10^{-4}}$ s^{-1}

$\boldsymbol{\lambda} = \frac{\boldsymbol{h\,c}}{\boldsymbol{e}} = \mathbf{1,7923 \cdot 10^{12}}$ m

2. $\boldsymbol{e_0} = \mathbf{1,026789\ \cdot 10^{-37}}$ J, $\boldsymbol{\gamma} = \mathbf{1{,}54962 \cdot 10^{-4}}$ s^{-1} $\boldsymbol{\lambda} = \mathbf{1,9344 \cdot 10^{12}}$m

As you can see, the graviton has an extremely low energy ($\boldsymbol{e} = \mathbf{6,917419 \cdot 10^{-19}}$ eV or $\boldsymbol{e_0} = \mathbf{6,408711 \cdot 10^{-19}}$eV). For this reason, even an intense flow of gravitons cannot be detected using modern instruments. Theoretically, this can be done with relatively close cosmic cataclysms (supernova explosion, collision of very dense and very massive cosmic bodies, etc.), when an extremely dense stream of gravitons comes from space. Only in this case fixation of gravitons is possible.

By analogy with gravitational strings, electromagnetic strings should exist between opposite elementary charges (that is, between an electron and a proton, an electron and a positron, etc.) Based on this assumption, by analogy with the higher formulas, we obtain the following formulas:

$$\boldsymbol{\gamma} = \frac{\boldsymbol{e}}{\boldsymbol{h}} = \frac{\boldsymbol{K}\cdot \boldsymbol{q}^2}{\boldsymbol{h}} = \frac{\mathbf{2{,}310275 \cdot 10^{-28}}}{\mathbf{6{,}62607 \cdot 10^{-34}}} = \mathbf{348664}\ c^{-1} \text{ or } \boldsymbol{v} = \boldsymbol{\gamma}/\boldsymbol{d}^2,\ \boldsymbol{d} = \sqrt{\boldsymbol{\gamma}/\boldsymbol{v}})$$

From here, with $\boldsymbol{v_{max}} = \boldsymbol{c}$, we get:

$$\boldsymbol{d_{min}} = \sqrt{\boldsymbol{\gamma}/\boldsymbol{c}} = \sqrt{\frac{\mathbf{348664}}{\boldsymbol{c}}} = \mathbf{3{,}4} \text{ cm}$$

where $\boldsymbol{v}$ is the vibrational speed of the electromagnetic string, m / s.

$\boldsymbol{e}$ - the energy of the electromagnetic string, $\mathbf{2{,}310275 \cdot 10^{-28}}$J

$\boldsymbol{q}$ is the value of elementary charges, $\boldsymbol{q} = \mathbf{1{,}60217733 \cdot 10^{-19}}$Cl.

$\boldsymbol{K}$ - coefficient of proportionality, $\mathbf{9 \cdot 10^{9}}$.

Thus, at a distance of $\boldsymbol{d_{min}} = \mathbf{3{,}4}$ cm, the electromagnetic string between the charges "breaks", and the elementary charges begin to interact directly without an intermediary string. Unfortunately, carrying out the same experiment as in determining the Casimir force will not make it possible to detect the limit of the action of the Coulomb forces. The first reason is the ultramicroscopic difference in strength between the direct interaction of elementary charges and the Coulomb interaction through strings. The second reason is the impossibility of carrying out such an experiment correctly. The fact is that for this it will be necessary to place a large number of densely located elementary charges on close parallel plates. And this is impossible because of the strong Coulomb interaction of these charges (repulsion and attraction), and, consequently, the inevitable movement of charges, both on the surface of the plates and between the plates.

(For a better perception of information in some of the higher formulas, the coefficients for converting units of measurement $\boldsymbol{k_{conv.}}$ are not specially set, because they are equal to 1).

The theory of gravitational cells makes it possible to apply the formula for the total energy of a moving body to the speed of a body in a gravitational field. Let's write this famous Einstein formula:

$$\boldsymbol{E_{full}} = \frac{m_0\, c^2}{\sqrt{1-\frac{v^2}{c^2}}} \quad \text{or} \quad \boldsymbol{E_{full}} = \frac{E_0}{\sqrt{1-\frac{v^2}{c^2}}} \qquad \textbf{(1-20)}$$

where $\boldsymbol{E_{full}}$ is the total energy of the moving body.

$\boldsymbol{E_0}$ is the energy of a body at rest.

$\boldsymbol{v}$ is the speed of the body.

Let's apply this formula to the motion of a body in a gravitational field:

$$\boldsymbol{E_{ful}} = \frac{E_0}{\sqrt{1-\frac{v^2}{c^2}}} \qquad \textbf{(1-21)}$$

$\boldsymbol{E_{ful}}$ full is the total energy of a moving body $\boldsymbol{m}$ in the gravitational field of mass $\boldsymbol{M}$, J.

$\boldsymbol{E_0}$ is the rest energy of the body $\boldsymbol{m}$, J.

From f. (1-21) get the formula for the speed of the body $\boldsymbol{m}$: $\boldsymbol{v_r = c\sqrt{1 - \frac{{E_0}^2}{{E_{full}}^2}}}$

(1-22)

where $\boldsymbol{v_r}$is the speed acquired by the body m in the gravitational field through $\boldsymbol{r = 1}$ m after the start of movement, m/s.

Let's expand the value of $\boldsymbol{E_{full}}$: $\boldsymbol{v_r = c\sqrt{1 - \frac{{E_0}^2}{(E_0 + E_g)^2}}}$ **(1-23)**

where $\boldsymbol{E_g}$ is the potential energy of the gravitational field at a distance $\boldsymbol{R}$ from the mass $\boldsymbol{M}$ at the location of the body $\boldsymbol{m}$, J.

Let's decompose $\boldsymbol{E_g}$ into constituent physical quantities: $\boldsymbol{E_g = \frac{GMm}{R}}$.

As a result, we obtain the following formula for the velocity of a body with mass m in the gravitational field, $\boldsymbol{E_g}$ acquired 1 m after the start of motion:

$\boldsymbol{v_r = c\sqrt{1 - \frac{m^2c^4}{\left(mc^2 + \frac{GMm}{R}\right)^2}}}$ **(1-24)** or $\boldsymbol{v_r = c\sqrt{1 - \frac{c^4}{\left(c^2 + \frac{GM}{R}\right)^2}}}$ **(1-25)**

Let's expand the formula (1-25):

$$\boldsymbol{v_r = \sqrt{\frac{c^2\left(c^2 + \frac{GM}{R}\right)^2 - c^6}{\left(c^2 + \frac{GM}{R}\right)^2}} = \sqrt{\frac{2\,c^4\frac{GM}{R} + c^2\frac{G^2M^2}{R^2}}{c^4 + 2\,c^2\frac{GM}{R} + \frac{G^2M^2}{R^2}}}}$$

Taking into account the extremely small value of $\boldsymbol{c^2\frac{G^2M^2}{R^2}}$ in comparison with $\boldsymbol{2\,c^4\frac{GM}{R}}$ and also $\boldsymbol{2\,c^2\frac{GM}{R} + \frac{G^2M^2}{R^2}}$ compared to $\boldsymbol{c^4}$ (the difference is $\boldsymbol{10^{27}}$ times), we get a simplified version of formula (1-25):

$$\boldsymbol{v_r = \sqrt{\frac{2\,c^4\frac{GM}{R}}{c^4}} = \sqrt{\frac{2GM}{R}}} \quad \textbf{(1-26)}$$

The result is a classical formula for the speed of a body in a gravitational field. Note that for very large values of the mass, the simplified (classical) formula (1-26) will give inaccurate results. At the same time, the relativistic formula (1-25) will give the exact value of the body's velocity.

The final speed $\boldsymbol{v_n}$ when the body $\boldsymbol{m}$ passes the entire distance $\boldsymbol{R_n}$ is determined by the following formula:

$$\boldsymbol{v_n = c\sqrt{1-\frac{c^4}{\left(c^2+\sum_{R=1_M}^{n}\frac{GM}{R}\right)^2}} = c\sqrt{1-\frac{c^4}{\left(c^2+GM\sum_{R=1_M}^{n}\frac{1}{R}\right)^2}}} \quad \textbf{(1-27)}$$

To calculate the speed of movement, when the distances between the bodies are huge $\boldsymbol{R_n} \to \infty$, it is necessary to use applied formulas. To obtain them, we use the reduced Euler formula $\boldsymbol{H_n \approx \ln n + \gamma}$. Let's apply this formula to the harmonic series $\boldsymbol{\sum_{R=1_M}^{n}\frac{1}{R}}$ in the obtained formula. As a result, we get:

$$\boldsymbol{v_n = c\sqrt{1-\frac{c^4}{(c^2+GM(\ln R_n+\gamma))^2}}} \quad \textbf{(1-28)}$$

where $\boldsymbol{v_n}$ is the final speed acquired by the body m when passing the distance $\boldsymbol{R_n}$.

$\boldsymbol{R_n}$ is the distance between $\boldsymbol{M}$ and $\boldsymbol{m}$.

$\boldsymbol{\gamma}$ is the Euler constant.

The resulting formulas 1-25, 1-27,1-28 are universal. Unlike the formulas of classical mechanics, these formulas give accurate results when huge masses and distances are involved in the calculations.

Gravity cells are a structural unit of mass $\boldsymbol{m}$. Therefore, with what speed the body m moves, then one cell $\boldsymbol{m_g}$ moves with the same speed. Based on this, we obtain from the above formulas the following formulas based on gravitational cells.

$$\boldsymbol{v_r = c\sqrt{1 - \frac{{m_g}^2c^4}{\left(m_gc^2 + e_s\frac{M}{R}\right)^2}}} \quad \textbf{(1-29)}$$

$$\boldsymbol{v_n = c\sqrt{1 - \frac{{m_g}^2c^4}{\left(m_gc^2 + e_sM\sum_{R=1м}^{n}\frac{1}{R}\right)^2}}} \quad \textbf{(1-30)}$$

$$\boldsymbol{v_n = c\sqrt{1 - \frac{{m_g}^2c^4}{\left(m_gc^2 + e_sM\,(\ln R_n + \gamma)\right)^2}}} \quad \textbf{(1-31)}$$

where $\boldsymbol{e_s}$ is the specific energy of the gravitational field, $\boldsymbol{,108293 \cdot 10^{-37}}$J · m/kg.

($\boldsymbol{e_s}$ is numerically equal to the energy of the gravitational string, where $\boldsymbol{e = 1,108293 \cdot 10^{-37}}$Дж **(ф. 1-7)**. Also $\boldsymbol{e_s = G\,m_g}$)

$\boldsymbol{m_g}$ is the mass of the gravitational cell, **1,660539** $\boldsymbol{\cdot\, 10^{-27}}$ kg.

Note that f. (1-29), which is based on energy, better shows the physical nature of the process of motion in a gravitational field than f. (1-25). Therefore f. (1-29) is primary in relation to f. (1-25).

It should be emphasized that the new formula (1-30) establishes the same limit of gravitational forces for all masses.

To verify this, consider the expression in formula (1-30): $\boldsymbol{e_sM\sum_{R=1м}^{n}\frac{1}{R}}$. This expression is the total energy of the gravitational field of mass $\boldsymbol{M}$, that is, $\boldsymbol{\sum E_g = e_sM\sum_{R=1м}^{n}\frac{1}{R}}$. Note that the gravitational field is created by the energy contained in the mass $\boldsymbol{M}$, equal to $\boldsymbol{E = Mc^2}$. Therefore, the value of $\boldsymbol{\sum E_g}$ in this formula will always be less than the value of $\boldsymbol{E = Mc^2}$, that is, $\sum \boldsymbol{E_g} < \boldsymbol{Mc^2}$. (It is assumed that the difference between these energies should be very significant: $\sum \boldsymbol{E_g} \ll \boldsymbol{Mc^2}$). As an equation, it looks like this:

$$\sum \boldsymbol{E_g} = \boldsymbol{k\,Mc^2} \quad \textbf{(1-33)}$$

where $\boldsymbol{k}$ is the reduction factor. (This coefficient can be considered as a conversion coefficient of a very small part of the internal energy of the mass $\boldsymbol{E = Mc^2}$ into the energy of the gravitational field $\sum \boldsymbol{E_g}$).

We open in f. 1-31 expression $\sum \boldsymbol{E_g}$: $\boldsymbol{eM \sum_{R=1м}^{n} \frac{1}{R} = k\,Mc^2}$

The same result is obtained from f. 1-33: $\boldsymbol{eM\,(\ln R_n + \gamma) = k\,Mc^2}$

We reduce the mass $\boldsymbol{M}$ in this equation and get:

$$\boldsymbol{\ln R_n = \frac{k\,c^2}{e} - \gamma}$$

The result obtained shows that the gravitational field of all bodies has the same action limit $\boldsymbol{\lim R_n}$, which does not depend on the value of the body mass. Beyond this distance $\boldsymbol{R_n}$, the gravitational forces of a body of any mass stop acting.

Results.

The main results of this research include the successful introduction of such important components as gravitational cells and gravitational strings into the concept of gravitational interaction. This made it possible to obtain such significant results as: the formula for the gravitational constant, the formula for the electron mass, the formula for the mass of the hydrogen atom, obtained through independent physical constants; obtaining the value of the graviton energy; obtaining the frequency and length of gravitational waves; determination of the minimum distance of action of gravitational forces; obtaining a formula for a single limit of the action of gravitational forces, etc.

In this work, Planck's constant was successfully applied to the theory of gravitational cells and strings. As a result, the formula for the minimum distance of gravitational interaction, the formula for the mass of an electron and the mass of a hydrogen atom was obtained. Calculations by these formulas completely coincided with the experimental data.

Through the synthesis of the theory of gravitational cells and the formula of the total energy of Einstein, a relativistic formula for the speed of a body in a gravitational field was obtained. This new formula can be used for the most accurate calculations of the speed of bodies in gravitational fields.

The scientific results obtained in this work completely coincide with the known scientific and experimental data.

Conclusion.

In this work, such concepts as gravitational cells and gravitational strings were successfully built into the theory of the gravitational field. This allowed to obtain significant scientific results. These results include: the gravitational constant formula, electron mass formula and hydrogen atom mass formula based on fundamental physical constants; the value of the minimum distance of the gravitational field; the new relativistic formula for the speed of a body in a gravitational field; the formula for a single limit of the action of gravitational forces, etc. Also in this work, a fixed the value of the graviton energy, the length and frequency of gravitational waves were determined, a new physical constant was obtained - the mass of the gravitational cell of a black hole.

A distinctive feature of this study is the fact that the new formulas are based on fundamental physical constants. All physical quantities and indicators obtained by these formulas completely coincide with known scientific and experimental data.

Declarations

1. **Availability of data and materials.**

All data obtained and analyzed in the course of this study is included in this article.

2. **Competing interests.** Not applicable (there are no competing interests).

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