UNCERTAINTY RELATIONS AS A CONSEQUENCE OF THE LORENTZ TRANSFORMATIONS

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Abstract

A macroscopic object consisting of a rod equipped with a pair of synchronized clocks is examined. General physical relations are directly derived from Lorentz transformations for the case of the rod's one-dimensional motion (along the X axis) – the uncertainty relation of the object's x coordinate and the projection of its impulse along the X axis, p_x, and the uncertainty relation of the object's observation time, t, and its energy, E. The relations take the form: $\Delta p_x \Delta x \geq H$ and $\Delta E \Delta t \geq H$. The H value in the relation has action dimensions and is dependent upon the precision of the rod's clocks and its mass.

It is shown that if the macroscopic object in and of itself performs the function of an ideal physical clock, the relations derived in the limiting case then take the form of $\Delta p_x \Delta x \geq h$ and $\Delta E \Delta t \geq h$, where h is the Planck constant.

Introduction

The uncertainty relation of a microparticle coordinate and the projection of its impulse along the coordinate axis, as well as the uncertainty relation of microparticle time and energy, falls into the ranks of the most important quantum relations that express the known uncertainty principle in a mathematical form. Quantum relations are not observed in the macrocosm in the sense that they are vanishingly small with respect to macrobodies and do not show themselves in practice. According to our data, no general physical relations have been reported in extant literature that extend to the macrocosm and that limit the simultaneous specification of the impulse and the coordinate of physical bodies. In light of existing notions concerning the properties of macroscopic bodies, the absence of such general physical uncertainty relations seems natural, since uncertainty relations have not been connected to measuring instrument errors, while it is possible to talk about macrobody coordinate, impulse, and energy inaccuracies, as they seem just as obvious today as measurement errors.

The objective of the work at hand was to demonstrate the existence of general physical uncertainty relations that extend to macrobodies. This objective was achieved over the course of solving a problem that consisted of determining the velocity and the velocity-related physical values of objects based on the degree of desynchronization of moving clocks.

The relations $\Delta p_x \Delta x \geq H$ and $\Delta E \Delta t \geq H$ were directly derived from Lorentz transformations. The first relation connects the uncertainty of the projection of the impulse, p_x, of the body under consideration, Δp_x, to the uncertainty of the x coordinate, Δx, while the second relation connects the uncertainty of the energy, E, of the object, ΔE, to the observation time, t, uncertainty, Δt. The H value in the relations has an action dimension and is dependent upon the precision of the rod's clocks and its mass.

Taking into account the fact that in Russia the recommendations formulated by metrologists for replacing the terms "error" with the term "uncertainty" are not compulsory in nature, and bearing in mind that these recommendations are still in the discussional stage [1-2], we used both terms in the work at hand.

We will take error to mean the inaccuracy of measurement results that is due to purely metrological causes. Increasing an instrument's measurement accuracy can reduce the error. The absolute error of the distance between two points can serve as an example of an error.

We will call the inaccuracy of measurement results that cannot be eliminated by means of increasing measurement instrument accuracy, and which may be due to terminological, conceptual, or linguistic causes, the uncertainty of physical values. The uncertainty of the distance between two spheres that are located close to one another can serve as an example of this uncertainty. This distance remains uncertain with an accuracy of up to the dimensions of the spheres, even in the presence of ideal measurement accuracy, while the thing that remains unclear is what is meant by the sought distance – the distance between the centers of mass of the spheres, the distance between their geometric centers, the distance between the closest points of the spheres, or something else. Construing uncertainty in this manner is mentioned in extant literature, albeit in general terms. In this vein, for example, taking into account the fact that it is only possible to specify the location of a spatially extended body by determining the position of a single solitary point that belongs to it with some degree of uncertainty, the uncertainty of the position of a sphere determined by the position of its center, which equals the radius of this sphere, is written about in reference [3].

The uncertainty of specifying the moment in time of a short-term process that does not occur instantaneously, but rather occupies a certain finite, let's say, very short time interval, can serve as another example of an uncertainty of this type. This uncertainty can be regarded as equal to half the duration of the process, if the moment in time of its transit is called the moment into which the middle of the process falls. These coordinate and time uncertainties, Δx and Δt, are precisely the ones that play a part in the uncertainty relations we derived.

1. Single-time and single-coordinate data. Determining the velocity of a rod based on the readings of the synchronized clocks appurtenant to it

We will visualize a thin rod of proper length, L, at two points, a and b, on which synchronously running clocks, A and B, are installed at a distance of d from one another.

Let's say that clocks A and B, like the clocks appurtenant to the K^0 reference system, where the rod is at rest, show this system's time; i.e., the readings of clocks A and B are always in agreement with the readings of the K^0 system's clocks. The length, d, of section ab, which is located between points a and b, may be equal to or less than the rod length, L; i.e., the condition $L \geq d$ holds true in the general case. If $L > d$, then the rod will look something like this:

----------*A*--------------------*B*-----------

Here, the A and B characters conditionally designate clock A and clock B, while the broken line shows the body of the rod.

If the distance, d, is equal to the rod length, L – i.e., if $L = d$, clocks A and B are then found at the ends of the rod.

We will call the arrangement that consists of this rod and the two running clocks, A and B, situated on it rod, R; i.e., clocks A and B will be regarded as integral parts of rod R, and we will treat the readings of clocks A and B as characteristic attributes of rod R.

Let's say that rod R, which is positioned parallel to the X^0 axis of inertial system K^0, is at rest relative to this system and moves at a constant velocity, V', along the X' axis of another reference system, K', remaining parallel to the X' axis and its direction of movement (the X^0 and X' axes of the K^0 and K' systems slide along one another over the course of their relative motion). We will call this rod motion longitudinal motion (with respect to its orientation in space), and it alone will be referred to in the future.

Pursuant to inverse Lorentz transformations, at a moment in time of t' of the K' system, the readings, $\tau_{A,t'}$ and $\tau_{B,t'}$, of clocks A and B, which are in agreement with the readings of the K^0 system's clocks, are determined by the relations

$$\tau_{A,t'} = \frac{t' + \frac{V'}{c^2} x'_{A,t'}}{\sqrt{1-(\frac{V'}{c})^2}} \text{ and } \tau_{B,t'} = \frac{t' + \frac{V'}{c^2} x'_{B,t'}}{\sqrt{1-(\frac{V'}{c})^2}},$$

where $x'_{A,t'}$ and $x'_{B,t'}$ – the coordinates of clocks *A* and *B* of rod *R* within system *K'* at a moment in tie of *t'*, while *c* – the speed of light in a vacuum.

As follows from the relations presented above, the difference in the readings of clocks *A* and *B* of rod *R* at a moment in time of *t'* for system *K'* equals

$$\tau_{B,t'} - \tau_{A,t'} = \frac{(x'_{B,t'} - x'_{A,t'})V'}{c^2\sqrt{1-(\frac{V'}{c})^2}}. \qquad (1)$$

Introducing the following notation for the purpose of saving writing space

$$U' = \frac{V'}{\sqrt{1-(\frac{V'}{c})^2}}, \qquad (2)$$

then from formula (1), with allowance for notation (2), we obtain:

$$U' = \frac{c^2(\tau_{B,t'} - \tau_{A,t'})}{x'_{B,t'} - x'_{A.t'}}. \qquad (3)$$

Thus, having the data on the coordinates and readings of clocks *A* and *B* at a moment in time of *t'*, formula (3) can be used to find the value of *U'*, and this value can in turn be used to find the velocity, *V'*, of rod *R* in system *K'*. We will call the data that characterize the object's spatially distributed elements, but that relate to one and the same moment in time, *t'*, single-time data.

In addition to the possibility of determining the rod's velocity using single-time data, the possibility also exists of determining the velocity, *V'*, of rod *R* in system *K'* using single-coordinate data. We will call the data successively recorded at different moments in time, but at one and the same point (with one and the same coordinate), which characterize the elements of a spatially extended object at the times that they are located at this (or near this) point, single-coordinate data. Data of this type include, for example, the $\tau_{A,x'}$ and $\tau_{B,x'}$ readings of clocks *A* and *B* of rod *R* that are successively recorded at moments in time of $t'_{A,x'}$ and $t'_{B,x'}$ at a point in system *K'* with a coordinate of *x'*, past which it is moving within this reference system.

According to inverse Lorentz transformations, the single-coordinate $\tau_{A,x'}$ and $\tau_{B,x'}$ readings of clocks *A* and *B* are connected to the moments in time, $t'_{A,x'}$ and $t'_{B,x'}$, during which clocks *A* and *B*, at a point with a coordinate of *x'*, show the relations

$$\tau_{A,x'} = \frac{t'_{A,x'} + \frac{V'}{c^2} x'}{\sqrt{1-(\frac{V'}{c})^2}} \text{ and } \tau_{B,x'} = \frac{t'_{B,x'} + \frac{V'}{c^2} x'}{\sqrt{1-(\frac{V'}{c})^2}}.$$

As follows from the relations presented above, the difference in the readings of clocks *A* and *B* of rod *R* at a point with a *K'* system coordinate of *x'* equals

$$\tau_{B,x'} - \tau_{A,x'} = \frac{t'_{B,x'} - t'_{A,x'}}{\sqrt{1-(\frac{V'}{c})^2}}. \qquad (4)$$

Introducing the notation $\Gamma' = 1/\sqrt{1-(V'/c)^2}$, then from formula (4), we obtain

$$\Gamma' = \frac{\tau_{B,x'} - \tau_{A,x'}}{t'_{B,x'} - t'_{A,x'}}, \qquad (5)$$

from which the velocity, V', of rod R can be learned as necessary.

The determination of velocity using single-coordinate data is interesting in that it does not require distance measurements, but rather is based on the measurement of the $\tau_{B,x'} - \tau_{A,x'}$ and $t'_{B,x'} - t'_{A,x'}$ time intervals.

2. Relation of rod velocity and coordinate uncertainties calculated using single-time data

In talking about the determination of the velocity of rod R using the difference in the readings of clocks A and B, we tacitly proceeded on the basis of the fact that clocks A and B of rod R run ideally; i.e., the readings of clocks A and B are in absolutely precise agreement with the ideally accurate readings of the K^0 system clocks. We speculate that a certain maximum absolute error exists in the time readings of each of clocks A and B, which are appurtenant to rod R. We will designate the absolute error of these clocks as $\Delta\tau$. Here, adhering to the generally accepted assumption, we will presume that all the clocks appurtenant to any inertial reference system, including the K^0 system, run with ideal accuracy.

The existence of an absolute error, $\Delta\tau$, in the readings of each of clocks A and B means that, at a given moment in time, t^0, within the K^0 system, the readings of each of these clocks of rod R can differ from the readings of the K^0 system clocks located close to them and running with ideal accuracy by a value that does not exceed $\Delta\tau$. In this regard, the remarks made above concerning the agreement of the reading of the K^0 system clocks with those of clocks A and B must be interpreted with allowance for the finite accuracy of the latter.

If the rate of the K' system clocks, the measured $x'_{B,t'} - x'_{A,t'}$ value, and the speed of light c value are as accurate as desired, the error in the U' value calculated using formula (3) will then be solely due to the existence of an absolute error, $\Delta(\tau_{B,t'} - \tau_{A,t'})$, in the difference of the $\tau_{B,t'} - \tau_{A,t'}$ readings of clocks A and B.

In this instance, the $\Delta U'$ error, with allowance for formula (3), is expressed by the equality

$$\Delta U' = \frac{c^2 \Delta(\tau_{B,t'} - \tau_{A,t'})}{x'_{B,t'} - x'_{A,t'}} \qquad (6)$$

In instances when the maximum absolute error of the difference in the readings of clocks A and B consists of the $\Delta\tau$ errors of each of these clocks – i.e., when $\Delta(\tau_{B,t'} - \tau_{A,t'}) = 2\Delta\tau$, it follows from equality (6) that:

$$(x'_{B,t'} - x'_{A,t'})\Delta U' = 2c^2 \Delta\tau . \qquad (7)$$

We note that the $\Delta\tau$ error is not dependent upon reference system selection, since it consists of the maximum possible difference between the readings of each of clocks A and B and the readings of the K^0 system clocks located close to them, where rod R is at rest. It is clear that this difference is not dependent upon the reference system within which it is picked up.

We will now imagine that, in addition to the condition of the single-time nature of the readings of clocks A and B within system K', the requirement of the single-coordinate nature of the specification of the location where rod R is situated at a moment in time of t' is satisfied. Let's say the essence of this requirement consists of using a single solitary x'_R coordinate to specify the location of the projection of rod R on the X' axis. This requirement can be satisfied if the rod length is ignored and it is regarded as a point. But if, due to the necessity of taking the property of the rod's spatial extent into account, it is impossible to ignore its length, the requirement of the single-coordinate nature of the specification of the position of rod R can only be satisfied in part. For example, the coordinate of any point appurtenant to rod R can be specified as its x'_R coordinate and a reference to its uncertainty can accompany the specification of this coordinate. In particular, the coordinate of the geometric center of rod R, or the coordinate of its center of mass, can serve as the coordinate of this point. In such cases, the distance from the point with a coordinate of x'_R to the point of the rod's projection on the X' axis farthest away from it can be regarded as the uncertainty, $\Delta x'_R$, of the x'_R coordinate.

When the position of rod R is specified in this manner, the x'_R coordinate indicates the location of one of a set of points of the projection of rod R that lies on the X' axis. If we give this point preference for one reason or another, the $\Delta x'_R$ uncertainty will then determine a range of point coordinates that, in the presence of other considerations, could also be regarded at the point coordinates of rod R.

For example, if the coordinate, x'_{ab}, of the geometric center (the midpoint) of the ab section of rod R parallel to the X' axis is selected as this section's coordinate, the uncertainty, $\Delta x'_{ab}$, of the x'_{ab} coordinate of the rod's ab section can by definition be regarded as a value equal to half the length of the section of the moving (within the K' system) rod.

Since the length, $d' = d\sqrt{1-(V'/c)^2}$, of the rod's moving ab section within the K' system equals $x'_{B,t'} - x'_{A,t'}$, the uncertainty, $\Delta x'_{ab}$, of the x'_{ab} coordinate of section ab of rod R then equals $\frac{1}{2}(x'_{B,t'} - x'_{A,t'})$. Thus, formula (7) can be presented in the form

$$\Delta U' \Delta x'_{ab} = c^2 \Delta\tau . \qquad (8)$$

Within the framework we have provided when introducing the determination of uncertainty, the $\Delta x'_{ab}$ value is absolutely an uncertainty and not an error, since it is dependent upon the length of the rod's ab section and cannot be reduced by means of increasing measurement accuracy.

Because $L \geq d$ in the general case, the $\Delta x'$ uncertainty of the x' coordinate of rod R within the arbitrary positioning of clocks A and B thereon ($\Delta x' = \frac{1}{2}L'$) can then generally both equal and exceed the $\Delta x'_{ab}$ value. And since the relation $\Delta x' \geq \Delta x'_{ab}$ holds true, then in the general case of the arbitrary positioning of the clocks on the rod, formula (8) takes the form:

$$\Delta U' \Delta x' \geq c^2 \Delta\tau . \qquad (9)$$

Relation (9) pertains to the general case of the arbitrary positioning of the clocks on the rod and makes the transition to the equality $\Delta U' \Delta x' = c^2 \Delta\tau$ in the special and most favorable case (as far as the determination of the U' value using single-time data) of clock positioning on the ends of the rod ($\Delta x' = \Delta x'_{ab}$).

The product of the error, $\Delta U'$, of the U' value and the uncertainty, $\Delta x'$, of the x' coordinate of rod R during an instantaneous observation will only be dependent upon the error in the readings of clocks A and B of rod R. Therefore, relation (9) remains unchanged in any inertial reference system and can be written for an arbitrary system in the form:

$$\Delta U_x \Delta x \geq c^2 \Delta\tau \qquad (10)$$

If the mass of rod R with clocks A and B is known without a doubt and equals M_R (here and further on, the concepts of Lorentz-invariant mass [4] will be used), relation (10) can be transformed into the relation $M_R \Delta U_x \Delta x \geq M_R c^2 \Delta\tau$ by multiplying its left-hand and right-hand members times M_R, whence, taking into account the fact that $M_R U_x = p_x$, we obtain:

$$\Delta p_x \Delta x \geq M_R c^2 \Delta\tau \ . \quad (11)$$

Introducing the notation

$$H = M_R c^2 \Delta\tau \ , \quad (12)$$

then from formula (11), we obtain

$$\Delta p_x \Delta x \geq H \ . \quad (13)$$

The $\Delta\tau$ error of clocks A and B of rod R is one of the internal parameters of rod R and is not a part of the parameters of the measuring devices that are external relative to rod R. Therefore, the ΔU_x and Δp_x errors in relations (10) and (13) can tentatively be referred to as external (relative to rod R) uncertainties. The internal properties of rod R itself (a salient feature of clocks A and B appurtenant to it) determine the external uncertainties ΔU_x and Δp_x, and in the presence of a specific Δx uncertainty, they cannot be eliminated by means of increasing the accuracy of the measuring instruments located beyond rod R.

3. Relation of rod energy and time uncertainties calculated using single-coordinate data

The error, $\Delta\Gamma'$, of the Γ' value can be derived from formula (5). Only the $\tau_{B,x'} - \tau_{A,x'}$ value error due to the $\Delta\tau$ error in the readings of clocks A and B determines the $\Delta\Gamma'$ error of the Γ' value, since the $t'_{B,x'} - t'_{A,x'}$ time interval at point x', according to our initial assumption, can be measured by the K' system clocks with an ideal accuracy. Therefore, from formula (5), we obtain:

$$\Delta\Gamma' = \frac{\Delta(\tau_{B,x'} - \tau_{A,x'})}{t'_{B,x'} - t'_{A,x'}} ,$$

or with allowance for the fact that $\Delta(\tau_{B,x'} - \tau_{A,x'}) = 2\Delta\tau$,

$$\Delta\Gamma' = \frac{2\Delta\tau}{t'_{B,x'} - t'_{A,x'}} ,$$

whence it follows that:

$$\Delta\Gamma'(t'_{B,x'} - t'_{A,x'}) = 2\Delta\tau \ . \quad (14)$$

We will now assume that, in addition to the condition of the single-coordinate nature of the observation clock readings, the requirement of the single-time nature of the specification of the observation time of the ab section of rod R, moving past point x', is imposed. Let's say the requirement consists of using a single solitary moment in time, $t'_{ab,x'}$, to specify the section ab observation time at point x'.

Since the observation at a point with a coordinate of x' is carried out over a time interval of $t'_{B,x'} - t'_{A,x'}$, it is then only possible to approximately specify the observation time by indicating, for example, the moment in time, $t'_{ab,x'}$, of the middle of the time interval, $t'_{B,x'} - t'_{A,x'}$, that goes toward observation. Here, the uncertainty, $\Delta t'_{ab,x'}$, of the moment in the observation time that equals half the $t'_{B,x'} - t'_{A,x'}$ observation time can be specified; i.e., it can be assumed that $\Delta t'_{ab,x'} = ½(t'_{B,x'} - t'_{A,x'})$. Then formula (14) can be presented in the form:

$$\Delta\Gamma'\Delta t'_{ab,x'} = \Delta\tau \,. \qquad (15)$$

For the arbitrary positioning of the clocks on the rod, the $\Delta t'_{x'}$ observation time for the entire rod, *R*, with a length of *L* proves to be greater than the observation time, $\Delta t'_{ab,x'}$, for the *ab* rod section; i.e., the condition $\Delta t'_{x'} \geq \Delta t'_{ab,x'}$ is satisfied, as a result of which it follows from formula (15) that

$$\Delta\Gamma'\Delta t'_{x'} \geq \Delta\tau \,. \qquad (16)$$

During an accurate observation, the product of the uncertainty, $\Delta t'_{x'}$, of a moment in time, $t'_{x'}$, of the observation of rod *R* and the $\Delta\Gamma'$ error of the Γ' value will only be dependent upon the $\Delta\tau$ error of the readings of clocks *A* and *B* of rod *R*. Therefore, relation (16) remains unchanged within any inertial reference system and can be written for an arbitrary system in the form:

$$\Delta\Gamma\Delta t_x \geq \Delta\tau \,. \qquad (17)$$

Multiplying the left-hand and right-hand members of relation (17) times $M_R c^2$, bearing in mind that $\Delta\Gamma M_R c^2 = \Delta E$, and using notation (12), we obtain

$$\Delta E\Delta t_x \geq H \,. \qquad (18)$$

If the $\Delta\tau$ error is regarded as a rod parameter that is not a part of the measuring equipment parameters, the $\Delta\Gamma$ and ΔE values can then be referred to as uncertainties.

4. A physical clock. Relation of the impulse and coordinate uncertainties of a spatially extended body

We will assume that each of clocks *A* and *B* discretely changes its reading with frequency, ν. The maximum absolute $\Delta\tau$ error in the readings of the moments in time of each of the clocks will equal $1/\nu$. We will also assume that this change in the clock readings occurs synchronously; i.e., not only are the clock readings at a given moment in time synchronized, but also the times of the change in readings.

In this instance, the maximum error of the difference in the readings of clocks *A* and *B* will equal not the sum of the two $\Delta\tau$ errors, but rather a single $\Delta\tau$ error. Then relations (13) and (18), deduced from the condition of the equality of the clock *A* and *B* difference error to the two $\Delta\tau$ errors, take the form:

$$\Delta p_x \Delta x \geq H/2 \qquad (19)$$

and

$$\Delta E\Delta t_x \geq H/2 \,. \qquad (20)$$

Let's imagine that each of clocks *A* and *B* consists of two components, one of which, being artificial ("manmade"), performs the function of a display and provides discrete time readings, changing them in a keeping with external signals, while the other one – we will call it a physical clock – generates these signals in a natural, easy manner and controls the change in the display's readings.

For the sake of clarity, we will visualize the second part of the physical clock as a piece of radioactive material with a long half-life (the material's radiant power can be regarded as constant for a sufficiently long time frame).

If the display reacts to a specific portion, ε, of the physical clock material's absorbed gamma-radiation energy by changing its readings, then in the presence of a material radiant power than equals *P*, the frequency, ν, of the change in the display readings will equal *P/*ε.

We will call the ε portion of the absorbed energy that leads to a change in the display's reading the energy of the perceived (by the display) physical clock signals.

We will assume that, regardless of the quantity of the physical clock material, the display absorbs all of the energy radiated, and that each ε portion of the energy absorbed performs the function of a reading change signal that is perceived by the display. The frequency, ν, of the physical clock materials signals perceived by the display, and accordingly the frequency of the change in the physical clock's readings, will then be proportional to the quantity of the physical clock's material. This means that if the frequency of the perceived signals equals ν_0 in the presence of a physical clock material unit mass of m_0, it will then equal $M_0\nu_0/m_0$ in the presence of a mass of M_0; i.e.,

$$\nu = M_0 \frac{\nu_0}{m_0}, \tag{21}$$

Since the maximum absolute Δτ error of the readings of each of the clocks equals 1/ν, the following expression can then be derived from equality (21):

$$\Delta\tau = \frac{m_0}{M_0 \nu_0}. \tag{22}$$

Taking the mass of the rod without the clocks to be negligible as compared to the mass of the physical clock material concentrated in clocks *A* and *B*, or assuming that the rod *R* consists entirely of the physical clock's material, the $2M_0$ value (since the mass of the material in both clocks equals $2M_0$) can be set to equal the mass, M_R, of rod *R* with clocks *A* and *B*. Taking this into account, it follows from formulas (12) and (22) that

$$H = \frac{2c^2 m_0}{\nu_0} \tag{23}$$

The *H* value is dependent upon physical clock type and display sensitivity, and is not a physical constant. The *H* becomes different when the display's sensitivity changes, or when the physical clock's radioactive material is replaced with a radioactive material that has a different radiant power.

In the context of the physical clock, relations (19) and (20) pertain to the case of the arbitrary distribution of the physical clock's material along the rod and make the transition to equalities in the special case when the physical clock's material is concentrated at the ends of rod *R*.

At first glance, the relations derived only hold true for the techniques of instantaneous and point observations of an object, and the uncertainties going into these relations consist exclusively of the uncertainties inherent in these techniques. In actuality, however, it is impossible to measure even the constant velocity of this rod R, equipped with clocks *A* and *B*, with absolute accuracy using conventional methods (based on the path traversed and the time), if the word combination "rod *R* with clocks *A* and *B*" is taken to mean a specific object, the complement of characteristic traits of which includes the difference in the readings of clocks *A* and *B* (or the events that characterize this object). In such cases, the velocity and the values derived from it (the impulse and energy) prove to be tied not to an extraneous reference system, but rather to this object's characteristics traits, for example, to time or event marks [5].

In order to grasp the essence of the latter comment, we will address the concepts of relativity and uncertainty.

It was shown in reference [5] that many of the questions arising in the quagmire of physical relativism are erased if attention is directed to the presence of uncertainty in physical relativity. Rather than talking about the relativity of the velocity of a body and about the fact that the velocity of a body without specifying a reference system makes no physical sense, it is proposed in reference [5] that the term "uncertain velocity" be used with respect to the irrelative velocity of a body. In this case, the velocity of a body that is not tied to a specific reference system should be referred to as uncertain velocity. The uncertainty of the irrelative velocity of a body equals the c constant. It can be said of the irrelative velocity of this body, for example, that it equals zero, while its uncertainty equals c. This specification of velocity does not differ qualitatively in any way from the conventional specification of a velocity value supplemented by the specification of its error.

We draw attention to two methods that make it possible to avoid the uncertainty of the velocity of a body and to give it certainty.

The first generally accepted method consists of specifying the reference system within which the velocity of a body is examined. After the reference system is specified, the velocity of this body becomes certain.

The second method, despite its obviousness, is scarcely mentioned at all in physics. This method consists of individualizing an object, which in turn consists of describing it in greater detail, and under certain conditions, it is capable of replacing the selection of a reference system.

In the example we examined, the object with respect to which relations (19) and (20) hold true is not a rod, R, equipped with clocks A and B, but rather a rod, R, equipped with clocks A and B, **and possessing a predetermined difference, $\tau_B - \tau_A$, in the readings, τ_A and τ_B, of clocks A and B**.

If one and the same rod, R, equipped with clocks A and B, is by definition regarded as a set of more concrete subobjects, each of which has an inherent difference, $\tau_B - \tau_A$, in the readings of clocks A and B, then these different objects will possess different velocities. The possibility of thus dividing an object into more concrete subobjects eludes relativists, since it puts an end to the objective nature of physical relativism. Relativists are incapable of understanding something that was clear to Heracles, who saw the difference between one and the same river and particular concrete "subobjects" of this river that differed from one another. At the same time, relativists themselves note that one and the same object differs in different reference systems due to the relativity of its single-time nature; i.e., it breaks down into subobjects of sorts. It is strange that they don't comprehend the fact that, having described a subobject, its velocity can often be determined based on "external appearance" without specifying a reference system.

For example, in the case we examined, a subobject such as a rod, R, that has a specific difference, $\tau_{B,t'} - \tau_{A,t'}$, in the readings, $\tau_{A,t'}$ and $\tau_{B,t'}$, of clocks A and B, moves at a specific longitudinal velocity, V_x. When the clocks run with ideal accuracy, the V_x velocity value is functionally dependent upon the $\tau_{B,t'} - \tau_{A,t'}$ difference value. A subobject such as a rod, R, with a difference, $\tau_{B,t'} - \tau_{A,t'}$, in the readings, $\tau_{A,t'}$ and $\tau_{B,t'}$, of clocks A and B that equals zero is at rest. Its longitudinal velocity, V_x, equals zero and cannot differ from zero in any reference system, since subobjects with a difference, $\tau_{B,t'} - \tau_{A,t'}$, in the readings of clocks A and B that equals zero do not exist in any reference system where this rod moves longitudinally. This rod, R, with clocks A and B, has different longitudinal velocities in different reference systems, but the subject rod, R, with a difference, $\tau_{B,t'} - \tau_{A,t'}$, in the readings of clocks A and B that equals zero, being a concrete subobject, only has a longitudinal velocity that equals zero. This fact is entirely independent of the manner in which the velocity is measured – based on the clock readings or using the path and distance traversed.

In addition to this, if clocks *A* and *B* provide discrete readings, the $\tau_{B,t'} - \tau_{A,t'}$ difference will also have a certain discreteness. Here, the longitudinal velocity value, V_x, will have an uncertainty of ΔV_x. In this case, a rod, *R*, with a given difference in the readings of clocks *A* and *B*, being a subobject, may be found in a certain set of reference systems in a state of motion at various longitudinal velocities that differ from one another by a magnitude that does not exceed a certain value, which is the ΔV_x uncertainty. This uncertainty in accuracy equals the uncertainty that occurs during the single-time determination of the V_x velocity of a given subobject.

If clocks *A* and *B* do not run, but rather stand still, continuously indicating an identical time, then the ΔV_x uncertainty of the longitudinal velocity of rod, *R*, with a difference of $\tau_{B,t'} - \tau_{A,t'}$ in the readings of clocks *A* and *B* that equals zero, will equal the speed of light, *c*. Such a rod, *R*, with a difference of $\tau_{B,t'} - \tau_{A,t'}$ in the readings of clocks *A* and *B* that equals zero, can be found in all reference systems and possesses any velocity over a range of zero to the speed of light, *c*.

Conclusion

The purpose of the work at hand consisted not of finding areas of common interest between Lorentzian physics and quantum mechanics, but rather of demonstrating the existence of general physical uncertainty relations in the physics of the macrocosm. The general physical relations derived are externally reminiscent of the known uncertainty relations of quantum mechanics; however, the physical essence of the values that go into the relations and that contain the relations themselves are different than those in quantum mechanics. In relation (13), the Δx uncertainty is taken to mean the uncertainty in specifying the position of a projection with a length of Δx of a spatially extended object using a single solitary coordinate, *x*, while in the Heisenberg relation, Δx is a probabilistic characteristic of the position of a microparticle described by the root-mean-square deviation from the mean value.

The Δp_x value in relation (13) is the p_x impulse error, which in the presence of a predetermined Δx uncertainty, generally speaking, can be reduced by using another type of physical clock, while Δp_x in the Heisenberg relation is an uncertainty that it is fundamentally impossible to reduce in the presence of a predetermined Δx value.

Different meanings are placed on the *H* and *h* values.

The *H* value in relations (13), (18), (19), and (20) is dependent upon display sensitivity and physical clock type. If the sensitivity of the display is changed or the physical clock's radioactive material is replaced with a radioactive material that has a different mass radiation frequency, the *H* value will be different. However, the fundamental Planck constant, *h*, is unrelated to the physical properties of any specific material. The fact that these relations prove to be connected to the Heisenberg relation, not only externally, but also internally, seems especially strange.

First, there is the question of the minimum value, H_{min}, of an *H* parameter with an action dimension. Can one assume that this value may be as small as desired in the macrocosm and may correspond , for example, to the condition $H_{min} \ll h$?

And second, relations (19) and (20) are formally transformed into the relations

$$\Delta p_x \Delta x \geq h/2 \text{ and } \Delta E \Delta t_x \geq h/2$$

via the simple substitution of the energy, $h\nu_0$, of a photon with a frequency of ν_0 in place of the unit energy, $m_0 c^2$, of the physical clock in formula (23); i.e., by taking the unit mass of a photon, the ν_0 frequency of which numerically equals the ν_0 frequency of the signals of a hypothetical change in the clock readings as the physical clock. It would be more correct to proceed on the basis of the concept of Lorentz-invariant mass and the equality of photon mass to zero, then a pair of photons coming from opposite directions with equal energies of $E = h\nu$ and with a resultant impulse, *P*, that equals zero, should be regarded as a physical clock of a unit mass of

m_0. Since the unit mass, m_0, of this clock equals $\sqrt{(\frac{2E}{c^2})^2 - (\frac{P}{c})^2}$ $=2E/c^2$, while the v_0 summation frequency of the electromagnetic oscillations equals $2v$, then taking the v_0 frequency of the unit mass physical clock to equal the $2v$ summation frequency of the photon pair, it follows from formula (23) that $H = H_{min} = h$.

Another approach is also possible.

In considering formula (23), if it is assumed that a certain H_{min} value exists that is common to all types of physical clocks, then $2m_0c^2/v_0 = H_{min}$. The latter equality only occurs when $m_0c^2 = ½ H_{min}v_0$. If the lowest energy of a hypothetic signal of a change in clock readings is taken as m_0c^2, then H_{min} must be equal to the Planck constant h, since the $½hv_0$ value is the minimum possible energy of the zero-point oscillations of an oscillator with a frequency of v_0.

The relations expressed by formula (23), if we move to them from relations (19) and (20), do not reflect the statistical nature of the generation of the clock reading change signals; thus, when using this approach, reference can only be made to the order of the parameter present in the right-hand member of the relations and not its precise value.

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