***V. N. Matveev and O. V. Matvejev***

# AN ENTERTAINING SIMULATION

***of the***
***Special***
***Theory of***
***Relativity***

Using Methods of Classical Physics

*In this booklet, relativistic time and the relativistic effects of Einstein's special theory of relativity – Lorentz contraction, time dilation, relativistic Doppler effects, the Skobeltsyn-Bell effect, and the relativistic addition of velocities – are simulated in an amusing form using elementary methods of classical physics. Lorentz transformations are obtained. Means for simulating four-dimensional space-time are shown.*

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ISBN 

ON THE BOOK BY V. N. MATVEEV AND O. V. MATVEEV “AN ENTERTAINING SIMULATION OF THE KINEMATIC EFFECTS OF THE SPECIAL THEORY OF RELATIVITY”

A large number of books, booklets, and articles at the most diverse levels – from straight-laced documents that have been mathematized to the greatest extent possible and that are intended for a small circle of specialists to popular scientific works – are devoted to Einstein’s special theory of relativity and its applications. The bulk of the popular books on the special theory of relativity were written in an amusing form based on examples of Einsteinian trains or rockets whizzing along relative to one another at sublight speed and peopled by nimble observers. This form is possible due to the fact that, despite the overall complexity of the special theory of relativity itself and its applications, its rudimentary foundations and principles are extremely simple and obvious. The simplicity and obviousness of the foundations of the special theory of relativity comprised the underlying condition whereby nonspecialists contributed to the discussion of the problems that actually exist in the special theory of relativity, which are generally interpretive and terminological in nature. And while specialists do not address, for example, the question of the correctness of Lorentz transformations in general – in practice, Lorentz transformations have confirmed their own correctness not only in theoretical physics, but also in engineering analyses – there are many people among the ranks of nonspecialists who are willing to cast doubt on the correctness of Lorentz transformations, as well as the concepts of Lorentzian time contraction and dilation that emanate from them. The latter would not be worth mentioning (in a democratic society, everyone is entitled to choose his or her own object of belief) if skepticism in the consideration of relativistic kinematics had not found its way into procedural materials that lay claim to seriousness. The “Recommendations for Stating the Special Theory of Relativity (STR) With Allowance for Standard Requirements” that are located on the Internet at the Russian website of the academic newspaper “Physics” of the First of September Publishing House can serve as an example of this. In these recommendations, it is first noted that “the question of measuring the length of a body in motion is not simple”, then the effect of the visual integrity of the shape of a sphere in different reference systems that was discovered “50 years after Einstein’s death” is mentioned, and finally allowance is made for this effect in reaching the conclusion that “in our view, the only correct solution in this situation consists of refusing to pose this question and all the problems related thereto”. Thereafter, the following remark is made: “It must be noted that we are unaware of a single direct practical application of the formula $l = l_0\sqrt{1-(v/c)^2}$ ”.

Moreover, there is no contradiction between the effect of the visual integrity of the shape of a sphere and Lorentz contraction. This effect is well familiar to specialists and is known as the Terrell-Penrose effect. Furthermore, the visual integrity of the shape of a sphere was theoretically predicted (the effect has not been observed experimentally) with allowance for metrological Lorentz contraction; i.e., with allowance for an effect that emanates from Lorentz transformations.

In this regard, the book by V. N. Matveev and O. V. Matvejev is quite timely. Being amusing in nature, it differs from many books of this type in that it is not the kinematic effects of the STR themselves that are considered therein, but rather effects similar thereto, which the authors simulate based on the example of barges that are at rest and in motion on a water surface at the “terrestrial” velocities to which we are accustomed. By virtue of its amusing nature, the book is primarily intended for those who, drawing knowledge from popular literature, have perceived relativistic phenomena as almost mysterious and extending outside the framework of our terrestrial notions of the material world. The booklet, so to speak, casts fantasy lovers down from the heavens to the wicked earth. In stating the materials, the authors refrain from using an approach involving observers, replacing the latter with instruments (hardware). This technique made it possible to tone down the taint of subjectivity that is present in publications involving the use of observers. This same technique made it possible to simulate the relativistic time on the scales of which the simulation instruments operate and observers fundamentally cannot function.

The book will be of interest to a wide range of readers. The possibility of simulating the basic kinematic phenomena of relativistic mechanics within an environment that is demonstrated in the book should not be correlated to the existence of a world environment. First, this possibility is in agreement with the formal sameness of the Lorentzian and Einsteinian world views that is known to specialists, and second, the simulation described in this book only encompasses a modicum of the phenomena considered in the special theory of relativity and does not extend, for example, to dynamics and electrodynamics.

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## FROM THE AUTHORS

In Soviet scientific literature, the question of synchronizing clocks is mentioned in general terms, if at all. In popular articles, as well as in special literature, almost no attention is given to this central problem in Einstein's entire special theory of relativity (STR). Apparently for this reason, many people in Russia even today, perhaps "through inertia", either are not aware of the importance of the question of clock synchronization or are very poorly informed of its essence in general. One of us literally fished a more or less detailed description of the problem of synchronization out of a heap of literature from the 1960s and 1970s. It consisted of individual articles, Marder's popular book "The Clock Paradox" [1], and an article by A. A. Tyapkin in Advances in the Physical Sciences (APS) [2].

The problematic nature of synchronizing clocks consists of the use of the condition of the equality of the speed of light in opposite directions for clock synchronization in the STR, while it is fundamentally impossible to experimentally verify this equality. In order to measure the speed of light from point *A* to point *B*, then from point *B* to point *A*, and then to compare these speeds, it is necessary to have synchronously running clocks at points *A* and *B*. However, it is only possible to synchronize the clocks at points *A* and *B* using the Einstein method by assuming that these velocities are equal even before they are measured. Naturally, after this assumption is made, they also become equal based on the measurement results.

It is also not possible to measure velocity by synchronizing a pair of clocks at point *A*, then moving one of them to point *B*, since the result of the synchronization and measurement of the speeds of light from point *A* to point *B* and back, $v_{AB}$ and $v_{BA}$, respectively, is dependent upon the speed at which the clocks are transported from one point to the other. When synchronizing clocks via the transfer technique, if the clocks being transported are transferred at different speeds in different instances, the $v_{AB}$ and $v_{BA}$ velocity measurement results will then be different in different instances. For example, after a clock is transferred from *A* to *B* at a velocity close to the speed of light, the $v_{AB}$ velocity subsequently measured will be arbitrarily great, while the $v_{BA}$ velocity will be arbitrarily close to $c/2$. During such synchronization, the light arrives at point *B* from point *A* almost instantaneously, but travels back two times slower than usual. During very slow transfer, the $v_{AB}$ and $v_{BA}$ velocities will be equal to one another.

So what clock transfer speed is "correct"? It is impossible to answer this question, especially since clocks at different points in space are synchronized in the STR using light signals rather than by means of moving them from one point to another. Many people today see the equality of the speeds of light in opposite directions as an obvious "fact", but no grounds exist for the *a priori* preference of the slow transportation of clocks over fast transportation.

It should be noted that the problem of the speed of light in one direction is not of topical interest in practice, since the speed of light is actually measured using one solitary clock and a mirror. During this solitary clock method, the time interval between light pulse dispatch to the mirror and the reception of the pulse returned to the initial point after being reflected from the mirror is measured. Velocity is calculated for the doubled distance between the clock and the mirror and the light travel time in the back and forth directions. Strictly speaking, velocity measured in this manner constitutes the average speed in the back and forth directions – this is because the speed there may not equal the speed back. The equality of this average speed of the *c* constant is an experimental fact.

No clock synchronization problems arise during the measurement of average speed. No matter how we synchronize the second clock, the average speed of light measured in the back and forth directions without assumptions would equal the *c* constant. This is obvious, since the experimental result is not dependent either upon the readings of the clock at point *B* or even upon its presence there.

It is frequently said that Rømer measured the speed of light in one direction. It may seem strange, but Rømer velocity is also the velocity obtained under the tacit assumption of the equality of the speeds of light in opposite directions. The fact of the matter is that Rømer and Cassini were speculating about the movement of Jupiter's satellites, automatically assuming that the observers' space was isotropic. The Australian physicist Karlov [3] showed that Rømer actually measured the speed of light by implicitly making the assumption of the equality of the speeds of light back and forth.

Poincare examined the proposition of the equality of the speed of light from *A* to *B* and the speed from *B* to *A*, and this proposition in particular became the principal postulate of Einstein's 1905 work [4], although it was not presented in the form of a postulate, but rather in the form of a "definition", which preceded two Einsteinian principals that are often called postulates. In a later work [5], Einstein called this "definition" an assumption, during which he noted that it pertains not only to the speed of light, but also to velocity in general. In this work, Einstein wrote: "But if velocity at the speed of light is fundamentally impossible to measure without arbitrary assumptions, we then also have the right to make arbitrary assumptions about the speed of light. We will now assume that the speed of light propagation in a vacuum from point *A* to point *B* is equal to the speed of light passing from *B* to *A*". In truth, unlike Poincare, who adhered to the conventionalist point of view, Einstein, by alluding to the impossibility of measuring velocity in one direction without arbitrary assumptions, was inclined to regard the arbitrary assumption of the inequality of the speed of light in opposite directions as unnatural and "highly improbable" [6].

It is often said that the equality of the speeds back and forth is obvious, since space is isotropic, and that inequality is unobvious. This is not the case. The fact that light requires more time to move from point *A* to point *B* than to move from *B* to *A* is also obvious if, for example, point *A* is located in the stern and point *B* in the bow of a spacecraft that is moving relative to us and we track the process of light movement from *A* to *B* and back not from within, but rather from without. In principle, both the equality and the inequality of this craft's light propagation times from point *A* to point *B* and back can be found from a host of other reference systems that are in motion relative to this craft, even if the clocks of these systems have been synchronized using Einstein's method. In this vein, what is the basis on which the clock inside the craft is synchronized without allowance for the objective results of the observation of light behavior inside the craft obtained from different reference systems outside the craft?

During the 1960s and 1970s, references were often encountered in abstract journals to foreign works in which versions of the special theory of relativity based on the proposition of the inequality of the speeds of light in opposite directions were examined. These versions were called ε-STR and consistently described everything that the STR describes. In truth, most of them were more "ponderous" and less convenient than Einstein's version, since they violated the requirement of the immutability of the mathematical form of notation of laws in different reference systems. Most of the works of these authors were not opposed to Einstein's version, but rather demonstrated the consistency of an untraditional approach. The authors of these works attempted, by disrupting the mathematical beauty of the STR, to uncover its physical content and to clear up the enigma of the speed of light in one direction. Why nature does not permit us to measure the speed of light in one direction without arbitrary assumptions! Is this randomness or something deeper? The developers of the alternative theories did not answer this question.

One of the authors of this booklet tried to answer these questions. By 2000, he had written the book "Entering the Third Millennium Without Physical Relativity?", which the *CheRo* Publishing House released that same year [7]. In the book, based on the principle of the equal status of assumptions of the equality and inequality of the speed of light in opposite directions, a means was proposed for solving the synchronization problem and the related problem of the dependence of the magnitude of the physical quantities of a body that are inherent in the body itself upon the reference systems.

The problem of relativistic quantities was solved by means of refining the concept of an “object” and viewing an object as a set of subobjects (objects with a higher degree of concretization), each of which has not relative, but rather absolute dimensions. The relativity of simultaneity is responsible for the existence of these subobjects.

The refinements in the concept of a “physical object” proved to be sufficient to do away with the relativity of the magnitude of physical quantities without the involvement of a dedicated reference system or a global environment. For this reason, the author felt that the matter was resolved (at least as far as he was concerned) and that dealing with a global environment was superfluous. The solution at which we arrived over the course of our joint work on developing the approach described in the book “Entering the Third Millennium Without Physical Relativity?” was even more unexpected. We discovered the possibility of simulating relativistic effects using the simplest techniques of pre-Einsteinian classical physics based on the example of the movement of objects in a material medium. Here, in order to facilitate simulation, it was not necessary for us to examine movement at velocities commensurate with the speed of light. Within the model, effects are manifested in an explicit form at the usual “terrestrial” velocities with which we deal in our everyday life. The possibility of simulating STR effects with the involvement of an environment and the absence of such models in other versions made it necessary to take a new look at the old and the apparently once and for all resolved problem of the existence of a world environment.

In the booklet that you are holding in your hands, a theoretical STR model is described, which we also call an STR simulation. The booklet is a portion of a book that we intend to write and release in the near future. In the booklet, Einstein’s STR is simulated based on the example of barges, shuttles, and boats that travel at the usual speeds in an aquatic environment. Simulation did not require anything from us other than the most elementary rules of classical physics. We hope that, in reading the booklet, you will see how simple the foundation of the theory now called the STR is. Would you not then come to the conclusion that the openwork four-dimensional mathematical superstructure adorning this simple, to the point of primitiveness, foundation is artificial in nature? Time will tell.

In the booklet, we are not revealing all the deliberations that led us to construct the simulation examined in the book. However, we would like to note that the simulation is based not on contrivances for the sake of contrivances, but rather on our notions of how interaction occurs in a material world, the elements of which are not linked to one another by anything other than interactions through a “void”.

The booklet includes the body of the text and attachments. During the first reading, it may be best not to refer to the materials in the attachments, so the essence of the simulation as a whole can be perceived. The reader may then either independently verify the claims made in the body of the text without detailed explanations (it is not hard to do this) or refer to the attachments.

## IN LIEU OF A PREFACE. THE ESSENCE OF THE SIMULATION

The behavior of objects that, being slow-moving, nonetheless act in accordance with laws similar to those of the special theory of relativity are examined in the booklet.

Individual barges and groups of barges located on the surface of a flat-bottomed water body with a depth of $h$, filled with slack water, will serve as the objects of our conceptual observation. The barges are equipped with hardware components that perform metrological operations. The hardware components have at their disposal speedboats that whisk over the water surface between the barges and high-speed underwater shuttles that travel between the barges and the bottom. The velocity of the speedboats and the shuttles equals $V$ and is unapproachable for the other watercraft, i.e., the velocity of the barges, $v$, which do not fall into the category of high-speed watercraft, correspond to the inequality $v < V$. Each barge is equipped with a clock, during which a high-speed shuttle that continuously moves along a plumb line (relative to this barge) between the barge and the bottom performs the function of the pendulum. Each shuttle trip to the bottom and back requires a time of $\Delta t(1) = 2h/V_Z$ , where $V_Z$ – the speed of submersion and surfacing of the underwater shuttle, and is accompanied by the replacement of the clock readings with a standard unit quantity that is uniform for the barge. This standard quantity for the barges both at rest and in motion equals $2h/V$. The shuttle clock "mechanism" controls not only the clock's hands, but also all the barge hardware components, thereby ensuring the proportionality of their working speed to the clock's working speed. We assumed that the $t$ time scale for barges at rest relative to the water equaled the time scale of our conventional "terrestrial" clock, as well as that the reading replacement rate on the barges at rest and our clock was identical.

During phase one, we examined a group of barges at rest. Here, we assumed that the clock readings on the this group's various barges were not synchronized, i.e., when the working speeds of the clocks on each barge in the group are identical, their readings at a given moment in time might be different.

Assuming that the barges might change their position due to certain external causes (for example, because of the wind), we entrusted the hardware components with the function of maintaining the distance between this group's barges by means of interaction between the barges using the speedboats.

The procedure for maintaining distance consists of the following.

A speedboat is dispatched from each barge to the neighboring barge, and upon reaching it, the boat goes back again. The barge's hardware components, using their clocks, measure the boat's time of movement to the neighboring barge and back, then approach or move away from the neighboring barge as necessary in order to maintain this time and the immutability of the "radar" distance. This method for maintaining the "radar" distance between barges does not require the synchronization of the readings on the different barges and makes it possible to track the distance of the neighboring barges from each of the barges independently, without resorting to the measurement of the boat movement time from one barge to the another using synchronously running clocks on these barges.

We then examined a group of barges located at the points of intersection of an imaginary coordinate grid of the $K'$ coordinate system. The group is initially at rest on the water body surface, after which it is transformed, together with the $K'$ coordinate system that belongs to it, from a state of rest to a state of motion at a velocity of $v$ in the direction of the $X'$ axis (this axis lies on the water surface). As the group of barges accelerates to a velocity of $v$, the speed at which the clocks tick and the response time of the hardware components on the barges decreases. This occurs due to the fact that as the barges move at a velocity of $v$, the $V_Z$ submersion and surfacing speed of a shuttle moving through the water between a barge and the bottom along the hypotenuses of right-angled triangles is equal to $V\sqrt{1-(v/V)^2}$ . Time on the moving barges, which we named simulated time, $t'$, also flows more slowly than our time, $t$, by $1/\sqrt{1-(v/V)^2}$ times.

The lateral dimensions of the group are retained in this instance.

Indeed, let us assume that a boat is sent out from and returns to a barge, $r'_{o'}$, that is moving within the $R'$ group and that is located at the origin of coordinates of the $K'$ system along the $Y'$ axis at a point with a coordinate of $y'$ relative to the neighboring barge, $r'_{y'}$, in this same group. If the $Y'$ axis is located on the water surface perpendicular to the $X'$ axis, the boat then moves over the water surface along the hypotenuses of right-angled triangles at a velocity of $V$. This corresponds to the movement of a boat along the $Y'$ axis at a velocity of $V_Y$ in our time scales and with a length equaling $V\sqrt{1-(v/V)^2}$ . Since the $t'$ time equals $t\sqrt{1-(v/V)^2}$ , the simulated time of movement of the boat from barge $r'_{o'}$ to barge $r'_{y'}$ and back, $\Delta t'$, is independent of the speed of movement of the $R'$ group, as well as the distance between barges $r'_{o'}$ and $r'_{y'}$, and the hardware components perceive the group as unchanged when the velocity changes.

However, the longitudinal dimensions (in the direction of the $X'$ axis) of the barge group in motion are contracted for the following reason.

In negotiating the distance, $l_{o'x'}$, between barge $r'_{o'}$, which is located at the origin of coordinates, O$'$, and barge $r'_{x'}$, which is located on the $X'$ axis at a point with a coordinate of $x'$, the boat needs a $\Delta t_1$ time that equals $l_{o'x'}/(V-v)$ in order to move from barge $r'_{o'}$ to barge $r'_{x'}$, and a $\Delta t_2$ time that equals $l_{o'x'}/(V+v)$ for the trip back. The total time of movement, $\Delta t_1 + \Delta t_2$, from barge $r'_{o'}$ to barge $r'_{x'}$ and back comes to $2l_{o'x'}V/(V^2 - v^2)$. According to the barge's slow clocks, the $\Delta t'_1 + \Delta t'_2$ time is $1/\sqrt{1-(v/V)^2}$ times shorter and comes to $2l_{o'x'}/V\sqrt{1-(v/V)^2}$ .

If the hardware components do not maintain the distance between barges, the instruments on barge $r'_{o'}$ would then perceive this as an increase in the distance between the barges in the direction of the $X'$ axis by $1/\sqrt{1-(v/V)^2}$ times. But the instruments, in tracking the distance between the barges using the radar technique, keep the radar distance unchanged, which we perceive as the contraction of $l_{o'x'}$ by $1/\sqrt{1-(v/V)^2}$ times. We called the physical quantities expressed through simulated distances and times the simulated quantities.

We then made the transition to an examination of the synchronization of the clocks of two groups of barges – group $R$ and group $R'$ – and the related coordinate systems, $K$ and $K'$. The $R$ group and the $K$ system are at rest on the water, while the $R'$ group and the $K'$ system are in motion on the water and relative to the $R$ group at a velocity of $v$.

Imagine that at a certain moment in time when the origin of coordinates and the axes of the $K$ and $K'$ coordinate systems coincide, the readings on all the barges of the barge groups at rest and in motion were reset to zero. From that moment in time forward, the synchronous change in the readings on all the barges of the barge group in motion occurs more slowly than the synchronous change in the readings on the barges of the group at rest.

If the hardware components on the barges of the group at rest, $R$, track the clock of barge $r'$ of the group in motion, $R'$, which is moving past them, they then record the slowness of the clock rate on moving barge $r'$. If the hardware components on the barges of the group in motion, $R'$, track the clock on barge $r$ of the $R$ group, which moving past them, but is at rest relative to water, they then record the fastness of the clock rate on barge $r$. There is no symmetry of any kind. What we have here is the asymmetry of the clock movement speeds on the barges at rest and in motion. The simulated time readings of the group in motion are linked to the time readings of the group at rest by the transformations $t' = t\sqrt{1-(v/V)^2}$ and $t = t'\Big/\sqrt{1-(v/V)^2}$ . The coordinate transformations take the form of $x' = (x - vt)\Big/\sqrt{1-(v/V)^2}$ , $x = (x' + v't')\sqrt{1-(v'/V')^2}$ , and $y' = y$, where the primed quantities are expressed in the distance and time scales of the barge group in motion.

It is clear that if the hardware components of the group in motion, $R'$, now measure the speed of movement of a boat from one of the barges in their group to another barge in this same group using the synchronously running clocks on these barges, they will then find that the boat's speed of movement in the barge group's direction of movement, which we see from the outside, and opposite its direction of movement, are different.

We then assumed that the hardware components on the $R$ and $R'$ group barges are not in contact with the water and have no information concerning their motion or rest relative to the water. Not finding a basis for synchronization during which the velocity of a boat back and forth is assumed to be different, the hardware components resynchronize the clocks within the group of barges in motion, $R'$, so that the boat's speed of movement there becomes identical to the boat's speed of movement back. In this instance, the time after resynchronization, $t''$ – we named this $t''$ time the double simulated time – is linked to the simulated time, $t'$, by the correlation $t'' = t' - x'v/V^2$, while the coordinates and the clock readings are linked by the transformations $x' = (x - vt)\Big/\sqrt{1-(v/V)^2}$ , $y' = y$ , and $t'' = (t - xv/V^2)\Big/\sqrt{1-(v/V)^2}$ , as well as $x = (x' + v''t'')\Big/\sqrt{1-(v''/V'')^2}$ , $y = y'$ , and $t = (t'' + x'v''/V''^2)\Big/\sqrt{1-(v''/V'')^2}$ . Here, the quantities with double primes are expressed through the double simulated time. The transformations obtained are consistent with the direct and inverse Lorentz transformations to notational accuracy. In particular, this results in the fact that by tracking the clock rate of barge $r$ at rest in the water, which is motionless relative to the water, but moves past a barge of the group in motion, the hardware components on the group of barges in motion, $R'$, detect the slowness of the clock rate on barge $r$. The results of the measurements made by the hardware components on the barges of the groups in motion and at rest become symmetrical. The same thing is true of the distances.

INTRODUCTION

Within the framework of the pre-Einsteinian ethereal world view, it was thought to be natural that in a laboratory moving through the ether at a velocity of $v$, the longitudinal speed of light, $c_{long}$, in the direction of its movement – from point $a$ on the "stern" to point $b$ on the "bow" – equals $c–v$, while in the direction opposite that of movement (from point $b$ to point $a$), $c+v$. The time of light propagation from point $a$ to point $b$, $\Delta t_{ab}$, must be equal to $L/(c–v)$, where $L$ – the distance between points $a$ and $b$, while the light propagation time in the reverse direction, $\Delta t_{ba}$, is $L/(c+v)$. It was assumed that the total time of light propagation from point $a$ to point $b$ and back to point $a$, $\Delta t_{aba}$, is determined by the formula

$$\Delta t_{aba} = \frac{2L}{c(1-v^2/c^2)}. \tag{I.1}$$

It must be different from the velocity in the ether, $c$, according to the concepts of this time, and the speed of light propagation in the laboratory in the direction perpendicular to the laboratory's longitudinal axis, which is aimed along the line of travel. In this instance, the lateral speeds of light propagation from one of the side walls to another and in the reverse direction, $c_{lat}$, must be equal to one another, and are linked to the $c$ and $v$ velocities by the formula $c_{lat} = c\sqrt{1-(v/c)^2}$. Consequently, the time required for light to traverse a distance of $L$ from point $a$ to point $d$ and back to point $a$ in the lateral direction, $\Delta t_{ada}$, should be linked to distance by the correlation

$$\Delta t_{ada} = \frac{2L}{c\sqrt{1-(v/c)^2}}. \tag{I.2}$$

It seemed obvious that, as is clear from formulas (I.1) and (I.2), the ratio of $\Delta t_{aba}$ to $\Delta t_{ada}$ when the distance of points $b$ and $d$ from point $a$ is identical, must be equal to $1\big/\sqrt{1-(v/c)^2}$. At the time, the technical capability existed for the indirect experimental determination of this ratio, and Michelson and Morley did it. The experiment indirectly demonstrated the equality of the $\Delta t_{aba}$ and $\Delta t_{ada}$ time values.

At first, this result seemed strange and inexplicable to the physicists of the late 19th century. However, FitzGerald and Lorentz quite quickly found an explanation for the result obtained. According to the explanation of FitzGerald and Lorentz, when moving through the ether, a body interacts with the latter and is shortened by $1\big/\sqrt{1-(v/c)^2}$ times. Due to this shortening, the time of light propagation back and forth in the longitudinal direction, $\Delta t_{aba}$, proves to be $1\big/\sqrt{1-(v/c)^2}$ times less than anticipated, and consequently, is exactly equal to the light propagation time back and forth in the lateral direction.

The possibility of detecting an ethereal wind by means of measuring the $\Delta t_{ada}$ time, and based on it, the lateral velocity, $c_{lat}$, equal to $2L/\Delta t_{ada}$, would seem to follow from formula (I.2), thereby doing away with the effect of longitudinal contraction on the measurement result. Michelson and Morley were unable to perform such a measurement for technical reasons;

however, it is clear to us now that the $\Delta t_{ada}$ time measured by a moving clock would not be increased by $1/\sqrt{1-(v/c)^2}$ times, as formula (I.2) indicates, due to the slowing of the rate of the moving clock not taken into account therein. This slowing offsets the anticipated increase in the $\Delta t_{ada}$ time. The $c_{lat}$ velocities in the ether and in the moving laboratory would be in agreement. An experiment that Kennedy and Thorndike conducted using an asymmetrical interferometer confirms this effect.

In popular and educational books on the theory of relativity, it is frequently claimed that Michelson and Morley experimentally proved the fallacy of the ethereal concept. This is an untrue statement. The outcome of the Michelson-Morley experiment demonstrated the impossibility of detecting ether using an experiment of this type, but not the absence of ether. One must not lose sight of the fact that the results of the Michelson and Morley experiment did not prevent the notions about the ether from being retained for a good two decades after they obtained their negative measurement result. Michelson himself and Lorentz shared these notions. Indeed, FitzGerald and Lorentz explained this result by way of the longitudinal shortening of objects moving through the ether, i.e., they explained it within the framework of the ethereal world view. And so it was that in the waning years of his life, in 1952, Einstein wrote in the article "Relativity and the Problem of Space": Concerning the experiment of Michelson and Morley, H. A. Lorentz showed that the result obtained at least does not contradict the theory of an ether at rest" [8].

In this regard, the remark of a proponent and popularizer of the theory of relativity, M. von Laue, should also be clear, who wrote: "…it was experimentally impossible to make a choice between this theory (the Lorentz theory) and Einstein's theory of relativity, and if the Lorentz theory nonetheless took a back seat – even though it still has proponents among physicists – this then undoubtedly occurred due to reasons of a philosophical nature" [9].

Commenting on this statement of the German physicist M. von Laue, Soviet physicist A. Timiryazev wrote: "This argument does not have compulsory force for a physicist: for him, philosophy not confirmed by experience is an empty sound" [10].

How should M. von Laue's remark that it is experimentally impossible to make a choice between the Lorentz theory and the Einstein theory be taken? Indeed, according to Lorentz, reference systems at rest in the ether and inertially absolutely moving through the ether are not physically equal. Is this circumstance really in agreement with the fact of the equality of inertial systems in Einstein's STR?

It is.

The equality of inertial systems in the STR is expressed by way of the invariance of the mathematical notation of the laws of nature in these systems, but this form of equality historically migrated to Einstein's STR from the Lorentz theory. Indeed, the transformations that ensure the immutable form of notation of these same Maxwell equations in different, physically unequal inertial reference systems appear in Lorentz's work as a consequence of the requirement for such immutability. While Einstein tied the immutability of the form of notation of the physical laws of nature in different reference system to physical equality, Lorentz demonstrated that this requirement can be met even in physically unequal systems absolutely at rest and absolutely in motion. I.e., Lorentz showed that physically unequal inertial reference systems can be transformed into mathematically equal ones by imposing the requirement of invariance on them.

Is this possible or not? The fact that it is possible is revealed on the pages of this booklet. Two groups of barges are examined in the booklet, one of which is at rest on a water surface, while the other is in motion relative thereto at a velocity of $v$. Primal processes occur on the barges, information on the progress of which is transferred from barge to barge by auxiliary boats that have a constant velocity of $V$ relative to the water. As concerns the barge group in motion, the velocity of the auxiliary boats in their direction of movement equals $V - v$, while in the direction opposite that of their movement, it is $V + v$. The processes occurring on the barges make it possible to fully simulate STR effects, including Lorentz contraction, time dilation, relativistic Doppler effects – both longitudinal and lateral – and the relativistic law of the addition of velocities. An analogy of the STR simulation model is achieved by assuming the equality of the velocities of the auxiliary boats relative to the barge group in motion in different directions. The possibility of presenting the simulated effects using a simulated model of space-time provides food for thought concerning the relationship of formal space-time to the real world. It is possible to arbitrarily interpret the material contained in the booklet based on an examination of the movement of the barges on the water as it relates to Einstein's STR, but a fact is still a fact – in the physically unequal and physically asymmetrical coordinate systems linked to the barge groups at rest on the water surface and in motion on the water, the simulation of the full symmetry of the processes being observed and the equality of the systems with reference to the formal description of these processes is possible.

# SIMULATION

***of the Kinematic Effects of the Special Theory of Relativity***

## Body of the Text

## 1. Subjects and Essence of the Simulation

In the body of the text, we will not go into the details, which can be examined separately from the description of the essence of the matter without detriment to the comprehension of the material. We have provided these details in the section entitled "Attachments".

Let us mentally observe "from the outside" the behavior of objects that, being slow-moving, nonetheless act in accordance with laws similar to those of the special theory of relativity. Two groups of barges distributed over the surface of a boundless flat-bottomed water body – group $R$ and group $R'$ – will serve as the subjects of our mental observation. Barge group $R$ is at rest on the surface, while the group $R'$ barges are in motion on this surface at the same velocity, $v$, and in the same direction. In examining the geometric dimensions of sections of the barge groups, we will regard the barges themselves as point objects, the dimensions of which are negligibly small as compared to those of the barge group sections.

We will presume that the water in the water body is slack. The depth of the water body is universally identical and equals $h$. On each barge, high-speed underwater shuttles that have a velocity of $V$ (relative to the water) deliver sand from the bottom of the water body. We will call the watercraft that, under our assumption, have an identical velocity of $V$ not attainable by the other watercraft high-speed. One high-speed cargo shuttle is assigned to each barge and a specific amount of sand is placed into each such shuttle, which we will call one shuttle of sand. Each shuttle continually makes shuttle trips from a barge to the bottom and back over the shortest possible route, moving along a plumb line that runs from a given barge to the bottom. The times required for a shuttle to pick up the sand from the bottom and to offload it from the shuttle onto a barge are negligibly small as compared to the shuttle movement time from the barge to the bottom and back. Thus, the time required to deliver the sand to a barge at rest, $\Delta t$, is given by the formula

$$\Delta t(1) = 2h/V \qquad (1)$$

for one shuttle of sand, and by the formula

$$\Delta t(k) = 2kh/V \qquad (2)$$

for $k$ shuttles of sand. By the time denoted with the letter $t$, we mean the time read by our clock – the clock of the outside observers. The number one and the letter $k$ in parentheses associated with the $\Delta t$ symbol in formulas (1) and (2) show that reference is being made the $\Delta t$ time interval needed in order to deliver one or $k$ shuttles of sand, respectively.

The plumb movement velocity (the submersion and surfacing speed), $V_Z$, of a shuttle delivering sand to a barge moving at a velocity of $v$ ($v < V$) is slower than the $V$ velocity and is given, as is clear from Fig. 1, by the formula

$$V_Z = V\sqrt{1-(v/V)^2}\ . \qquad (3)$$

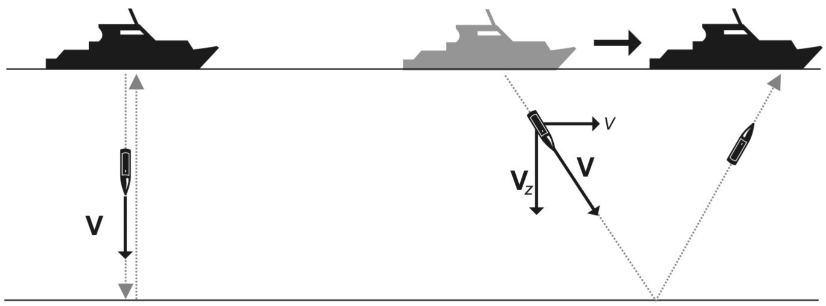


*Fig. 1. Barge r (on the left) is at rest on the water surface. A shuttle is moving from the barge to the bottom and back at a velocity of V. Barge r′ (on the right) is in motion on the water body surface at a velocity of v. The speed of movement of the shuttle equals V, the shuttle's horizontal velocity component equals v, and its vertical component, $V_Z$, equals* $V\sqrt{1-(v/V)^2}$ .

Thus, a time of $\Delta t(1') = 2h/V_Z$ is needed in order to deliver one shuttle of sand to a barge drifting at a velocity of $v$, or with allowance for formula (3)

$$\Delta t(1') = \frac{2h}{V\sqrt{1-(v/V)^2}}, \quad (4)$$

The prime near the number one means that reference is being made to the delivery of sand to a barge in motion (not at rest).

Delivering $k'$ shuttles of sand to a barge proceeding at a velocity of $v$ requires a time of:

$$\Delta t(k') = \frac{2k'h}{V\sqrt{1-(v/V)^2}}. \quad (5)$$

The letter $k'$ in parenthesis in the notation $\Delta t(k')$ indicates that reference is being made to the $\Delta t$ time interval needed in order to deliver $k'$ shuttles of sand. As in the case of the primed number one, the presence of a prime near the letter $k$ suggests the delivery of sand to a barge in motion (not at rest).

Among the barges, if there is a barge $r'$ that is in motion on the water surface at a velocity of $v$ and a barge $r$ that is at rest on the water, the rate of increase in the quantity of sand on barges $r'$ and $r$ will be different. It follows from formulas (2) and (5) that at $k' = k$

$$\Delta t(k') = \Delta t(k)\Big/\sqrt{1-(v/V)^2}, \quad (6)$$

while at $\Delta t(k') = \Delta t(k)$

$$k' = k\sqrt{1-(v/V)^2}, \quad (7)$$

i.e., the times required for delivering an identical quantity of sand to a certain barge $r'$ in motion at a velocity of $v$ and to a certain barge $r$ at rest differ from one another by $1\Big/\sqrt{1-(v/V)^2}$ times. The quantities of sand delivered to barge $r$ at rest and to barge $r'$ in motion when the time for its delivery is identical also differ from one another by as many times.

Let's say that the barges have a roughly identical maximum load-carrying capacity, and assuming that the quantity of sand onboard is close to critical, they sink and cease to exist, whereupon new barges appear to replace them, on which there is no sand at the time of their appearance ("birth"). If the critical quantity of sand for the barges in motion equals an average of $K'$, then according to formula (5), the average "lifetime" of the barges, $\overline{\Delta t}(K') = \dfrac{2K'h}{V\sqrt{1-(v/V)^2}}$, from the moment of their "birth", which consists of the commencement of the loading of sand onto them, till their "death", is dependent upon their speeds of movement. If it is presumed that the critical quantity of sand for the barges in motion and those at rest is identical, i.e., if $K' = K$, then the barges in motion at a velocity of $v$ will live an average of $1\big/\sqrt{1-(v/V)^2}$ times longer than the barges at rest.

We are talking about the average lifetime of an individual barge, assuming that the lifetime of an actual barge might differ somewhat from the average lifetime due to the approximate nature of the critical quantity of sand, or due to unforeseen circumstances (for example, emergency situations). For this reason, we assume that even among barges residing in an identical kinematic state (for example, in a state of rest), a host of "mixed-age" barges with different quantities of sand onboard is present on the water body's surface.

The dependence of the average lifetime of the barges upon speed of movement, as well as some of their other properties, is a convenient feature that makes it possible to simulate the special theory of relativity using elementary methods of classical mechanics. Simulation yields Lorentz transformations, the relativistic addition of velocities, the effects of relativistic time dilation and the contraction of the longitudinal dimensions of moving objects, the relativity of simultaneity, and the relativistic Doppler effect, including the transverse effect. In general, simulation yields all the effects of the special theory of relativity and is easily presented in the form of a model of the four-dimensional space-time world. Moreover, simulation affords the opportunity of clearly seeing the causes of the relativistic effects and paradoxes of the special theory of relativity, such as the twin paradox for instance, and makes it possible to answer not only the question of "How?", but also the question of "Why?".

At first glance, it is impossible to simulate not only the special theory of relativity, but even the time dilation it describes based on the slowing of the rate of sand loading onto the barges during their movement, if only for the reason that the special theory of relativity is a relativistic theory. The slowing of process time on one of two identical bodies, *a* and *b*, in motion relative to one another occurs therein relatively and symmetrically. The relativity and symmetry are manifested by way of the fact that if the processes in body *b* are slowed relative to the reference system associated with body *a*, the processes in body *a* are then also exactly slowed relative to the reference system associated with body *b*. In our case, however, the increase in the quantity of sand on the barge in motion, $r'$, occurs more slowly than the increase in the quantity of sand on the barge at rest, $r$, absolutely and asymmetrically. The absoluteness and asymmetry are manifested by way of the fact that if the quantity of sand on the barge in motion increases more slowly than the quantity of sand on the barge at rest, this fact is not dependent upon the barge from which these processes are observed. This would seem to make the model involving barges obviously unacceptable for simulating the special theory of relativity.

But we will not jump to conclusions! We are after all talking about a model, and the model's objective consists not of its complete oneness with the object being modeled, but rather the formal equivalence of the phenomena it describes under specific conditions to the phenomena that are observed within the object being modeled.

## 2. Hardware Components on the Barges. Primary Objective of the Hardware Components

We will assume that we, as outside observers, have all the essential tools for observing the barges, as well as the devices for measuring physical quantities. We will also assume that there are no observers on the barges – hardware measuring devices have been placed on them that possess limited capabilities. The makeup of the hardware components on the barges does not include long rulers or rods that connect the individual barges, and all communications and interactions between the barges are accomplished using speedboats that travel between them. Our conventional clocks that consistently measure time on the barges at rest and in motion are not present on the barges – all processes on the barges occur in simulated time, which we will talk about further on in this text.

There are no instruments on the barges that make contact with the water, which would make it possible to record an instance of barge motion or rest relative to the water. There are also no optical instruments and radio devices on the barges that are capable of almost instantaneously transmitting information from barge to barge. The transfer of information from barge to barge on physical media is only accomplished directly (when the barges are located in direct proximity to one another) or using speedboats (that ply the water surface at a velocity of $V$), which carry the physical information media from one barge to another. Only the information contained on the physical media is regarded as documentary (documented) information.

The primary objective of the hardware components, having information at their disposal concerning the essence of the environment and concerning the fact that the rate of sand loading onto the barges at rest in the environment is higher than the rate of sand loading onto the barges in motion, consists of determining the means for exchanging documented information on the quantity of sand on the different barges, the barges that the sand reaches more quickly, and accordingly which of them are at rest. As strange as it sounds, it is impossible to solve this seemingly simple problem given the limitations cited.

### 3. Symmetry of Recording the Processes of Sand Delivery to the Barges From a Barge at Rest and a Barge in Motion

If the barges are inertial and are either not encountered at one point at all or are only encountered once, changes in the quantity of sand on the barges can only be compared using speedboats (traveling at a velocity of $V$), on which documents concerning the quantity of sand are delivered from one barge to another. For example, after meeting a barge at rest, $r$, when information concerning the quantity of sand on the barges is directly transferred from craft to craft, if barge $r'$ continues to move in a straight line, while barge $r$ remains motionless (barges $r$ and $r'$ are inertial), barges $r$ and $r'$ then cannot meet a second time. Thus, it is only possible to again obtain information concerning the quantity of sand on the other barge some time after a meeting if a boat is used. In this instance, a document indicating the quantity of sand on the other barge reaches this barge when the quantity of sand on the other barge is already not the same as it was at the time that the boat was dispatched from it. Only if the $V$ velocity is much greater than the $v$ velocity, i.e., if $V \gg v$, can the information be regarded as having been transferred instantaneously. In this case, the changes in the quantities of sand that occur between the time that the barges meet and the time that the document is transferred are directly compared. But, here, the $1/\sqrt{1-(v/V)^2}$ coefficient is almost equal to unity and the comparison results are symmetrical by virtue of the sameness of the sand increase rates on the barge at rest and the barge in motion. However, if the $V$ and $v$ velocities are commensurate, the $1/\sqrt{1-(v/V)^2}$ coefficient is then sufficiently great and the difference in the sand loading rates is great, but the effect of the delay in information transfer by boat is also great. The consequence of this effect is such that when information is transferred by boat and when conventional, identically running clocks are not present on the barges at rest and in motion, then as attachment 1 demonstrates, it is only possible to obtain symmetrical results, which do not permit the detection of the difference in the rates of increase of the quantity of sand on the barge at rest, *r*, and the barge inertially in motion, *r′*.

Yet another method is suggested for comparing the rates at which the sand reaches the barges.

If the number of boats for transferring information is unlimited, the hardware components on each barge can then continuously send information concerning the arrival of the next, preagreed – signal – portion of sand at their barge by dispatching a boat to the other barge each time that carries information on said arrival. This makes it possible to compare the frequency of arrival of signal portions of sand at a given barge to the frequency of the arrival of boats at it from the other barge.

According to the classical Doppler effect formula, the frequency of the arrival of the boats dispatched from barge *r′* at barge *r*, $f_{r\leftarrow r'}$, and the frequency of the arrival of the boats dispatched from barge *r* at barge *r′*, $f_{r'\leftarrow r}$, will be dependent upon the velocity, *v*, of barge *r′* relative to the water, as well as upon which of the barges plays the role of the transmitter and which plays the role of the receiver of the information. As barge *r′* moves away from barge *r*, the $f_{r\leftarrow r'}$ and $f_{r'\leftarrow r}$ frequencies are given by the formulas

$$f_{r\leftarrow r'} = f_{r'}/(1+v/V),$$
$$f_{r'\leftarrow r} = f_r(1-v/V),$$

where $f_r$ and $f_{r'}$ – the frequencies of the arrival of signal quantities of sand at barges *r* and *r′*, respectively, and the frequencies of the dispatch of boats from barges and *r* and *r′*, respectively, which are numerically equal to them.

According to these formulas, when the *v* velocity of barge *r′* approaches the *V* velocity, the frequency of boat arrival at the barge at rest, *r*, $f_{r\leftarrow r'}$, approaches $f_{r'}/2$, while the frequency of boat arrival at the barge in motion, *r′*, $f_{r'\leftarrow r}$, approaches zero at a finite frequency of $f_r$.

As barge *r′* approaches barge *r*, the $f_{r\leftarrow r'}$ and $f_{r'\leftarrow r}$ frequencies are then given by the formulas:

$$f_{r\leftarrow r'} = f_{r'}/(1-v/V),$$
$$f_{r'\leftarrow r} = f_r(1+v/V).$$

When the *v* velocity of barge *r′* approaches the *V* velocity and when the $f_{r'}$ value is different from zero, the frequency of boat arrival at the barge at rest, *r*, $f_{r\leftarrow r'}$, approaches infinity, while the frequency of boat arrival at barge *r′*, $f_{r'\leftarrow r}$, approaches $2f_r$.

If the $f_r$ and $f_{r'}$ frequencies are to equal one another, the $f_{r\leftarrow r'}$ and $f_{r'\leftarrow r}$ frequencies would then be different at $v \neq 0$. The $f_{r\leftarrow r'}/f_r$ and $f_{r'\leftarrow r}/f_{r'}$ ratios of the frequencies of boat arrival at a barge to the frequencies of signal quantities of sand reaching them would also be different. However, in our case, the $f_r$ and $f_{r'}$ frequencies are linked to one another by the correlation $f_{r'} = f_r\sqrt{1-(v/V)^2}$. For this reason, the following equalities can be written using the previous formulas

$$f_{r\leftarrow r'} = f_r\sqrt{1-v/V}\Big/\sqrt{1+v/V},$$
$$f_{r'\leftarrow r} = f_{r'}\sqrt{1-v/V}\Big/\sqrt{1+v/V}$$

for the case of barge $r'$ moving away from $r$, as can the equalities

$$f_{r\leftarrow r'} = f_r \sqrt{1+v/V}\Big/\sqrt{1-v/V} \,,$$
$$f_{r'\leftarrow r} = f_{r'} \sqrt{1+v/V}\Big/\sqrt{1-v/V}$$

for the case of their convergence.

The $f_{r\leftarrow r'}/f_r$ and $f_{r'\leftarrow r}/f_{r'}$ ratios of the frequencies of boat arrival at each barge to the frequencies of signal quantities of sand reaching it for the barge at rest on the water and for the barge in motion are identical and equal $\sqrt{1-v/V}\big/\sqrt{1+v/V}$ as barge $r'$ moves away from barge $r$, or $\sqrt{1+v/V}\big/\sqrt{1-v/V}$ as barge $r'$ approaches barge $r$.

This is addressed in greater details in attachment 2.

If even one of the barges violates the condition of inertness, it is then possible to ensure that barges $r$ and $r'$, having met once, will meet again some time later. For example, if some time after the barges meet, barge $r'$, having changed its direction of movement, returns to the first meeting point at the same velocity (barge $r'$ becomes noninertial at the time that it turns), it is then possible to ensure that the barges meet again and to make a second direct comparison of the quantities of sand on the barges. The data acquired will make it possible to determine the increase in sand on the barges during the time between the two barge meetings. In this instance, it becomes clear that the increase in the quantity of sand on barge $r'$ during this period is Γ times smaller than the increase in the quantity of sand on barge $r$. It is not difficult for us, as outsiders, to calculate the Γ coefficient. It equals $1\big/\sqrt{1-(v/V)^2}$ .

However, this experiment does not afford the opportunity, based on the results obtained and the information concerning the slowness of the processes of sand loading onto the barge in motion, to achieve the primary objective and to reach the conclusion that barge $r$ is at rest in the environment. The fact is that, after barges $r$ and $r'$ meet, if barge $r'$ continues moving, while barge $r$ remains at rest for a certain, let's say, arbitrarily long amount of time, then leaving the train of barges at rest, picks up the necessary speed and catches up to barge $r'$, the increase in the sand on barge $r$ would be smaller when barges $r$ and $r'$ meet. Here, this decrease would be such that it might be interpreted as proof that barge $r'$ is at rest in the environment, while barge $r$ is in motion back and forth. Based on the results of the experiments involving inertial barges, it is only possible to establish the fact that the slowing of the increase in the quantity of sand on one of the two barges during the period of time between the two meetings can be tied to its inertness, during which, formally, this slowing is qualitatively and quantitatively similar to the slowing of the aging of one of two twins in the well-known paradox. This is addressed in greater detail in attachment 3.

## 4. Simulation of Time on Individual Barges. Conventional and Simulated Times

Let's say that counters of the quantities of sand reaching the barges and identical clocks with identical faces have been placed on all the barges. The clocks are triggered by the sand quantity counters in such a way that the clock on each barge "ticks" at a frequency proportional to that of shuttle movement. The hands of the clocks on the barges traveling at a velocity of $v$ move $1\big/\sqrt{1-(v/V)^2}$ times more slowly than the hands of the clocks on the barges at rest. We will presume that the speed of movement of the clock hands on the barges at rest equals the speed of movement of the hands of our clock – the clock of the outside observers – i.e., time, $t$, including its numeric values, also flows identically for us on the barges at rest. We will denote the reading of a clock on a certain individual barge at rest, $r$, using the symbol $t_r$. Here, we will assume that the readings, $t_r$, $t_a$, $t_b$, and $t_c$, of the clocks on different barges at rest, $r$, $a$, $b$, and $c$, can differ from one another at the same moment in time up to the point that these readings are no longer synchronized. We do not view this difference in readings when the rate of their replacement is identical as a difference in the passage of time, just as we do not presume that our terrestrial time, $t$, passes differently in London and in Moscow, even though the time (the clock readings) in London $t_L$, and in Moscow, $t_M$, differ from one another at each moment in time. By the sameness of the passage of time, we mean not the coincidence of the $t_L$ and $t_M$ clock readings, which does not occur, but rather than equality of the $\Delta t_L$ and $\Delta t_M$ time intervals in these cities between two specific world events.

Unlike our time, $t$, we will call the time given by the readings of the clocks on the barges in motion at a velocity of $v$ the simulated time of the barges in motion and we will denote it using the letter $t'$ (with a prime). Concerning the simulated time on the barges in motion, $t'$, we will say that, based on our observation results, it passes more slowly that the time on the barges at rest, $t$. We will denote the $t'$ clock reading on a certain individual barge in motion, $r'$, using the symbol $t'_{r'}$ (with primes), assuming that, as in the case of the barges at rest, the clock readings on the other barges in motion may differ from one another and from the $t'_{r'}$ reading up until the moment of their synchronization.

We will presume that the signals from the sand quantity counters proceed in the form of sync pulses not only to the clocks, but also to all the hardware components located on the barges without exception, thereby assigning their operating rate and ensuring hardware component performance on the simulated time scale. The operating rate (the response time) of the hardware components on the barges in motion will then be slower than the operating rate of the hardware components on the barges at rest by $1\big/\sqrt{1-(v/V)^2}$ times.

Let's say that the time intervals $\Delta t(\Delta n_{time})$ and $\Delta t'(\Delta n'_{time})$ are used as the units of measurement of the time on the barges at rest and in motion, respectively, over the course of which the sand quantity counter readings increase by $\Delta n_{time}$ and $\Delta n'_{time}$, respectively. so that, being common and standard, $\Delta n_{time} = \Delta n'_{time}$. In this instance, the $\Delta t$ time interval and the $\Delta t'$ simulated time interval for any pair of barges in motion relative to one another between two identical events that we record are linked by the correlations

$$\Delta t' = \Delta t\sqrt{1-(v/V)^2} \text{ and } \Delta t = \Delta t'\big/\sqrt{1-(v/V)^2}\,. \qquad (8)$$

If, for any reason, the $\Delta t(\Delta n_{time})$ time measurement unit on the barges at rest has the same denomination as the $\Delta t'(\Delta n'_{time})$ simulated time unit on the barges in motion, for example, if both these units are called a minute, then according to our observations, it is possible to say that a minute of simulated time on the barges in motion lasts $1\big/\sqrt{1-(v/V)^2}$ times longer than a minute of time on the barges at rest.

If the number of operations they perform dictates the service life of the individual devices that make up the hardware components, then according to our observation results, the service life (the "lifetime") of the devices on the barges in motion will be the same $1\big/\sqrt{1-(v/V)^2}$ times greater than on the barges at rest. I.e., the "life" of the observation devices located on the barges in motion will pass more slowly than the "life" of the similar devices on the barges at rest. We note that, due to the synchronism of their own operations with those of the auxiliary devices and with the movement of the shuttles, the hardware components themselves, which may also include automatic devices, on the barges at rest and in motion "perceive" the change in the quantity of sand over the course of their lives and all the processes that occur synchronously with the operation of the sand counters on their barges as entirely identical. It is impossible for any of the instruments that are a part of the hardware components on each of the barges in motion to detect the slowness of the operating rates on a barge in motion. Due to the synchronism of the operation of these instruments with that of the other instruments and devices, all the processes and operations on the barges in motion in simulated time also occur exactly like the similar processes on the barges at rest in conventional time.

It is not difficult to see that, as noted in the previous section, if it is impossible to detect the difference in the rates at which the sand reaches the barges by means of a direct comparison, then due to the proportionality of the counter readings to the readings of the clocks on the barges, it is also impossible to detect the difference in the passage of conventional time on the barges at rest and simulated time on the barges in motion using speedboats to transfer the clock reading information. Moreover, it is impossible to detect the difference in the passage of time by simulating the Doppler effect within the aquatic environment in which the barges are located. For example, if boats are dispatched from barge $r$ to barge $r'$ with a frequency of $f_r$ and boats are dispatched from barge $r'$ to barge $r$ with a frequency of $f'_{r'}$ (in simulated time), which is numerically equal to the $f_r$ frequency, it is then not difficult to show that as barge $r'$ moves away from barge $r$, the $f'_{r'\leftarrow r}$ and $f_{r\leftarrow r'}$ frequencies of boat arrival at barges $r'$ and $r$, respectively, are identical and are given by the symmetrical formulas $f'_{r'\leftarrow r} = f_r \sqrt{1-v/V}\big/\sqrt{1+v/V}$ and $f_{r\leftarrow r'} = f'_{r'} \sqrt{1-v/V}\big/\sqrt{1+v/V}$, which, being similar to the relativistic Doppler effect formulas, do not make it possible to detect the difference in the clock rate on barges $r$ and $r'$.

As the barges converge, the $f'_{r'\leftarrow r}$ and $f_{r\leftarrow r'}$ frequencies of boat arrival at barges $r'$ and $r$, respectively, are identical and are given by the symmetrical formulas $f'_{r'\leftarrow r} = f_r \sqrt{1+v/V}\big/\sqrt{1-v/V}$ and $f_{r\leftarrow r'} = f'_{r'} \sqrt{1+v/V}\big/\sqrt{1-v/V}$.

If barge $r'$ moves along a line from which barge $r$ is located a certain distance way, the observation of a “boat-type relativistic” transverse Doppler effect is then possible, during which the equalities $f'_{r'\leftarrow r}\big/f_r = f_{r\leftarrow r'}\big/f'_{r'} = \sqrt{1-(v/V)^2}$ hold true. See attachment 4.

## 5. Simulation of the Lorentz Contraction of the Distance Between Moving Elements

We will now tie the Σ and Σ' Cartesian coordinate systems with mutually parallel axes of $X$ and $X'$, $Y$ and $Y'$, and $Z$ and $Z'$ to the barge groups at rest, $R$, and in motion, $R'$, respectively. We will direct the system $Z$ and $Z'$ axes perpendicular to the water surface and the $X$ and $X'$ axes in the direction of movement of the $R'$ group, while we will lead the $Y$ and $Y'$ axes perpendicular to the $X$, $X'$ and $Z$, $Z'$ axes, which is acceptable to do in rectangular Cartesian coordinate systems. We will presume that the hardware components of each of the barges are capable of independently measuring the distance from a given barge to the individual points of the coordinate system tied to it without the involvement of the hardware components of the other barges and without the synchronization of the clocks on the different barges. According to our proposition, the distance is measured remotely without using long rulers or tape measures in the following manner.

Let’s assume that in the Σ coordinate system, the hardware components on barge $r$, which is located at the origin of coordinates, $O$, determine the distance from the origin of coordinates, $O$, to a certain point, $a$, at an arbitrary location in the Σ system using a method that we will call pseudoradar. The essence of the pseudoradar method is as follows. A speedboat is dispatched from barge $r$ at point $O$, which goes to point $a$ using the shortest possible route, and once there, goes back to point $O$. The boat’s travel time back and forth, $\Delta t_{OaO}$, is determined at the moments of its departure and return using the readings of the clock on barge $r$, then the distance between points $O$ and $a$ is calculated using the formula $\frac{1}{2}\tilde{V}\Delta t_{OaO}$, where $\tilde{V}$ – the average velocity of the boat en route from point $O$ to point $a$ and back. Since velocity $\tilde{V}$ is not determined based on distance and time in the Σ system, but rather distance is determined based on velocity $\tilde{V}$ and time, a velocity value that is standard and unified for all the Σ system barges can either be assigned by the hardware components of the Σ system barges or taken from the outside (for example, from us). It is clear that in the Σ system, the average velocity en route back and forth, $\tilde{V}$, equals the $V$ velocity. We will denote the distance between point $O$ and point $a$ measured in this manner by the hardware components on barge $r$ using the symbol $l(½\Delta t_{OaO})$. We will denote this same distance, but measured or calculated by us in any available way, using the symbol $l_{Oa}$. The $l(½\Delta t_{OaO})$ distance and the $l_{Oa}$ distance are one and the same, while the $l(½\Delta t_{OaO})$ and $l_{Oa}$ quantities only differ from one another by the method and the location in which they are determined.

If the barges change their position due to certain external causes (for example, because of the wind), the hardware components can then maintain the distance between the barges in a given group using the speedboats. To this end, speedboats are regularly dispatched from each barge to the neighboring barges and back again. Using their clocks, the barge hardware components measure the boat movement time to the neighboring barges and back, then approach or move away from the neighboring barges as necessary in order to maintain these times and the immutability of the pseudoradar distances.

We will presume that in the Σ' coordinate system, the hardware components of a certain barge $r'$, located at the origin of coordinates, $O'$, determines the distance from the origin of coordinates, $O'$, to point $a'$ in the Σ' system exactly as this is done in the Σ system. Let's say that a quantity equal to the product of $\frac{1}{2}\tilde{V}'\Delta t'_{O'a'O'}$ is by definition regarded as the distance measured in this manner in the case at hand, $l'(½\Delta t'_{O'a'O'})$. Here, $\tilde{V}'$ is simulated, i.e., the average velocity of a boat en route from point $O'$ to point $a'$ and back, expressed through simulated time, $t'$, is by definition numerically equal to the $\tilde{V}$ velocity and consequently the $V$ velocity, while $\Delta t'_{O'a'O'}$ is the simulated time of movement of the boat en route from point $O'$ to point $a'$ and back. Unlike the conventional average velocity, $\tilde{V}$, we denote the simulated average velocity using the symbol $\tilde{V}'$ (with a prime!). We will call the pseudoradar distance determined in this manner by the hardware components of barge $r'$, $l'(½\Delta t'_{O'a'O'})$, the simulated distance, $l'(½\Delta t'_{O'a'O'})$. The simulated distance has two features that are useful to us. First, by definition, it ensures the equality of the simulated average (en route back and forth) velocity, $\tilde{V}'$, and the $V$ velocity. And second, based on our observation results, it equals the conventional distance in a direction that is transverse relative to Σ' system movement, but is $1\big/\sqrt{1-(v/V)^2}$ times greater than the conventional distance in the direction of Σ' system movement. I.e., the conventional distances that we measure between the elements of the Σ' movement system in the direction of movement are $1\big/\sqrt{1-(v/V)^2}$ times shorter than the distances between the subject elements in this system.

In point of fact, if a speedboat moves along the $Y'$ axis between point $O'$ (the origin of coordinates) and a point with a coordinate of $y'$ that lies at the $Y'$ axis – we will call this point the $y'$ point, the boat's $V$ velocity component that we record from the outside (the speed of movement to the boat along a segment of a straight line that connects points $O'$ and $y'$), $V_Y$, is then given by the formula

$$V_Y = V\sqrt{1-(v/V)^2}\,. \tag{9}$$

According to our calculations, the conventional distance between points $O'$ and $y'$ in the Σ' movement system that we record, $l_{O'y'}$, can be represented by the formula $l_{O'y'} = ½V_Y\Delta t_{O'y'O'}$, where $\Delta t_{O'y'O'}$ – the boat's conventional time of movement (that we measure using our clock) from point $O'$ to point $y'$ and back, or with allowance for formula (9)

$$l_{O'y'} = \tfrac{1}{2}V\sqrt{1-(v/V)^2}\,\Delta t_{O'y'O'}, \tag{10}$$

while according to barge $r'$ hardware component data, the simulated distance between points $O'$ and $y'$, $l'(\frac{1}{2}\Delta t'_{O'y'O'})$, is expressed by the formula

$$l'(\tfrac{1}{2}\Delta t'_{O'y'O'}) = \tfrac{1}{2}\tilde{V}'\Delta t'_{O'y'O'}. \qquad (11)$$

where $\Delta t'_{O'y'O'}$ is the boat's time of movement from point $O'$ to point $y'$ and back, simulated on the barge at point $O'$.

By analogy with the left-hand equality of correlation (8), since

$$\Delta t'_{O'y'O'} = \Delta t_{O'y'O'}\sqrt{1-(v/V)^2},$$

while $\tilde{V}'$ by definition equals $V$, it then follows from formulas (10) and (11) that

$$l_{O'y'} = l'(\tfrac{1}{2}\Delta t'_{O'y'O'}), \qquad (12)$$

which suggests the equality of the numeric values of the conventional distance, $l_{O'y'}$, and the simulated distance, $l'(\frac{1}{2}\Delta t'_{O'y'O'})$, and in generalized terms, implies the equality of the numeric values of the lateral dimensions.

We will now examine the movement of a speedboat between point $O'$ (the origin of coordinates) and a point with a coordinate of $x'$ that lies at the $X'$ axis – we will call it point $x'$. According to our data, the boat's speeds of movement relative to these points in opposite directions equal $V - v$ and $V + v$. At the conventional distance between points $O'$ and $x'$, which equals $l_{O'x'}$, the boat's time of movement from point $O'$ to point $x'$ and back, $\Delta t_{O'x'O'}$, equals $l_{O'x'}/(V - v) + l_{O'x'}/(V + v)$, i.e.,

$$\Delta t_{O'x'O'} = \frac{2l_{O'x'}}{V(1-v^2/V^2)}. \qquad (13)$$

According to our data, the boats average speed of movement along the $X'$ axis relative to points $O'$ and $x'$ en route back and forth, $\tilde{V}_{X'}$, equals $2l_{O'x'}/\Delta t_{O'x'O'}$, or with allowance for the previous equality,

$$\tilde{V}_{X'} = V(1-v^2/V^2). \qquad (14)$$

According to our calculations, the conventional distance between points $O'$ and $x'$ in the $\Sigma'$ movement system, $l_{O'x'}$, can be expressed by the formula

$$l_{O'x'} = \tfrac{1}{2}\tilde{V}_{X'}\Delta t_{O'x'O'}, \qquad (15)$$

while according to the calculations of the hardware components on barge $r'$, the simulated distance between them, $l'(\frac{1}{2}\Delta t'_{O'x'O'})$, is expressed by the equality

$$l'(\tfrac{1}{2}\Delta t'_{O'x'O'}) = \tfrac{1}{2}\tilde{V}'_{X'}\,\Delta t'_{O'x'O'}. \qquad (16)$$

By analogy with the right-hand equality of correlation (8), since $\Delta t_{O'x'O'} = \Delta t'_{O'x'O'}\big/\sqrt{1-(v/V)^2}$, then taking formula (14) into account, it follows from formulas (15) and (16) that

$$l_{O'x'} = \sqrt{1-(v/V)^2}\, l'(\tfrac{1}{2}\Delta t'_{O'x'O'}) \text{ or } l'(\tfrac{1}{2}\Delta t'_{O'x'O'}) = l_{O'x'} \Big/ \sqrt{1-(v/V)^2} \quad . \quad (17)$$

According to formula (17), the numeric value of the distance that we measure between points *O′* and *x′*, $l_{O'x'}$, is $1\Big/\sqrt{1-(v/V)^2}$ times smaller than the numeric value of the distance measured in the Σ' coordinate system, $l'(½\Delta t'_{O'x'O'})$. In generalized terms, this suggests the contraction of sections of the group in motion, *R′*, by $1\Big/\sqrt{1-(v/V)^2}$ times.

Strictly speaking, formulas (12) and (17) should be written in the form

$$\{l'(\tfrac{1}{2}\Delta t'_{O'y'O'})\} = \{l_{O'y'}\},$$
$$\{l'(\tfrac{1}{2}\Delta t'_{O'x'O'})\} = \{l_{O'x'} \Big/ \sqrt{1-(v/V)^2}\},$$

where the numeric values of the physical quantities are indicated in the braces. In fact, until the equality of the physical quantity units in different reference systems is proven, the question of the content of the measured physical quantities remains open.

If $l'(½\Delta t'_{O'x'O'})$ equals $l'(½\Delta t'_{O'y'O'})$, while $l'(½\Delta t'_{O'y'O'})$ equals $l_{Oy}$, and the *X′* axis slides along the *X* axis, then at the moment in time when the *O* and *O′* origins of coordinates coincide and points *y* and *y′* coincide, points *x* and *x′* at *x* = *y*, due to the shortness of the *O′x′* segment that follows from correlation (17), will be in different locations according to our observation results (point *x′* will be located closer to the origin of coordinates than point *x*).

We note that the hardware components of groups *R* and *R′* cannot make a direct comparison of their kilometer and a moving kilometer by means of combining them at a certain moment in time before clock synchronization has been performed; therefore, the possibility of fixing the positions of moving elements at different points on the water surface at a given moment in time is not ensured.

### 6. Synchronization of the *R* and *R′* Group Clocks

Imagine that the readings of the group *R* clocks have been synchronized in such a manner that at a given moment in our time, *t*, they are identical according to our observation results. The group *R* hardware components can synchronize the clocks in two ways. First, they can transfer the readings of our clock to all the clocks on their barges at any moment in our time. And second, they can do this by obtaining information from us that their group is at rest on the water and that the velocity of the boats is identical in all directions. For example, in order to synchronize the clocks on the barges, one of which is located at the origin of coordinates, *O*, of the Σ system, while another is located on this system's *X* axis at a point with a coordinate of *x*, it is necessary to first send a boat from point *O* to point *x*, and once it reaches point *x*, to get it back. By taking time readings at point *O* at the moment that the boat is dispatched and at the moment that it comes back, the boat's time of movement between the origin of coordinates, *O*, and point *x* back and forth, $\Delta t_{OxO}$, can be determined. A boat carrying documents concerning the clock readings at the moment of boat dispatch must then again be dispatched from the origin of coordinates, *O*, to point *x*. Having received the document and the information concerning the fact that the boat trip time to a neighboring barge and back equals $\Delta t_{OxO}$, the hardware components on the barge at which the boat arrived, proceeding on the basis of the equality of the boat's velocity back and forth, establish a clock reading that exceeds the reading specified in the document they received by $½\Delta t_{OxO}$. Thereafter, they in turn dispatch a boat to the barge on which the clock reading has not yet been synchronized. By continuing these actions, the hardware components on the barges of the group at rest, $R$, can synchronize all the $R$ group clocks at the $X$ axis. The clocks located at all the point in the Σ system can be synchronized in this manner.

We denote the group $R$ time assigned by readings that are identical for all the group $R$ barges using the symbol $t_R$.

Following clock synchronization, as outside observers, we see identical $t_R$ clock readings on all the barges of the group at rest on the water, $R$, at any moment in time. For purposes of notational convenience, we will assume that the $t$ readings on our clock and the $t_R$ time readings on the group $R$ clocks are always identical, i.e., $t = t_R$.

When the clocks on the barges of the group at rest, $R$, are synchronized, the slowing of the clock rate on each drifting barge can be recorded. To this end, it is sufficient to compare the changing reading of a $t_{r'}$ clock on a barge in motion, $r'$, to the readings of the $t_R$ clocks on the barges of the group at rest, $R$, that are located at different points on the water body surface. By pinpointing the position of the start and end of different rows of the groups in motion at a certain moment in time, the lengths of these rows can also be compared to one another and to the lengths of the group $R$ rows. Following clock synchronization, the group $R$ hardware components can measure the speed of movement of the group $R'$ barges and the speed of movement of the auxiliary boats in any direction. It is not possible for the group $R'$ hardware components to perform similar operations until this group's clocks have been synchronized.

Let's say the group $R'$ clocks have also been synchronized in such a manner that, based on our observation results, the sameness of the clock readings on the different group $R'$ barges is ensured at any moment in our time. We will denote the group $R'$ time synchronized in this manner using the symbol $t'_{R'}$. Furthermore, we will presume that as a result of resetting to zero and due to random coincidences at the moment in time when the origins of coordinates, $O$ and $O'$, of the Σ and Σ' systems are located at the same point, the clocks of all the barges in both groups will have a zero reading. It then follows from formula (8) that the group $R$ and $R'$ readings at any subsequent moment in time at any point on the water body will be linked to one another by the correlations

$$t'_{R'} = t_R\sqrt{1-(v/V)^2} \text{ and } t_R = t'_{R'}\Big/\sqrt{1-(v/V)^2}\,. \qquad (18)$$

The $t_R$ and $t'_{R'}$ readings are not dependent upon the coordinates and ensure the absoluteness of simultaneity in both barge groups and in coordinate systems – Σ and Σ'. By absoluteness of simultaneity, we refer to the fact that if two events simultaneously occur at different locations within the Σ coordinate system at a moment in time of $t_R$, they also simultaneously occur in the Σ' system at a moment in time of $t'_{R'}$. Following clock synchronization in the $R$ and $R'$ groups, it becomes possible to fix the position of the ends of the barge rows in each of these groups at a certain moment in time, as well as to measure distances and lengths using not only the pseudoradar, but also the conventional method – by means of comparing them to one another or to proper length units.

Let's say that the lengths (the distances between barges) $l(½\Delta t_{\alpha\beta\alpha})$ and $l'(½\Delta t'_{\alpha'\beta'\alpha'})$ of the standards αβ and α'β', made up of a pair of barges, α and β, in the Σ coordinate system and a pair of barges, α' and β' in the Σ' system, are respectively used as distance measurement units in the groups at rest and in motion, $R$ and $R'$.

We will presume that a speedboat requires time intervals of $\Delta t_{\alpha\beta\alpha}$ and $\Delta t'_{\alpha'\beta'\alpha}$ in order to traverse each of these distances back and forth, so that the numeric values of these intervals are standardized and equal one another. If the $l(½\Delta t_{\alpha\beta\alpha})$ distance measurement unit of the standard at rest has the same denomination as the $l'(½\Delta t'_{\alpha'\beta'\alpha'})$ simulated distance measurement unit of the standard in motion, for example, if both units are called a kilometer, then as is clear from formulas (12) and (17), the simulated and conventional lateral kilometers equal one another, while according to our data, the simulated moving longitudinal kilometer is $1\Big/\sqrt{1-(v/V)^2}$ times shorter than the resting conventional kilometer.

Taking into account the fact that the distance we measured between points $O'$ and $x'$, $l_{O'x'}$, equals $x–vt_R$, where $x$ – the coordinate of point $x'$ in the Σ system, and assuming that $l'(½\Delta t'_{O'x'O'})$ = $x'$, then from the right-hand equality of correlation (17), we obtain the direct transformation of the coordinates

$$x' = (x - vt_R)\Big/\sqrt{1-(v/V)^2}\ . \qquad (19)$$

Returning to the synchronization of the $R'$ group clocks, we note that the group $R'$ hardware components can only technically perform clock synchronization of this type by means of directly transferring the group $R$ clock readings at a certain moment in time to the barges of their group, or through the use of speedboats. In the latter instance, the hardware components of the group $R'$ barges must be furnished with information on precisely which $R'$ group is in motion, during which it is moving so that the simulated speed of movement of the water relative to the Σ' coordinate system, $v'$, is aimed in the direction opposite that of the $X'$ axis. If we know the rule for converting the velocity that we observe from the outside, $v$, into simulated velocity, $v'$, and the rule for converting the $V$ velocity into $V'$ simulated velocity, we can then transfer $v'$ and $V'$ simulated velocity information to the hardware components operating on the simulated time scale. The latter can be expressed in simulated distance and simulated time units. Knowing the rule expressed by formula (19) for converting the $x$ coordinate into the $x'$ coordinate, regarding the ratio $–x'/t'_{R'}$ as the point $O$ velocity (the origin of coordinates of the Σ system) in the Σ' system, and equating $x$ to zero, then from formulas (18) and (19), we obtain

$$v' = v\big/(1 - v^2/V^2)\ . \qquad (20)$$

Substituting first $x = –Vt_R$, then $x = Vt_R$ in formula (19), we find the absolute value of the $–x'/t'_{R'}$ boat velocity in the Σ' system with the current in the first case and the absolute value of the $x'/t'_R$ boat velocity against the current in the second case. Denoting $–x'/t'_{R'}$ for movement with the current through $V_1$ and $x'/t'_{R'}$ for movement against the current through $V_2$, and taking $t'_{R'}$ from the left-hand side of formula (18), we obtain:

$$V'_1 = (V + v)\big/(1 - v^2/V^2)\ ; \qquad (21)$$
$$V'_2 = (V - v)\big/(1 - v^2/V^2)\ . \qquad (22)$$

Introducing the notation

$$V' = V\big/(1 - v^2/V^2)$$

and dividing the $v'$ velocity presented in formula (20) by $V'$, we obtain

$$v'/V' = v/V. \qquad (23)$$

Taking formulas (20) and (23) into account, equalities (21) and (22) can be presented in the form

$$V'_1 = V' + v' \qquad (24)$$
$$V'_2 = V' - v'. \qquad (25)$$

The $V'_1$ and $V'_2$ velocities represent the simulated boat velocities in the Σ' system with the water current and against the current. The physical significance of the $V'$ quantity is clear from formulas (24) and (25). This quantity represents the boat velocity relative to the water surface, expressed in simulated group $R'$ distance (length) and time units.

Having received information on the $v'$ and $V'$ velocities, the group $R'$ hardware components, using formulas (24) and (25), can calculate the $V'_1$ and $V'_2$ velocities for the boats with the current and against the current. Then, by dispatching a boat from barge $r'$ to point $O'$ and to point $x'$, they can also transfer the clock reading from barge $r'$ to the barge at point $x'$, having added the $V'_2\Delta t'_{O'x'O'}$ quantity to this reading.

Using formula (23) and bearing in mind the independence of time upon the coordinate, which makes it possible to group the symbols using simple algebraic rules, we can write formula (20) in the form

$$v = v'(1 - v'^2 / V'^2). \qquad (26)$$

Substituting $v$ and $t_R = t'_{R'}\big/\sqrt{1-(v/V)^2}$ in formula (19), performing direct algebraic transformations (they are permissible due to the independence of time upon the coordinate), and taking formula (23) into account, we obtain the transformation

$$x = (x' + v't'_{R'})\sqrt{1-(v'/V')^2}\ , \qquad (27)$$

where $V'$ and $v'$ appear in the expression under the radical.

Using formula (19) and the left-hand side of formula (18), the direct coordinate and time transformations can be written in the form

$$x' = (x - vt_R)\big/\sqrt{1-(v/V)^2}\ ,\ y' = y,\ \ t'_{R'} = t_R\sqrt{1-(v/V)^2}\ , \qquad (28)$$

Using the right-hand side of formula (18) and formula (27), the inverse transformations can be written

$$x = (x' + v't'_{R'})\sqrt{1-(v'/V')^2}\ ,\ \ y' = y\ \ \ t_R = t'_{R'}\big/\sqrt{1-(v'/V')^2}\ . \qquad (29)$$

Transformations (28) and (29) for the $x$ and $x'$ coordinates and the $t_R$ and $t'_{R'}$ time values are asymmetrical. If the group $R$ and $R'$ hardware components perceive their proper longitudinal kilometer and their proper second as key, they then perceive the kilometer and second of the other group as erroneous. In this instance, the group $R$ hardware components regard the group $R'$ kilometer as too short and the group $R'$ second as extremely protracted. At the same time, the group $R'$ hardware components regard the group $R$ kilometer as too long and the second as truncated. In general, the hardware components of the group at rest regard the geometric dimensions of the moving objects made up of the barges in motion, as well as the passage of time on the individual barges in motion, like they regard the observers or the instruments in a given coordinate system of the special theory of relativity. However, the group $R'$ hardware components regard the dimensions of the objects made up of the barges at rest and the passage of time thereon in a manner opposite the one in which the instruments of a coordinate system of the special theory of relativity do this.

**7. Simulation of the Symmetry of Relativistic Effects**

In order to derive the symmetry of the coordinate and time transformations used in the special theory of relativity, it is necessary to simulate *R′* group (Σ' system) clock synchronization in such a manner that the speeds of movement of a boat from the origin of coordinates, *O′*, to point *x′* and back to the origin of coordinates, *O′*, are identical. During the time over the course of which a boat moving at a velocity of $V - v$ travels from the origin of coordinates, *O′*, to point *x′*, $\Delta t_{O'x'}$, the *t* reading on our clock is increases by $\Delta t = l_{O'x'}/(V - v)$, while the $t'_{R'}$ reading on the group *R′* clocks, which run $1\big/\sqrt{1-(v/V)^2}$ times more slowly than our clock, increases by $\Delta t' = l_{O'x'}\sqrt{1+v/V}\big/(V\sqrt{1-v/V})$.

If a boat is dispatched from the origin of coordinates, *O′*, of the Σ' system to point *x′*, then returns from point *x′* to the origin of coordinates, *O′*, the reading of our clock will increase by $\dfrac{2l_{O'x'}}{V(1-v^2/V^2)}$ during this boat's voyage according to formula (13). During this period of time, the readings on the group *R′* barges will increase by a value that is $1\big/\sqrt{1-(v/V)^2}$ times less and that equals $2l_{O'x'}\big/(V\sqrt{1-(v/V)^2})$. The equality of the boat's velocities in opposite directions within the Σ' system can be achieved if the difference in the group *R′* clock reading at point *x′* at the moment that the boat arrives there and the clock reading at the origin of the coordinate system at the moment that the boat is dispatched from it is not $l_{O'x'}\sqrt{1+v/V}\big/(V\sqrt{1-v/V})$, but rather half the value of $2l_{O'x'}\big/(V\sqrt{1-(v/V)^2})$, i.e., $l_{O'x'}\big/(V\sqrt{1-(v/V)^2})$. I.e., in order to achieve the equality of boat's velocities in opposite directions, the $t''_{R'}$ clock reading at a point with a coordinate of *x′* must be less than the $t'_{R'}$ reading for the difference in the $l_{O'x'}\sqrt{1+v/V}\big/(V\sqrt{1-v/V})$ and $l_{O'x'}\big/(V\sqrt{1-(v/V)^2})$ values. Taking into account the fact that $l_{O'x'} = x'\sqrt{1-(v/V)^2}$, this difference equals $l_{O'x'}v\big/(V^2\sqrt{1-(v/V)^2})$, i.e.,

$$t'_{R'} - t''_{R'} = \frac{l_{O'x'}v}{V^2\sqrt{1-(v/V)^2}},$$

whence

$$t''_{R'} = t'_{R'} - \frac{l_{O'x'}v}{V^2\sqrt{1-(v/V)^2}} \qquad (30)$$

and

$$t'_{R'} = t''_{R'} + \frac{l_{O'x'}v}{V^2\sqrt{1-(v/V)^2}} \qquad (31)$$

Using formulas (30) and (19), as well as the left-hand side of formula (18), and bearing in mind that $l_{O'x'} = x - vt_R$, we obtain $t''_{R'} = (t_R - xv/V^2)\big/\sqrt{1-(v/V)^2}$, which, together with formula (19), yields the transformations

$$x' = (x - vt_R)\big/\sqrt{1-(v/V)^2}\,;\;\; y' = y\,;\;\; t''_{R'} = (t_R - xv/V^2)\big/\sqrt{1-(v/V)^2} \qquad (32)$$

The transformations in formula (32) differ radically from those in formula (28).

We will call the $t''_{R'}$ time the double simulated time and the quantities expressed through this time the double simulated quantities. From the transformations in formula (32), it is possible to find the $x'/t''_{R'}$ ratio under the condition of $x = 0$. This ratio represents the double simulated velocity, $v''$, of the origin of coordinates of the Σ system within the Σ' system and equals the $v$ velocity, i.e.,

$$v'' = v.$$

The equality of the $V$ boat velocity to the $V''$ double simulated boat velocity in any direction follows from the condition of the equality of the boat velocities en route back and forth, as well as from the condition of the equality of the boat velocity there and the boat velocity back. Using the $v'' = v$ and $V'' = V$ equalities obtained, it is easy to find the inverse transformations from the transformations in formulas (28) and (31), which take the form

$$x = (x' + v''t''_{R'}) \Big/ \sqrt{1-(v''/V'')^2}\ ;\ y = y';\ t_R = (t''_{R'} + x'v''/V''^2) \Big/ \sqrt{1-(v''/V'')^2}\ . \qquad (33)$$

The transformations obtained in formulas (32) and (33) for our two-dimensional case are indistinguishable from the Lorentz transformations to notational accuracy. The transformations are symmetrical. The group $R$ and $R'$ hardware components, which perceive their proper longitudinal kilometer and their proper second as key, perceive the geometric dimensions of the other group's objects, including the dimensions of the kilometer standard, as abbreviated and the time as slow.

## 8. Addition of Velocities

The result of the addition of the simulated velocities is obvious, since it follows from the transformations in formulas (32) and (33), which are indistinguishable from the Lorentz transformations. If, for example, a certain watercraft moves at a velocity of $u$ within the $R$ group Σ coordinate system in the direction of the $X$ axis and the equation $x = ut_R$ describes the dependence of its $x$ coordinate upon time, then by substituting $ut_R$ in place of $x$ in the first transformation in formula (32), we obtain $x' = (u-v)t_R \Big/ \sqrt{1-(v/V)^2}$ . By substituting $x = ut_R$ in the last transformation in formula (32), we obtain $t''_{R'} = (1-uv/V^2)t_R) \Big/ \sqrt{1-(v/V)^2}$ . Dividing the $x'$ value of the watercraft we are examining by $t''_{R'}$, we obtain the double simulated velocity, $u''$, which can be expressed by the formula

$$u'' = \frac{u-v}{1-uv/V^2}\,.$$

If the watercraft move in accordance with the law $x = -ut_R$, i.e., in the direction opposite that of the $X$ axis, the velocity addition formula then takes the form

$$u'' = \frac{u+v}{1+uv/V^2}\,.$$

It is apparent from the latter formula that the watercraft's double simulated velocity cannot exceed the $V$ velocity, and when the $u$ and $v$ velocities approach $V$, it is not $2V$ that is approached, but rather $V$.

## 9. Simulation of the Simplest Effects of Noninertial Bodies

The simulation model we are proposing also makes it possible to examine the simplest effects on noninertial barges and within noninertial barge groups.

Let's say that each individual barge group simulates a solid physical body. The immutability of the distances between the component parts of the solid body, fixed in its own coordinate system, simulate the maintenance of the radar distance between the barges in each group.

We will examine two barge groups at rest, which, located a great distance from one another, simultaneously get under way and accelerate in accordance with identical programs along the line on which they are located according to our clock and according to the synchronized clocks of the barge groups at rest. In this case, according to our observations, the longitudinal distances between the barges in each of the two groups moving one after the other begin to shorten after a certain time. Here, the instruments on the barges will maintain the immutability of the radar distances within each group. However, according to our observation results, the distance between the barge groups remains immutable, first, due to the sameness of the acceleration programs, and second, since the tracking and maintenance of the distances between the barges are only performed within each group. I.e., from our point of view as outside observers, each group is contracted in the direction of movement, while the distance between the groups remains the same as before. After acceleration comes to an end, if the group instruments measure the distance between the groups using boats that make trips back and forth, or using lengths standards, they will then find that the groups have drifted apart and that the distance between them has increased. This effect is presently called the Bell paradox, although it was described before Bell, in particular, by D. V. Skobeltsyn [11].

The increase in the distance between the groups recorded by the instruments is due to the contraction of the groups, as well as the length standard that pertains to them, in the direction of movement and has a purely metrological relative nature.

After a certain time, if the barge groups begin to perform a reverse operation and simultaneously begin to decelerate, the result of this deceleration will then be dependent upon group clock synchronization.

After acceleration comes to an end and before deceleration begins, if the instruments within the groups do not resynchronize the clocks and simultaneously begin to decelerate in our time, $t$, and in that same time, $t_R$ (as well as simultaneously in single stimulated time, $t'_{R'}$), the reverse process will occur in such a manner that the groups and the length standards that pertain to them, following the completion of deceleration and standstill, will again be expanded, and the groups will return to the original state. Due to the expansion of the length standards, the instruments will record a decrease in distance to the initial (starting) value. This will occur at an immutable actual distance between the groups.

If, however, the instruments of a pair of groups do resynchronize the clocks "according to Einstein" and the groups simultaneously begin to decelerate in double simulated time, $t''_{R'}$, then according to our clock, they begin to decelerate at different times (the rear group of the pair begins to decelerate earlier that the front group). In this instance, despite the expansion of the groups and the standards, after the groups of barges stop in the water, the instruments record a sequent increase in the distance between the groups, since, as it is easy to demonstrate, the increase in the distance between the groups due to the actual difference in the times that they begin to decelerate exceeds the expansion of the groups and the length standards by $1\big/\sqrt{1-(v/V)^2}$ times.

The Bell paradox will be examined in greater detail in our book.

## 10. Simulated "Space-Time"

In deriving the transformations in formulas (32) and (33), we did, as a matter of fact, also simulate pseudo-Euclidean space-time, since these transformations ensure the invariance of the space-time interval in the Σ and Σ' systems, as well as in any other systems associated with groups of barges in motion at different velocities. It is clear that this "space-time" has nothing at all to do with enigmatic multidimensional worlds and is an elementary mathematical construct that pertains more to the formalization of the measurement errors caused by the failure to take the presence of an aquatic environment into account than to the behavioral features of the barges on the water surface. But this is a separate topic of discussion. We will dwell on this subject in greater detail in the book on which we are presently working.

# ATTACHMENTS

**Attachment 1**

**Direct comparison of the rates of sand loading onto the barges**. Let us presume that the hardware components on a barge at rest, *r*, and on a barge in motion, *r'*, experimentally match the rates of increase in the quantity of sand on these barges.

We will track the operations of the hardware components using all the means available to us.

We will examine two versions of experimental comparisons of the rates of increase in the quantity of sand on the barges.

In the first version, we will imagine that barge *r'* moves past a barge at rest, *r*, at a certain initial moment in time and that the hardware components exchange documentary data containing information on the quantity of sand on barge *r* and on barge *r'* at the moment that they meet. We will presume that the work associated with conveying the sand has just begun on both barge *r* and barge *r'* at this moment in time, and that the quantity of sand on these two watercraft equals zero. We can denote this moment in time using the symbols $t(0)$ or $t(0')$ with equal success, emphasizing through the presence of a zero or a zero with a prime in parentheses that the initial moment in time is the moment in time at which the quantity of sand on barge *r* and on barge *r'* equals zero.

Let's say that some time after the meeting, at a moment in time, $t(n_1)$, when $n_1$ portions of sand have come into existence on barge *r*, the hardware components located on the barge at rest, *r*, send a speedboat after the barge passing it, *r'*, for information concerning the quantity of sand on barge *r'*. At this moment in time, $t(n_1)$, $n'_1$ portions of sand are located on barge *r'*; therefore, we can denote this moment in time, $t(n_1)$, as $t(n'_1)$. I.e., the moment in time of $t(n_1)$ and the moment in time of $t(n'_1)$ are one and the same moment in time, during which $n_1$ and $n'_1$ portions of sand, respectively, are located on barges *r* and *r'*. It is clear to us that $n'_1 = n_1\sqrt{1-(v/V)^2}$ , but neither the hardware components on barge *r* nor those on barge *r'* are able to documentarily compare these quantities. During the time of the boat's movement from barge *r* to barge *r'*, the quantity of sand on the latter increases by $\Delta n'_1$ and becomes equal to $n'_2 = n'_1 + \Delta n'_1$. According to our data, at the moment that the boat reaches barge *r'*, $n_2 = n'_2\big/\sqrt{1-(v/V)^2}$ portions of sand are located on barge *r*. At a moment in time of $t(n_2)$, or at a moment of $t(n'_2)$, which is the same time, when the boat catches up to barge *r'*, the hardware components on barge *r'* dispatch a boat to barge *r* with a document that contains information concerning the quantity of sand on barge *r'* at that moment in time, $n'_2$. During the time of the boat's return to barge *r*, the quantity of sand on the latter further increases by $\Delta n_2$. The boat reaches barge *r* at a moment in time, $t(n_3)$, when the quantity of sand on it equals $n_3 = n_2 + \Delta n_2$.

***Documentary fact 1.*** *The hardware components on barge r, being unable to documentarily compare the $n_2$ and $n'_2$ quantities at the same moment in time, only record the fact that at the moment that they received the document informing them of the presence of $n'_2$ portions of sand on barge r' (at the moment that the boat reached it and was instantaneously dispatched from it), $n_3$ portions of sand were present on barge r.*

We will now examine the second version, in which we will assume that some time after barges *r'* and *r* meet and exchange data concerning the commencement of sand loading onto both barges, a speedboat is dispatched from barge *r'* to barge *r* for information concerning the quantity of sand on barge $r$. The boat is dispatched at a moment in time of $t(m'_1) = t(m_1)$, when $m'_1$ portions of sand are present on the barge in motion, $r'$, while $m_1$ portions of sand are present on barge $r$. Let's say that, having received a boat, the hardware components on barge $r$ then and there transfer a document to barge $r'$ concerning the quantity of sand, $m_2$, on barge $r$ at the time, $t(m_2)$, that the boat reached it and it instantaneously dispatched a boat back to barge $r'$. It is clear to us, as outside observers, that at the time when the boat makes its trip to barge $r$, $t(m_2)$, the quantity of sand on it, $m_2$, is $1\big/\sqrt{1-(v/V)^2}$ times greater than the quantity of sand on barge $r'$, $m'_2$, i.e., $m_2 = m'_2\big/\sqrt{1-(v/V)^2}$ , but due to the delay in information, the hardware components on the barges cannot record this. The hardware components on barge $r'$ receive the document advising that $m_2$ portions of sand are present on barge $r$ when $m'_3$ portions of sand are present on the latter.

***Documentary fact 2***. *The hardware components on barge r', being unable to documentarily compare the $m'_2$ and $m_2$ quantities at the same moment in time, only record the fact that at the time that they receive a document informing them that $m_2$ portions of sand are present on barge r (at the time that the boat reaches it and a boat is instantaneously dispatched from it), $m'_3$ portions of sand are present on r'.*

It is not difficult to show that if the quantity of sand on barge $r$, $n_1$, and the quantity of sand on barge $r'$, $m'_1$, is identical in the first and second versions, i.e., if $m'_1 = n_1$, then the equalities $m_2 = n'_2$ and $m'_3 = n_3$ hold true, i.e., under the identical initial conditions expressed by the equality $n_1 = m'_1$, which are documented, the results of the observations made by the hardware components on barge $r$ and on barge $r'$ will be identical (symmetrical). In subsequently comparing the documented results, the hardware components are unable to determine on which of the watercraft – on barge $r$ or on barge $r'$ – the quantity of sand is increasing more quickly and which of them is at rest. We will perform small calculations that demonstrate the symmetry of the documented results.

Using these calculations, we will estimate the $n'_2$ and $n_3$ quantities documentarily recorded by the hardware components on barge $r$ in the first version.

According to formula (2) in the body of the text of this booklet, since the time required to load $n_1$ portions of sand onto barge $r$, $\Delta t(n_1)$, equals $2n_1h/V$, then moving at a velocity of $v$, barge $r'$, over a time of $\Delta t(n_1)$, travels a distance from barge $r$ of $L_1$, which equals

$$L_1 = 2n_1hv/V. \qquad \text{(A1.1)}$$

Starting at this distance between barges, moving toward barge $r'$, and traveling at a velocity of $V - v$ relative to barge $r'$, the boat catches up to it in a time of $\Delta t(\Delta n_1) = L_1/(V - v)$, over the course of which the quantity of sand on barge $r$ increases by another $\Delta n_1$ portions. Taking formula (A1.1) into account, this time may be written in the form

$$\Delta t(\Delta n_1) = \frac{2n_1hv}{V(V-v)}. \qquad \text{(A1.2)}$$

According to formula (1), since a time of $\Delta t(1) = 2h/V$ is required in order to load one portion of sand onto barge $r$, the quantity of sand on barge $r$ over a time interval of $\Delta t(\Delta n_1)$ is then increased by $\Delta n_1 = \Delta t(\Delta n_1)/\Delta t(1)$ or by $\Delta n_1 = \dfrac{n_1 v}{V-v}$. Thus, upon the expiration of the $\Delta t(\Delta n_1)$ time interval, at a moment in time of $t(n'_2)$, the quantity of sand on barge $r$, $n_2$, becomes equal to $n_1 + \dfrac{n_1 v}{V-v} = \dfrac{n_1 V}{V-v}$. The quantity of sand on barge $r'$, $n'_2$, at a moment in time of $t(n'_2)$, or which is the same thing, at a moment of $t(n_2)$, is $1\big/\sqrt{1-(v/V)^2}$ times less and equals

$\frac{n_1 V\sqrt{1-(v/V)^2}}{V-v}$, or following a small transformation, $\frac{n_1\sqrt{V+v}}{\sqrt{V-v}}$. The hardware components on barge $r'$ indicate precisely this quantity of sand, $n'_2 = \frac{n_1\sqrt{V+v}}{\sqrt{V-v}}$, in the document that they send to barge $r$.

Over the course of the boat's return from the location where a document from barge $r'$ is transferred onto the boat for barge $r$, the quantity of sand on barge $r$ will increase by another $\Delta n_2$. Since the return time, $\Delta t(\Delta n_2)$, is numerically equal to the $\Delta t(\Delta n_1)$ time interval (the time of movement of the boat from barge $r$ to barge $r'$ and instantly back again in slack water is identical), then like $\Delta n_2$, $\Delta n_2 = \frac{n_1 v}{V-v}$. Therefore, the quantity of sand on barge $r$ at the time of the boat's return will be $\frac{n_1 V}{V-v} + \frac{n_1 v}{V-v} = \frac{n_1(V+v)}{V-v}$.

***Documentary fact 1 (calculation refinement).*** *At the moment that the hardware components on barge r receive the document advising that* $n'_2 = \frac{n_1\sqrt{V+v}}{\sqrt{V-v}}$ *portions of sand are present on barge r' (at the moment that the boat reaches it and is instantaneously dispatched from it),* $n'_2 = \frac{n_1\sqrt{V+v}}{\sqrt{V-v}}$ *portions of sand are present on barge r.*

We will now take a took from the outside at what the $m_2$ and $m'_3$ quantities documentarily recorded by the hardware components on barge $r'$ equal.

According to formula (5) in the body of the text, since the time required to load $m'_1$ portions of sand onto barge $r'$, $\Delta t(m'_1)$, is given by the equality

$$\Delta t(m'_1) = \frac{2m'_1 h}{V\sqrt{1-(v/V)^2}}, \qquad \text{(A1.3)}$$

then barge $r'$, traveling at a velocity of $v$ over a time of $\Delta t(m'_1)$, moves away from barge $r$ a distance of $L_1$, which equals $\Delta t(m'_1)v$, or with allowance for (A1.3),

$$L_1 = \frac{2m'_1 hv}{V\sqrt{1-(v/V)^2}}. \qquad \text{(A1.4)}$$

In starting to move from barge $r'$ to barge $r$ at the moment in time when the distance from barge $r'$ to barge $r$, $L_1$, equals $\frac{2m'_1 hv}{V\sqrt{1-(v/V)^2}}$, the boat, traveling at a velocity of $V$ relative to barge $r$, traverses this distance and reaches barge $r$ in a time of $\Delta t(\Delta m'_1) = L_1/V$, or with allowance for formula (A1.4), in a time of

$$\Delta t(\Delta m'_1) = \frac{2m'_1 hv}{V^2\sqrt{1-(v/V)^2}}. \qquad \text{(A1.5)}$$

According to formula (4), since the time for loading one portion of sand onto barge $r'$, $\Delta t(1')$, equals $\frac{2h}{V\sqrt{1-(v/V)^2}}$, then over the course of the $\Delta t(\Delta m'_1) = \frac{2m'_1 hv}{V^2\sqrt{1-(v/V)^2}}$ time frame, the quantity of sand on barge $r'$ increases by $\Delta m'_1 = \Delta t(\Delta m'_1)/\Delta t(1')$, or by $\Delta m'_1 = \frac{m'_1 v}{V}$. In this instance, the quantity of sand on barge $r$ increases by $\Delta m_1 = \frac{m'_1 v}{V\sqrt{1-(v/V)^2}}$.

Over the course of the $\Delta t(\Delta m'_1) = \frac{2m'_1 hv}{V^2\sqrt{1-(v/V)^2}}$ time frame, barge $r'$ traverses a distance of

$$L_2 = \frac{2m'_1 hv^2}{V^2\sqrt{1-(v/V)^2}}. \qquad \text{(A1.6)}$$

The boat that the hardware components on barge $r'$ dispatch reaches barge $r$ in a time of $\Delta t(m'_1) + \Delta t(\Delta m'_1)$ after the moment that barge $r'$ and barge $r$ meet; here, with allowance for formulas (A1.3) and (A1.5),

$$\Delta t(m'_1) + \Delta t(\Delta m'_1) = \frac{2m'_1 h\sqrt{V+v}}{V\sqrt{V-v}}. \qquad \text{(A1.7)}$$

At this moment in time, $m_2 = [\Delta t(m'_1) + \Delta t(\Delta m'_1)]/\Delta t(1)$ portions of sand will be present on barge $r$, or with allowance for formula (A1.7) and formula (1) in the body of the text,

$$m_2 = \frac{m'_1\sqrt{V+v}}{\sqrt{V-v}}.$$

The hardware components on barge $r$ enter this quantity of sand into the document that they transfer by boat to barge $r'$.

Using formulas (A1.4) and (A1.6), the distance between barge $r$ and barge $r'$ at this moment in time, $L_1 + L_2$, can be found. It is given by the formula

$$L_1 + L_2 = \frac{2m'_1 hv\sqrt{V+v}}{V\sqrt{V-v}}.$$

Moving at a velocity of $V - v$ relative to barge $r'$, the boat covers this distance in a time of

$$\Delta t(\Delta m'_2) = \frac{2m'_1 hv\sqrt{V+v}}{V(V-v)\sqrt{V-v}}, \qquad \text{(A1.8)}$$

over the course of which the quantity of sand on barge $r'$ increases by $\Delta m'_2$ and becomes equal to $m'_3$.

From the moment that barge $r'$ meets barge $r$ until the moment that the boat dispatched to barge $r$ returns to barge $r'$, a time of $\Delta t(m'_3)$ passes, which equals the sum of the $\Delta t(m'_1)$, $\Delta t(\Delta m'_1)$, and $\Delta t(\Delta m'_2)$ times. Using formulas (A1.7) and (A1.8), it is easy to obtain

$$\Delta t(m'_1) + \Delta t(\Delta m'_1) + \Delta t(m'_2) = \frac{2m'_1 h(V+v)}{V\sqrt{1-(v/V)^2}\,(V-v)}.$$

During this time, the quantity of sand on barge *r'*, $m'_3 = \Delta t(m'_3)/\Delta t(1')$, becomes equal to $\frac{m_1'(V+v)}{V-v}$.

***Documentary fact 2 (calculation refinement).*** *At the moment that the hardware components on barge r' receive the documents advising that* $m_2 = \frac{m'_1\sqrt{V+v}}{\sqrt{V-v}}$ *portions of sand are present on barge r (at the moment that the boat reaches it and is instantaneously dispatched from it),* $m'_3 = \frac{m'_1(V+v)}{V-v}$ *portions of sand are present on barge r'.*

When the initial conditions in the first and in the second versions are identical, expressed by the equality of the numeric values of $n_1$ and $m'_1$ ($n_1 = m'_1$), the documented results of the calculation performed by the hardware components on barge *r* and on barge *r'* are identical (symmetrical) to notational accuracy and do not make it possible to detect the difference in the rates of increase of the quantities of sand on barge *r* and on barge *r'*.

**Attachment 2**

**Doppler effect during the direct comparison of the rates of sand loading onto the barges.** Let's assume that of two inertial barges, *r* and *r'*, one, *r*, is at rest, while the other, *r'*, is moving away from it at a velocity of *v*. We will presume that at the time that they meet, by mutual agreement, the hardware components on each of the barges documentarily inform the hardware components on the other barge of each sequent increase in the quantity of sand on their barges using a specific value that we will call the signal quantity. They send documents containing the information on a sequent increase in the quantity of sand to this signal value to the other barge using speedboats. Each such boat can be viewed as a certain "signal" that carries a message. Thus, two lines of signal boats carrying messages move between the barges that are headed toward one another.

It is clear that if the signal quantity of sand on both the barges is identical, while the rate of sand loading onto the barge at rest is $1\big/\sqrt{1-(v/V)^2}$ times higher than the rate of sand loading onto the barge in motion, then the frequency of the signals sent (the boat dispatched) from the barge at rest will also be $1\big/\sqrt{1-(v/V)^2}$ times higher than the frequency of the signals sent (the boat dispatched) from the barge in motion.

Looking from the outside and estimating the time based on our clock, we find that the period of time over the course of which the quantity of sand on the barge at rest, *r*, increases to the signal quantity, $\Delta k$, equals $\Delta t(\Delta k)$, while the frequency of the increases in the quantity of sand by $\Delta k$ portions and the frequency of dispatches of boats carrying information from barge *r* to barge *r'*, respectively, $f_r$, equals $1/\Delta t(\Delta k)$. The distance between the boats leaving barge *r* at a velocity of *V* equals $V\Delta t(\Delta k)$ or $V/f_r$. From our point of view, being the point of view of outside observers, the speed of movement of the boats headed toward receding barge *r'*, which equals *V* relative to the water, equals $V - v$ relative to the receding barge *r'*. Dividing the velocity $V - v$ by the distance between the boats, which equals $V/f_r$, we obtain the frequency of information receipt (the frequency of boat arrival) from barge *r* to receding barge *r'*, $f_{r'\leftarrow r}$, which equals $f_r(V-v)/V$, i.e.,

$$f_{r'\leftarrow r} = f_r(V-v)/V\ .$$

For the barge in motion, $r'$, the time required to take $\Delta k'$ portions onboard, $\Delta t(\Delta k')$, with allowance for the equality $\Delta k = \Delta k'$, equals $\Delta t(\Delta k) \big/ \sqrt{1-(v/V)^2}$, while the frequency of receipt of signal quantities, $f_{r'}$, since $f_{r'} = 1/\Delta t(\Delta k')$, equals $f_r\sqrt{1-(v/V)^2}$. The $f_{r'\leftarrow r}/f_{r'}$ ratio equals $\sqrt{1-v/V}\big/\sqrt{1+v/V}$, i.e.,

$$f_{r'\leftarrow r}/f_{r'} = \frac{\sqrt{1-v/V}}{\sqrt{1+v/V}}$$

In the case of the convergence of barges $r$ and $r'$, the $f_{r'\leftarrow r}/f_{r'}$ ratio, which is not difficult to demonstrate, equals $\sqrt{1+v/V}\big/\sqrt{1-v/V}$.

The frequency of the increases in the quantity of sand by $\Delta k'$ portions on the barge in motion, $r'$, and respectively the frequency of boat dispatch from it to barge $r$, $f_{r'}$, equals $1/\Delta t(\Delta k')$. From our point of view, the speed of movement of the boats relative to barge $r'$ equals $V + v$. Therefore, the distance between the boats departing from barge $r'$ at a velocity of $V + v$ equals $(V + v)\Delta t(\Delta k')$ or $(V + v)/f_{r'}$. Dividing the $V$ velocity at which the boats move toward the barge at rest, $r$, by the distance between the boats, which equals $(V + v)/f_{r'}$, we obtain the frequency of information receipt (boat arrival) from barge $r'$ to barge $r$, $f_{r\leftarrow r'}$. This $f_{r\leftarrow r'}$ frequency equals $f_{r'}V/(V+v)$ or

$$f_{r\leftarrow r'} = \frac{f_{r'}}{1+v/V}.$$

Due to the fact that the time required for $\Delta k$ portions to reach the barge at rest, $r$, $\Delta t(\Delta k)$, equals $\Delta t(\Delta k')\sqrt{1-(v/V)^2}$, the frequency of these arrivals, $f_r$, equals $f_{r'}\big/\sqrt{1-(v/V)^2}$. The $f_{r\leftarrow r'}/f_r$ ratio once again proves to equal $\sqrt{1-v/V}\big/\sqrt{1+v/V}$ as barge $r'$ moves away from barge $r$ and $\sqrt{1+v/V}\big/\sqrt{1-v/V}$ as barges $r$ and $r'$ converge. Thus,

$$\frac{f_{r'\leftarrow r}}{f_{r'}} = \frac{f_{r\leftarrow r'}}{f_r},$$

i.e., given the equality of the $\Delta k$ and $\Delta k'$ signal quantities ($\Delta k = \Delta k'$) concerning the receipt onboard of which the barge hardware components inform each other using speedboats, the ratio the frequency of boat arrival at this barge from the other barge to the frequency of the arrival of signal quantities of sand at this barge is identical on both barges. These ratios are given to notational accuracy by expressions similar to the ratio of the frequency of signal receipt to the eigenfrequency on bodies moving relative to one another in the special theory of relativity.

It is not difficult to see that the ratio of the aforementioned signal (boat dispatch) frequencies is only dependent upon the relative velocity of the barges and not upon the absolute speeds of movement of the barges relative to the water.

A transverse effect of the ratio of the frequencies of boat dispatch and arrival also exists in the model we are examining. The ratio of the frequencies of the signals received and the frequencies of the receipt of signal quantities of sand in this instance is given by the formula $f_{r'\leftarrow r}/f_{r'} = f_{r\leftarrow r'}/f_r = \sqrt{1-(v/V)^2}$.

**Attachment 3**

**Analog of the twin paradox during the direct comparison of the rates of sand loading onto the barges**. We will examine two cases of the movement of "twin" barges, one of which is inertial. If the "twin" barges were initially at rest at a single point, then one of them, getting up to a velocity of $v$, begins to move away, and after going a certain distance, turns and comes back to the initial point at a velocity of $v$, the result is obvious. Since the receipt of sand on the barge traveling at a velocity of $v$ occurs $1/\sqrt{1-(v/V)^2}$ times more slowly than on the barge at rest, then at the time that the barges part, over the course of which the quantity of sand on the barge at rest increases by $k$ shuttles, the quantity of sand on the barge moving at a velocity of $v$ increases by a lesser quantity of $k'$, which equals $k\sqrt{1-(v/V)^2}$ shuttles. The velocity of the barge proves to have been altered when it meets the "younger" barge, which remained in place, and the hardware components on the barge are able to documentarily establish this.

If the "twin" barges initially travel side by side at a velocity of $v$, then one of the barges stops in the water, and after standing still for some time, picks up the necessary speed and catches up to the barge pulling away, the result is then less obvious, but the barge that changed speed also proves to be "younger" upon meeting in this instance.

We will examine the two aforementioned cases in greater detail.

Let's say that at the moment of "birth" of the twin barges, $g$ and $h$, which consists of the commencement of the loading of sand on them, they are at rest in the water side by side, during which barge $h$ remains in a state of rest relative to the water immediately after its "birth", while noninertial barge $g$ begins to move away from inertial barge $h$ at a velocity of $v$. At this moment in time, there is no sand on the barges, which the hardware components on the barges can documentarily record by mutually transferring documents to one another. Thereafter, as barge $g$ pulls a certain distance away from the barge at rest, $h$, it turns and travels back at this same velocity of $v$. Let's say that at the time this turn is made, the quantity of sand on barge $g$ equals ½$k'_g$, while at the moment of the barge's return to the initial location, it is $k'_g$. During the time that passes from the moment of barge "birth" until the moment that barge $g$ returns to barge $h$, the increase in the quantity of sand on barge $g$ will be $1/\sqrt{1-(v/V)^2}$ times less than the increase in the quantity of sand on barge $h$. Therefore, the quantity of sand on barge $g$ at the moment of its return, $k'_g$, will also be $1/\sqrt{1-(v/V)^2}$ times less than the quantity of sand on barge $h$, $k_h$, i.e.,

$$k'_g = k_h\sqrt{1-(v/V)^2} \qquad \text{(A3.1)}$$

The hardware components on barges $g$ and $h$ can detect this fact based on documented data. Without using the concept of velocity, they find that $k'_g = k_h/\Gamma$, where $\Gamma$ is a coefficient greater than unity for the hardware components.

After it returns, if noninertial barge $g$ comes to a stop alongside barge $h$, it will then "live" (in the terminology that we provided above) longer than barge $h$ and sinks later than twin barge $h$, since it ends up being "younger" because of its journey.

We will now examine the second case.

We will imagine that at the moment of "birth" of barges $g$ and $h$, $t_0$, when there is still no sand on the barges, they are moving in the water side by side at a velocity of $v$ in the same direction. Let's say that immediately after their "birth", barge $g$ stops, while barge $h$ keeps moving, pulling away from barge $g$.

Let's say that after standing still for some time, $\Delta t_1$, barge $g$ begins to move at a moment in time of $t_1$, when the quantity of sand on it is ½ $k'_g$, and departing at a velocity of $u$, which is greater than the $v$ velocity, in the wake of barge $h$, which is pulling away from it, it begins to catch up to it. Due to the state of rest that barge $g$ achieved during the $\Delta t_1$ time frame, the rate of delivery of sand to it is $1\big/\sqrt{1-(v/V)^2}$ times greater than the rate of delivery of sand to barge *h*, which is still in motion. For this reason, at a moment in time of $t_1$, the quantity of sand present on barge *h*, which is still in motion, $k'_h$, equals $\frac{1}{2}k'_g\sqrt{1-(v/V)^2}$, i.e.,

$$k'_h(\Delta t_1)=\tfrac{1}{2}k'_g\sqrt{1-(v/V)^2}\,. \qquad \text{(A3.2)}$$

We will presume that the *u* velocity is such that when barge *g* catches up to barge *h*, the quantity of sand on barge *g* equals $k'_g$, while the quantity of sand on barge *h* equals $k'_h$.[1]

What do you think, on which barge will there be more sand at this moment in time?

You might think that, since the sand was delivered to barge *g* more quickly during its standing period than to inertial barge *h* still in motion, then after barge *g* catches up to barge *h*, the quantity of sand on the latter, $k'_h$, should be less than the quantity of sand on barge *g*, $k'_g$.

No! In all circumstances, there will be more sand on barge *h*. Here, the quantity of sand on barge *h* when it meets barge *g*, $k'_h$, is identical in the first and second instances, i.e., if the $k'_g$ value in the first and second instances is identical, then the equality $k'_h = k_h$ holds true, and the equality in the second instance is true

$$k'_g=k'_h\sqrt{1-(v/V)^2}\,. \qquad \text{(A3.3)}$$

The hardware components on the barges record the equality derived in the form $k'_g = k'_h/\Gamma$, where $\Gamma$ is numerically the same coefficient as in the first instance.

We will demonstrate this.

Based on the condition that during the period of time that barge *g* returns to barge *h*, $\Delta t2$, since as much sand reaches barge *g*, moving at a velocity of *u*, as reached it during its time at rest, $\Delta t_1$, then

$$\Delta t_2=\Delta t_1\Big/\sqrt{1-(u/V)^2}\,. \qquad \text{(A3.4)}$$

Because barge *h* was moving at a velocity of *v* during the time that barge *g* achieved rest, $\Delta t_1$, the distance between barges *g* and *h* at a moment in time of $t_1$, *l*, then equals $v\Delta t_1$, while $\Delta t_1 = l/v$. When the distance between barges *g* and *h* is *l* at a moment in time of $t_1$, the $\Delta t_2$ time can be represented through the speed of movement of barge *g* relative to barge *h* at a velocity of $u - v$ by the expression $l/(u - v)$. Substituting $\Delta t_1 = l/v$ and $\Delta t_2 = l/(u - v)$ in equality (A3.4), we obtain $u-v=v\sqrt{1-(u/V)^2}$, whence it follows that

$$u=\frac{2v}{1+(v/V)^2}\,. \qquad \text{(A3.5)}$$

Substituting formula (A3.5) in formula (A3.4), we obtain

$$\frac{\Delta t_2}{\Delta t_1}=\frac{1+(v/V)^2}{1-(v/V)^2}\,.$$

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[1] It is fundamentally possible to ensure this velocity, if only for the reason that at a *u* velocity that just barely exceeds the *v* velocity, the $k'_g$ value can be arbitrarily large, while at a *u* velocity, the value of which approaches the *V* velocity, it can remain equal to $\frac{1}{2}k'_g$. Due to the monotonous nature of the dependence of the sand increase upon barge velocity, any intermediate value is also possible.

If $k'_h(\Delta t_1)$ of sand reaches the inertial barge in motion, $h$, during the $\Delta t_1$ time frame, which numerically equals $\frac{1}{2}k'_g\sqrt{1-(v/V)^2}$, then $\dfrac{1+(v/V)^2}{1-(v/V)^2}$ times more reaches it during the $\Delta t_2$ time frame, i.e.,

$$k'_{h,}(\Delta t_2)=\tfrac{1}{2}k'_g\,\frac{1+(v/V)^2}{\sqrt{1-(v/V)^2}}\,. \qquad \text{(A3.6)}$$

During the $\Delta t_1 + \Delta t_2$ time frame, a total of $k'_h = k'_h(\Delta t_1) + k'_h(\Delta t_2)$ of sand reaches barge $h$, whence, with allowance for formulas (A3.2) and (A3.6), it follows that

$$k'_g = k'_h\sqrt{1-(v/V)^2}\,, \qquad \text{(A3.7)}$$

i.e., the quantity of sand on barge $g$ at the moment of its return to barge $h$ is $1\big/\sqrt{1-(v/V)^2}$ times less than on barge $h$.

Thus, formulas (A3.1) and (A3.7) demonstrate the symmetry of the instances to which they pertain. We note that when conducting experiments involving a pair of barges that meet twice, one of which is noninertial, the smallest sand increase will always be on the noninertial barge, which changes its speed or direction of movement at a certain moment in time.

## Attachment 4

**Simulation of the Doppler effect using simulated time**. Let's say that of two inertial barges, $r$ and $r'$, one is at rest, $r$, while the other, $r'$, is moving away from it at a velocity of $v$. We will presume that speedboats carrying information are dispatched from each barge to the other barge. Expressed through $t$ time for barge $r$ and through $t'$ simulated time for barge $r'$, the frequencies of speedboat dispatches, $f_r$ and $f'_{r'}$, are numerically equal to one another. Each such boat can be viewed as a "signal" that carries a message.

It is clear that if the simulated $f_r$ and $f'_{r'}$ frequencies, i.e., respectively expressed in $t$ and $t'$ times, are identical, then the $f_r$ frequency we record for the signals (the boat dispatches) sent from the barge at rest is $1\big/\sqrt{1-(v/V)^2}$ times higher than the conventional $f_{r'}$ frequency we record (an expressed through our conventional time) for the signals (the boat dispatches) sent from the barge in motion.

The distance between the boats moving away from barge $r$ at a velocity of $V$ equals $V/f_r$. From our point of view, being the point of view of outside observers, the speed of movement of the boats headed toward receding barge $r'$, being equal to $V$ relative to the barge at rest and to the water, equals $V - v$ relative to barge $r'$, moving at a velocity of $v$. Dividing the $V - v$ velocity by the distance between boats, which equals $V/f_r$, we obtain the frequency of information receipt (boat arrival) from barge $r$ to receding barge $r'$, $f_{r'\leftarrow r}$, which equals $f_r(V-v)/V$, i.e.,

$$f_{r'\leftarrow r} = f_r(V-v)/V\,. \qquad \text{(A4.1)}$$

Taking into account the fact that the conventional frequency, $f_{r'\leftarrow r}$, is $1\big/\sqrt{1-(v/V)^2}$ times smaller than the simulated frequency, $f'_{r-r'}$, expressed through simulated time, $t'$, i.e., with allowance for the fact that $f_{r'\leftarrow r} = f'_{r'\leftarrow r}\sqrt{1-(v/V)^2}$, then from formula (A4.1) we obtain

$$f'_{r'\leftarrow r} = f_r \frac{\sqrt{1 - v/V}}{\sqrt{1 + v/V}}. \qquad \text{(A4.2)}$$

In the event that the approach of barge $r'$ to a barge other than barge $r$ is true, which it is not hard to demonstrate, the equality is

$$f'_{r'\leftarrow r} = f_r \frac{\sqrt{1 + v/V}}{\sqrt{1 - v/V}}. \qquad \text{(A4.3)}$$

But what happens to the boats that carry the information from the barge in motion, $r'$, to the barge at rest, $r$?

From our point of view, the speed of movement of the boats relative to barge $r'$ equals $V + v$. Therefore, the distance between the boats departing from barge $r'$ at a velocity of $V + v$ equals $(V + v)/f_{r'}$. Dividing the $V$ velocity at which the boats move toward the barge at rest, $r$, by the distance between the boats, which equals $(V + v)/f_{r'}$, we obtain the frequency of information receipt (boat arrival) from barge $r'$ at the barge at rest, $r$, $f_{r\leftarrow r'}$:

$$f_{r\leftarrow r'} = \frac{f_{r'}}{1 + v/V}. \qquad \text{(A4.4)}$$

The frequency of the signals (the boat dispatches) that we record, $f_{r'}$, equals $f'_{r'}\sqrt{1-(v/V)^2}$, where $f'_{r'}$ – the simulated frequency of the signals (the boat dispatches) from barge $r'$. Taking into account the fact that the $f_{r\leftarrow r'}$ frequency equals the simulated frequency, which has the same notation, $f_{r\leftarrow r'}$, and substituting $f_{r'} = f'_{r'}\sqrt{1-(v/V)^2}$ in formula (4), we obtain

$$f_{r\leftarrow r'} = f'_{r'} \frac{\sqrt{1 - v/V}}{\sqrt{1 + v/V}}. \qquad \text{(A4.5)}$$

In the event that the convergence of barges $r'$ and $r$ is true, which it is not hard to demonstrate, the equality is

$$f_{r\leftarrow r'} = f'_{r'} \frac{\sqrt{1 + v/V}}{\sqrt{1 - v/V}}. \qquad \text{(A4.6)}$$

Formulas (A4.2) and (A4.5), as well as formulas (A4.3) and (A4.6), similar to the formulas of the special theory of relativity, demonstrate the symmetry of the frequencies of the information reaching them that the hardware components on barges $r$ and $r'$ record in simulated times.

We are affording the reader the opportunity of convincing himself or herself, without prompting from the outside, that when a barge moves in a direction away from a barge, a transverse Doppler effect is observed that is expressed by the correlations $f_{r\leftarrow r'} = f'_{r'}\sqrt{1-(v/V)^2}$ and $f'_{r'\leftarrow r} = f_r\sqrt{1-(v/V)^2}$.

We arbitrarily selected barges $r$ and $r'$. The conclusion concerning the impossibility of observing asymmetrical processes extends to all the pairs of barges that are located on the surface of a water body. The symmetry of the processes accessible for recording on the barges at rest and in motion demonstrates that, using documented information alone without resorting to contact with the water, automatic devices cannot, independently of one another, solve a problem that consists of determining which among them is located on the barge in motion and which is located on the barge at rest.

## Conclusion

The special theory of relativity is closely linked to philosophical suppositions, and many of the problems that arise over the course of interpreting its physical content are philosophical in nature. Interpretational problems are not to be solved by constraining philosophers from solving philosophical problems in modern physics. The total disagreement in evaluating the content of the concepts used in the special theory of relativity can serve as evidence of this, during which it is not so much philosophers that create this disagreement as physicists themselves. Hermann Weyl probably foresaw something similar when he wrote: “Despite the disheartening leapfrog of philosophical systems, we cannot refuse to address it unless we want knowledge to be transformed into senseless chaos” [12].

What is the essence of kinematic phenomena? Is Lorentz contraction a real or apparent phenomenon? Is four-dimensional space-time an objective reality or a mathematical formalism? Physicists give not so much categorical answers to these and other questions as answers that mutually exclude one another.

In V. G. Ugarov’s textbook [13] for schools of higher learning, it is directly stated that there is no real Lorentz contraction. After hearing remarks of this type, a considerable number of students remain convinced their entire lives that the theory of relativity is far from reality. It is sufficient to “browse” physics forums on the Internet to be convinced that the situation surrounding the interpretation of the statements of the special theory of relativity is unhealthy. A good half of all the squabbles in these physics forums involve the special theory of relativity.

A clear illustration of the confusion that exists in the theory of relativity consists the campaign to modify the concept of mass.

The concept of relativistic, i.e., velocity-dependent, mass has enjoyed the broadest possible use since the time that Einstein’s special theory of relativity came into being, and it is still used in many articles and books today. Einstein, Born, Pauli, Møller, Gamow, Feynman, and other eminent physicists of the twentieth century wrote about the dependence of mass upon velocity. The fact of the experimental confirmation of the dependence of the mass of elementary particles upon velocity in particle accelerators has continuously been cited in learning aids and bibliographic literature. In addition, after academician L. B. Okun published his article in the physics journal APS [14], a campaign was launched in the Soviet Union, then in Russia to replace statement concerning the dependence of mass upon velocity with a statement concerning its independence upon the latter. This campaign culminated in the “revocation” of the physical statement concerning the dependence of mass upon velocity and the adjustment of the world-renowned formula “E equals mc square” by means of the seemingly insignificant replacement therein of the letter E with $E_0$ (with a zero subscript). One result of this campaign consisted of the fact that the obsolete concept of mass dependent upon velocity was stripped from the State Physics Program in Russia in 2006 and “Recommendations for Describing the STR With Allowance for a Standard” were formulated.

However, having rejected the concept of relativistic mass, the school reform leaders retained a term that coexisted with the term “relativistic mass” and which makes no sense at all without this concept. We are talking about the concept of mass at rest. The reform initiators insisted on removing the concepts of relativistic mass and mass at rest from circulation, as well as replacing them with the concept of invariant mass. As the reform initiators understood it, mass at rest was a no less meaningless quantity than relativistic mass, but whether they did not understand the essence of the adjustments of the reform initiators or whether they did not fully accept them, the school reform leaders eliminated the concept of relativistic mass on the one hand, while on the other hand, they perverted the concept of invariant mass, identifying the latter with mass at rest. It quickly became necessary either to revert to relativistic mass or to understand and accept L. B. Okun and reject mass at rest. But will schoolchildren survive this mockery of the “unshakable” statements of one of the most precise sciences – physics?

In the article by L. B. Okun [14], the following situation that American physicist C. Adler experienced is described.

“Does mass really depend on velocity, dad?”, C. Adler was asked by his son.

“Well, yes…” “Actually, no, but don’t tell your teacher”, C. Adler answered.

The next day – Adler writes – his son dropped physics.

The situation with teaching the principles of the special theory of relativity in schools is such that, given the current casts of guidance counselors, not only will students soon stop studying it, but teachers will also refuse to teach it.

In addition, the special theory of relativity is very simple and does not involve any problems other than the problems of its interpretation. It can be described in the simplest language and using the simplest examples from our everyday life. There is nothing in it that is unintelligible or that signifies the four-dimensional world as inaccessible to human imagination.

The simulation presented in this booklet quite dramatically demonstrates the simplicity of the special theory of relativity and its “earthiness”. It is not difficult to see that the possibility of using a “four-dimensional formalism” that does not differ from Minkowski formalism in this model issues from a simulation that yield Lorentz transformations. I.e., a most primitive model in an amusing form that is based on nothing more than sand (on “hourglasses”) results in the possibility of describing the “operating principle” of this children’s game model in four-dimensional space-time.

A more detailed examination of four-dimensional space-time led us to the conclusion that space-time is a space of errors and must be relegated to the error theory rather than to the phantasmagoric world theory. But this is a separate question that we intend to examine in our book.

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**The principles of the special theory of relativity are extremely simple. A knowledge of the Pythagorean theorem and an ability to perform the simplest algebraic operations are sufficient to be conversant with the kinematics of the special theory of relativity, as well as the time dilation and contraction of the longitudinal dimensions of moving bodies that are associated with relative motion. However, the simplicity of the fundamentals of the theory of relativity are in surprising contrast with the difficulty of the perception and at times the total nonacceptance of the consequences of the special theory of relativity by skeptics based on ordinary common sense. The authors of certain popular books on the theory of relativity explain the existence of this contrast by way of the fact that the common sense of skeptics cut its teeth on a "stark notion of our everyday life". In the opinion of many physicists, the concept of common sense has taken on another meaning, and the presence of madness in ideas rather than their conformance to the requirements of common sense has almost become the criterion of validity in physics.**

**The special theory of relativity is simulated in this book in an amusing form based on the simplest examples of the movement of barges, shuttles, and boats in an aquatic environment. It has been simulated without rejecting the customary ordinary common sense that was squashed in the past century by the celebration of "mad ideas".**