



Inertial Forces and the Laws of Dynamics

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ABSTRACT

The basic concepts and laws of classical dynamics are analyzed from the standpoint of their adequacy to the physical nature of material bodies and to the dynamical processes. What Newton called absolute immovable space is the world ether that generates any forces, including the inertial forces imposing constraints on the magnitude of the acceleration. Inertial reference frames are frames moving translationally, rectilinearly, and uniformly relative to the ether. The physical nature of the principle of relativity is that the acceleration of a material point in all inertial reference frames coincides with its acceleration relative to the ether, and, therefore, Newton's dynamical equation retains the same form in any inertial reference frame. The principle of relativity is valid as long as Newton's dynamical equation is valid. In new formulations, the four laws of dynamics contain the concepts of ether and inertial forces. These laws are independent between themselves, and each of them expresses only one elementary truth.

Keywords: Ether, Inertial reference frame, Principle of relativity

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INTRODUCTION

The foundations of dynamics consisting of a few laws and concepts in which these laws are outlined seem simple and eternal truths to all of us, because we are inculcated with them in the young age when we are still incapable of critically perceiving such important information. However, if we turn to the origins of the physical foundations of mechanics and try to reconstruct the development of ideas accompanying the shaping of one of the laws, then we will suddenly find that these outwardly simple truths are extremely complex and can be understood only at the cost of an unusually high concentration of attention and a great stretching of mind. At the same time, mathematics turns out to be completely out of demand, because it can neither confirm nor refute any of the fundamental physical ideas of mechanics in principle. Newton laid solid foundations for mathematical modeling not only in mechanics but generally

in all exact sciences and engineering. However, the laws bearing his name had long been prepared by the works of his predecessors, among which we must primarily mention Aristotle (384–322 B.C.), Archimedes (287–212 B.C.), Ptolemy (100–178), Copernicus (1473–1543), Benedetti (1530–1590), Gilbert (1544–1603), Tycho Brahe (1546–1601), Stevin (1548–1620), Galileo (1564–1642), Kepler (1571–1630), Roberval (Personier) (1602–1675), Borelli (1608–1679), Huygens (1629–1695), and Hooke (1635–1705).

The role of Hooke, who was the main generator of scientific ideas in the Royal Society over four decades and verbally expressed the content of the law of universal gravitation, is particularly great. The physical intuition of Hook was unique in its depth and power. After Newton, a strong trend toward mathematical formalism emerged in mechanics, which began to take it increasingly far away from

the method of physical reasoning bequeathed to us by Galileo and Hooke. A particularly sharp turn toward mathematics occurred after Lagrange's brilliant analytical works. The erroneous opinion that the physical foundations of mechanics were established once and for all and it only remained to develop its mathematical apparatus was formed imperceptibly. Meanwhile, Newton's first law is a particular case of the second one. There was no room in the laws of dynamics for the inertial forces about which much new and useful was said in "Principia" (Newton, 1686). We still do not understand the physical nature of inertial reference frames and the principle of inertia.

Newton left us a very brief and not quite clear proof of the law of composition of forces. In this proof, it is assumed that the action of a force does not change in the presence of other forces. However, acceleration-dependent forces do not obey this rule. Enough examples of such forces are given in the monograph by A. Emelyanov (2011). For example, a demonstration rocket model lifting off vertically under the action of a water jet expelled by compressed air is moved by a force that grows as the rocket acceleration increases. In comparison with his predecessors, Newton made a big step forward in solving the very complex problem of inertial forces, but he achieved no proper clarity, leaving the problem not only unsolved but also with contradictions. There were many debates on this subject after Newton, but they only exacerbated the complexity of the problem. Sorting out the vestiges of long-forgotten battles over the inertial forces, we find many categorical assertions in them in an almost complete absence of well thought-out irrefutable reasoning. Meanwhile, the question of inertial forces is very difficult to solve precisely because the decisive arguments are elusive and they are very few.

CRASH OF THE MYTH ABOUT THE INERTIA OF MASS

Imagine a spacious hall whose floor is an accurately machined plane made of polished granite. A cylinder with a mass of 100 tons rests on the floor (Fig 1).

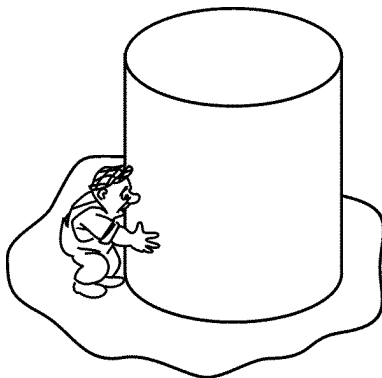


Fig 1. Motion of a massive cylinder over a thin layer of compressed gas.

There are porous inserts in the central region of the cylinder base through which a compressed gas filling a cavity inside the cylinder outflows. A thin layer of compressed gas making the cylinder friction on the floor so insignificant that

it may be disregarded is formed between the cylinder base and the floor. You press your palms against the lateral surface of the cylinder and push it with a force of 100 newtons. It is easy to calculate that the acceleration of the cylinder axis will be 0.001 m/s^2 and the axis will acquire a velocity of about one meter per minute in 17 seconds. Now, to stop the cylinder by our force of 100 newtons, it will have to be decelerated for 17 seconds. Pushing the cylinder, your palms and entire body will feel a reaction to your force. This reaction is an inertial force Φ that is equal in magnitude and opposite in direction to the force exerted by you. On the other hand, in accordance with Newton's second law, this inertial force is defined by the expression

$$\Phi = -mw \quad (1)$$

where m is the mass of the body, and w the acceleration of its translational motion. Thus, in accordance with the law of action and reaction, the inertial force can be called a reaction force with respect to the force F that causes an accelerated motion of the body. However, we understand that any force must have a physically clear origin. According to Newton, the inertial force is the resistance of material bodies to their accelerated motion relative to the absolute space, which is an "innate property of matter". But can we press on the cylinder by our hands for 17 seconds without pushing off from the floor by our legs? Of course not! And how can the cylinder made of dead matter press on our palms for all these 17 seconds without interacting with some third object? There exists the opinion that Newton's term "inertial force" was introduced through a misunderstanding, because what is at issue is the reaction force (Ishlinsky, 1986).

Let us consider this objection. To say that "this is a reaction force rather than an inertial one" is just the same as to state that "this case is a bookcase rather than an oak one". We are faced with the substitution of heterogeneous concepts. What is at issue is a force that is both an inertial force and a reaction force simultaneously. While talking about the reaction force, we focus our attention on whether this force belongs to the action-reaction dyad. From the viewpoint of the physical nature of forces, the term "reaction" is noninformative and vacuous. This reaction could not arise if the world was organized differently and if no force proportional to the acceleration and directed oppositely to it arose in the body's accelerated motion. We have this mind when talking about the inertial force. Thus, the term "inertial force" has a completely different meaning-it points to the physical nature of the force. We cannot content ourselves with the formal "reaction force" without thinking about the mechanism of this reaction.

Attributing the "innate force" of resistance to any changes in the velocity relative to the "absolute space" to matter, Newton thus endowed all bodies, including stones, with two unreal properties:

1. The ability to control any changes in the velocity relative to the "absolute space". Indeed, the bodies cannot resist any changes in their absolute velocity without this ability.
2. The ability to generate inertial forces directed oppositely to the body's absolute acceleration in the absence of any force

interaction between the "absolute space" and the body. Note that this property is attributed to each atom of the body, because these are particles of matter endowed with a certain mass.

Everyone who is able to concentrate his attention on these two properties and to bring them into correspondence with the real essence of the objects of dead matter must recognize that the very thought of the existence of such properties in nonliving bodies is absurd, because what is at issue are the objects that are basically doomed to retain their complete indifference to those motions into which they are drawn. The myth about the inertia of mass originates from the very old proposition about the "inactivity of matter". In the works of Benedetti (1530–1590), a great predecessor of Galileo, the inertia of bodies is already inherent not only in the state of rest but also in motion. This was progress compared to Aristotle, who asserted that any body stops as soon as the motive force ceases to act. Kepler, a direct predecessor of Hooke and Newton in this concept, interpreted inertia only as a resistance to motion, but, on the other hand, he associated this property with the quantity of matter. So, Newton (1686) made a significant step forward in "Principia" by interpreting inertia both as a "resistance" and as a "pressure" of matter. The myth about the inertia of mass is akin in its origin to two old and long-rejected propositions: to deem the accelerated fall of bodies to the Earth, along with the curvilinear motion of planets, to be simply natural motions. The great Galileo believed these views to be absolutely correct, and only Hooke found them to be completely untenable. Such propositions liberated one from the reflections on the causes of the accelerated fall of bodies and the curvilinear motion of planets and were needed in order not to lose one's mind from the inability to guess the existence of gravitational forces. By the same token, the proposition about the inertial properties of bodies liberates one from the painful reflections on the physical nature of the mysterious object generating the inertial forces. All of this can be understood as a historically temporary point of view dictated by the immense complexity of the problem.

THE PHYSICAL NATURE OF INERTIAL FORCES

Thus, it has been found that the body itself with an acceleration \mathbf{w} relative to Newton's "absolute space" cannot create an inertial force. Hence, there exists a material object unknown to us and being the source of the inertial force applied to the body itself. There exists the fairly widespread assertion that the inertial forces are fictitious, because they have no sources and they do not obey the law of action and reaction (Newton's proposition that the inertial force emanates from the body itself moving with an acceleration is evident in the latter argument). And anyone who believes under the influence of Mach's propositions that the inertial forces emanate from distant stars is mistaken. Indeed, the inertial force of a material point reacts to any change in the acceleration immediately, without the slightest delay, and this is possible only if the inertial force emanates from the material object located in the same place where the material point moving with an acceleration is located.

Here, however, we again, as in the case of discussing the

nature of gravitational forces, reach the conclusion that the entire world, including all interatomic and intermolecular spaces, is not empty but is filled with the ether, a medium with a very fine structure created from forms of matter completely different from those known to us. This difference lies primarily in the fact that the ether generating the gravitational and inertial forces must itself be massless and (if Newton's language is used) have no inertia. The latter means that even if the matter of the ether admits any structural microdisplacements, these displacements can occur very rapidly, because there are no inertial forces decelerating them. The high propagation velocity of light in the ether serves as a confirmation of this. The ether is versatile.

However, (Kirpichev, 1951) raised yet another objection whose meaning is as follows:

If the force \mathbf{F} causing a body's acceleration \mathbf{w} and the inertial force $\Phi = -m\mathbf{w}$ are applied to the same body, then these two forces are mutually balanced. And this means that the body itself must be at rest or move uniformly and rectilinearly, while it actually moves with the acceleration

$$\mathbf{w} = \mathbf{F}/m \quad (2)$$

This contradiction seemingly proves that the inertial force is fictitious. However, the above reasoning is erroneous. And Newton himself gave a cause for this error by defining the force as follows:

"An exerted force is an action upon a body, in order to change its state, either of rest, or of uniform rectilinear motion" (Newton, 1686).

Newton's inconsistency is obvious: according to this definition, the inertial force introduced by him previously is not a force. This misunderstanding is resolved by adopting the following classification of forces: All forces in dynamics should be divided into two distinctly different classes. Some are the causes of an accelerated motion of bodies and can be called accelerating forces. All forces, except for the inertial ones, belong to this class: these include the active forces, constraint forces, and forces of resistance. The inertial forces that arise as a result of an accelerated motion of bodies constitute the second class. Although, similar to any mass forces, the inertial forces produce the same strains and stresses in bodies, their dynamical effect is not only nonequivalent to the effect of accelerating forces but also directly opposite to it: inertial forces do not cause an accelerated motion of bodies, but, on the contrary, impose constraints on the magnitude of the acceleration. As regards the term "forces", a collective meaning should be retained for it, as is required by linguistics. We foresee the following objection: "Since an accelerated motion of bodies can be caused only by active forces, the constraint forces cannot be called accelerating ones". The answer to this objection can be the following: a book rests on a table, while two accelerating forces (the gravitational one and the table reaction) act on it; each of these forces causes an acceleration of the book, but the vector sum of these accelerations is zero.

The absence of the term "accelerating forces" leads to an ambiguity of the term "forces": all forces, except the inertial ones, but, occasionally, all forces, including the inertial ones,

most often stand behind it at present. For example, we write the equation

$$m\mathbf{w} = \sum_{k=1}^n \mathbf{F}_k \quad (3)$$

and say that the product of the mass of a material point and its acceleration is equal to the sum of all forces acting on the point. But this is completely wrong, because only the accelerating forces are presented on the right-hand side of Eq(3). Equation (3) itself expresses an equilibrium between the accelerating forces and the inertial force reflected on its left-hand side with the opposite sign.

A static equilibrium is an equilibrium under the action a balanced system of only accelerating forces. This can also be seen from Eq (3) in which $\mathbf{w} = 0$ when and only when the accelerating forces are balanced between themselves. If, however, a balanced system of forces containing an inertial force is involved, then this is a dynamic equilibrium of forces corresponding to an accelerated motion of a material point. Thus, the above-mentioned objection negating the action of inertial forces on the accelerating body itself is completely untenable, because in this objection, the property of an accelerating force is implicitly ascribed to the inertial force. The situation where the inertial forces are declared to be fictitious, i.e., existing only in our imagination, is instructive as a typical example of a deviation from the truth. Whereas experimental facts have allowed one only to admit the existence of difficulties with the recognition of the object generating the inertial forces and, thus, to identify a fundamental problem waiting for its solution, the scientific community has been tempted by an easier way.

This way originates from the perpetual inclination of humanity toward a gross exaggeration of the extent to which the Universe has been studied. Each generation believes that none of the objects hidden from the astute minds of scientists have remained in nature. An object generating inertial forces is visually indistinguishable, and the properties ascribed to it bear no resemblance whatsoever to the properties of ordinary matter "given to us in sensations". Therefore, the choice fell on the simplest but false solution: there is no such object in nature and, hence, there are also no inertial forces. The logic of our quest for the truth is directly opposite. When analyzing experimental facts, we detect inertial forces. And these forces point with the greatest confidence to an immovable, pervasive world ether. And no matter how unusual its surprising properties would seem to us, we accept them based on an analysis of experimental facts. And this is correct, because physics constructed without the ether turns out to be explicitly or implicitly in the captivity of mysticism. Returning to Newton's term "absolute immovable space", we find it inapt, but only because of the word "space". An empty space cannot influence the pattern of motion of bodies that is determined only by the operating forces, while no forces can be in a void. If, however, we admit that Newton's space is filled with an ether, then the latter is the main object, while the role of a simple container is assigned to the space. Therefore, we replace Newton's "absolute immovable space" with the more appropriate term "ether". The ether is indeed immovable in the sense that some of its parts cannot move

relative to other parts. If this were not the case, then a free body traversing the regions where some parts of the ether move relative to the nearby ones would move nonuniformly and generally not rectilinearly. So, we endow the ether with the property of immobility based on experimental facts. The widespread opinion that the ether does not manifest its presence in any way and, therefore, the very fact of its existence raises serious doubts is absolutely untenable. Indeed, suppose we are in a moving vehicle and we are pressed to the seat back as it quickly gathers speed, while our body uncontrollably leans forward as it brakes sharply. This is a result of the direct action of the inertial forces exerted to our body from the ether. Thus, we constantly feel the direct action of the ether on us, but by habit we see only Newton's "inertia of mass" in this.

The motion of a terrestrial laboratory relative to the ether was detected in experiments (Michelson & Gale, 1925; Miller, 1933; Sagnac, 1913; Shtyrkov, 2005) and was confirmed by a theoretical analysis of various experimental data (A. V. Emelyanov, 2014; A. V. Emelyanov & Emelyanov, 2015).

It is presently known that the Sun together with the Solar system move relative to the ether with a constant velocity of ~250 km/s or slightly greater, but no higher than 300 km/s. This velocity is almost orthogonal to the ecliptic plane and is directed approximately toward the star ζ Dra (Miller point). A refinement of these data is restrained by the absence of present-day information about the precessional rotation of the orbits of Venus, Earth, Mars, and the asteroid Athene (A. V. Emelyanov, 2014). The radar methods of determining the coordinates of celestial bodies mastered by observational astronomy half a century ago have long allowed this to be done with the necessary accuracy.

THE ROLE OF INERTIAL FORCES IN DYNAMICS

Imagine a spaceship outside the Solar system and far from large masses. The engines of the spaceship have been switched off and it does not rotate relative to the stars, representing an inertial reference frame. There are two astronauts inside the spaceship with their backs leaned against the opposite walls of the spaceship that toss a lead ball with a mass of 100 kg between themselves. When the astronaut catches the ball, he applies a force to slow it down. Then, he continues to push the ball away, forcing it to move with an acceleration toward the second astronaut. Having separated from the astronaut's hands, the ball moves rectilinearly and uniformly to the point of contact with the hands of the second astronaut. Let us formulate two questions that arise in the essence of this example.

First question: Why does the ball come into motion with quite a definite acceleration relative to the ether under the action of a definite force? How is this exactly definite magnitude of the acceleration is achieved rather than smaller or larger ones?

Answer: If we think over the meaning and logic of this question, then we will reach the only correct conclusion. There can be no other mechanism except the force one to ensure a close correspondence between the accelerating force and the acceleration caused by it. Let us explain the essence

of this mechanism. If the ball-center acceleration gained under the action of a force F were smaller than F/m , then the inertial force acting on the ball from the ether would be smaller than the force F . In this case, the accelerating action of the force F would continue until the acceleration reaches F/m at which the inertial force would completely balance the accelerating force F .

If the acceleration were larger than F/m , then the counter-accelerating action of the inertial force would prevail, which would lead to a drop in the acceleration to the required magnitude. But we must adopt the views that the inertial force balancing the accelerating force arises without delays if we admit that the law of action and reaction formulated by Newton is universal.

Second question: Why does the ball center persistently retain its rectilinear and uniform motion on its way from one astronaut to the other?

Answer: This is possible only if there are forces stabilizing this motion. And such forces actually exist. These are the inertial forces. The first sign of a deviation of the ball center from its rectilinear and uniform motion is the emergence of a nonzero center-of-mass acceleration. In this case, however, the inertial forces whose resultant is applied to the ball center and is directed oppositely to the acceleration immediately arise. If there were no inertial forces opposing the accelerated motion of material bodies relative to the ether, then any randomly emerged deviations from their rectilinear and uniform motion would destroy the stability of a free or so-called inertial motion.

Let us consider a few more questions related to the issue being discussed.

Question: We are accustomed to seeing the difference between statics and dynamics in the fact that the forces are balanced in statics and unbalanced in dynamics. Now, it turns out that the forces are balanced always. Then, what distinguishes the mechanism of an accelerated motion from the mechanism of rest?

Answer: If a material point is at rest or moves rectilinearly and uniformly relative to an inertial reference frame (and, hence, relative to the ether), then this material point is affected by only the accelerating forces that are balanced between themselves. An accelerated motion of the material point arises when the resultant of the accelerating forces is nonzero. In this case, the acceleration of the point relative to the ether is set to be equal to the resultant of the accelerating forces divided by the mass of the point. This acceleration is established owing to the inertial force balancing the accelerating forces and, thus, stopping a further growth of the acceleration.

Question: How would dynamics look like if there were no inertial forces in nature?

Answer: Such questions are not quite legitimate, because we must bring our judgments into correspondence with the real world, which is given to us in one variant and only with inertial forces. However, it is this question that cannot be called a completely idle one, because a reasonable answer can be given to it. We should rely on the fact that the inertial forces always oppose the accelerating forces and balance them. If we imagine that this balance has been upset due to a

drop in the acceleration, then the action of the accelerating forces will become dominant over the counter-accelerating action of the inertial forces. This will lead to a growth of the acceleration until a complete equilibrium between the forces is established. Now, we can easily imagine the dynamics of bodies in a virtual world without any inertial forces. It is quite obvious that in this case, any accelerating force will cause infinitely large acceleration of a material particle, because this is equivalent to the motion of a massless particle in our real world, as can be seen from Eq (1) for the inertial force.

Question: Mechanics developed without mentioning the inertial forces as the real forces acting on material objects moving with an acceleration allows virtually any problems of science and engineering to be solved, with no deviations from experiments being observed. Therefore, the debates about the nature and role of inertial forces seem unnecessary to many people.

Answer: The problems of science consist not only in calculating, achieving good agreement between the calculations and experimental data, but also in having undistorted knowledge of the laws of nature and the processes governed by these laws. In addition, the sciences must strive for simplicity and clarity, while theories based on misconceptions never meet these requirements. The geocentric model of the Universe developed by Ptolemy also allowed all problems of celestial mechanics to be solved before the times of Tycho Brahe. But the heliocentric model of the Solar System developed by Copernicus is more correct and simpler. And the completely erroneous caloric theory also allowed the heat exchange problems to be solved correctly. So, correct numbers can be combined with misconceptions about the processes standing behind these numbers. Complete clarity in understanding the physical processes underlying the cosmos must be achieved, because any misunderstanding in such important questions sooner or later turns out to be a whole set of very serious errors. There is also the very popular opinion that it is not worthwhile to argue over trifles when one can do more useful work. This is simply a common reaction to a problem that you do not know how to treat because it seems as if this problem is absent. Meanwhile, the inertial forces everyday remind us of their reality.

We are faced not simply with one of the complex problems of dynamics but with the most complex one. Newton attempted to solve it. But he made only the first steps in the necessary direction and stopped, being deluded and declaring that the inertial forces were generated by the bodies themselves moving with an acceleration. In this way, he created an illusion of clarity where it was not; and the problem of inertial forces turned out to be preserved without being solved. But we should not blame Newton for not resolving the problem of inertial forces, because it is very difficult for perception even today, i.e., three centuries and a quarter later. It is useful to remember that at any stage of development of civilization, humanity tried to present the scientific knowledge as more complete and free of errors than it actually was. And this severely hinders the progress of science. It should not be allowed that any uncertainty in the

foundations of science be masked by pseudo-scientific concoctions or be declared to be insignificant. On the contrary, scientists are obliged to honestly distinguish and identify all incompletely clear physical processes and concepts and to constantly return to their rethinking as the knowledge is accumulated.

FORCES IN NONINERTIAL REFERENCE FRAMES

Figure 2 presents two reference frames: an inertial or conditionally absolute frame $\xi\eta\zeta$ and a noninertial or relative frame xyz .

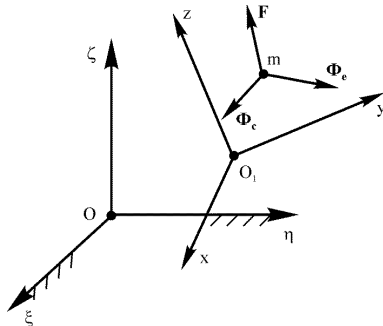


Fig 2. Motion of a particle with mass m in absolute ($\xi\eta\zeta$) and noninertial (xyz) reference frames.

In accordance with the Coriolis theorem, the absolute acceleration w of a material point is the sum of its relative, w_r transport, w_e and Coriolis, w_c accelerations:

$$w = w_r + w_e + w_c \tag{5}$$

Substituting Eq (5) into Eq (1) for the inertial force yields

$$\Phi = \Phi_r + \Phi_e + \Phi_c \tag{6}$$

Here,

$$\Phi_r = -mw_r, \Phi_e = -mw_e, \Phi_c = -mw_c \tag{7}$$

and Φ_r , Φ_e and Φ_c are the relative, transport, and Coriolis inertial forces, respectively. With allowance for Eqs (5-7), Eq (3) takes the form

$$mw_r = F + \Phi_e + \Phi_c \tag{8}$$

where F means the resultant of all the accelerating forces applied to a material point of mass m should be meant by F . Equality (8) is the equation of motion of a material point in a noninertial reference frame. It means that the product of the point's mass and its relative acceleration is equal to the sum of all the accelerating forces acting on the point plus the transport and Coriolis inertial forces. If the left-hand side of Eq(8), which is a reflection of the relative inertial force (with the opposite sign), is treated simply as the product of mass and acceleration, then the forces acting on the material point turn out to be dependent on the observer's reference frame, which contradicts the physical concept of force. Any forces in mechanics manifest themselves via measurable effects of

their static or dynamic action on material bodies. Note that such effects do not depend on the observer's reference frame.

For example, if some accelerating force F acts along a deformable rod and causes an accelerated motion of the rod, then the rod lengthens if the force F is applied to its front end (Fig 3a). If, however, the force F is applied to the back end of the rod, then the rod shortens (Fig 3b).

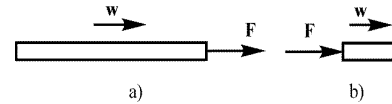


Fig 3. Two cases of rod deformation under the action of an accelerating force F and the inertial forces of the rod molecules: a) stretching; b) compression.

In this example, the rod deformation is caused by the action of the lumped force F and the inertial force continuously distributed along the rod length. The rod length depends only on the point of application of the force F and on the absolute acceleration of the rod w . In classical mechanics, the rod length is the same for observers located in any reference frame. And this means that the force is a concept that does not depend on the reference frame. Let us now consider the motion of a material point with mass m under the action of an accelerating force F in an absolute reference frame $\xi\eta\zeta$ and in a noninertial frame xyz moving translationally and rectilinearly (Fig 4).

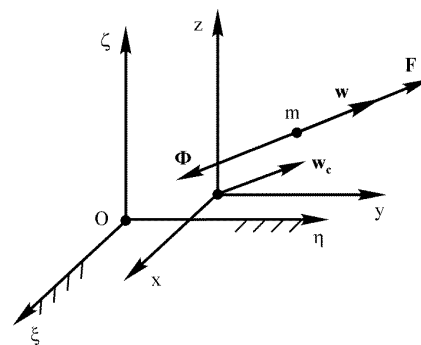


Fig 4. The forces acting on a material particle in a noninertial reference frame (xyz) moving translationally and rectilinearly.

Let the acceleration w_e of the moving reference frame always remain codirectional to the absolute acceleration w of the material point. Let, in addition, w_e increase from zero to w . In this case, Eq. (8) takes the form

$$mw_r = F + \Phi_e \tag{9}$$

where

$$\Phi_e = -mw_e$$

The observer located in the noninertial reference frame xyz will find that the force Φ_e increases monotonically as w_e approaches w . However, this increase of Φ_e will be accompanied by the decrease of the left-hand side of Eq (9). Note that the force Φ_e increases just to the same extent as the product mw_r decreases. Hence, a clever observer should

understand that the left-hand side of Eq (9) describes the relative inertial force acting on the material point. This force and the transport inertial force Φ_e constitute the same absolute inertial force Φ (see Eq (1)) that does not depend on the observer's reference frame. If, however, the observer in the frame xyz denies that the left-hand side of Eq (9) is the relative inertial force Φ_r , written with the opposite sign, then he must reach the absurd conclusion that the forces acting on the material point must depend on the observer acceleration. In the latter case, we cannot get rid of the feeling that the force Φ_e is inadequate. And hence, we are already not far from declaring the concept of force to be the product of mental constructs rather than the reflection of objective reality.

The concept of force belongs to the fundamental categories of mechanics, and we cannot construct the correct picture of mechanical processes and understand them without this concept. Any attempts to banish the concept of force from mechanics and to emasculate it will never move us forward, because mechanics without forces is just the same as thermodynamics without temperature. It is no coincidence that Newton defined mechanics as "the science of motions resulting from any forces whatsoever, and of the forces required to produce any motions, accurately proposed and proven".

Let us now make the last, very important comment on inertial forces in arbitrary reference frames.

Although the sum of the relative, Φ_r transport, Φ_e and Coriolis, Φ_c inertial forces in any noninertial reference frame is always equal to the absolute inertial force Φ that does not depend on the way of introducing a reference frame, the component vectors Φ_r , Φ_e and Φ_c themselves can have a multitude of variants corresponding to different ways of introducing a reference frame. In this sense, the relative, transport, and Coriolis inertial forces are conditional, as are the components of any vector decomposed in three arbitrarily chosen directions.

For example, in the Ptolemaic reference frame rigidly bound to the Earth, the numerical values of Φ_r , Φ_e , and Φ_c increase without limit as the distance between the celestial body and the Earth increases, while their vector sum that represents the absolute inertial force balancing the gravitational force decreases inversely proportional to the square of the distance from the Sun. This is because the motion of a celestial body in the Ptolemaic reference frame turns out to be artificially complicated and unnatural. In the Copernican reference frame, motions of celestial bodies get the simplicity and clarity that usually accompany the truth.

REVISION OF SOME CONCEPTS OF CLASSICAL MECHANICS

Those functions that Newton ascribed to the "absolute space" can actually be performed only by the ether.

Definition1: The immovable medium generating the inertial and gravitational forces is called the ether.

The ether is the medium through which the electric, magnetic, and nuclear forces are transmitted. The ether fills the entire Universe. It is a special form of matter with a very fine structure, because it permeates all bodies, filling all

intermolecular and interatomic spaces. The ether does not impede the rectilinear and uniform motion of a material object. In the case of motion with an acceleration, the ether creates forces directed oppositely to the acceleration.

Can we assert that the ether is produced by all the known matter of the Universe? This assertion is absolutely groundless. We know nothing about the origin of the ether and the matter whose structure has been partially studied. Therefore, we should not go into the speculative reasoning of whether one form of matter can transform into another or the world is organized in such a way that this is absolutely impossible. We still know too little about the structure of the Universe, and the real wisdom is to recall this more often and not to create the impression that humanity has already approached the solution of the last mysteries of the Universe.

Definition2: Any reference frame immovable relative to the ether is called an absolute one.

Definition3: Any reference frame moving relative to the ether translationally, rectilinearly, and uniformly is called an inertial one.

The theorem on composition of accelerations makes it possible to formulate the main property of inertial reference frames. The acceleration of a material point relative to any inertial reference frame coincides with its acceleration relative to the ether.

If a material point moves rectilinearly and uniformly relative to the ether, then its motion in any inertial reference frame is also rectilinear and uniform. Note that there are no reference frames in Newton's works. The concept of an inertial frame was introduced by Streintz (1848–1892) in 1883, but under a different name. The present-day name was put into circulation two years later. We think that Gilbert (1544–1603) and Newton were right in their definition of mass as a measure of the quantity of matter if everything except the ether is meant by matter here. Indeed, the gravitational force between two bodies depends not on the chemical composition of these bodies but on the total quantity of matter contained in them. The presence of electric charges and magnetic ores does not affect the gravitational forces either. This means that the gravitational and inertial forces created by the ether are proportional to some most general characteristic of matter. We see no alternative to the quantity of matter for the role of such a characteristic. However, if someone will deem these arguments inconclusive, then he can regard Newton's definition as a hypothetical one that presently can be neither proven nor refuted in a form capable of satisfying the demands of the guardians of scientific rigor. The maniac adherence to rigor never takes into account our limited knowledge of the structure of the Universe and the common sense. Anyway, Newton's definition of mass is more preferable and deeper than the relativistic interpretation of this concept as a quantity dependent on the relative velocity of a material body and, consequently, on the observer's reference frame. The mass understood as a measure of the quantity of matter cannot depend on the velocity. However, there is reason to hope that at a high velocity in the ether the inertial force depends not only on the absolute acceleration but also on the absolute velocity (A. V. Emelyanov, 2014). Many attempts to give a

rigorous definition of force are known. They all, but for different reasons, are unsatisfactory, and some of them are simply absurd. At present, it will suffice to have the correct concept of force encompassing not only the accelerating forces, as has been done up until now, but also the inertial forces. The forces are those actions whose presence completely determines the magnitude and direction of the acceleration of a material point relative to the ether. The forces cannot be transmitted through a void. They can be present only in material objects, to which the ether also belongs. Mechanics operates only with real forces. There are no fictitious forces and pseudo-forces in it. A force is characterized by its magnitude and direction. The vector nature of forces must be considered as an experimental fact reflecting one of the properties of the real world. The reality of forces in mechanics manifests itself in the emergence of measurable effects of their static or dynamic action on material bodies that are independent of the observer's reference frame. All forces in dynamics are divided into two fundamentally different classes.

1. The class of accelerating forces that are the cause of an accelerated motion of material particles and bodies. All specified and so-called active forces as well as the constraint forces and resisting forces are the accelerating ones.

2. The class of inertial forces arising from an accelerated motion of material particles and bodies. The inertial forces are generated by the ether, act on the accelerating material objects themselves, and impose constraints on the magnitude of the absolute acceleration of a material object.

THE LAWS OF CLASSICAL DYNAMICS IN NEW FORMULATIONS

What we have found out up to this point allows us to look at the system of laws of mechanics physically more clearly. This view leads to a different formulation of the first two laws and to revisions in the other two laws. As a result, the system of laws benefits in completeness, integrity, and physical clarity.

The first law or the law of inertial force. A material particle moving with an acceleration \mathbf{w} relative to the ether is subject to the action of an inertial force Φ generated by the ether, directed oppositely to the acceleration, and equal to the product of the particle mass and acceleration.

$$\Phi = -m\mathbf{w} \quad (10)$$

The second or main law. An accelerating force \mathbf{F} imparts an acceleration \mathbf{w} to a material particle relative to the ether at which the inertial force Φ balances the force \mathbf{F} . Newton's particular equation follows as,

$$\mathbf{F} + \Phi = 0, \text{ or } m\mathbf{w} = \mathbf{F} \quad (11)$$

Corollary: A material particle free from the action of accelerating forces moves rectilinearly and uniformly relative to the ether and any inertial reference frame.

The third law or the law of composition of forces. The simultaneous action of several accelerating forces $\mathbf{F}_1, \mathbf{F}_2, \dots, \mathbf{F}_n$ on a material particle is equivalent to the action of a single force \mathbf{F} equal to their vector sum:

$$\mathbf{F} = \mathbf{F}_1 + \mathbf{F}_2 + \dots + \mathbf{F}_n \quad (12)$$

Note: The inertial forces should not be included in this law, because the vector nature of the inertial forces follows from the vector nature of the acceleration following from kinematics. A joint consideration of Eqs (11) and (12) leads to Newton's general equation

$$\sum_{k=1}^n \mathbf{F}_k + \Phi = 0, \text{ or } m\mathbf{w} = \sum_{k=1}^n \mathbf{F}_k \quad (13)$$

It means that in any state of motion or rest of a material particle, the forces acting on it are mutually balanced. If a material particle moves with an acceleration relative to the ether or, equivalently, relative to any inertial reference frame, then the action of the accelerating forces on it is balanced by the inertial force. If, however, a particle is at rest or moves relative to the ether uniformly and rectilinearly, then the accelerating forces applied to it are mutually balanced, and the following equation is valid,

$$\sum_{k=1}^n \mathbf{F}_k = 0 \quad (14)$$

Since in a noninertial reference frame

$$\mathbf{w} = \mathbf{w}_r + \mathbf{w}_e + \mathbf{w}_c \quad (15)$$

the second equation in (13) can be represented as

$$m\mathbf{w}_r = \sum_{k=1}^n \mathbf{F}_k - m\mathbf{w}_e - m\mathbf{w}_c \quad (16)$$

Since all terms of this equation are forces, it does not provoke the reasoning about the relativity of forces and the fictitiousness of some of them. The fourth law or the law of action and reaction. The forces with which two material particles interact are equal in magnitude and are directed oppositely along one straight line. Here, the third Newton's law is renumbered into the fourth one. As is well known, Newton did not include the rule of composition of forces in his system of laws, thinking it to be a simple corollary of his first two laws. If he noticed that his proof was logically flawed and admitted that the law of composition of forces was independent, then beyond any doubt he would place it immediately after the main law, leaving his law of action and reaction in the last place as before. This is dictated by the logic that Eq (13) follows immediately after Eq (11).

EXPLANATIONS TO THE LAWS OF CLASSICAL MECHANICS

These laws cannot be called axioms, because physical laws are the results of generalization of experimental facts. Anyone who creates physical theories in which the initial hypotheses are called axioms wants these hypotheses to be considered as the truths that need no justifications and explanations. We can and must occasionally test physical laws for their close correspondence to experimental facts. In contrast, the axioms are the concepts of pure mathematics accepted without any proof and unprovable as the simplest and obvious truths. Physics is more complex than mathematics in the sense what seems obvious today may turn out to be a fallacy tomorrow. In the history of physics, this is

traced as inevitability and by no means as a chance. It should be kept in mind that reducing the number of laws by combining some of them (for example, the first and second, the second and third) is not an achievement and is inadmissible, because each law must express only one elementary physical truth.

An axiom of release from constraints is occasionally said to be required in dynamics. This is wrong. Once the constraint force has been brought into consideration, there is no need whatsoever to remove the constraint, because there can be no other action in mechanics than the action by virtue of forces. A constraint influences a moving object only through the constraint force. It should also be remembered that the very idea of release from constraints is a farfetched theoretical operation rather than a physical law of nature. It originates from the immature views that the laws of dynamics are supposedly formulated for a free material point and, hence, the operation of release from constraints is needed to have the right to apply these laws to the dynamics of coupled bodies. This is a primitive look at the laws of dynamics. These laws must be a priori suitable for developing all branches of mechanics. If they do not satisfy this requirement, then the system of laws is imperfect. Therefore, if it is revealed at some stage of development of mechanics that the problems for which the existing system of laws or the concepts in which these laws were formulated lack something, then one should revise, refine, and possibly extend the formulations of basic laws and the meaning of basic concepts, but not to invent corrective axioms. Therefore, when formulating the laws of dynamics for a material particle, we should admit that any forces encountered in mechanics, including the constraint forces, can act on it and should not restrict the class of acting forces to the examples presented by Newton three centuries ago. If someone will assert that a small asteroid moves as a free body in curved space, then we will correct him in two ways.

1. The pattern of motion of a body is determined only by the forces acting on it. Any other mechanism of influence on the motion of a body except the action by virtue of forces is a mystical concoction.

2. The stability of the orbital motion of an asteroid is provided by the inertial forces. The gravitational forces are not suitable for this role.

Note that the concept of a material point introduced after Newton is not quite apt. Newton considered motions of only material bodies. However, bodies can rotate, and this makes the consideration not always proper. However, a material point is an object with an infinite density, because it has a mass but does not have a volume. Apart from the fact that the density of material objects is always limited by the values corresponding to known chemical elements, this gives rise to inconveniences when the mechanics of points is extended to the mechanics of solid, liquid, and gaseous bodies. We consider a volume element and suppose it to be identical to a material point, which is absolutely wrong.

But that's not the only issue. Elementary particles with finite sizes and densities move according to the laws of quantum mechanics. Wave-particle duality should be considered the only possible way for particles of such small

sizes to move in the ether. And here a material point appears to be a completely improper and farfetched object. The listed difficulties disappear if instead of a material point we use the concept of a material particle whose sizes are arbitrarily small compared to the sizes of macroscopic bodies, but, at the same time, they have a reasonable density and contain enough atoms in order not to obey the laws of quantum mechanics.

ON THE PRINCIPLE OF RELATIVITY

This principle was introduced by Galileo. We will outline the essence of the principle of relativity in our own words, retaining the content of ideas in the original. If a ship moves over a calm sea with a constant velocity without changing its course, then all mechanical processes inside the ship proceed in the same way as if the ship was immovable. For example, the billiard players in the ship's saloon will not detect any anomalies in the motion of balls. This illustration of the principle of relativity according to Galileo is very clear but not quite correct since any ship rotating with the Earth and, besides, moving over a spherical surface does not represent an inertial reference frame.

A modern illustration of the essence of the principle of relativity must look somewhat differently. A spaceship with its engines turned off moves translationally, rectilinearly, and uniformly relative to the ether. The influence of the nearest celestial bodies can be neglected due to their remoteness. In this case, all mechanical processes inside the spaceship must proceed in exactly the same way as if the spaceship was at rest relative to the ether. Since the times of Mach, it has been customary to consider the principle of relativity separately from the laws of classical mechanics and to treat it not only as an independent physical law but also as a more general one. According to Einstein, all physical processes proceed identically in all inertial reference frames. In fact, this principle is a corollary of the laws of classical mechanics. Indeed, the left-hand side of Newton's equation depends on the acceleration relative to the ether. However, the acceleration relative to the spaceship is identical to the absolute acceleration. Therefore, under the same accelerating forces and the same initial conditions, any material object inside the spaceship will move identically for any absolute velocity of the spaceship. The principle of relativity can be said to be valid as long as Newton's equation (13) is valid. If we now recall that Newton's equation is valid as long as Eq(10) for the inertial force is valid, then we can say that the principle of relativity is a corollary of the first law, or the law of the force of inertia, of classical mechanics (in a new formulation). Let us list those issues whose ignorance leads to a misconception about the validity range of the principle of relativity. First, these include assigning the status of special objects, which define the "physical properties of the space", to inertial reference frames. In fact, what appears as the "physical properties of the space" is a manifestation of the physical properties of the ether. Physical properties cannot be immanent to the space itself. Inertial reference frames are nothing more than frames moving translationally, uniformly, and rectilinearly relative to the ether. Second, these include the obscurity of the physical meaning of the inertial force (10). In fact, this force is caused by the ether and applied to

the accelerating material body itself.

As soon as Newton's Eq(11) is replaced by the equation of relativistic dynamics, the acceleration of the same material particle turns out to be different in different inertial reference frames, and the principle of relativity loses its validity. The accuracy of Newtonian mechanics is known to be very high but, nevertheless, limited. This was first found through observations of the precession of Mercury's orbit. Where is the source of errors of classical mechanics? What are the prospects for refinement of classical mechanics? If the predictions of the theory (A. V. Emelyanov, 2014) will be confirmed by observational astronomy, then only the law of inertia is to be refined in the presented laws of classical dynamics. This law will appear as follows: A material particle moving with a velocity v relative to the ether is subject to the inertial force caused by the ether and determined by the expression

$$\Phi = -\frac{d}{dt} \left(\frac{mv}{\sqrt{1-v^2/c^2}} \right) \quad (17)$$

Where c is the speed of light in the ether. Newton's equation (11) is replaced by a more accurate one:

$$\frac{d}{dt} \left(\frac{mv}{\sqrt{1-v^2/c^2}} \right) = F \quad (18)$$

This equation differs from the equation of relativistic dynamics in two respects. First, the velocity v in the new equation (18) is the velocity relative to the ether and not relative to an arbitrary reference frame. Second, the particle mass in Eq. (18) is represented by the symbol m and not by the expression $m/\sqrt{1-v^2/c^2}$. It can be said that the inertial force increases more rapidly than it does in Newtonian mechanics as v in Eq(18) grows. But the mass m of the particle does not depend on its velocity.

RESULTS AND CONCLUSIONS

1. Our understanding of the physical nature of inertial forces points with the greatest certainty to the existence of an immovable pervasive world ether that plays a key role in the structure of the Universe.

What Newton called the absolute immovable space whose mysterious influence underlies the dynamical processes in the Universe is actually an immovable ether. An empty space cannot exert any influence on the motion of bodies.

2. Newton ascribed the crucial influence on the dynamical

processes to the "immovable absolute space" in the absence of a force relation between it and material objects moving with acceleration. This is an error. In fact, the laws of motion of bodies in dynamics are governed by the ether acting on the material objects, which change their velocities relative to the ether, by virtue of inertial forces.

3. Newton endowed material objects with the ability to generate inertial forces impeding any changes in the absolute velocity of the bodies. He called this an "innate property of matter". However, this proposition implicitly ascribes to the stones the ability to recognize any attempts to change their absolute velocity and to produce forces directed oppositely to the absolute acceleration. Nonliving bodies cannot have such properties, because they, in essence, are doomed to retain their complete indifference to those motions into which they are drawn by external forces. The inertial forces caused by the ether are applied to the bodies themselves moving with acceleration.

4. All forces in dynamics are divided into two fundamentally different classes: (i) the accelerating forces to which all active forces, constraint forces, and resisting forces belong and (ii) the inertial forces. The accelerating forces are the causes of accelerated motion of bodies. The inertial forces restrict the growth of the acceleration, balancing the action of the accelerating forces at a strictly definite acceleration.

5. The concept of an immovable ether completely resolves the problem of obscurity of the physical nature of inertial reference frames. Any reference frame moving relative to the ether translationally, rectilinearly, and uniformly is an inertial one. The particular simplicity of the laws of motion in inertial reference frames is explained by the fact that the relative acceleration in such frames is exactly coincident with the absolute acceleration in the immovable ether.

6. The physical nature of the principle of relativity is as follows: since the acceleration of a material point in any inertial reference frame coincides with its absolute acceleration with respect to the immovable ether, Newton's equation

$$m\mathbf{w} = \mathbf{F} \quad (19)$$

where \mathbf{F} is the resultant of the accelerating forces, is also valid in any inertial reference frame. Therefore, under the same initial conditions, the motion of bodies in all inertial reference frames will be the same. However, as soon as Eq(19) is replaced by the equation of relativistic dynamics, the principle of relativity ceases to hold.

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