

Reinterpreting Galileo's Inclined Plane and Pendulum Experiments

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Abstract

Galileo made significant contributions to the development of physics, including his discovery of inertia through the inclined plane experiment with a small ball. However, the limited understanding of the natural universe in Galileo's era prevented a complete interpretation of his findings. Even today, physicists grapple with fundamental questions such as why matter possesses inertia and what its true nature is. Addressing these questions is critical for refining classical mechanics and interpreting the concept of inertial reference frames. Since Galileo's time, physics has undergone centuries of development, accumulating a wealth of knowledge that was unavailable to early pioneers like Galileo, Descartes, and Newton. This progress has introduced new ideas and methods for tackling fundamental problems in physics. Consequently, it is both timely and necessary to reinterpret foundational classical physics experiments using contemporary insights. This article presents a reinterpretation of Galileo's inclined plane and pendulum experiments, leveraging modern physics knowledge and alternative perspectives. The study reveals that inertia fundamentally arises from the conservation of energy and offers a clear explanation for phenomena such as why an accelerating free-falling elevator qualifies as an inertial frame of reference. It also explores the origins of energy in the universe and reports several other significant findings. These discoveries, which have implications for bridging classical and modern physics, are discussed in detail.

Keywords

Nature of inertia, Galileo's inclined plane experiment, free-falling elevator, inertial reference frame, conservation of energy, Newton's laws of motion, free-fall motion, uniform linear motion, origin of energy, simple pendulum experiment, Descartes' physics

Explanation of References

The classic experiments discussed in this study were conducted centuries ago, and their essence is well-documented in modern physics textbooks. These textbooks provide comprehensive interpretations and results of the experiments, making them the primary references for this article. The author believes that referencing original historical documents from hundreds of years ago is less meaningful in this context.

Given the wealth of resources available in today's era of highly developed internet technology, readers who are interested in the original sources of these experiments can easily access them

online. This approach ensures that the focus remains on the updated interpretation of these foundational experiments.

Introduction

As is well known, many fundamental scientific problems in classical physics have remained unresolved for centuries. Examples include the origin and nature of gravity, the source of energy, the definition of an inertial frame of reference, the nature of inertia, and the composition of the universe. These challenges have persisted for hundreds or even thousands of years. I believe the primary reason for this is that the approaches and methodologies historically employed to address these problems have been flawed or inadequate. In science, the foundation of progress lies in adopting the right ideas and methods—ideas determine the way forward. To resolve these fundamental problems, it is essential to first establish a set of correct principles and methodologies. Without this foundation, classical physics risks remaining at an impasse.

My perspective is that physics problems should be approached from the standpoint of material basis, physical mechanisms, and natural laws, rather than relying solely on mathematical models that are disconnected from physical reality. Based on this framework, I previously conducted a physical analysis of Newton's gravitational formula, focusing on physical facts and processes. This analysis yielded significant results: it resolved questions about the origin and nature of gravity, the composition of the universe, the source of the universe's initial driving force, and other long-standing scientific problems [1]. These findings demonstrated that this new perspective and methodology are effective for addressing fundamental scientific questions.

To further validate this approach, I have reinterpreted Galileo's inclined plane experiment and simple pendulum experiment from the perspective of material basis, physical mechanisms, and natural laws. This article presents a detailed explanation and discussion of this reinterpretation process and its results.

Galileo's inclined plane experiment with a rolling ball is a seminal example of combining physical experimentation with thought experiments [2]. From physical observations, Galileo discovered that if a smooth ball is released from a point *I* on an inclined plane, as shown in Figure 1, and allowed to roll down and ascend another inclined plane, the highest point it reaches on the second plane will be at the same height as the initial point *I*. Furthermore, when he adjusted the angle of the second inclined plane, he observed that the ball's final height always remained consistent with its starting height, regardless of the plane's angle. This finding demonstrated that the ball inherently tends to return to its original height when no external force acts upon it.

Building on these experimental results, Galileo devised a thought experiment. He reasoned that if the second inclined plane were completely flat, the ball—although retaining the ability to return to its initial height—would no longer have the opportunity to ascend and would instead continue moving indefinitely along the plane. Theoretically, this motion would persist forever unless interrupted by an external force.

From this reasoning, Galileo concluded that matter possesses an inherent property that allows it to maintain its state of motion, a property he termed **inertia**. He defined motion sustained

without external force as **inertial motion**. However, Galileo did not investigate further into the underlying causes of inertia or its fundamental nature. His conclusions were based on observable phenomena but did not delve into the essential reasons behind this behavior. This limitation indicates that while his work was groundbreaking, it left the deeper nature of inertia unexplored.

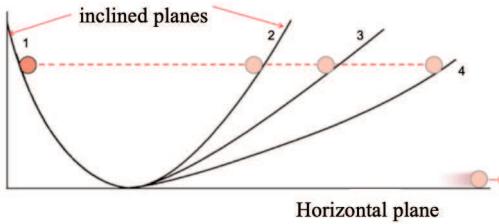


Figure 1. Schematic diagram of Galileo's experiment with a small ball on an inclined plane. Galileo observed that when the ball rolled down from point 1, the height it achieved on the second inclined plane—regardless of its angle—was always equal to the initial height at point 1. From this physical observation, he logically concluded that if the second inclined plane were made flat, the ball would continue to move indefinitely without stopping, provided no external force acted upon it.

Nevertheless, Galileo's research had a revolutionary impact on the development of physics. It challenged and ultimately overturned Aristotle's traditional concept, derived from everyday experience, that "force is the cause of maintaining an object's motion." Galileo's discovery of inertia demonstrated that force is not necessary to sustain motion; rather, the inertial motion of the ball on the plane occurs without any applied force. He redefined the role of force, correctly identifying it as "the cause of a change in an object's state of motion." This groundbreaking insight later became a cornerstone in the formulation of Newtonian mechanics, fundamentally shaping the trajectory of classical physics.

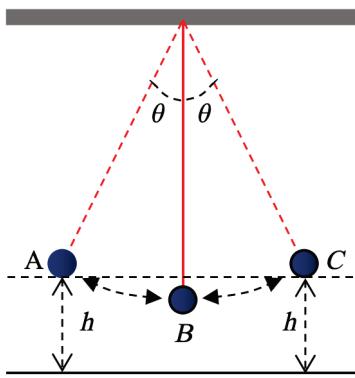


Figure 2. Schematic diagram of Galileo's simple pendulum experiment. In the absence of external forces, the ball's swing reaches a height at the endpoint C that is always equal to the height at the starting point A.

In addition to his inclined plane experiment with a small ball, Galileo also conducted the well-known simple pendulum experiment [3], as shown in Figure 2. He discovered that the

same simple pendulum exhibits the same swing angle, whether it moves from left to right or from right to left. In other words, during the pendulum's motion, the height at the endpoint *C* is always the same as the height at the starting point *A*. Based on this observation, Galileo formulated the important principle of "isochronism" for pendulums, which states that the period of oscillation is independent of the amplitude, provided the amplitude is small.

However, in his study of the pendulum, Galileo did not connect this motion with the inclined plane experiment involving the ball. As a result, the pendulum and inclined plane experiments were treated as separate phenomena in Galileo's framework. To him, there appeared to be no inherent relationship between the two. This view persisted in Newtonian mechanics and remains the prevailing perspective today. Nevertheless, as shown in this study, the underlying essence of both experiments is, in fact, the same.

Galileo's inclined plane experiment was originally conducted on the surface of the Earth, specifically on a horizontal plane. As shown in Figure 3, the horizontal plane is actually a part of the spherical surface of the Earth. However, Descartes later interpreted Galileo's experiment in a more abstract form [4]. He conceptualized the horizontal plane in Galileo's experiment as an idealized, perfectly flat surface. With this abstraction, Descartes concluded that when the ball rolling down the inclined plane is not influenced by any external force—or when the net external force is zero—the ball will continue to move with uniform linear motion, maintaining its original speed and direction.

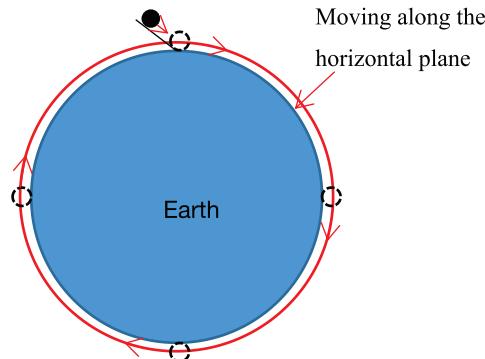


Figure 3. Galileo's inclined plane experiment was originally conducted on the horizontal plane of the Earth.

Building on Descartes' ideas, Newton formulated the famous law of inertial motion: "An object that is not acted upon by an external force will either remain at rest or move in a straight line with constant speed, unless acted upon by an external force." This law became the first of Newton's three laws of motion. As a result, Galileo's concept of inertial motion along a horizontal plane evolved into the modern interpretation of uniform linear motion. This view remains in place today. However, this abstraction clearly differs from the specific results of Galileo's original experiment, which did not involve an idealized flat plane, but rather the practical conditions of Earth's surface.

Unfortunately, Newton's three laws of motion are descriptive in nature—they merely describe observed phenomena. Neither Newton nor other physicists have provided theoretical explanations for why these phenomena occur. As a result, Newton's laws are essentially

subjective postulates, lacking a solid theoretical foundation. This has led to a situation where even fundamental concepts, such as the definition of an inertial frame of reference, cannot be clearly explained using Newton's laws.

I argue that any theory that fails to explain physical phenomena from the perspective of material basis, physical mechanisms, and natural laws is incomplete. This limitation may be a reflection of the scientific understanding at the time. Therefore, it is essential to use the advancements in scientific knowledge made after Galileo and Newton to reinterpret Galileo's inclined plane experiment, as well as other classical physics experiments. Such reinterpretation will allow us to derive more accurate conclusions based on the work of these predecessors. This is the motivation and purpose of the present study.

Reinterpretations and discussions

1. Result of the small ball inclined plane experiment and uniform linear motion

Upon reviewing Galileo's original experiment, it becomes clear that the so-called "plane" in the small ball inclined plane experiment is not an idealized straight surface but the horizontal plane of the Earth. Therefore, Descartes' interpretation that the result of Galileo's experiment indicates that the ball is in uniform linear motion does not align with the objective facts.

The actual result of Galileo's inclined plane experiment is that the small ball moves along a curved path on the horizontal plane of the Earth, rather than in a straight line. Descartes' conclusion that the motion is uniform linear motion is an abstract, idealized interpretation detached from the real-world conditions of the experiment. From the perspective of abstract reasoning, the inertial motion of uniform linear motion seems to align with Galileo's principle of inertia. However, this conclusion overlooks the fact that the ball in Galileo's experiment is actually following a curved path on the horizontal plane.

On a cosmic scale, true uniform linear motion does not occur in the universe. All straight lines in the cosmic context are, in fact, approximations. Newton's classical mechanics system was built upon Descartes' abstract concept of straight lines. This is one of the reasons why Newton's theory is valid at small scales but exhibits significant errors when applied on a cosmic scale. It also explains why Newton's three laws of motion do not hold in the realms of cosmology or the microscopic world. In short, the motion observed in Galileo's inclined plane experiment is not true uniform linear motion but rather uniform motion along the horizontal plane of the Earth.

2. The inclined plane experiment and simple pendulum experiment

Although Galileo and later physicists did not analyze or interpret the small ball inclined plane experiment and the simple pendulum experiment together, these two experiments actually adhere to the same fundamental physical laws. A comparison between the small ball inclined plane experiment and the simple pendulum experiment reveals key similarities. Specifically, in both cases, the height of the initial point is the same as the height of the endpoint.

In the small ball inclined plane experiment, the ball rolls between two inclined planes, while in the simple pendulum experiment, the pendulum swings back and forth. Both motions follow the same natural laws, and the key to understanding the essential connection between these

phenomena lies in the nature of inertia. Once inertia is fully understood, the underlying relationship between the two physical phenomena becomes immediately clear.

3. The nature of inertia, and energy conservation

In the era of Galileo and Newton, the law of conservation of energy was not yet known, so the phenomenon of inertia could only be described in terms of motion and forces. They could not explain inertia from an energy perspective. However, the inertia of matter can be easily understood through the conservation of energy. In fact, inertia is a physical manifestation of energy conservation.

In Galileo's inclined plane experiment, all the energy at the initial point is potential energy. As the ball rolls down the inclined plane, its potential energy is gradually converted into kinetic energy. When the ball rolls up the second inclined plane, its kinetic energy is fully converted back into potential energy. Throughout this process, the sum of potential energy and kinetic energy remains constant, assuming no external forces intervene. Therefore, as long as the total energy of the ball remains unchanged, it will reach the endpoint at the same height as the initial point. The reason the small ball can theoretically roll forever on the horizontal plane is that its total energy remains constant. As long as the total mechanical energy of the ball is conserved, it will continue to move indefinitely. This law of energy conservation manifests as inertial motion in physical systems.

The same principle applies to the simple pendulum. It is a process of converting potential energy into kinetic energy, and vice versa. As long as the total energy of the pendulum is conserved during its swing, it will continue swinging indefinitely. Therefore, the motions of the simple pendulum and the inclined plane ball are governed by the same principle: the law of conservation of energy.

From this, it becomes clear that the essence of material inertia is rooted in energy conservation. The concept of uniform linear inertial motion described in Newton's first law is, in fact, an idealized or abstract representation of the energy conservation phenomenon. In reality, true uniform linear motion does not exist on a cosmic scale.

4. What is the nature of the inertial frame of reference?

By understanding that the essence of inertia is the conservation of energy, many long-standing problems in classical mechanics can be resolved. One such problem is the definition of an inertial frame of reference.

From the perspective of energy, an inertial frame of reference is a reference system in which the total energy remains unchanged. Uniform linear motion on Earth is not a true, absolute inertial frame of reference. In the natural universe, true absolute uniform linear motion cannot exist. In contrast, the free-falling reference system represents a genuine inertial frame of reference.

In a free-falling reference system, all directions—up, down, forward, backward, left, and right—meet the criteria for an inertial frame of reference. This makes the free-falling reference system the perfect example of an inertial frame of reference.

5. The relationship between free fall and force

A critical aspect of interpreting Galileo's inclined plane experiment involves addressing the problem of universal gravitation. If the concept of universal gravitation were ignored, Descartes' conclusion that inertial motion is uniform linear motion would be reasonable. However, in the real world, universal gravitation cannot be overlooked. This issue is present in Galileo's inclined plane experiment as well. The question arises: why can the ball continue to move indefinitely along the horizontal plane, which is not a straight line, after rolling down the inclined plane? This can only be explained from an energy perspective.

Whether the ball rolls down or up the inclined plane, its total energy remains unchanged. This indicates that the ball in the experiment is not influenced by external forces. To illustrate this concept further, if the first inclined plane is made vertical, the ball will perform free-fall motion. Throughout the entire falling process, the sum of the ball's potential and kinetic energy remains constant. This demonstrates that vertical free fall is also a motion governed by energy conservation, much like the uniform linear inertial motion. The same conclusion can be drawn from the simple pendulum experiment.

Since both free fall and the inertial motion of the small ball are energy-conserving motions, they are not affected by external forces. Consequently, both Galileo's inclined plane experiment and the pendulum experiment show that free fall motion is a forceless motion. This aligns with my previous analysis of Newton's gravitational formula[1]. It is because free-fall motion is forceless that the motion of the small ball on the horizontal plane can be considered inertial and unimpeded by force, allowing it to continue indefinitely.

The realization that free-fall motion is forceless is fundamental to a correct understanding of the natural world. As I have explained in previous works, the origin of free-fall acceleration is determined by the property field of matter. Its mathematical expression is given by $g=G_mD$, where g is the free-fall acceleration, G_m is the Unification Constant, and D is the property field strength. From this formula, it is evident that free-fall acceleration is entirely determined by the strength of the property field D .

This sheds light on why, in Newtonian mechanics, free-fall acceleration is often referred to as gravitational field strength ($E=g=GM/r^2$). In reality, Newton's gravitational field strength is merely a mathematical definition without physical significance. The physical field responsible for universal gravitation should be identified as the property field, rather than the gravitational field. The property field strength $D=M/4\pi r^2$ is the physical quantity that truly reflects the field strength responsible for gravitational phenomena.

6. Redefinition of physical field and vacuum space

It is very important to identify physical field and vacuum space in order to correctly understand physical phenomena. A physical field is a spatial region with a specific physical function. Any space exhibiting effects is considered a physical field. A physical field possesses attributes such as strength, range, and direction. When physical functions are not involved, a space can be treated simply as a spatial region without associated physical properties.

A vacuum, on the other hand, refers to a space devoid of physical functions for specific phenomena. For example, a region without air does not support the transmission of sound waves,

thus making it a vacuum for sound. However, the same airless space still enables the transmission of electromagnetic waves and supports gravitational phenomena, meaning that it is not a vacuum for electromagnetic transmission or gravitational phenomena.

Therefore, the classification of a space as a "vacuum" depends on the specific physical function under consideration. We cannot universally label outer space as a vacuum. While it is a vacuum for sound transmission, it is not a vacuum for electromagnetic waves or gravitational phenomena, as it still allows these interactions to occur.

In summary, whether a space is considered a physical field or a vacuum is determined by the presence or absence of physical functions in that particular space. Thus, outer space, while void of air, still serves as a medium for the propagation of electromagnetic waves and gravitational effects, disqualifying it from being a "vacuum" in the broader physical sense.

7. A new understanding of force

Through Galileo's inclined plane experiment, it was discovered that matter has inertia, and that inertial motion is motion without the influence of force. This was a revolutionary departure from Aristotle's long-held belief that force is required to maintain the motion of objects. Galileo's insight marked a profound shift in understanding.

Now, in light of the reinterpretations in this paper, we can extend this understanding further: free fall motion is also motion without force, just as inertial motion is. This finding is as groundbreaking and transformative as Galileo's original discovery. We must adopt the perspective that objects can experience free fall acceleration without the need for an external force, just as we accepted Galileo's argument that objects can experience inertial motion without external influence.

This new understanding of force comes from recognizing that both inertial motion and free fall motion are governed by the conservation of energy. The total energy of an object remains constant as it moves in both scenarios: in inertial motion, energy is conserved within the system; in free fall, potential energy is converted into kinetic energy, but the total energy remains unchanged. This explains why both motions can occur without external force.

Furthermore, this framework helps clarify why a free-falling elevator is considered an inertial frame of reference. In this scenario, all motion is governed by the principle of energy conservation, which supports the idea that the frame is inertial despite it is accelerating.

8. Why does the revolution of celestial bodies not consume energy?

Once we understand that both inertial motion and free fall motion are motions without external forces, it becomes easier to explain why the revolution of celestial bodies does not consume energy. The circular motion of celestial bodies, like the motion of a small ball on Earth's horizontal plane, is not simply one kind of motion, but rather a composite motion that combines uniform linear motion and free fall motion.

In this case, the uniform linear motion occurs tangentially to the orbit, and the free fall motion occurs in the direction perpendicular to the plane of motion. Both of these types of motion are unforced motions, meaning that they do not require an external force to sustain them. When

combined, they result in circular motion for the celestial body. This implies that the total mechanical energy of the celestial body remains constant throughout its orbit. The celestial body is not losing energy, because the motion is not being continuously influenced by an external force.

In other words, the celestial body's motion is governed by the free fall and uniform linear motions, which is a natural, unforced process. There is no external force continually acting on the body to slow it down or alter its motion. Therefore, unless the celestial body is affected by other external bodies (such as collisions), it can continue its motion indefinitely.

This is why the revolution of celestial bodies in their orbits is so stable and lasting. It is a self-sustaining motion that does not require energy input to maintain its course. Instead of losing energy as traditional mechanics might suggest, the celestial body continues to move due to the inherent properties of its motion governed by the principles of inertia and energy conservation.

9. The bridge connecting classical mechanics and modern mechanics

There has been no fusion between Newtonian mechanics and energy, primarily because Newtonian mechanics explains natural phenomena from the perspective of force and motion. By analyzing Galileo's inclined plane and pendulum experiments through the lens of the conservation of energy, we have successfully identified the relationship between Newtonian mechanics and energy. This approach allows us to bridge the gap between the seemingly incompatible frameworks of Newtonian and modern mechanics, resolving the issue of their incompatibility.

As we know, the key difference between modern theoretical physics and classical physics is that modern theoretical physics is based on energy to understand and explain the natural world, whereas classical physics focuses on force and motion. With the major discovery that the essence of inertia is energy conservation, we can use energy as a bridge to connect classical physics with modern physics. In this way, the long-standing problem of the incompatibility between classical and modern physics can be resolved.

10. How does energy originate?

As indicated previously, matter is the inseparable unity of solid and field. The solid and property field are both fundamental components of matter [1]. The origin of energy can be traced back to the property field of matter and the asymmetry that arises between the natural properties of matter. This concept can be illustrated through the example of free fall acceleration.

Free fall acceleration originates from the property field of matter. When an object falls freely in a property field, it undergoes its most basic form of motion: unforced free fall movement. Therefore, the origin of energy can be linked directly to the fundamental property field of matter.

As shown in Figure 4a, when an isolated object is at rest, its property field and center of mass are completely symmetrical. This state of perfect symmetry is associated with stability, and

importantly, it corresponds to zero energy. There is no motion or force in this state because the system is perfectly balanced.

However, as shown in 4b, when two objects exist in proximity, their property fields and centers of mass are no longer symmetrical relative to each other. This cross-asymmetry between the two objects introduces instability, which is the source of energy. This asymmetry creates a potential difference, which leads to the generation of potential energy. In other words, the potential energy is the result of the cross-asymmetry between the property fields and the centers of mass of two objects.

Additionally, as shown in 4c, when the asymmetry involves only one object, such as in the case of motion, the property field and the center of mass of the object itself become asymmetric, generating kinetic energy. The more asymmetry there is in the relationship between the property field and the center of mass, the greater the energy produced, whether it be kinetic or potential.

In essence, the origin of energy can be traced back to the inherent asymmetry between the fundamental natural properties of matter. Energy emerges whenever there is an asymmetry between the property fields and the center of mass. Whether the energy is kinetic or potential, it is the result of this asymmetry within the physical system. As long as this asymmetry exists between the property fields and centers of mass, energy will exist.

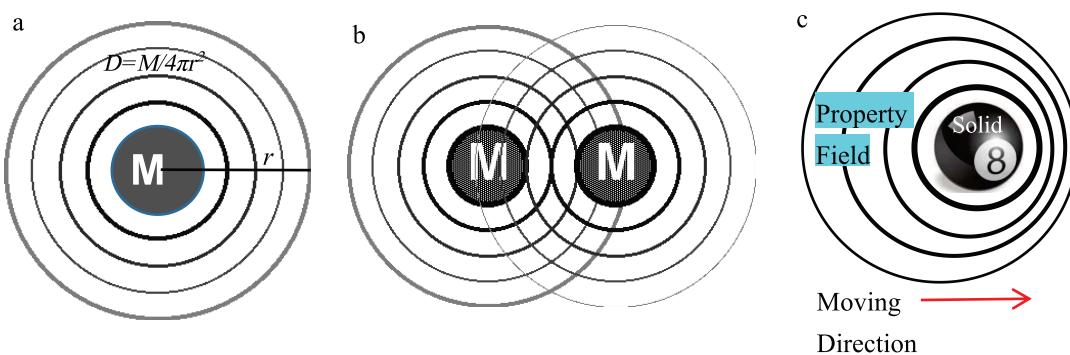


Figure 4. Schematic diagrams of the relationship between the two fundamental natural properties of matter and the origin of energy. a. The property field of a stationary object is in a completely symmetrical state with its center of mass. In this state, the object carries no energy. b. When two objects exist simultaneously, the property fields of the two objects are in a cross-asymmetric state relative to their centers of mass. This cross-asymmetry generates potential energy between the two objects. c. When an object's property field and its own center of mass are in an asymmetric state, the object possesses kinetic energy. Energy originates from the asymmetry between the fundamental natural properties of matter itself.

11. How to distinguish between stillness and uniform linear motion?

Newton's law of inertia cannot fundamentally distinguish between stillness and inertial motion. However, the fundamental natural properties of matter provide a clear distinction. Stillness occurs when the property field of an object is in symmetry with its center of mass. An isolated object at rest carries no energy. In contrast, in inertial motion, the property field of an object is

asymmetrical in relation to its center of mass, and this asymmetry remains constant. From an energy perspective, a stationary object does not possess kinetic energy, and thus it cannot perform work. On the other hand, an object in inertial motion has the ability to do work. This highlights the essential difference between stillness and inertial motion. It becomes evident that explaining classical physics problems through the lens of energy yields better and clearer results.

12. The reason for the limitations of Newtonian mechanics

Because Newton's understanding of Galileo's experiment was incorrect, the Newtonian mechanics he established was also theoretically flawed. This is why calculations of cosmic-scale phenomena using Newtonian theory result in significant errors.

13. What are the correct ideas and methods for studying basic theoretical problems in physics?

This study has demonstrated that for theoretical problems in physics, the correct answers can only be found by looking for solutions from the material basis, physical mechanisms, and natural laws. The correct answer cannot be found by relying solely on mathematics. Times are changing, and future generations have the obligation to reinterpret the experiments of their predecessors using new discoveries. Only in this way can we extract correct information from previous experiments. One reason why research on basic theories in physics has stagnated for so long is that, for a long time, the methods and ideas used by main stream physicists have deviated from the correct general direction.

Conclusions

Through the reinterpretation and discussion of Galileo's ball inclined plane experiment and pendulum experiment, the following conclusions can be drawn:

1. The essence of inertia is the conservation of energy.
2. An inertial frame of reference is a reference system in which there is no process of mechanical energy input or output.
3. The essential difference between stillness and uniform linear motion in inertial phenomena is that the property field of a stationary object and its center of mass are symmetrical, while the property field of an object in uniform linear motion and its center of mass are asymmetrical.
4. All energy in the universe originates from the asymmetry between the fundamental natural properties of matter.
5. The accelerated motion of a free-falling object is a force-free motion, similar to the inertial motion of an object moving in uniform linear motion.
6. The reference frame of a free-falling object in accelerated motion is also an inertial frame of reference.
7. The circular motion of celestial bodies is a motion formed by the combination of force-free uniform linear motion and force-free free-fall motion. As a result, it is also a force-free motion. Since it is a state of energy conservation, it can continue indefinitely.
8. A more accurate redefinition of force: Force is the reason for changing the state of motion of an object, but it is not the only cause of changes in speed or direction. A more precise definition is that force is the reason for changing the total mechanical energy of a physical system.

9. The reason why Newtonian mechanics is only approximately correct is that Newton misunderstood the nature of inertia. Like Galileo and Descartes, he did not understand inertia from the perspective of energy conservation.
10. Descartes' mistake was that his conclusion that inertial motion is uniform straight-line motion only holds in abstract theory, and cannot be accurately realized in reality. He overlooked the phenomenon of gravity in Galileo's inclined plane experiment.
11. The root cause of the issues in Newtonian mechanics is the lack of explanation of physical phenomena from the perspective of energy.
12. The reason classical mechanics and modern mechanics have long been incompatible is that classical mechanics has never been fully explained from the standpoint of energy.
13. Classical experiments must be reinterpreted with updated perspectives and methodologies in order to understand them correctly.
14. Only by solving fundamental problems in physics from the material basis, physical mechanisms, and natural laws can these problems be completely resolved.

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