Inertial Mass and the Inertial Reaction Force Revisited

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Abstract

The inertial mass of an object is a property of the object linking the acceleration of the object relative to a field in space that I will term the temporal inertial (TI) field. This linkage resists the acceleration of the object relative to the TI field. While inertial mass is a property of the object, it is the TI field, not the object, that asserts the force that resists the acceleration of the object relative to the TI field. This force is termed the inertial reaction force and it is a real, not a fictitious force. The inertial reaction force is a physical force between an object and the TI field. It is not a force derived from a change in a frame of reference. In one instance, the inertial reaction force manifests as the weight of an object at rest on the surface of a gravitational body, such as Earth. It derives from the acceleration of the TI field at the object and toward the center of mass of Earth. This interaction occurs because the TI field is directly subject to gravity and matter objects are not. Accordingly, the TI field is accelerated toward the center of mass of Earth. Absent air resistance, a free falling object is accelerated at the same rate as the TI field toward the center of mass of Earth. It is the acceleration of the TI field toward Earth that determines that all objects, regardless of mass, accelerate toward Earth at the same rate, at the same rate as the TI field! Ever wonder what the acceleration of gravity means? It is the acceleration of the TI field in response to gravity. The roles of inertial mass and the inertial reaction force are examined in five different scenarios to illustrate their interaction.

Table of Contents

List of Tables
Table 1 Some Properties and Behavior of the TI Field
Table 2 Characterizing the Source of the Inertial Reaction Force
Table 3 An Object Accelerated by a Non-Gravitational Force Outside Any Gravitational Field
Table 4 An Object at Rest on the Surface of a Gravitational Body
Table 5 An Object in Free Fall in a Gravitational Field
Table 6 An Object in Orbit About a Gravitational Body
Table 7 Two Gravitational Bodies Orbiting Each Other
Table 8 Takeaways on the Inertial Reaction Force
Table 9 Conclusions
Table 10 Glossary
Table 11 References

1.0 Introduction: The Contemporary View of the Inertial Reaction Force

The inertial reaction force, also known as the inertial force or fictitious force, is a force that appears to act on an object when it is in an accelerating or rotating frame of reference. It is called "fictitious" because it does not arise from any physical interaction between objects but rather from the choice of a non-inertial reference frame.

When an object is in an accelerating or rotating frame of reference, it experiences accelerations that are not directly caused by any real forces acting on it. Instead, these accelerations are caused by the motion of the frame of reference itself. To account for these accelerations, we introduce the concept of the inertial reaction force.

The inertial reaction force is equal in magnitude and opposite in direction to the acceleration of the frame of reference. It is necessary to introduce this fictitious force in order to maintain the validity of Newton's laws of motion in non-inertial reference frames.

For example, consider a person standing in a bus that suddenly accelerates forward. From the perspective of the person inside the bus, they will feel as though a force is pushing them backward. This sensation is due to the inertia of their body trying to resist the change in motion caused by the acceleration of the bus. This apparent force is the inertial reaction force.

It's important to note that the inertial reaction force is not a real force in the sense that it does not arise from any physical interaction. It is simply a mathematical construct used to describe the effects of being in a non-inertial frame of reference.

1.1 Contradiction of the Contemporary View

1. The inertial reaction force is a real force, not a fictitious force.
2. The inertial reaction force arises from the physical interaction between an object and the temporal inertial (TI) field.
3. The TI field asserts a real force on an object proportional to the difference in acceleration between the object and the TI field.
4. If an external force is applied to an unrestrained object, the object accelerates relative to the TI field. The inertial reaction force of the TI field acts to oppose the external force. Equilibrium is achieved when the inertial reaction force balances the external force.
5. If there is a difference in acceleration between an object and the TI field, the inertial reaction force is asserted by the TI field onto the object so as to reduce the difference in acceleration between the object and the TI field.

6. The source of the inertial reaction force is the TI field, not the object.

We will examine the action of the inertial reaction force in four different scenarios to support our contention that the inertial reaction force is a real, not a fictitious force.

2.0 Use of Chat.GPT

While chat can be a valuable resource for certain types of communication and collaboration, it may not always be the ultimate resource for information. Other resources, such as reputable websites, databases, and experts in the field, may be more appropriate for obtaining accurate and comprehensive information. A good motto for using Chat.GBT is: Trust, but verify.

Despite these caveats, A portion of the text in this paper was created by Chat.GBT.

Chat.GBT is an API (Application Programming Interface) that provides developers with access to a large language model trained by OpenAI. This language model is based on the GPT (Generative Pre-trained Transformer) architecture and is currently one of the largest and most advanced language models available.

When a user sends a request to the Chat.GBT API, the API receives the request and sends it to the language model for processing. The language model then generates a response based on the input it received and sends it back to the API, which returns it to the user.

The language model is trained on a massive corpus of text data, including papers, articles, and websites, which enables it to understand a wide range of topics and generate responses that are contextually appropriate and grammatically correct. The model is also able to learn from user interactions, so it can improve over time and provide more accurate and helpful responses.

Developers can use the Chat.GBT API to build conversational interfaces for a wide range of applications, including customer service bots, virtual assistants, and chatbots for social media platforms.

3.0 The Temporal Inertial (TI) Field in Brief

Table 1. Some Properties and Behavior of the TI Field
The TI field is a field of particles that participates in the inertial and gravitational interactions.
The TI field is not subject to the electromagnetic force.
The TI field is subject to gravity.
Matter objects are not directly subject to gravity.
Relativistic effects notwithstanding, objects move at constant velocity through the TI field without effect.
Particles of the TI field permeate space at every scale from subatomic to intergalactic and beyond.
Acceleration of the TI field in its response to gravity is moderated by a second field termed the static field.
The TI field supports the propagation of nature's force particle particles, notably: photons and gravitons.
The speed of photons and gravitons is their speed relative to the TI field.
The time dilation of a process is a function of the velocity of the process relative to the TI field.

3.1 Characterizing the Source of the Inertial Reaction Force

The inertial reaction force (IRF) is a real force on an object and is proportional to the difference in acceleration between the object and the TI field.

Table 2. Characterizing the Source of the Inertial Reaction Force
The source of the IRF must be either the TI field or the object.
Assume that the IRF is generated by the TI field.
The IRF is proportional to the acceleration of the object relative to the TI field.
The only fraction of the TI field to apply a force on an object is within the volume of the object itself.
In addition, the interaction between the TI field and the object is proportional to the density of the object.
To summarize: The IRF is proportional to the volume and the density of the object. The product of volume and density yields the mass of the object. Accordingly, the IRF is proportional to the mass of the object.
The inertial mass of an object is a measure of the resistance by the TI field of the acceleration of an object relative to the TI field.
The IRF exerted on the object by the TI field equals the product of the inertial mass of the object and the acceleration of the object relative to the TI field (F = ma).

3.2 The Four Fundamental Forces

> 'There are four fundamental forces at work in the universe: the strong force, the weak force, the electromagnetic force, and the gravitational force.'

We have shown that the TI field is subject only to the gravitational force and not to any of the three fundamental forces recognized in the Standard Model ; the electromagnetic force, the weak nuclear force and the strong nuclear force. Objects comprising matter particles are not directly subject to the gravitational force. The weak and strong nuclear forces are extremely short range and do not affect the interactions of concern in this study.

3.3 The Inertial Reaction Force (IRF) is a Real Force

The inertial reaction force is the force that opposes the acceleration of an object relative to the TI field. The IRF arises from the difference in acceleration between an object and the TI field. The IRF is exerted by the TI field when the acceleration of the object differs from that of the TI field. The IRF is not one of the three acknowledged fundamental forces of the Standard Model, nor is it a gravitational force, but it is a real force.

4.0 Thought Experiments on the Inertial Reaction Force

Five thought experiments on the inertial reaction force (IRF) are detailed in the following sections.

1. An Object Accelerated by a Non-Gravitational Force Outside Any Gravitational Field
2. An Object at Rest on the Surface of a Gravitational Body
3. An Object in Free Fall in a Gravitational Field
4. An Object in Orbit About a Gravitational Body
5. Two Gravitational Bodies in Orbit About Each Other

The behavior of the inertial reaction force (IRF) is developed in the following sections.

4.1 An Object Accelerated by a Non-Gravitational Force Outside Any Gravitational Field

Table 3. An Object Accelerated by a Non-Gravitational Force Outside Any Gravitational Field
The object accelerates relative to the TI field.
An IRF is generated by the TI field and applied to the object as a function of the difference in acceleration between the object and the TI field.
The direction of the IRF on the object is the same as the acceleration of the TI field relative to the object.
The magnitude of the IRF equals the product of the inertial mass of the object and the difference in acceleration between the object and the TI field.
The IRF is transmitted from the object to the agency providing the applied force.
The IRF thus opposes the applied force with equal magnitude but in the opposite direction of the applied force.

4.2 An Object at Rest on the Surface of a Gravitational Body

Table 4. An Object at Rest on the Surface of a Gravitational Body
The TI field is accelerated toward the center of mass of the GB that is the source of the gravitational field.
The acceleration of the TI field is constant at the surface of the GB.
An IRF is generated by the TI field and applied to the object as a function of the difference in acceleration between the object and the TI field.
The direction of the IRF on the object is the same as the acceleration of the TI field relative to the object.
The magnitude of the IRF equals the product of the inertial mass of the object and the difference in acceleration between the TI field and the object.
The IRF on the object is transmitted to the surface of the GB as the weight of the object.
In sum, gravity does not pull the object down, the TI field pushes the object down in response to the acceleration of the TI field which is itself pulled down by gravity.
Time Dilation
If the object at rest on the surface of a gravitational body embodies a process, the process is subject to time dilation.
The time dilation experienced by the process is a function of the infall velocity of the TI field at the object.
The infall velocity of the TI field is the same magnitude, but opposite sign, of the escape velocity from the GB.
The Infall velocity of the TI field accounts in full for the time dilation experienced by the process.

4.3 An Object in Free Fall in a Gravitational Field

Absent air resistance, an object in free fall in a gravitational field interacts with only one entity, the TI field. The object is not directly subject to gravity, but the TI field is. The inertial reaction force acts to nullify any difference in acceleration between the TI field and the object. Thus the object accelerates at the same rate as the TI field.

4.3.1 The Weak Equivalence Principle

> 'The trajectory of a point mass in a gravitational field depends only on its initial position and velocity, and is independent of its composition and *structure*.' [Equivalence principle]

> 'The weak equivalence principle (WEP) states that in a uniform gravitational field all objects, regardless of their composition, fall with precisely the same acceleration.' [Wagner, et al]

> 'In other words, passive gravitational mass must be proportional to inertial mass for all objects.' [Equivalence principle]

The first two quotes express the meaning of the weak equivalence principle and lead to the conclusion of the third quote.

Numerous experiments have been conducted over a period of literally centuries to validate the weak equivalence principle (WEP) by testing the proportionality of the passive gravitational mass to inertial mass of objects of different composition. To date, these experiments have validated this proportionality with increasing precision.

We might ask if there is another mechanism that explains how objects of different composition all fall with precisely the same acceleration in a uniform gravitational field. Does this mechanism imply that the passive gravitational mass must be proportional to the inertial mass for all objects?

The indication that such a mechanism must exist is given in Table 2 in Section 3. The fourth property in the table says that matter objects are not directly subject to gravity. In other words, matter objects do not exhibit passive gravitational mass. Our hypothetical mechanism that enables all objects, regardless of their composition, to accelerate at the same rate in a uniform gravitational field actually mimics the existence of passive gravitational mass of an object and its proportionality with the inertial mass of the object.

What is this mechanism and how might this mechanism work? The TI field is directly subject to gravity and accelerates toward a gravitational body (GB). An object within the TI field is subject to a force generated by the TI field that causes a freely moving object

to accelerate toward the GB. The force on the object acts to nullify the difference in acceleration between the TI field and the object. Hence the object accelerates toward the center of mass of the GB at the same rate as the TI field.

The relationship between the TI field and the equivalence principle is discussed in more detail in references [Peters Hidden Parameters…] and [Peters Unification…]

Table 6 summarizes the behavior of an object in free fall in a gravitational field.

Table 5. An Object in Free Fall in a Gravitational Field
The TI field is accelerated toward the GB that is the source of the gravitational field.
The acceleration of the TI field increases continuously as the TI field gets closer to the GB.
An IRF is generated by the TI field and applied to the object as a function of the difference in acceleration between the object and the TI field.
The direction of the IRF on the object is the same as the acceleration of the TI field relative to the object.
The effect of the IRF is the nullification of the difference in acceleration between the object and the TI field.
Thus the object accelerates at the same rate as the TI field.
As the object accelerates at the same rate as the TI field, there is no change in velocity of the object relative to the TI field as the object descends toward the center of mass of the GB.
The behavior of an object in free fall is identical for all objects regardless of their constituents (atoms).
Thus the acceleration of an object in free fall in a gravitational field is determined solely by the acceleration of the TI field.
There is no force between the object and the GB.
These observations hold regardless of the path of the object provided no extraneous force acts on the object.
Time Dilation
Time dilation of a process is caused by a difference in velocity between the process and the TI field.
As an object in free fall in a gravitational field accelerates at the same rate as the TI field, there is no change in velocity of the object relative to the TI field.

Table 5. An Object in Free Fall in a Gravitational Field
As there is no change in velocity of the object relative to the TI field, there is no change in time dilation of any process embodied in the object.
If an object embodying a process is held stationary relative to the GB the process will experience time dilation due to the velocity of the TI field at the object.

4.3.2 Time Dilation of an Object in Free Fall in a Gravitational Field

An object in free fall in a gravitational field accelerates at the same rate as the TI field in its response to gravity. Thus the velocity of the object relative to the TI field remains constant during the free fall of the object. If the object embodies a process, there is no change in time dilation of the process as there is no change in velocity of the process relative to the TI field. This action is in accord with the analysis in reference [Schutz] that argues that there is no redshift in a freely falling frame.

Does the fact that there is no time dilation of a process in a freely falling frame cause the object to accelerate at the same rate as the TI field? Certainly not, but we now have supporting information that an object in free fall in a gravitational field does indeed accelerate at the same rate as the TI field.

4.3.3 What Role Does the Inertial Mass of an Object Play in the Free Fall of the Object in a Gravitational Field?

The resistance of an object to its acceleration relative to the TI field is inversely proportional to the inertial mass of the object. Any difference in acceleration between the TI field and the object produces a force from the TI field to the object to nullify the difference in acceleration between the two. An object in free fall in a gravitational field thus accelerates at the same rate as the TI field. The inertial mass of the object links the acceleration of the object to that of the TI field. Absent the inertial mass of the object, the object would be impervious to the acceleration of the TI field in its response to gravity.

4.4 An Object in Orbit About a Gravitational Body

Table 6. An Object in Orbit About a Gravitational Body
An object in orbit about a GB is, in essence, in free fall.
The TI field is accelerated toward the GB that is the source of the gravitational field.
An IRF is generated by the TI field and applied to the object as a function of the difference in acceleration between the object and the TI field.
The direction of the IRF on the object is the same as the acceleration of the TI field relative to the object.
The effect of the IRF is the nullification of the difference in acceleration between the object and the TI field.
The object accelerates toward the center of mass of the GB at the same rate as the TI field.
There is no force between the object and the GB.
Time Dilation
If an object in orbit about a GB embodies a process, the process experiences time dilation.
The time dilation of the process is a function of the velocity of the object relative to the TI field.
There are two components of the velocity of the object relative to the TI field: the orbital velocity of the object and the infall velocity of the TI field at the object.
The vector sum of these two components of velocity comprises the total velocity of the object relative to the TI field.
The time dilation experienced by the process is accounted for in full by this total velocity of the object relative to the TI field.

4.5 Two Gravitational Bodies in Orbit About Each Other

Table 7. Two Gravitational Bodies in Orbit About Each Other
Two gravitational bodies in orbit about each other are each in free fall.
The behavior of each GB is similar to that described above for a single object in free fall in a gravitational field.
The interaction between the two bodies is force-free.

5.0 Takeaways on the Inertial Reaction Force

Table 8. Takeaways on the Inertial Reaction Force
An Object Subject to a Non-Gravitational Force
The IRF on the object opposes the applied force.
An Object at Rest on the Surface of a Gravitational Body
The IRF on the object is transmitted to the surface of the GB as the weight of the object.
An Object in Free Fall in a Gravitational Field
The IRF on the object acts to nullify the difference in acceleration between the TI field and the object. Hence the object accelerates toward the center of mass of the GB at the same rate as the TI field.
An Object in Orbit About a Gravitational Body
An object in orbit about a GB is in free fall. The IRF nullifies the difference in acceleration between the TI field and the object. Hence the object accelerates toward the center of mass of the GB at the same rate as the TI field.
Two Gravitational Bodies in Orbit About Each Other
Two gravitational bodies in orbit about each other are each in free fall.
Time Dilation
There is no change in time dilation of a process (e.g., a clock) in free fall as the velocity of the process relative to the TI field does not change.
The time dilation of a process (e.g., a clock) at rest on the surface of a GB is accounted for in full by the infall velocity of the TI field at the process.
Time dilation of a process is not caused directly by gravity.
Summary
An IRF is generated by the TI field and applied to the object as a function of the difference in acceleration between the object and the TI field.
The IRF on the object is in the same direction as the acceleration of the TI field relative to the object.
The magnitude of the IRF equals the product of the inertial mass of the object and the difference in acceleration between the TI field and the object.

6.0 Conclusions

Table 9. Conclusions
An Object Subject to a Non-Gravitational Force
An IRF is generated by the TI field and applied to the object as a function of the difference in acceleration between the object and the TI field.
The IRF applied to the object is in the same direction as the acceleration of the TI field relative to the object.
The magnitude of the IRF equals the product of the inertial mass of the object and the difference in acceleration between the TI field and the object.
An Object at Rest on the Surface of a Gravitational Body
An object at rest on the surface of a GB is subject to the acceleration of the TI field at the location of the object.
An IRF is generated by the TI field and applied to the object as a function of the difference in acceleration between the object and the TI field.
The IRF applied to the object is in the same direction as the acceleration of the TI field relative to the object.
The magnitude of the IRF equals the product of the inertial mass of the object and the difference in acceleration between the TI field and the object.
The IRF applied to the object is transmitted to the surface of the GB as the weight of the object.
In sum, gravity does not pull the object down, theTI field pushes the object down in response to the acceleration of the TI field which is itself pulled down by gravity.
The Infall velocity of the TI field accounts in full for the time dilation experienced by a process at rest on the surface of a GB.
An Object in Free Fall in a Gravitational Field
An IRF is generated by the TI field and applied to the object as a function of the difference in acceleration between the object and the TI field.
The Inertial mass of an object is a measure of the resistance by the TI field of the acceleration of the object relative to the TI field. This resistance by the TI field of the acceleration of an object forces an object in free fall to accelerate at the same rate as the TI field at the object.

Table 9. Conclusions
The behavior of an object in free fall is identical for all objects regardless of their constituents (atoms).
The acceleration of an object in free fall in a gravitational field is determined solely by the acceleration of the TI field.
As there is no change in velocity of an object in free fall relative to the TI field, there is no change in time dilation of any process embodied in the object.
These observations of an object in free fall hold regardless of the path of the object provided no extraneous force acts on the object.
An Object in Orbit About a Gravitational Body
An object in orbit about a GB is, in essence, in free fall.
There is no force between an object in orbit about a GB and the GB.
Two Gravitational Bodies in Orbit About Each Other
Two gravitational bodies in orbit about each other are each in free fall.
The behavior of each GB in orbit about the other is similar to that described above for a single object in free fall in a gravitational field.
The interaction between the two bodies in orbit about each other is force-free.
Major Conclusion
The IRF is not one of the three acknowledged fundamental forces of the Standard Model, nor is it a gravitational force, but it is a real force.

7.0 Glossary

Table 10. Glossary	
Term	**Definition**
Electromagnetic force	Electromagnetic force is an interaction between electrically charged particles. The force is attractive between unlike charges and repulsive between like charges.
Free fall	The motion of an object in a gravitational field where there is no electromagnetic force on the object. We cannot say that gravity is the only force on the object as an object is not subject to gravity.
Gravitational body (GB)	In this study, a gravitational body is a spherically symmetric, massive body such as a planet or star.
Gravitational compression	As particles of the TI field (TIPs) flow toward the center of a gravitational body (GB) the particle density of TIPs will increase without some counteracting agency.
Graviton	A graviton is the hypothetical elementary particle that mediates the force of gravity. Gravitons propagate at the speed of light.
Gravity	Gravity is one of the four fundamental forces in the Universe even though not acknowledged in the Standard Model.
Inertia	Inertia is a property of an object that enables the TI field to resist acceleration of the object relative to the TI field. See Section 3.2.
Inertial reaction force (IRF)	The inertial reaction force (IRF) is a force generated by the TI field and applied to an object as a function of the difference in acceleration between the object and the TI field.

Table 10. Glossary	
Term	**Definition**
Mass	There are three forms of mass: active gravitational mass, passive gravitational mass and inertial mass. 1. Active gravitational mass is a measure of the strength of an object's contribution to gravity. 2. Passive gravitational mass is a measure of an object's response to the gravitational force. 3. Inertial mass is a measure of the resistance by the TI field of the acceleration of an object relative to the TI field. See Section 3.2.
Matter particle	I define matter particles by their properties of mass rather than by their constituents, e.g., sub-atomic particles. One or more matter particles comprise an object.
Object	I define an object by its properties of mass rather than by its constituents. A matter object comprises one or more matter particles. A particle of the TI field (which is not a matter particle) may also comprise an object. The context in which I use the term object determines whether I mean a matter object or a particle of the TI field.
Particle density of the TI field	The number of particles of the TI field (TIPs) within a unit volume of space occupied by the TI field.
Particle of the TI field	An elementary particle of the TI field. Properties and behavior of the TI field are described in Table 2 in Section 3.
Process	a continuous action, operation or series of changes taking place in a definite manner'
Static field	A hypothetical field that resists the acceleration of particles of the TI field in its response to gravity.
Temporal Inertial (TI) field model of gravity and inertia	The Temporal Inertial (TI) field model is a conjecture of this author. This hypothetical model mediates the force of gravity. The TI field permeates all of space from the space within atoms to the expanse of the Universe. A few properties and behavior of the TI field are listed in Table 2 in Section 3.
Time dilation	Time dilation is the slowing of a process as a function of the velocity of the process relative to the TI field. No other function causes time dilation; not gravity and not acceleration.
TIP	A particle of the TI field

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