The Twin Paradox, Falling Clocks and the Global Positioning System

Richard A. Peters

Abstract

To advance a model describing attributes of nature, we are free to claim properties of the model that we believe support those attributes. Absent real experiments we can perform thought experiments to evaluate whether the assumed properties of the model support the attributes we're attempting to model. At the same time, we must consider alternative models that may also support those attributes. Our model is not validated unless we can invalidate the alternatives. Two models are examined: the familiar Newtonian model of gravity and inertia and the TI field model of gravity and inertia, which is a concept of this author. These two models differ in how matter objects interact with gravity and how each model supports the propagation of nature's force particles. We look at these two models to determine which supports correctly the time dilation that occurs during four phenomena: the twin paradox, the Global Positioning System (GPS), a clock in free fall in a gravitational field and a clock at rest on the surface of a gravitational body.

Table of Contents

Table of Contents

Table of Contents

	List of Tables
Table	**Contents**

1.0 First Matters

The object of this paper is to compare the properties of the Newtonian and TI field models of gravity that affect their roles in mediating gravity and in time dilation. These properties are examined by considering the gravitational interaction of each model on matter objects and on the time dilation seen in clocks moving through space.

1.1 The Newtonian and Temporal Inertial (TI) Field Models of Gravity and Inertia

The properties and behavior of a model of gravity that I've named the TI field model of gravity and inertia are compared with the properties of the familiar Newtonian model. The manner in which matter objects and particles of the TI field interact with gravity distinguishes the Newtonian and TI field models of gravity. We look at how the choice of gravitational model affects the time dilation that occurs in the clocks of the Global Positioning System (GPS) and in clocks in free fall and at rest relative to a gravitational body.

The TI field model of gravity and inertia differs from the Newtonian model in how the TI field model explains certain phenomena (time dilation) that are not explained by the Newtonian model.

The two models are compared briefly in Table 1.1 and described more fully in Appendix A.

Table 1.1

Table 1.1	Brief Comparison of Properties of the TI Field Model and Newtonian Model of Gravity and Inertia
TI Field Model of Gravity and Inertia	**Newtonian Model of Gravity and Inertia**
The TI field is directly subject to gravity.	The TI field is not subject to gravity.
The acceleration of the TI field in response to gravity is resisted by the Static field.	NA
The TI field does not assert the gravitational force.	The TI field does not assert the gravitational force.
The TI field supports the propagation of nature's force particles.	NA

Table 1.1	Brief Comparison of Properties of the TI Field Model and Newtonian Model of Gravity and Inertia
TI Field Model of Gravity and Inertia	**Newtonian Model of Gravity and Inertia**
The acceleration of the TI field in response to gravity applies the same acceleration to a freely moving matter object within the TI field. [7]	NA
Matter objects are not directly subject to gravity.	Matter objects are directly subject to gravity.
The acceleration of a matter object in response to a non-gravitational force is resisted by the TI field.	The acceleration of a matter object in response to either a gravitational or non-gravitational force is resisted by the TI field.
Matter objects assert the gravitational force.	Matter objects assert the gravitational force.

1.2 Time Dilation

Time dilation is defined as the decrease in the rate of flow of time in a frame moving relative to an outside observer. I take exception to this definition of time dilation. I assert that the passage of time is constant everywhere, but that a process that moves through ‘space’ takes longer than the process that is stationary or moves more slowly through ‘space’. The ‘space’ I refer to is permeated at every scale from subatomic to extra-galactic by a medium that supports the propagation of nature’s force particles. I will show that time dilation of a process is caused by motion of the process through this medium of space. I give this medium a name: the temporal inertial (TI) field. The TI field is thus a frame of reference for motion.

See Appendix B for more detail on time dilation.

1.3 What is a Process?

A process is an operation, activity or sequence of changes that takes time. The process can be atomic, such as the emission of light from an atom; chemical, such as the reaction of oxidation; biological, such as the aging of an astronaut; or mechanical, such as the rhythm of a metronome or the ticking of a clock.

1.4 The Clock Hypothesis

> ‘The clock hypothesis is the assumption that the rate at which a clock is affected by time dilation does not depend on its acceleration but only on its instantaneous velocity.’
>
> ‘The clock hypothesis was implicitly (but not explicitly) included in Einstein's original 1905 formulation of special relativity. Since then, it has become a standard assumption and is usually included in the axioms of special relativity, especially in the light of experimental verification up to very high accelerations in particle accelerators.’ [10]

Note that the quote above does not specify the frame of reference for velocity. Again, my nominee for this frame of reference is the TI field which is described briefly in Appendix A.

1.5 Three Phenomena

One process that embodies a sensitive and accurate means of measuring the time dilation that occurs when that process moves relative to the TI field is a clock. Thus the time dilation of clocks is featured in the three phenomena to be examined in this study:

1. The twin paradox
2. The Global Positioning System (GPS)
3. Clocks moving and at rest in a gravitational field

1.51 The Section on the Twin Paradox Examines the Effect of the Motion of a Process on Time Dilation

Time dilation of a process is a function of the velocity of the process relative to the temporal inertial (TI) field, not relative to any arbitrary frame of reference. The TI field is a fundamental frame of reference for motion in the Universe.

1.5.2 The Section on the Global Positioning System Examines the Effect of the Earth’s Motion on Time Dilation

Clocks in the GPS satellites experience time dilation as they orbit the Earth. The value of time dilation in each clock must be taken into account and compensated for in order for the GPS to function properly. Time dilation of the GPS satellites depends on the motions of the Earth and the TI field in their response to the gravitational fields of the Earth and Sun (and beyond, but I’ll not get into that). The motions of the Earth and the

TI field in their response to the gravitational fields of the Earth and Sun depend on the model of gravitation that best describes that behavior.

Two models of gravity are examined to determine which supports proper operation of the GPS:

1. The Newtonian model of gravity: Matter objects are subject to gravity, but particles of the TI field are not.
2. The TI field model: Particles of the TI field are subject to gravity, but matter objects are not.

It will be shown that of the two models of gravity examined, only one supports proper operation of the GPS.

1.5.3 The Section on Clocks in a Gravitational Field Examines the Effects of Gravity on Time Dilation

The effect of gravity on the time dilation of a clock in a gravitational field is examined. In the first study, a clock is in free fall in a gravitational field. In the second study the clock is at rest on the surface of a gravitational body (GB). The motion of the clock relative to the TI field in these two studies depends on the gravitational model considered. The same two models of gravity that were considered in the GPS study are considered here. Again, only one model emerges to represent correctly the time dilation experienced by clocks in a gravitational field.

2.0 The Twin Paradox

The treatment in this section is adapted largely and/or verbatim from reference [7].

The twin paradox arises in a thought experiment in which one twin travels at relativistic speed away from his sibling and returns some time later to find that his twin has aged more than he the traveler.

The paradox occurs because of the apparent reciprocity in the view of each twin that his sibling has aged more than he has during the experiment. In a universe without a fundamental frame of reference for motion, the motion of each twin relative to the other is equally valid in assessing the rate at which each twin ages. But in the experiment one twin ages, the other does not, or, rather, one ages more slowly than the other. How should one resolve the apparent discrepancy?

2.1 Reciprocity Failure

Conventional resolutions of the twin paradox are based on the difference in velocity between the two twins and the determination of which of the two twins accelerated during the journey. The twin who accelerated is the twin who ages more slowly.

My disagreement with such explanations centers on the premise that the physics of the interaction with time can be reckoned to the velocity difference between the moving twin and his sibling who is stationary relative to an arbitrarily chosen frame of reference. Motion relative to an arbitrary frame does not explain the physics of how time dilation is produced by such motion. As will be shown in the thought experiment, time dilation of a process (e.g., the aging of an astronaut or the ticking of a clock) is caused by the velocity of the process relative to the TI field.

2.2 A Thought Experiment of the Twin Paradox

Clocks provide a better comparison of elapsed times than the aging of twins, but this example is applicable to the (live) twin paradox.

In our thought experiment the outside observer is spaceship A and its clock A which are both stationary relative to the TI field.

Imagine two spaceships, A and B, located in space far away from any gravitational masses. The two ships contain identical, accurate clocks. The purpose of the experiment is to determine the effect of the motion of Ship B on the timekeeping of its clock compared with the stationary reference clock in Ship A.

The experiment is conducted as listed in Table 2.1. Time dilation occurs as shown in Table 2.2 during each phase of flight, except when the ‘moving’ clock is stationary.

Table 2.1	Phases of Flight
Phase	**Description**
Initial Conditions	Two accurate, identical clocks A and B are in spaceships A and B, respectively. Clocks A and B are synchronized to tick at the same rate and indicate the same time at the start of the experiment. Ship A and its clock remain stationary throughout the experiment.
A. Outbound Acceleration	Ship B accelerates away from Ship A.
B. Outbound Coast	Ship B moves away from Ship A at relativistic speed for some time.
C. Outbound Deceleration	Ship B decelerates until its speed relative to Ship A is zero.
D. Outbound Stop	Ship B remains at its midpoint stop for a short time.
E. Inbound Acceleration	Ship B accelerates up to relativistic speed back toward Ship A.
F. Inbound Coast	Ship B moves toward Ship A at relativistic speed for some time.
G. Inbound Deceleration	Ship B decelerates and comes to a stop at the location of Ship A.
H. Inbound Stop	Ship B stops next to Ship A and the expired time on Clock B is compared with that on Clock A.
End	At the end of the experiment, it is found that the elapsed time on Clock B is less than that on Clock A.

Table 2.2	Phases of Flight and the Effect on Clock Period
Phase	
A, C, E, G. All Acceleration and Deceleration Phases	As acceleration does not cause time dilation, the period of moving Clock B at any given instant during the acceleration and deceleration phases of the experiment is a function of the instantaneous velocity, relative to reference Clock A, of Ship B and Clock B at said instant.
B, F. Outbound and Inbound Coast Phases	The period of moving Clock B during either coast phase of the experiment is a function of the velocity, relative to Ship A and reference Clock A, of Ship B and Clock B during a given coast phase.
D. Outbound Stop	When Ship B and Clock B are stationary relative to reference Clock A, the period of Clock B is the same as that of reference Clock A.
H. Inbound Stop	Ship B and Clock B are again stationary relative to reference Clock A, so the period of Clock B is the same as that of reference Clock A. The elapsed time on Clock B is less than that on Clock A.

2.3 Discussion of the Thought Experiment of the Twin Paradox

What do we know about the relation between the motion of Ship B and the period of its clock?

As Clock B in our thought experiment moves through space its period increases as a function of its velocity relative to reference Clock A. But Clock A has no influence on the period of Clock B. Clock A is merely a place holder, a means of measuring the difference in elapsed time between the two clocks at the end of the experiment. What influences the period of Clock B as it moves through space? It must be some entity in immediate and intimate contact with the clock. The motion of the clock relative to the entity affects the period of the clock, a real physical effect. Therefore, this undefined entity must be physical, not merely a mathematical construct.

The entity must offer a mechanism by which the pace of a process (e.g., the ticking of a clock) can be affected by motion of the process relative to the entity.

At the most fundamental level, particle exchanges underlie all processes: atomic, chemical and biological. Nature's forces are mediated by the exchange of these particles, particles whose propagation through space is supported by some medium.

This medium is the temporal inertial (TI) field. I assert that these exchanges take longer when the process encompassing the exchange is moving through the medium of the TI field. I describe such a mechanism in reference [5]. In this reference I show that the exchange of particles takes longer when the process encompassing the particle exchange is moving relative to the medium through which the particles propagate.

In this same reference I show that time dilation is a function of the velocity of the process relative to the TI field in accord with Eq (B-1) in Appendix B.

2.4 The Temporal Inertial (TI) Field is the Fundamental Frame of Reference for Motion

It is clear from our thought experiment that a change in velocity of Ship B and Clock B relative to 'some frame of reference' in space produces a change in the period of the clock. The ratio between the elapsed time of the moving clock and Clock A, that is stationary relative to this frame of reference, is a function of the velocity relative to this frame of space of the moving clock.

The question is what comprises the frame of reference of space? The term frame is a mathematical concept, such as a coordinate system, by which to reckon position and motion of physical objects, but is not itself a physical entity. A physical entity such as a field must constitute this frame.

The difference in time measured between the moving and stationary clocks is not merely an appearance wrought from the mathematics of frames moving relative to one another and the finite speed of light. Such a construct is the essence of the so-called twin paradox. Conventionally, this paradox is resolved by determining which twin accelerates in the scenario. In contrast, the thesis of this paper resolves the paradox by determining the velocity of the moving twin (Clock B) relative to the aforementioned field of space, not relative to the stationary twin (Clock A).

The difference in time measured between moving and stationary clocks is intrinsic and absolute. A moving clock really does tick more slowly than its stationary counterpart. We can safely conclude that if the velocity of a clock relative to this field of space causes a change in the timekeeping of the clock then there is an interaction between the timekeeping process of the clock and its velocity relative to this field.

The TI field constitutes this frame of reference for motion. The name temporal-inertial (TI) field derives from its role in time dilation and the inertial interaction. The inertial interaction is not discussed in this paper.

2.5 The Clock is Representative of a Process

A process is a change or sequence of changes that takes time. We use a clock as representative of a process that also measures the time taken by the process. The process can be atomic, such as the emission of light from an atom; chemical such as the reaction of oxidation or biological such as the aging of an astronaut. The rate at which any process proceeds depends solely on its velocity through the TI field not on its velocity relative to an arbitrarily chosen frame of reference. Accordingly, the twin paradox is resolved, just as our thought experiment with the two clocks, when the motion of the moving twin is reckoned relative to the TI field not to the frame of reference of the stationary twin.

3.0 The Global Positioning System (GPS)

The Global Positioning System (GPS) provides an unequivocal test of relativity. Two phenomena described in the theories of relativity affect the clock rates of GPS satellites: gravitational time dilation and time dilation caused by motion relative to the TI field. We'll discuss gravitational time dilation in the GPS briefly in Section 4.5. Neglecting gravitational time dilation for the moment, the Global Positioning System compensates for the time dilation of each GPS satellite's clock based on the difference between the satellite clock's orbital velocity and the velocity of the ground-based reference clock. Considering the Earth's many motions including its orbit about the Sun, about the galactic center and its motion with the galaxy relative to the Cosmic Microwave Background (CMB), requires that the TI field and the Earth move in concert.

Consider what would happen if this were not true. If the Earth moved with respect to the TI field, the velocity with respect to the TI field of an orbiting GPS satellite would be greater when a component of the satellite's velocity is in the same direction as the Earth's velocity and less when a component of the satellite's velocity is opposite the direction of the Earth's velocity. Then the rate of its clock due to time dilation would vary continuously during the orbit. Such behavior is not observed. Given that the Global Positioning System works flawlessly and that our interpretation of the thought experiment is correct, only one conclusion can be drawn: the Earth does not move with respect to the TI field.

Now, let us apply this conclusion to determine the interaction of gravity with the Earth and the TI field.

3.1 The Thought Experiments

The motions of the Earth and the TI field in their response to the gravitational fields of the Earth and Sun depend on the model of gravitation that best describes that behavior.

We need some criterion by which to discriminate between the two models of gravity. The two models differ primarily in how matter objects and particles of the TI field react to gravity. The premises for the two models are the following:

1. Premise of the Newtonian model of gravity: Matter objects are directly subject to gravity, but particles of the TI field are not.
2. Premise of the TI field model: Particles of the TI field are directly subject to gravity, but matter objects are not.

In the TI field model of gravity, matter objects are not ***directly*** subject to gravity. This means that gravity acts through the mediation of the TI field, not directly on matter objects. Gravity accelerates particles of the TI field. Any difference in acceleration between the TI field and a matter object applies a force to the matter object that eliminates the difference in acceleration. Gravity is the prime mover in the transaction, but operates ***indirectly*** through the TI field.

In the Newtonian model of gravity, gravity acts directly on matter objects to accelerate them toward the gravitational body. The TI field is not subject to gravity.

Tables 3.1 and 3.2 present the arguments and conclusions from these thought experiments. It will be shown that of the two models of gravity examined, only one supports proper operation of the GPS.

3.1.1 Premise of the Newtonian Model of Gravity: The Earth Is Directly Subject to Gravity, but the TI Field Is Not Subject to Gravity

Table 3.1 The Global Positioning System Premise of the Newtonian Model of Gravity: The Earth Is Directly Subject to Gravity, but the TI Field Is Not Subject to Gravity
Observations
If the Earth and the TI field orbit the Sun in concert, then their acceleration in response to the gravitational field of the Sun must be the same.
If the TI field is not subject to gravity, its motion cannot equal that of the Earth in response to the gravitational force of the Sun.
Conclusion
The Earth cannot be directly subject to gravity while the TI field is not.
The premise of the Newtonian model of gravity is violated.

3.1.2 Premise of the TI Field Model of Gravity: The TI Field Is Directly Subject to Gravity, but the Earth Is Not

Table 3.2 The Global Positioning System Premise of the TI Field Model of Gravity: The TI Field Is Directly Subject to Gravity, but the Earth Is Not
Observations
If the Earth and the TI field orbit the Sun in concert, then their acceleration in response to the gravitational field of the Sun must be the same.
The TI field is subject to gravity and is accelerated by the gravitational field of the Sun.
Any difference in acceleration of the Earth relative to the TI field applies a force to the Earth that maintains the acceleration of the Earth at the same rate as that of the TI field.
The acceleration of the TI field in its response to the gravitational field of the Sun imparts the same acceleration to the Earth, thus the Earth is entrained in the motion of the TI field permeating the Earth.

Table 3.2 The Global Positioning System Premise of the TI Field Model of Gravity: The TI Field Is Directly Subject to Gravity, but the Earth Is Not
Conclusions
The TI field is directly subject to gravity and the Earth and matter objects are not directly subject to gravity.
The premise of the TI field model of gravity is validated.

4.0 Time Dilation in a Gravitational Field

We examine the time dilation of a clock in free fall in a gravitational field. We then examine the time dilation of a clock at rest on the surface of a GB. The motion of a clock relative to the TI field in these studies of gravitational time dilation depends on the gravitational model considered. Two models of gravitation are examined to determine which yields the correct value of time dilation of a clock in a gravitational field whether the clock is in free fall or stationary relative to the GB.

The properties of the two gravitational models that are pertinent to the study of time dilation in a gravitational field are listed in Tables 4.1 and 4.2.

Table 4.1

Table 4.1 Properties of the Newtonian Model of Gravity that are Pertinent to the Time Dilation of a Process (a ticking clock) in a Gravitational Field
Matter objects are directly subject to gravity.
The TI field is not subject to gravity.
Matter objects are accelerated toward the gravitational center of a GB. Accordingly, the infall velocity of a matter object increases with proximity to the GB.
There is no redshift in a freely falling frame. [9]

Table 4.2

Table 4.2 Properties of the TI Field Model of Gravity that are Pertinent to the Time Dilation of a Process (a ticking clock) in a Gravitational Field
Matter objects are not directly subject to gravity.
The TI field is directly subject to gravity.
Particles of the TI field are accelerated toward the gravitational center of a GB. Accordingly, the infall velocity of particles of the TI field increases with proximity to the GB. [6] [8]
The acceleration of the TI field in its response to gravity applies the same acceleration to a freely moving matter object within the TI field. [7]
There is no redshift in a freely falling frame. [9]

4.1 Two Gravitational Models

We saw in Section 2 on the twin paradox that time dilation was caused by the velocity of a clock relative to the TI field. In this study we'll show that the cause of time dilation in a gravitational field depends on the operative gravitational model.

Tables 4.3 through 4.6 present the arguments and conclusions from these thought experiments. If the premise of a given gravitational model is violated then that gravitational model is invalidated.

It will be shown that of the two models of gravity examined, only one yields the proper value of time dilation in a gravitational field.

4.2 A Clock in Free Fall in a Gravitational Field

There is no redshift (time dilation) of a process in free fall in a gravitational field. [9] Each premise in this section posits a different gravitational model. If the model leads to the time dilation of the clock in free fall, the premise is violated and the gravitational model is invalid.

The following condition is assumed for each of the three thought experiments described below:

> The gravitational body (GB) is at rest relative to the TI field, the infall velocity of the TI field notwithstanding.

4.2.1 Premise of the Newtonian Model of Gravity: Matter Objects Are Directly Subject to Gravity, but the TI Field is Not

Table 4.3 A Clock in Free Fall in a Gravitational Field Premise of the Newtonian Model of Gravity: Matter Objects Are Directly Subject to Gravity, but the TI Field is Not
Observations
A clock in free fall toward a gravitational body (GB) experiences an increase in the strength of the gravitational field of the GB and an increase in velocity relative to the TI field.
Both the increase in strength of the gravitational strength and the increase in velocity of the clock, relative to the TI field, increase the time dilation of the clock.
Conclusions
As there is no redshift in a freely falling frame, there can be no time dilation of the freely falling clock caused by the increase in strength of the gravitational field.
As there is no redshift in a freely falling frame, there can be no time dilation of the freely falling clock caused by the increase in velocity of the clock relative to the TI field.
The premise of the Newtonian model of gravity is violated.
Matter objects cannot be directly subject to gravity while the TI field is not.
The Newtonian model of gravity is invalidated.
Gravity does not directly cause time dilation.

4.2.2 Premise of the TI Field Model of Gravity: The TI Field is Directly Subject to Gravity, but Matter Objects Are Not

Table 4.4 A Clock in Free Fall in a Gravitational Field Premise of the TI Field Model of Gravity: The TI Field is Directly Subject to Gravity, but Matter Objects Are Not
Observations
A clock in free fall toward a gravitational body (GB) experiences an increase in the strength of the gravitational field of the GB.
A clock in free fall toward a gravitational body accelerates at the same rate as particles of the TI field, hence the velocity of the clock relative to the TI field is constant throughout its free fall.
Conclusions
As there is no change in velocity of the clock relative to the TI field, there is no change in time dilation caused by this phenomenon.
As there is no redshift in a freely falling frame, there can be no time dilation of the freely falling clock caused by the increase in strength of the gravitational field.
Gravity does not directly cause time dilation.
The premise of the TI field model of gravity is upheld: The TI field is directly subject to gravity and matter objects (e.g., the clock) are not directly subject to gravity.

Of the two gravitational models evaluated for a clock in free fall in a gravitational field, only the model in which the TI field is directly subject to gravity and matter objects are not is validated.

4.3 A Clock at Rest in a Gravitational Field

In studying a clock in free fall in a gravitational field it was shown in that the TI field is directly subject to gravity and matter objects are not. Now we'll examine a clock at rest in a gravitational field to see if the conclusions reached in that study are upheld by the example of a clock at rest on the surface of a GB.

A process in a gravitational field experiences time dilation. The question is what is the direct cause of this phenomenon? The conventional view is that time dilation of a process is directly caused by the gravitational field. We have seen that time dilation of a process is not caused directly by a gravitational field. We will see in this section that time dilation of a process is caused by the infall velocity of the TI field relative to the process that is itself stationary relative to the gravitational field. Let's see how that conclusion determines the viability of the two gravitational models of our thought experiments.

4.3.1 Premise of the Newtonian Model of Gravity: Matter Objects Are Directly Subject to Gravity, but the TI Field is Not

Table 4.5 A Clock at Rest in a Gravitational Field Premise of the Newtonian Model of Gravity: Matter Objects Are Directly Subject to Gravity, but the TI Field is Not
Observations
A clock at rest in the gravitational field of a GB is subject to the gravitational field of the GB.
Conclusion
It was determined in Section 4.2 that time dilation is not directly caused by gravity.
The gravitational field of the GB at the clock at rest on the surface of the GB does not directly cause time dilation of the clock.
Observations
As the TI field is not subject to gravity there is no velocity of the TI field at the surface of the GB and no motion of the clock relative to the TI field
As there is no velocity of the clock relative to the TI field at the surface of the GB there is no time dilation of the clock.
Conclusions
In the real world a clock at rest on the surface of a GB would experience time dilation.
The premise that matter objects are directly subject to gravity and the TI field is not is violated.
The Newtonian model of gravity is invalidated.
This thought experiment cannot distinguish whether or not matter objects (such as the clock) are subject to gravity.

4.3.2 Premise of the TI Field Model of Gravity: The TI Field is Directly Subject to Gravity, but Matter Objects Are Not

Table 4.6 A Clock at Rest in a Gravitational Field Premise of the TI Field Model of Gravity: The TI Field is Directly Subject to Gravity, but Matter Objects Are Not
Observations
A clock at rest in the gravitational field of a GB is subject to the gravitational field of the GB.
Conclusions
It was determined in Section 4.2 that time dilation is not directly caused by gravity.
The gravitational field of the GB at the clock at rest on the surface of the GB does not directly cause time dilation of the clock.
The infall velocity of the TI field relative to the clock at rest on the surface of the GB causes time dilation of the clock. See Section 4.4 and Appendix B.
The idea that the velocity of a process relative to the TI field is the only cause of time dilation is affirmed.
This thought experiment shows that the TI field is directly subject to gravity.
This thought experiment cannot determine whether or not matter objects (such as the clock) are directly subject to gravity.

4.4 Quantifying the Infall Velocity of the TI Field Toward a Gravitational Body

Gravity does not directly cause time dilation. While gravity is the prime mover in the phenomenon, it acts only indirectly by accelerating particles of the TI field. The velocity of a process relative to the TI field is the only cause of time dilation. What is the velocity of particles of the TI field as they fall toward a GB? As described in Section B.4 of Appendix B, that velocity is the negative of the escape velocity at the point of regard.

4.5 Gravitational Time Dilation in the Global Positioning System

The question of gravitational time dilation in the Global Positioning System has been deferred until now. We have seen in the previous sections that gravity does not directly cause time dilation. The question is: What causes the gravitational time dilation that does occur in the GPS? As mentioned in Section 4.4, the velocity of a process relative to the TI field is the only cause of time dilation. There are two components of a GPS satellite's velocity relative to the TI field: the satellite's orbital velocity and the infall velocity of the TI field at the location of the satellite. (See Appendix B.) The total velocity of the GPS clock with respect to the TI field is the vector sum of its orbital velocity and the velocity of the TI field flowing toward the Earth at the GPS clock's altitude. The time dilation of the satellite's clock is a function of this velocity of the clock relative to the TI field.

5.0 The Weight of a Matter Object

We've quantified the value of the infall velocity of the TI field in response to the gravitational force. Why is this important? While gravity is the prime mover in the phenomenon, the infall velocity of the TI field at the process as the proximate cause of gravitational time dilation.

> 'In the ISO International standard ISO 80000-4:2006 describing the basic physical quantities and units in mechanics as a part of the International standard ISO/IEC 80000, the definition of *weight* is given as: [11]
>
> $$F_g = mg$$
>
> where m is mass and g is local acceleration of free fall.'

I clarify that mass in the equation in the quotation means the inertial mass of the matter object. The given definition does not include the effect of the buoyancy of the atmosphere surrounding the object, nor does it include the effect of the centrifugal force of the rotation of the Earth at the location of the measurement.

5.1 What is Accelerating?

What I like about the definition of weight given in the quotation is the definition of g. The definition of g is the local acceleration of free fall. For the equation to make any sense at all, the local acceleration of free fall should have direct influence on the matter object. If the matter object is at rest on the surface of the Earth, for example, just what is accelerating that directly affects the matter object? The matter object is not accelerating relative to the Earth, it is at rest on the surface of the Earth.

There is one frame of reference for motion that is not even contemplated by the equation: the TI field. Up to this point in the discussion, our emphasis on the TI field has been on its role in time dilation.

5.2 The Role of the TI Field on Time Dilation of a Process and the Force on a Matter Object

The following bullet points emphasize the role of the TI field in time dilation of a process and the force on a matter object.

- ***Time dilation*** of a process is all about the ***velocity*** of the process relative to the TI field.
- The ***force*** on a matter object is all about the ***acceleration*** of the object relative to the TI field.
- Alternatively, the force on a matter object is all about the acceleration of the TI field relative to the matter object.

The acceleration of an object in response to a non-gravitational force is resisted by the TI field. The inertial reaction force is the force that resists acceleration of a matter object relative to the TI field. The magnitude of the inertial reaction force equals the product of the inertial mass of the object and the acceleration of the object relative to the TI field. See Appendix A, Table A.1. As the TI field is accelerated by the gravitational field of the Earth it applies a force to the matter object at rest on the surface of the Earth. This force is the weight of the matter object which is balanced by the surface of the Earth holding up the object.

6.0 Conclusions

6.1 Conclusions by Argument

Table 6.1 Conclusions by Argument
The Twin Paradox
Time dilation of a process is a function of the velocity of the process relative to the temporal inertial (TI) field, not relative to any arbitrary frame of reference. The TI field is a fundamental frame of reference for motion in the Universe.
The Global Positioning System (GPS)
The TI field and the Earth orbit the Sun in concert.
The TI field model of gravity is affirmed.
Clocks in a Gravitational Field
There is no time dilation of a clock in free fall in a gravitational field. The velocity of a process relative to the TI field is the sole cause of time dilation of the process. The time dilation of a clock at rest relative to a GB is caused by the infall velocity of the TI field at the clock. Gravity does not directly cause time dilation. Matter objects are not directly subject to gravity. Particles of the TI field are directly subject to gravity. The TI field model of gravity is affirmed.
The Weight of a Matter Object
The weight of a matter object at rest relative to a gravitational body is caused by the infall acceleration of the TI field at the object. The weight of the object is not caused directly by gravity.
The weight of an object at rest relative to a gravitational body is equal to the product of the inertial mass of the object and the infall acceleration of the TI field toward the center of mass of the GB.
Quantifying the Infall Velocity of the TI Field Toward a Gravitational Body
The infall velocity of the TI field is equal in magnitude, but opposite in sign, to the escape velocity from the GB at the point of measurement.
The Takeaway
The TI field model of gravity is affirmed.

6.2 Conclusions by Category

Table 6.2 Conclusions by Category
Time Dilation
Time dilation of a process is a function of the velocity of the process relative to the temporal inertial (TI) field, not relative to any arbitrary frame of reference.
The velocity of a process relative to the TI field is the sole cause of time dilation of the process.
The TI field is a fundamental frame of reference for motion in the Universe.
Gravity does not directly cause time dilation.
Gravitational Model
The TI field model of gravity is validated.
The Newtonian model of gravity is invalidated.
Matter objects are not directly subject to gravity.
Particles of the TI field are directly subject to gravity.
Motion of the TI Field
The infall velocity of the TI field toward a GB is equal in magnitude, but opposite in sign, to the escape velocity from the GB at the point of measurement.
The time dilation of a clock at rest relative to a GB is caused by the infall velocity of the TI field at the clock.
The weight of a matter object on the surface of a GB is the product of the inertial mass of the object and the infall acceleration of the TI field at the object.
The TI field and the Earth orbit the Sun in concert.

7.0 References

1. **^** Cutner, https://books.google.com/books?id=2QVmiMW0O0MC&pg=PA128#v=onepage&q&f=false
2. ^ **a b** Escape velocity, https://en.wikipedia.org/wiki/Escape_velocity, Retrieved Nov 2020.
3. **^** Gravitational time dilation, https://en.wikipedia.org/wiki/Gravitational_time_dilation, Retrieved Nov 2020.
4. **^** Mass, https://en.wikipedia.org/wiki/Mass, Retrieved Nov 2020.
5. **^** Peters, Richard A., Conjecture on the True Cause and Meaning of Time Dilation, https://vixra.org/pdf/1212.0115v1.pdf, Retrieved Oct 2020.
6. **^** Peters, Richard A., Conjecture on Time Dilation, Gravity and Inertia, https://vixra.org/pdf/1205.0112v1.pdf, Retrieved Oct 2020.
7. ^ **a b c** Peters, Richard A., Time Dilation and the Twin Paradox Revisited, https://vixra.org/pdf/1407.0073v1.pdf, Retrieved Oct 2020.
8. **^** Peters, Richard A., Time Dilation, Gravity and Inertia, The Physics Heresies, Ch 1, ISBN 9781483552682, Apr 2015, https://store.bookbaby.com/book/the-physics-heresies
9. ^ **a b c** Schultz, B. F., *A First Course in General Relativity (2 ed.),* p. 115, (Cambridge University Press, Cambridge, 2009), https://www.amazon.com/First-Course-General-Relativity/dp/0521887054.
10. **^** Time dilation, https://en.wikipedia.org/wiki/Time_dilation, Retrieved Nov 2020.
11. **^** Weight, https://en.wikipedia.org/wiki/Weight, Retrieved Nov 2020.

Appendix A

Summary of the Properties of the Temporal Inertial Field

A.0 Introduction

The concept of the TI field is a creation of this author and has been developed in several previous publications without citation.

A.1 Definitions of Mass

A brief description follows of the forms of mass existent in the two models of gravity described in this paper. I paraphrase the three definitions of mass offered by Wikipedia [4] for the Newtonian model and modify those definitions where appropriate for the TI field model.

Table A.1	Definitions of Mass
Mass in the Newtonian Model	**Definition**
Active gravitational mass of a matter object	A measure of the gravitational force exerted by a matter object.
Passive gravitational mass of a matter object	A measure of the gravitational force experienced by a matter object in a known gravitational field.
Inertial mass of a matter object	A measure of a matter object's resistance to being accelerated relative to the TI field by a gravitational or non-gravitational force.
Mass in the TI Field Model	**Definition**
Active gravitational mass of a particle of the TI field	Particles of the TI field do not possess active gravitational mass.
Active gravitational mass of a matter object	A measure of the gravitational force exerted by a matter object.

Table A.1	Definitions of Mass
Passive gravitational mass of a particle of the TI field	A measure of the gravitational force experienced by a particle of the TI field in a known gravitational field.
Passive gravitational mass of a matter object	Matter objects do not possess passive gravitational mass.
Inertial mass of a particle of the TI field	A measure of the resistance of a particle of the TI field to being accelerated relative to the Static field by the force of gravity.
Inertial mass of a matter object	A measure of a matter object's resistance to being accelerated relative to the TI field by a non-gravitational force.

A.2 Mass Properties of the Newtonian and TI Field Models of Gravity

Table A.2 Mass Properties of the Newtonian and TI Field Models of Gravity

Gravitational Model	Active Gravitational Mass	Passive Gravitational Mass	Inertial Mass
Matter Objects in the Newtonian Model	Yes, matter objects assert the gravitational force.	Yes, matter objects are directly subject to gravity.	Yes, matter objects resist acceleration relative to the TI field in response to either a gravitational or non-gravitational force.
Matter Objects in the TI Field Model	Yes, matter objects assert the gravitational force.	No, matter objects are not directly subject to gravity.	Yes, matter objects resist acceleration relative to the TI field in response to a non-gravitational force.

Particles of the TI Field in the Newtonian Model	No, particles of the TI field do not assert the gravitational force.	No, particles of the TI field are not subject to gravity.	Yes, particles of the TI field resist acceleration relative to the static field.
Particles of the TI Field in the TI Field Model	No, particles of the TI field do not assert the gravitational force.	Yes, particles of the TI field are directly subject to gravity.	Yes, particles of the TI field resist acceleration relative to the static field in response to a gravitational force.

A.3 Properties and Behavior of Objects in the TI Field Model of Gravity

The properties and behavior of objects in the TI model of gravity and inertia depend on the properties of mass of objects in this model.

Table A.3 Properties and Behavior of Objects in the TI Field Model of Gravity
Objects Possess Active Gravitational Mass
Objects exert the gravitational force by the emission of gravitons.
The rate of emission of gravitons by an object is proportional to the active gravitational mass of the object.
Objects Do Not Possess Passive Gravitational Mass
Objects are not directly subject to gravity.
Objects respond to the gravitational force indirectly through the intermediation of the TI field. See Table A.4 below.
Objects Possess Inertial Mass
The inertial mass of a matter object is a measure of the resistance of the object to its acceleration relative to the TI field in response to a non-gravitational force.
The resistance of an object to the acceleration caused by the application of a non-gravitational force is proportional to the product of the inertial mass of the object and the acceleration of the object relative to the TI field. ($F = ma$).

A.4 Properties and Behavior of the TI Field in the TI Field Model of Gravity

The properties and behavior of the TI field itself in the TI model of gravity and inertia depend on the properties of mass of particles of the TI field in this model.

Table A.4 Properties and Behavior of the TI Field in the TI Field Model of Gravity
Particles of the TI Field Do Not Possess Active Gravitational Mass
Particles of the TI field do not exert the gravitational force.
Particles of the TI Field Possess Passive Gravitational Mass
Particles of the TI field experience the gravitational force through their interaction with gravitons.
The gravitational force experienced by a particle of the TI field is proportional to the passive gravitational mass of the particle.
The acceleration of a particle of the TI field is proportional to the graviton flux at the particle.
Particles of the TI Field Possess Inertial Mass
Particles of the TI field resist the application of the gravitational force.
The resistance of a particle of the TI field to the application of a gravitational force is proportional to the inertial mass of the particle.
Interaction of Objects with the TI Field
The inertial mass of an object is a measure of its coupling with the TI field.
The acceleration of the TI field in its response to gravity applies a force to any object within the TI field. This force causes the object to accelerate at the same rate as particles of the TI field at the location of the object.

A.5 Properties and Behavior of the Static Field in the TI Field Model of Gravity

The static field is a conjecture of this author that is required to resist the acceleration of particles of the TI field in their response to gravity. Absent such resistance, the acceleration of particles of the TI field would be unlimited.

Table A.5 Properties and Behavior of the Static Field in the TI Field Model of Gravity
Particles of the Static Field Do Not Possess Active Gravitational Mass
Particles of the static field do not exert the gravitational force.
Particles of the Static Field Do Not Possess Passive Gravitational Mass
Particles of the static field do not experience the gravitational force.
Whether Or Not Particles of the Static Field Possess Inertial Mass Is Undefined
The static field resists the acceleration of particles of the TI field in the response of the TI field to gravity.

Gravitational Time Dilation

B.0 Introduction

Time dilation is defined as the difference in time measured by two clocks in motion relative to each other or by two clocks located at two different levels of gravitational potential. We saw in the studies of the twin paradox and of clocks in a gravitational field that neither of these definitions held true. I argued in those studies that the time dilation in a process (such as the ticking of a clock) is caused solely by the velocity of the process relative to the TI field. I also argued that time dilation is not caused directly by gravity.

B.1 Time Dilation Due to Motion

Consider two accurate, identical clocks. One clock serves as a reference clock, the second clock moves at relativistic speed away from the reference clock.

The period of the moving clock relative to the reference clock is given by Eq (B-1), that is adapted from Cutner. [1] :

$$t_2 / t_1 = 1 / (1 - v_2^2 / c^2)^{1/2} \tag{B-1}$$

where

t_1 is the period of the reference clock.

t_2 is the period of the moving clock.

v_2 is the velocity of the moving clock relative to the reference clock.

Let me restrict the validity of Eq (B-1) by requiring reference clock that measures the value of t_1 to be stationary relative to the TI field.

Equation (B-1) tells us that the period of the moving clock is greater than that of the stationary reference clock. The moving clock ticks more slowly than the stationary reference clock. The difference in period of the two clocks is a function of the velocity of the moving clock relative to the stationary clock. As I've specified that the reference clock is stationary relative to the TI field, the velocity of the moving clock is thus measured relative to the TI field. As we'll see in the thought experiment on the twin paradox, this is a critical distinction that differs dramatically from the conventional explanation of the cause of time dilation.

B.2 Gravitational Time Dilation

The conventional equation for the gravitational time dilation of a process at rest relative to a homogeneous, non-rotating spherical gravitational body is given by Eq (B-2), that is adapted from reference [3].

$$t_2 / t_1 = 1 / (1 - 2GM / (r c^2))^{1/2} \qquad \text{(B-2)}$$

where

t_1 is the period of a reference clock located at a distance beyond the gravitational influence of the GB in question or any other GB.

t_2 is the period of a clock (an example of a process) located at a distance r relative to the center of mass of the GB.

G is the universal gravitational constant.

M is the active gravitational mass of the GB.

r is the distance of the clock located nearest the GB and at rest relative to the GB.

c is the speed of light.

B.3 Escape Velocity

The escape velocity of an object is the speed that the object must attain at launch to escape, without further means of propulsion, the gravitational field of a gravitational body. The escape velocity from a spherically symmetric GB is given by Eq (B-3) [2]

$$v_{escape} = (2 \, GM / r)^{1/2} \qquad \text{(B-3)}$$

where

v_{escape} is the escape velocity of the object.

G is the universal gravitational constant.

M is the active gravitational mass of the GB.

r is the distance of the object before launch from the center of mass of the GB.

B.4 Quantifying the Infall Velocity of the TI Field Toward a Gravitational Body

> '… a body that falls under the force of gravitational attraction of mass M, from infinity, starting with zero velocity, will strike the massive object with a velocity equal to its escape velocity given by the same formula.' [2] (Eq (B-3))

Note that the expression $2 \, GM / r$ for the square of the escape velocity appears in Eq (B-2) for gravitational time dilation. This is no mere happenstance. While gravity does not directly cause time dilation, gravity is the prime mover of the phenomenon and acts only indirectly by accelerating particles of the TI field. The velocity of a process relative to the TI field is the only cause of time dilation. What is the velocity of particles of the TI field as they fall toward a GB? According to the quote at the start of this section, that velocity is the negative of the escape velocity at the point of regard.

Insert the value for the escape velocity in Eq (B-3) from the GB into Eq (B-2), the equation for gravitational time dilation to yield the equation for gravitational time dilation in terms of the escape velocity from the GB.

$$t_2 / t_1 = 1 / (1 - v_{escape}^2 / c^2)^{1/2} \qquad \text{(B-4)}$$

where

t_1 is the period of a reference clock located at a distance beyond the gravitational influence of the GB in question or any other GB.

t_2 is the period of a clock located at a distance r relative to the center of mass of the GB.

v_{escape} is the escape velocity of the object.

r is the distance of the clock from the center of mass of the GB and at rest relative to the GB.

c is the speed of light.

As was discovered in our thought experiments on a freely falling clock, gravity does not directly cause time dilation of the clock; only velocity of the clock relative to the TI field causes time dilation of the clock (or any process). Accordingly, Eq (B-4) correctly expresses the relation between the infall velocity of the TI field and the time dilation of a clock, or any process. Thus we've quantified the value of the infall velocity of the TI field in response to the gravitational force.

Both Eq (B-2) and Eq (B-4) are correct. Equation (B-2) emphasizes the role of gravity as the prime mover in the phenomenon. Equation (B-4) identifies the infall velocity of the TI field at the process as the proximate cause of gravitational time dilation.