Richard A. Peters

Affiliation: None

Time Dilation in the Global Positioning System Has Implications for the Theory of Gravity

Abstract

The observation of two occurrences of time dilation underlie new conclusions about the essence of gravity that cascade logically from these observations, but are at odds with the descriptions of gravity offered by conventional physics. 1) An examination of the time dilation of a process reveals that it is a function of the velocity of the process relative to space itself, not relative to an arbitrary frame of reference. A fundamental frame of reference for motion in the Universe must permeate all space at both the greatest and smallest scales. A field of particles that I call the Temporal-Inertial (TI) field that supports the propagation of nature's force particles meets the requirements of such a fundamental frame of reference for motion. 2) The Global Positioning System (GPS) compensates precisely for the time dilation introduced by the GPS satellite's orbital speed and the gravitational field of Earth. I argue that this precise compensation is achievable only if Earth is at rest relative to the TI field. Accordingly, Earth and particles of the TI field must orbit the Sun in concert. Hence, particles of the TI field must be subject to gravity. Several other behaviors ensue from these two observations of time dilation: 3) the TI field mediates gravity, 4) massive particles and objects comprising massive particles are not directly subject to gravity, 5) in the 'near' vicinity of a gravitational body the velocity of the TI field is directed toward the center of mass of the body, 6) gravitational time dilation is caused by the infall velocity of the TI field toward a gravitational body, not directly by gravity.

Table of Contents

Table of Contents

1.0 First Matters

This paper is all about a particle field that I call the ***Temporal-Inertial*** (TI) field. The relationship between the TI field and the Higgs field is undefined in this paper. The name of this field is derived from the role of the field in time dilation and the inertial interaction. In characterizing the TI field the properties we determine must support observed phenomena. Properties of the TI field can be deduced from the observation of two behaviors: the occurrence of time dilation of a process moving through space and the function of the Global Positioning System (GPS). The TI field exhibits a number of properties given, but not restricted, by the list below.

- Particles of the TI field permeate space from the smallest to the largest scale.
- Acceleration relative to the TI field of matter particles and objects comprising matter particles causes the familiar inertial reaction force.
- The TI field supports the propagation of nature's force particles.
- Time dilation of a process is a function of the velocity of the process relative to the TI field.
- The TI field is subject to gravity.

This list will be expanded as we examine the occurrence of time dilation in thought experiments of processes exemplified by clocks moving through space.

2.0 The Line of Reasoning

In observing the phenomenon of time dilation in processes moving through space a line of reasoning is developed that concludes with a description of gravity that is at odds with the current description of how gravity works in the Universe. Observations of the occurrence of time dilation are described in Appendix A, The Twin (Clock) Non-Paradox and in Appendix C, Time Dilation in the Global Positioning System.

A brief summary of the line of reasoning, without the math, is given in Table 1. More detail follows in Table 2.

Item	Table 1. The Line of Reasoning
1	Considerations of the Twin Clock Non-Paradox (Appendix A) show that time dilation is a function of the velocity of a process (e.g. a ticking clock) relative to the TI field.
2	The Global Positioning System accounts precisely for time dilation.
3	Operation of the Global Positioning System (Appendix C) shows that the velocity of Earth through space does not contribute to time dilation in the GPS clocks.
4	Items 1 and 3 insure that Earth must orbit the Sun precisely in concert with the TI field.
5	The TI field must therefore be ***subject to gravity***.
6	Acceleration of Earth in its orbit of the Sun is coincident with and determined by the acceleration of the TI field in its orbit of the Sun.
7	The TI field ***mediates gravity***.
8	The TI field is the field responsible for the ***inertial reaction force***.
9	Massive particles and objects comprising massive particles (e.g. Earth) are not directly subject to gravity.
10	Particles of the TI field fall radially toward the center of mass of Earth.
11	Gravitational time dilation is caused by the infall velocity of the TI field toward a gravitational body, not directly by gravity.

3.0 A Logical Sequence of Observations Points to the Existence of the Temporal-Inertial Field Model of Gravity

Observations of the occurrence of time dilation presented in Appendix A, The Twin Clock Non-Paradox, lead to the assertion that a fundamental frame of reference comprising a particle field that permeates space at the smallest scale must exist to resolve the so-called twin paradox.

Observations of the occurrence of time dilation presented in Appendix C, Time Dilation in The Global Positioning System (GPS), produce a cascade of evidence yielding a new rationale for gravitational time dilation and, more fundamentally, for how gravity works.

The observations, inferences and conclusions reached in Appendices A and C are listed in Table 2.

Item	Table 2. A Sequence of Observations
1	First Observations
2	Define a process as a transaction, or a transition or a sequence of actions or events that takes time. When I talk about the time dilation occurring in an object I'm talking about the time dilation that occurs in a process embodied in the object. Employ a clock as an example of a process. Let the clock move at high speed through space. Choose a frame of reference for motion of the clock that is defined to be stationary relative to 'space' (the reference frame of space to be defined later). As will be shown, the tick rate of the clock is slower at high speed than it is at a lower speed. An increase in the velocity of the clock relative to the reference frame slows the tick rate of the clock. A decrease in the velocity of the clock increases the tick rate of the clock. Whatever influences the tick rate of the clock as its speed through space changes must be in the immediate vicinity of the clock and must permeate space at the smallest scale.
3	The logical description of time dilation requires the existence of a field to serve as a fundamental reference for motion in the vicinity of the object. I label this field the Temporal-Inertial (TI) field. The extent and motion of the TI field itself is undefined at this point in the discussion.
4	Time Dilation is the Slowing of a Process that Moves Through Space [1] Ch1

Item	Table 2. A Sequence of Observations
5	Time dilation has been explained as a slowing of time for a process moving relative to another process. If object A embodying a process moves relative to object B embodying an identical process, then object B, reciprocally, moves at the same rate, but in the opposite direction, as object A. The process in each object *would appear* to run more slowly than the other. Appearances aside, it is not possible for each process to run more slowly than the other.
6	A process (such as the ticking of a clock) takes longer when moving at high speed through space than that process takes if moving at a slower speed through space. This slowing of the process (e.g. the ticking of a clock) is called time dilation. It is shown in Appendix A that time dilation is a function of the velocity of the process relative to space itself, not relative to an arbitrary frame of reference [1], Ch 1.
7	If there is no fundamental frame of reference for motion, any attempt to explain time dilation as a function of the velocity of one process relative to a second process results in a paradox since each process moves at the same rate relative to the other. In a test where one process (clock) accelerates away from a so-called reference clock, time dilation cannot be explained by attributing it to the process (clock) that accelerated. The time dilation ongoing in a process cannot depend on the history of how that process acquired its velocity [2].
8	To obviate this paradox, there must be a fundamental reference for motion in the immediate vicinity of the processes of interest. This frame of reference cannot be some arbitrarily selected set of coordinates, but must embody an entity that influences nature's timekeeping at the most fundamental level. This entity must permeate space in the immediate vicinity of the processes and at the smallest scale to be able to influence nature's timekeeping at atomic and subatomic levels [1], Ch 2.
9	Time Dilation is a Function of Velocity Relative to Space Not Relative to an Arbitrary Frame of Reference [1] Ch 1
10	Summing the arguments above leads to the conclusion that time dilation in a process is a function of the velocity of that process relative to the TI field. An increase in velocity of a process relative to the TI field increases the time dilation of that process. A decrease in velocity of a process relative to the TI field decreases the time dilation of that process. A process proceeds at its fastest pace when that process is stationary relative to the TI field [1], Ch 1.

Item	Table 2. A Sequence of Observations
11	The TI field meets the requirements of an entity that influences nature's timekeeping and serves as a fundamental frame of reference for motion [1], Ch 2. Again, the extent and motion of the TI field is undefined at this point in the discussion.
12	Proper Functioning of the Global Positioning System (GPS) Leads to the Conclusion that the TI Field is Subject to Gravity [1] Ch 1
13	The Global Positioning System (GPS) works properly even as its satellites orbit Earth. The time dilation of the GPS clocks in the satellites orbiting Earth must be accounted for or the distance measurements of the system would develop huge errors. Clearly, this accounting is done correctly.
14	Earth is orbiting the Sun and the galaxy but these motions through space do not affect the time keeping of the GPS satellites. This null effect can occur only if Earth does not move relative to the TI field, and this can occur only if Earth and the TI field orbit the Sun and the galaxy in concert. Other motions of Earth and Solar System exist as well, but the null effects on time dilation of these motions are accounted for only if Earth and the TI field move in concert.
15	The TI Field Mediates Gravity and is the Source of the Inertial Force. Matter Particles Are Not Directly Subject to Gravity [1], Ch 3, Ch 7
16	Accepting Item 14 leads to the conclusion that the TI field is subject to gravity.
17	The observed precision of the GPS demands that there be no difference in velocity between the TI field and Earth in their orbits about the Sun nor in their other motions through space. The orbit of the TI field about the Sun is caused by the gravitational field of the Sun, not by that of Earth. Earth does not drag the TI field about the Sun. On the contrary, the TI field drags Earth about the Sun! (If the reader has any doubts that the TI field has the strength to move a planet in its orbit, see Reference [3].)
18	Any deviation in velocity of Earth from that of the TI field is seen as an acceleration relative to the field that applies a corrective force (the inertial reaction force) that keeps Earth moving in concert with the TI field in its orbit about the Sun. This behavior combined with the subjugation of the TI field to gravity means that the TI field mediates the gravitational force.
19	Items 17 and 18 express two conclusions: 1) Earth is not directly subject to gravity, but responds only to the acceleration of the TI field in its response to gravity and 2) acceleration of a massive object relative to the TI field produces the inertial reaction force that opposes the acceleration.

Item	Table 2. A Sequence of Observations
20	Acceleration of the TI field in response to gravity applies a force to matter particles within the field. Any acceleration of matter particles relative to the TI field produces a force on the matter particles to decrease that relative acceleration. Accordingly, matter particles within the TI field are accelerated at the same rate as the field.
21	The Infall Velocity of the TI Field Toward a Gravitational Body Reaches the Escape Velocity at any Given Radius from the Body [1], Ch 1
22	At the surface of Earth, the ***acceleration*** of the TI field toward Earth's center of gravity is 1 g or 9.8 m / sec^2. How do we know this? This assertion derives from the fact that, in our currently developing theory, the weight of an object on the surface of Earth is caused by the acceleration of the TI field toward the center of mass of Earth. An object, free of other forces, will accelerate at 1 g or 9.8 m / sec^2 if a force is applied equal to the weight of the object. The object at rest on the surface of Earth is subject to an acceleration of 1 g relative to the TI field and experiences the inertial reaction force equal to its own weight. In addition, if the object is released in a vacuum near the surface of Earth it will accelerate at 1 g or 9.8 m / sec^2. The acceleration of the TI field, which we cannot see, must be the same value as the observed acceleration of the object because the acceleration of the TI field is responsible for the acceleration of the object.
23	The infall ***velocity*** of the TI field at the surface of a gravitational body (GB) is equal in magnitude, but opposite in direction to the escape velocity at the surface of the body (or at any radius from the body). This conclusion derives from the fact that objects comprising matter particles falling from a great distance toward a GB will achieve the escape velocity from the body at any given radius from the body. The path of the object is determined solely by the acceleration of the TI field and thus both object and TI field maintain the same velocity profile during their fall toward the GB.
24	Gravitational Time Dilation is Caused by the Infall Velocity of the TI field in its Response to Gravity [1], Ch 1
25	Gravitational time dilation is caused by the infall ***velocity*** of the TI field in its response to gravity. Gravitational time dilation of a process is not directly caused by gravity, but by the ***velocity of the process relative to the TI field.*** The time dilation of a process at a given distance from a gravitational body is caused by the difference between the infall ***velocity*** of the TI field at that distance and the velocity of the process, not directly by gravity.
26	There Is No Time Dilation in a Freely Falling Object [1] Ch 1, Ch 3

Item	Table 2. A Sequence of Observations
27	There is no time dilation in a freely falling object. This results from the fact that an object in free fall does not experience a change in ***velocity*** relative to the TI field. At any radius from a gravitational body, an object and the TI field both accelerate at the same rate. Hence the difference in ***velocity*** between the TI field and the object at the point of release of the object does not change during free fall of the object. With no change in ***velocity*** relative to the TI field there is no change in time dilation of the process embodied in the object.
28	An object in free fall experiences an increasing flux of gravitons as it approaches the GB, yet a process embodied in the object does not experience an increase in time dilation. We must conclude that graviton flux plays no direct part in time dilation, but acts only through the acceleration of the TI field.
29	Accepting the logic of Items 27 and 28 it is clear that gravity causes time dilation only indirectly through the acceleration of the TI field regardless of the motion of the object relative to the GB. Time dilation has only one cause: velocity of a process relative to the TI field. Gravity does not cause time dilation directly, but acts only by accelerating the TI field. The resultant velocity of the TI field relative to a process within the TI field causes time dilation.

4.0 Conclusions

Item	Table 3. Conclusions
1	Time dilation of a process is a function of the velocity of the process relative to the TI field, not a function of the velocity of the process relative to an arbitrary frame of reference.
2	The observed proper functioning of the Global Positioning System (GPS) requires that Earth and the TI field move through space in concert.
3	The TI Field is a Fundamental Reference for Motion
4	The logical description of time dilation of a process requires the existence of a field that serves as a fundamental reference for motion in the immediate vicinity of the process. I label this field the Temporal-Inertial (TI) field.
5	To compare the difference in time dilation between two clocks, each of which is moving relative to the TI field, we must evaluate the time dilation of each clock separately as a function of its velocity relative to the TI field, not as a function of the difference in velocity between the two clocks.
6	The TI Field Mediates Gravity and Inertia
7	The TI field is subject to gravity.
8	***Acceleration*** of a massive object relative to the TI field produces the inertial reaction force on the object.
9	The TI field mediates gravity. ***Acceleration*** of the TI field in response to gravity accelerates matter particles within the field at the same rate as particles of the TI field.
10	Matter particles and objects comprising matter particles are not directly subject to gravity, but are ***accelerated*** by the TI field in its response to gravity.
11	The weight of an object on the surface of a gravitational body is caused by the ***acceleration*** of particles of the TI field relative to the object.

Item	Table 3. Conclusions
12	It follows from these behaviors of the TI field and massive particles that Earth is not directly subject to gravity, but orbits the Sun and galaxy in concert with the TI field that is itself directly subject to gravity. Other motions of Earth and the Solar System exist as well, but the null effects on time dilation of these motions are accounted for only if Earth and the TI field move in concert.
13	The Infall Velocity of Particles of the TI Field Toward a Gravitational Body Accounts for Gravitational Time Dilation
14	The infall ***velocity*** of the TI field toward a gravitational body reaches the magnitude of the escape velocity at a given radius from the body [1], Ch 1.
15	Gravitational time dilation is not caused directly by gravity, but is caused by the infall ***velocity*** of the TI field in its response to gravity [1], Ch 1.
16	There is no time dilation in a freely falling object because the acceleration of the freely falling object and the TI field are the same, hence the difference in ***velocity*** of the freely falling object and the TI field does not change.
16	An object in free fall experiences an increasing flux of gravitons as it approaches the GB, yet a process embodied in the object does not experience an increase in time dilation. We must conclude that graviton flux plays no direct part in time dilation, but acts only through the acceleration of the TI field.
17	The particle density of the TI field is constant even as particles of the field flow toward the center of mass of a gravitational body. See Appendix D.

5.0 References

Order	References
1	Peters, Richard A. The Physics Heresies, ISBN 9781483552682, Apr 2015.
2	Clock hypothesis, https://en.wikipedia.org/wiki/Clock_hypothesis, Retrieved Aug 2016.
3	Peters, Richard A., Substantiation Without Substance, Work in Progress.
4	Kutner, Mark Leslie (2003). *Astronomy, A Physical Perspective*. Cambridge University Press. p. 128. ISBN 0-521-82196-7.
5	Time dilation, https://en.wikipedia.org/wiki/Time_dilation, Retrieved Sep 2016.
6	Ashby, Neil, Relativity in the Global Positioning System, Dept. of Physics, University of Colorado, Boulder, CO 80309-0390, http://relativity.livingreviews.org/Articles/lrr-2003-1/download/lrr-2003-1Color.pdf, Retrieved Aug 2016.
7	Gravitational time dilation, https://en.wikipedia.org/wiki/Gravitational_time_dilation, Retrieved Aug 2016.
8	Escape velocity, https://en.wikipedia.org/wiki/Escape_velocity, Retrieved Aug 2016.
9	Cosmic microwave background, https://en.wikipedia.org/wiki/Cosmic_microwave_background, Retrieved Aug 2016.
10	Earth-centered inertial, https://en.wikipedia.org/wiki/Earth-centered_inertial, Retrieved Aug 2016.
11	Fraknoi, Andrew, How Fast Are You Moving When You are Sitting Still?, https://astrosociety.org/edu/publications/tnl/71/howfast.html, Retrieved Aug 2016.

Appendix A

The Twin (Clock) Non-Paradox

> ‘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?
>
> Conventional resolutions of the twin paradox are based on the difference in velocity between the twins and the determination of which of the twins accelerated during the journey. My disagreement with such explanations centers on the premise that the physics of the interaction with time can be reckoned to the velocity 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.’ [1], Ch 4.

A.1.0 A Simple Thought Experiment

Let’s perform a thought experiment to see how time dilation must work. Select two identical, accurate clocks rather than twin persons; clocks are better timekeepers than aging twins. Define a process as a transaction, a transition or a sequence of actions or events that takes time. The two clocks represent two processes to be compared. Designate the moving clock as Clock 2. Select an identical clock, Clock 1, to serve as a reference timepiece and identifier for the frame of reference for motion. Stipulate that the reference clock must be stationary relative to particles of the TI field. And let’s tabulate the sequence of events in the experiment as in Table A.

Table A.1 The Twin Clock Experiment
The Temporal-Inertial (TI) field will serve as the fundamental frame of reference for motion in this experiment.
Initiate the experiment with two clocks, Clock 1 and Clock 2, at rest relative to the TI field.
As the TI field is invisible, we need a physical entity to identify our frame of reference for motion. Identify Clock 1 as the reference clock that is to remain at rest relative to the TI field.
We also need a reference for reckoning elapsed time in our experiment.
Identify Clock 1 as the clock that will remain at rest relative to the TI field during the experiment. As such, Clock 1 serves both as the physical marker for the frame of reference for motion and as the reference for elapsed time in the experiment.
Identify Clock 2 as the moving clock in this experiment.
At the beginning of the experiment, we place both clocks next to each other and set both clocks to the same time. At the end of the experiment we note the difference, if any, in the expired time on both clocks. These are the only measurements we make during the experiment.
To begin, Clock 2 accelerates away from Clock 1 and reaches a high velocity relative to Clock 1 and the TI field.
After traveling for some time, Clock 2 decelerates and comes to a stop relative to Clock 1 and the TI field.
Clock 2 then accelerates back toward Clock 1, moves at high velocity relative to Clock 1 and the TI field, then decelerates and comes to a stop next to Clock 1.
At the conclusion of the experiment we note that the elapsed time on Clock 2 is less than that on Clock 1.

A.2.0 Inferences to be Drawn from the Experiment

Table A.2 Inferences to be Drawn from the Experiment
The initial synchronization of the clocks and the difference in elapsed time between the two clocks at the end are the only measurements that were made during the experiment.
At the end of the experiment, the elapsed time on Clock 2 was less than that on Clock 1. During one or more phases of the experiment, the tick rate of Clock 2 was slower than that of reference Clock 1.
Kutner [4] and many other sources [5] express time dilation as a function of velocity of one process relative to another. I further stipulate that this is true only if one of the processes is at rest relative to the TI field.
Accordingly, we know from Kutner [4] that at any given instant, the ratio of the period of Clock 2 relative to that of Clock 1 is given by the formula: $$t_2 / t_1 = 1 / (1 - v_2^2 / c^2)^{1/2}$$ where t_2 is the period (between ticks) of Clock 2, t_1 is the period of Clock 1, v_2 is the velocity of Clock 2 relative to Clock 1 and the TI field and c is the velocity of light. ***Note that the velocity of Clock 1 does not appear, it is zero in our test.*** This formula holds during all phases of the experiment whether Clock 2 is accelerating or not. Acceleration of the clock does not cause time dilation, except through the accompanying change in velocity of Clock 2 [2].
When Clock 2 accelerated away from Clock 1 its velocity increased and in accord with the formula its tick rate decreased. When Clock 2 decelerated and its velocity relative to Clock 1 decreased to zero at its most distant remove from Clock 1, its tick rate increased to that of Clock 1. The sequence was repeated in reverse when Clock 2 returned to the position of Clock 1. Due to the slowing of the tick rate of Clock 2 during its journey, the elapsed time on Clock 2 was less than that on Clock 1 at the end of the experiment.

A.3.0 Conclusions to be Drawn from the Experiment

Table A.3 Conclusions to be Drawn from the Experiment
At no point during the experiment did Clock 1 influence the tick rate of Clock 2. Clock 1 served only as a place holder, fixing the geometric start and end of the test and keeping track of the time that elapsed on the clock that was at rest relative to the TI field.
What could have influenced the tick rate of Clock 2? The influence must have been in immediate and intimate contact with Clock 2. The only such entity is the space through which Clock 2 moved. ***More specifically, it is not the space through which the clock moved that caused time dilation, it is the space that moved through the clock.*** This space must be permeated with a field that affects the fundamental time keeping of the clock.
The fundamental pace of any process embodied in an object starts at the subatomic level, at the level where nature's force particles are exchanged. If an object moves through space at some velocity the exchange of force particles takes longer than if the object were moving more slowly through space [1], Ch 2. This space is not empty but must be permeated at the smallest scale with a particle field that supports the propagation of nature's force particles.
The phenomenon of time dilation demands the existence of such a field. I label this field the ***Temporal-Inertial (TI) field.***
Time dilation occurs when an ongoing process moves relative to space, relative to this TI field. The greater the velocity of the process relative to the TI field the greater is the time dilation experienced by that process. The rate at which the timing of a process is slowed ***or accelerated*** is intrinsic and absolute and depends solely on the velocity of the process relative to the TI field [1].

Appendix B

Time Dilation Formulas

B.1.0 Time Dilation, Defined

> 'Conventionally, time dilation is defined as the decrease in the rate of flow of time in a frame moving relative to an outside observer. I argue that any process (exemplified by, say, a clock) that moves through space takes longer than that process would take if that process were moving more slowly through space.' [1]

B.2.0 Time Dilation In a Process Is a Function of the Velocity of that Process Relative to the TI Field

In the GPS and studies of relativity comparisons are made of the difference in time dilation between clocks on the ground and clocks moving in orbital vehicles or aircraft.

Kutner [4] and many other sources [5] assert that the difference in time dilation between two processes is a function of the velocity of one process relative to the other. When comparing the time dilation between two processes (often expressed as two observers, who are each viewing a process by which they can reckon the passage of time) it is necessary to measure the difference in time dilation between the two processes not the difference in velocity between the two.

The reason for this distinction is that time dilation in a process is a function of the velocity of that process relative to the TI field, not a function of the velocity of the process relative to the arbitrary frame of reference of another observer. This fact was shown when we examined the twin (clock) non-paradox in Appendix A and saw that the clock velocities in our thought experiment had to be measured relative to the TI field, not relative to an arbitrary frame of reference.

Accordingly, if we want to compare the difference in time dilation between two clocks, each of which is moving relative to the TI field, we must evaluate the time dilation of each clock separately as a function of its velocity relative to the TI field, not as a function of the difference in velocity between the two clocks.

B.2.1 The Difference in Time Dilation Between Two Processes is Not a Function of the Difference in Velocity Between the Two Processes

Let clocks represent the processes in our evaluation of time dilation between processes.

To compare the difference in time dilation between two clocks moving relative to the TI field, we must introduce a third clock, Clock 0, to serve as a reference clock that marks the frame of reference for motion in the experiment, the starting time of the experiment and keeps track of the elapsed time. Identify Clock 1 and Clock 2 as the moving clocks in the experiment.

Reverting to Kutner [4], the expression for the time dilation of a clock in motion relative to another is given by Eq (B-1). We are going to use Eq (B-1) to develop the equation for the difference in time dilation between Clock 2 and Clock 1, but we will see that this relationship is not a simple function of the difference in velocity between Clock 2 and Clock 1. The velocity v_1 of Clock 1 is measured relative to Clock 0 and the TI field, but the velocity v_2 of Clock 2 is measured relative to Clock 1. The difference in velocity v_r between Clock 2 and reference Clock 0 and the TI field is the vector sum of v_2 and v_1.

$$t_2 / t_0 = 1 / (1 - v_r^2 / c^2)^{1/2} \qquad \text{(B-1)}$$

where

t_2 is the period of Clock 2.

t_0 is the period of reference Clock 0 that is at rest relative to the TI field.

v_r is the velocity of Clock 2 relative to Clock 0 and the TI field.

c is the velocity of light in vacuo.

The conclusions reached in Appendix A stressed that the time dilation occurring in a clock moving through space is caused by the velocity relative to the TI field of the moving clock. Equation (B-1) expresses the time dilation of Clock 2, relative to reference Clock 0, as a function of the difference in velocity between the two clocks. I assert that Eq (B-1) is valid only if the velocity of Clock 0 relative to the TI field is zero. ***Final emphasis: the velocity of Clock 0 relative to the TI field is zero.***

B.2.1.1 Simplify the Basic Time Dilation Formula

First, let's simplify Eq (B-1). This simplification is valid if $v_r^2 / c^2 << 1$, which it is in the Global Positioning System (GPS).

$$t_2 / t_0 = 1 / [(1 - v_r^2 / (2 c^2)] \qquad \text{(B-2)}$$

Now, multiply both numerator and denominator of Eq (B-2) by $(1 + v_r^2 / (2 c^2)$. If $v_r^4 / (4 c^4) << 1$, which it is in the GPS, then Eq (B-2) can be further simplified:

$$t_2 / t_0 = 1 + v_r^2 / (2 c^2) \qquad \text{(B-3)}$$

where, again

v_r is the velocity of Clock 2 relative to Clock 0 and the TI field.

B.2.1.2 Iterate the Definition of the Reference Frame for Motion in the Time Dilation Formula

Remember that the objective in this exercise is to develop an equation defining the difference in time dilation between two moving clocks. In this section Clock 1 and Clock 2 are the two moving clocks.

To repeat, we need to define the reference frame for motion as the TI field. We must also specify that Clock 0 is at rest relative to the TI field. Clock 0 is our reference for time and serves as the marker for velocity relative to the TI field.

B.2.1.3 Calculate the Difference Between the Time Dilation of Two Moving Clocks

The form of Eq (B-3) can be used correctly to express the time dilation of Clock 1, because its velocity is reckoned relative to the TI field.

$$t_1 / t_0 = 1 + v_1^2 / (2 c^2) \qquad \text{(B-4)}$$

where

t_1 is the period of Clock 1.

t_0 is the period of reference Clock 0 that is at rest relative to the TI field.

v_1 is the velocity of Clock 1 relative to Clock 0 and the TI field.

Calculate the change in period of Clock 1.

Let

$$t_1 = t_0 + \Delta t_1 \qquad \text{(B-5)}$$

where

Δt_1 is the change in period of Clock 1 relative to Clock 0.

Then

$$(t_0 + \Delta t_1) / t_0 = 1 + v_1^2 / (2 c^2) \qquad \text{(B-6)}$$

$$\Delta t_1 / t_0 = v_1^2 / (2 c^2) \qquad \text{(B-7)}$$

or

$$\Delta t_1 = t_0 v_1^2 / (2 c^2) \qquad \text{(B-8)}$$

Perform the same operation for Eq (B-3) to yield:

$$\Delta t_2 = t_0 v_r^2 / (2 c^2) \qquad \text{(B-9)}$$

Equation (B-8) and Eq (B-9) show the change in period due to time dilation of Clock 1 and Clock 2, respectively, caused by their velocities relative to Clock 0 and the TI field, but we have yet to relate the changes in time dilation of Clock 2 to that of Clock 1.

Remember that v_2 is the velocity of Clock 2 relative to Clock 1 and v_1 is the velocity of Clock 1 relative to the TI field.

Time dilation is normally expressed as a function of the velocity of a process relative to 'some' reference, where the direction of the velocity is not a factor to consider. However, Eq (B-9) expresses the time dilation of Clock 2 as a function of the ***sum of the velocities of the two moving clocks*** not the difference in velocity between the two clocks. The velocities of these two clocks are vectors that may or may not be collinear. ***Their sum must be calculated vectorially,*** not algebraically.

Accommodating the Law of Cosines, we calculate the addition of the velocities of Clock1 and Clock 2. Figure B.1 shows the square of the vector sum v_r^2 in Eq (B-9) shown below in Eq (B-10).

$$v_r^2 = v_1^2 + v_2^2 + 2\, v_1\, v_2 \cos \alpha \qquad \text{(B-10)}$$

where

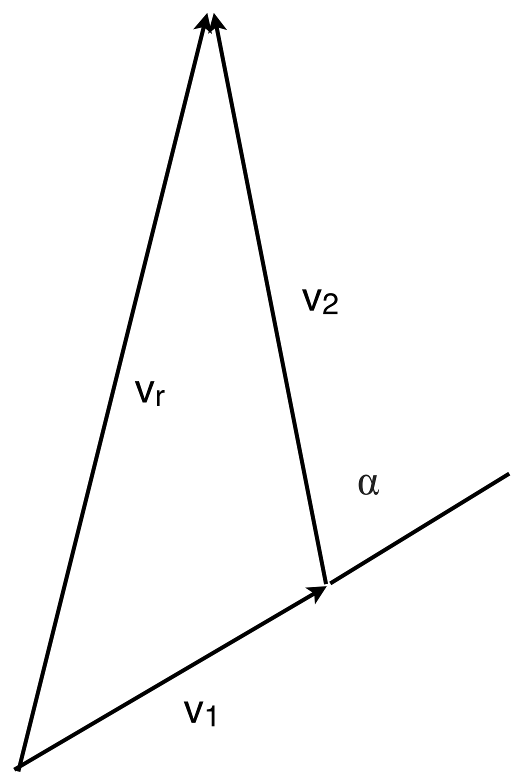
v_r is the vector sum of the velocities v_1 and v_2 of the two clocks.

v_1 is the velocity of Clock 1 relative to the TI field.

v_2 is the velocity of Clock 2 relative to the position of Clock 1.

v_r is thus the velocity of Clock 2 relative to the TI field.

α is the angle between velocity vectors v_1 and v_2.



$$v_r^2 = v_1^2 + v_2^2 + 2\, v_1 * v_2 * \cos\alpha$$

Figure B.1 Vector Addition of Clock Velocities in the Calculation of Time Dilation

Inserting the value of v_r^2 for the square of the vector sum of the velocities of the two clocks into Eq (B-9) yields Eq (B-11) that expresses the difference in period between Clock 2 and Clock 0, the clock that is at rest relative to the TI field. Only the period of Clock 0 appears in Eq (B-11), not its velocity which is zero relative to the TI field.

$$\Delta t_2 = t_0 (v_1^2 + v_2^2 + 2 v_1 v_2 \cos \alpha) / (2 c^2) \qquad \text{(B-11)}$$

Finally, we can express the difference in time dilation between the two moving clocks:

$$(\Delta t_2 - \Delta t_1) = t_0 (v_2^2 + 2 v_1 v_2 \cos \alpha) / (2 c^2) \qquad \text{(B-12)}$$

Note that Eq (B-12) is not a simple function of the difference in velocity v_2 between the two moving clocks. This simpler relationship will be developed in the next section.

B.2.2 The Difference in Time Dilation Between Two Processes is a Function of the Differences in Velocity of Each Process Relative to the TI Field

Our objective in this section is to express the difference in time dilation between two processes represented by two ticking clocks. First, let our reference clock, Clock 0, be at rest relative to the TI field. Then allow our other two clocks, Clock 1 and Clock 2, to be moving at velocities v_1 and v_2, respectively, relative to the TI field and to Clock 0. These definitions differ from the development in the section above in that the velocity of each clock is reckoned relative to the TI field.

$$t_2 / t_0 = 1 / (1 - v_2^2 / c^2)^{1/2} \qquad \text{(B-13)}$$

$$t_1 / t_0 = 1 / (1 - v_1^2 / c^2)^{1/2} \qquad \text{(B-14)}$$

where

t_2 is the period of Clock 2.

t_1 is the period of Clock 1.

t_0 is the period of Clock 0 that is at rest relative to the TI field.

v_2 is the velocity of Clock 2 relative to Clock 0 and the TI field.

v_1 is the velocity of Clock 1 relative to Clock 0 and the TI field.

c is the velocity of light in vacuo.

Let n = 1 or 2. If $v_n^2 / c^2 << 1$ which it is in the GPS, then Eq (B-13) and Eq (B-14) simplify to Eq (B-15) and Eq (B-16), respectively.

$$t_2 / t_0 = 1 / [(1 - v_2^2 / (2 c^2)] \qquad \text{(B-15)}$$

$$t_1 / t_0 = 1 / [(1 - v_1^2 / (2 c^2)] \qquad \text{(B-16)}$$

Multiply both numerator and denominator of Eq (B-15) by $[(1 + v_2^2 / (2 c^2)]$ and simplify using the assumption that $v_2^4 / (4 c^4) << 1$. This results in:

$$t_2 / t_0 = 1 + v_2^2 / (2 c^2) \qquad \text{(B-17)}$$

Let

$$t_2 = t_0 + \Delta t_2 \qquad \text{(B-18)}$$

where

Δt_2 is the change in period of Clock 2 relative to the reference Clock 0 at rest relative to the TI field.

Then

$$(t_0 + \Delta t_2) / t_0 = 1 + v_2^2 / (2 c^2) \qquad \text{(B-19)}$$

$$\Delta t_2 = t_0 v_2^2 / (2 c^2) \qquad \text{(B-20)}$$

Perform the same operations for Eq (B-16) to yield:

$$\Delta t_1 = t_0 v_1^2 / (2 c^2) \qquad \text{(B-21)}$$

At last, the difference in period between Clock 2 and Clock 1 is given by the difference in time dilation of each clock relative to the TI field as in Eq (B-22).

$$(\Delta t_2 - \Delta t_1) = t_0 (v_2^2 - v_1^2) / (2 c^2) \qquad \text{(B-22)}$$

Equation (B-22) expresses the difference in period between the two clocks at any given instant. Compare this value with the value of Eq (B-12) calculated as a function of the difference in velocity between the two clocks. The difference between the two equations may be confusing as Eq (B-22) appears to express the time dilation between the two clocks as a function of the difference in velocity between the two clocks, which it surely does. While Eq (B-12) was calculated using the TI field as the frame of reference for the velocity of Clock 1, while Clock 1 itself was the frame of reference for the motion of Clock 2. Equation (B-22) was calculated using the TI field for the frame of reference for the motion of both clocks.

The time dilation formulation of Eq (B-22) is pertinent to the form used in Appendix C describing the Global Positioning System (GPS) [6].

The whole point of this exercise is to show that the difference in time dilation between two processes (e.g.clocks) is not a simple function of the difference in velocity between the two processes, but is a function of the difference in time dilation between the two processes. To iterate the point yet another time, time dilation is a function of the velocity of a process relative to the TI field, not a function of the velocity of the process relative to an arbitrary frame of reference which may itself be in motion.

B.3.0 Gravitational Time Dilation

Reference [7] expresses the time dilation caused by gravity.

$$t_2 / t_0 = 1 / [(1 - 2GM / (r c^2)] ^{1/2} \qquad \text{(B-23)}$$

where

> t_2 is the period of a clock located a distance r from the center of mass of a gravitational body (GB) of mass M.
>
> t_0 is the period of an identical clock located at such a great distance from any GB that its tick rate is unaffected.
>
> GM is the standard gravitational parameter.
>
> r is the distance of the clock from the center of mass of the GB.
>
> c is the velocity of light in vacuo.

Performing the same simplification of Eq (B-23) that was done in the previous section yields:

$$t_2 / t_0 = 1 + GM / (r c^2) \qquad \text{(B-24)}$$

B.4.0 Escape Velocity

> '… the escape velocity at a point in space is equal to the speed that an object would have if it started at rest from an infinite distance and was pulled by gravity to that point.' [8]

B.4.1 Particles of the TI Field are Accelerated Toward the Center of Mass of a Gravitational Body

As particles of the TI field are subject to gravity, they are accelerated toward the center of mass of a gravitational body (GB). Matter particles and objects comprising matter particles are entrained by the TI field and accelerated at the same rate as the field. The escape velocity of an object from a given radius from the center of a GB is derived by calculating the work required to move an object from a distance r from the GB to infinity while subject to the force expressed in Newton's law:

$$F = GM\, m / r^2 \qquad \text{(B-25)}$$

where

F is the gravitational force on an object.

GM is the standard gravitational parameter.

m is the inertial mass of the object.

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

The derivation yields Eq (B-26) for the escape velocity.

$$v = (2\, GM / r)^{1/2} \qquad \text{(B-26)}$$

The magnitude of the velocity of the TI field as it accelerates toward the center of a GB reaches the escape velocity of matter particles at any given radius from the center of mass of the GB in accord with Eq (B-26).

Substitute the value for velocity v from Eq (B-26) into Eq (B-24) and you get an expression of the same form as Eq (B-17) which suggests that if the TI field were falling toward the gravitational body (GB) at the escape velocity at that radius from the GB, the process would experience the same magnitude time dilation as gravity would produce at that radius.

It has been written that the substitution of the escape velocity for gravity in Eq (B-24) represents the wrong physics, but I assert that it is the correct physics, and, indeed, it is the only physics that satisfies the phenomena seen in the operation of the Global Positioning System (GPS). We'll examine these phenomena in Appendix C.

B.4.2 Phenomena Associated With the Descent of the TI Field Toward a Gravitational Body

The descent of the TI field toward the center of mass of a gravitational body (GB) accounts for a number of phenomena:

- The infall velocity of the TI field at a given radius from a GB causes time dilation of a process in agreement with the value attributed to gravity in Eq (B-23). Thus gravity's contribution to time dilation is limited to its acceleration of the TI field.
- Gravitational time dilation is not caused directly by gravity, but only indirectly by the infall velocity of the TI field in its response to gravity.
- The absence of a change in time dilation in a freely falling object embodying a process occurs because in free fall the velocity of the object relative to the TI field does not change as the object accelerates at the same rate as the infalling TI field.
- An object in free fall experiences an increasing flux of gravitons as it approaches the GB, yet a process embodied in the object does not experience an increase in time dilation. We must conclude that graviton flux plays no direct part in time dilation, but acts only through the acceleration of the TI field. A conservative Nature implements only one cause of time dilation after all.
- The weight of an object at rest relative to the GB is caused by the acceleration of the TI field at the object, not directly by gravity. Just look at the classical equation for the weight of an object, $W = mg$, where W is the weight of the object at rest on the surface of the GB, m is the inertial mass of the object and g is the acceleration of gravity. Ask yourself this: If the object is at rest on the surface of the GB, what is accelerating? In the TI field model of gravity it is the TI field itself (or particles thereof) that is (are) accelerating relative to the object. See [1], Ch 7.

Appendix C

Time Dilation in The Global Positioning System (GPS)

C.1.0 How the Motion of Earth Through Space Would Affect the Time Dilation of GPS Satellite Clocks

I have shown in Appendix A and in Appendix B that time dilation of a process is a function of the velocity of that process (say a ticking clock) relative to a field of space that I term the Temporal-Inertial (TI) field. I have yet to characterize the extent or motion of the TI field. This characterization will emerge when we consider the operation of the Global Positioning System (GPS). At this point, assume that the TI field is at rest relative to the Cosmic Microwave Background (CMB) [9], the ultimate frame of reference for motion in the Universe.

The Global Positioning system (GPS) must compensate for time dilation caused by the velocity of its orbiting satellites and by gravitational time dilation at the satellite's orbital altitude. Similarly, compensation must be made for time dilation caused by the surface velocity of Earth (due to its rotation) at the location of clocks on the surface and for gravitational time dilation at the location of clocks on the ground. An Earth Centered Inertial System of coordinates is used [10]. In determining the effects of velocity and gravity on the time dilation of the GPS clocks, the motion of the center of mass of Earth itself is not considered [6]. ***I will argue that this exclusion is meaningful and has significant consequences for the understanding of how gravity works.***

C.1.1 Resolving a GPS Satellite's Velocity Through Space

To begin, we'll include how the motion of Earth relative to the TI field, ***if it exists,*** would affect time dilation measurements in the GPS. Earth does have several independent motions through space as shown in Table C.1. The directions of these motions are not the same and change with the orbital motions of Earth about the Sun and of the Solar System about the galactic center. The are other motions of Earth, not shown in the table; e.g. the motion of Earth about the barycenter of the Earth-Moon system and the oscillatory motion of the Solar system about the mid-plane of the galaxy. As shown in the table, the GPS satellite orbital velocity is very small compared with the velocity of Earth through space.

Table C.1. The Speed of GPS Satellites and of Earth Through Space [6] [11]	**Speed in km / sec**
Orbital velocity of a GPS satellite relative to the center of mass of Earth	3.87
Earth's orbit about the Sun	30
The Solar System's orbit about the galactic center	220
The galaxy's motion relative to the Cosmic Microwave Background	583

Equation (B-20), repeated below as Eq (C-1), expresses the time dilation for a process (exemplified by a clock) moving at velocity v_2 relative to the TI field.

$$\Delta t_2 = t_0 v_2^2 / (2 c^2) \tag{C-1}$$

where

Δt_2 is the difference in period of the moving clock relative to that of a clock at rest relative to the TI field.

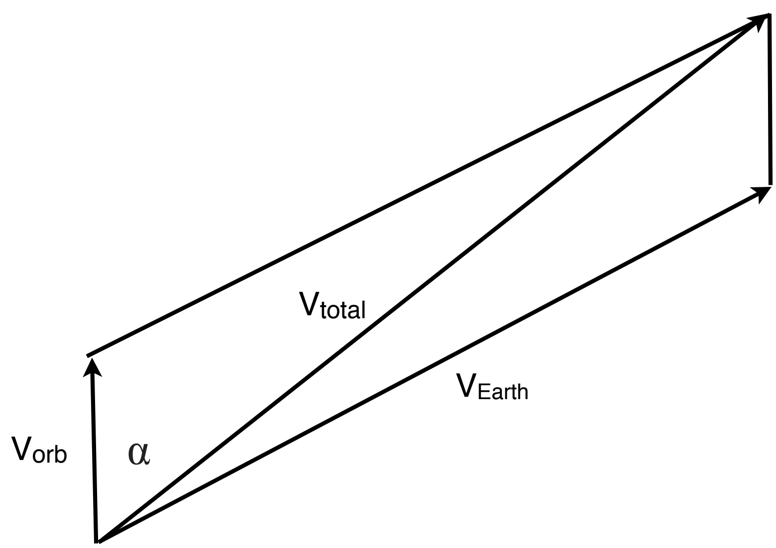
t_0 is the period of a clock removed from any gravitational body and at rest with the TI field.

v_2 is the velocity relative to the TI field of the moving clock.

c is the velocity of light in vacuo.

The velocity of a GPS satellite clock relative to the TI field includes the vector sum of the satellite's orbital velocity relative to Earth and Earth's velocity (if it exists) relative to the TI field. Recall that to start we've assumed that the TI field is at rest relative to the CMB. The vector sum of the velocities shown in the table comprise the main contributions to Earth's velocity relative to the CMB. This vector sum exceeds by two orders of magnitude the orbital velocity of a GPS satellite. Figure C.1 is not to scale, but does illustrate how the orbital velocity V_{orb} of a GPS satellite relative to Earth combines with the velocity V_{Earth} of Earth through space to yield the vector sum V_{total}. The angle between the GPS satellite orbital velocity and Earth's velocity through space is α. The angle α varies by 360 deg for every orbit of a GPS satellite. The orientation and magnitude of Earth's velocity vector changes as Earth orbits the Sun, but at any instant, Earth's velocity vector and the velocity vector of an orbiting satellite define a plane in space and can be represented as in Figure C.1. The square of the velocity of the satellite relative to space is given by the equation in the figure:

$$V_{total}^2 = V_{Earth}^2 + V_{orb}^2 + 2\ V_{Earth} * V_{orb} * \cos \alpha \qquad \text{(C-2)}$$



$$V_{total}^2 = V_{Earth}^2 + V_{orb}^2 + 2\ V_{Earth} * V_{orb} * \cos\alpha$$

Figure C.1 Combining the Satellite Orbital Velocity with Earth's Velocity Through Space (Figure is not to scale.)

Clearly, the velocity of a GPS satellite ***relative to space*** is dominated by the contribution of Earth's velocity through space. If the TI field is at rest relative to the CMB, then the velocity of Earth relative to the TI field would be the same as its velocity relative to space itself or the CMB. If this value were used in Eq (C-1) to determine the time dilation of a GPS satellite clock, the result would not be consistent with what is observed in the GPS [6]. Furthermore, there would be a fluctuation in the measured time dilation at the orbital period of the satellite caused by the $2\ V_{Earth} * V_{orb} * \cos \alpha$ term of Eq (C-2). This fluctuation is not observed in the GPS.

The time dilation of a GPS satellite clock contributed by its orbital velocity is given only by the orbital velocity of the satellite and does not contain a contribution from Earth's velocity through space. Let's examine how this can be true.

C.1.2 A Thought Experiment

Consider an experimental setup with three clocks, one in orbit about Earth, one on the surface of Earth and one at the center of mass of Earth. (Suspend your disbelief that a clock would function at the center of Earth; it's a thought experiment after all.)

In this experiment

v_1 is the velocity of Earth's center relative to the TI field.

v_2 is the velocity of the surface of Earth at the location of Clock 2 relative to Earth's center.

v_3 is the velocity of the GPS satellite clock relative to Earth's center.

$\Delta t_1 / t_0$ is the time dilation of a clock at Earth's center relative to a hypothetical clock at infinity. Infinity is merely a metaphor for a location far removed from any gravitational source and at rest relative to the TI field.

$\Delta t_2 / t_0$ is the time dilation of a clock on Earth's surface relative to a hypothetical clock at infinity.

$\Delta t_3 / t_0$ is the time dilation of a clock in an orbiting GPS satellite relative to a hypothetical clock at infinity.

Now, calculate the time dilation for each of the three clocks produced by its motion relative to the TI field. ***Recognize that these velocities are vector quantities and must be added vectorially, not algebraically.*** Accordingly, there will be cyclic variations in the time dilation of the clocks on Earth and in orbit. These variations occur in a satellite clock as the direction of the orbital speed of the satellite changes with respect to the direction of motion of Earth's center of mass. Similarly, time dilation of a clock on Earth's surface will change as the surface speed of Earth changes its direction with respect to that of Earth's motion (if it exists) through the space of the TI field.

Time dilation of a clock at Earth's center relative to a clock at infinity:

$$\Delta t_1 / t_0 = v_1^2 / (2 c^2) \qquad \text{(C-2)}$$

Time dilation of a clock on Earth's surface relative to a clock at infinity:

$$\Delta t_2 / t_0 = (v_1 + v_2)^2 / (2 c^2) \qquad \text{(C-3)}$$

Time dilation of a clock in an orbiting GPS satellite relative to a clock at infinity:

$$\Delta t_3 / t_0 = (v_1 + v_3)^2 / (2 c^2) \qquad \text{(C-4)}$$

C.1.3 Conclusion from the Thought Experiment

Given that the velocity of Earth through space (and the TI field?) is much greater than either the orbital velocity of GPS satellites or the surface rotation velocity of the planet, then the velocity of Earth through space would completely dominate the time dilation experienced by Earth-bound and orbital clocks. Ignore for the moment the contribution to time dilation caused by gravity, that for the satellite clocks is actually greater than that caused by orbital velocity. The difference in time dilation (caused only by velocity effects) between a satellite clock and a clock on Earth's surface would be

$$(\Delta t_3 - \Delta t_2) / t_0 = [(v_1 + v_3)^2 - (v_1 + v_2)^2] / (2 c^2) \qquad \text{(C-5)}$$

or

$$(\Delta t_3 - \Delta t_2) / t_0 = [(v_3^2 - v_2^2 + 2 v_1 (v_3 - v_2)] / (2 c^2) \qquad \text{(C-6)}$$

The magnitude of the term $2 v_1 (v_3 - v_2)$ in Eq (C-6) contributed by Earth's velocity through space is much larger than the terms v_3^2 and v_2^2. Discounting the effects of gravity, the evaluation of the difference in time dilation expressed by Eq (C-6) is far larger than measured in the GPS.

There can be only one conclusion drawn from this discrepancy: ***Regardless of the velocity of Earth through space, the velocity v_1 of Earth relative to the TI field must be zero. This can occur only if the orbits about the Sun of the TI field and Earth are coincident. Similarly, the orbits about the galaxy of the Sun and the TI field are coincident.***

Setting the velocity v_1 of Earth relative to the TI field to zero in Eq (C-6) yields the correct measurement (not counting gravitational effects) for the difference in the period between a satellite clock and a clock on Earth's surface as shown in Eq (C-7).

$$(\Delta t_3 - \Delta t_2) / t_0 = (v_3^2 - v_2^2) / (2 c^2) \qquad \text{(C-7)}$$

Individually, the changes in time dilation of a clock on the ground and a clock in orbit are given by setting v_1 to zero in Eq (C-3) and Eq (C-4), respectively. Thus:
The time dilation of a clock on Earth's surface relative to a clock at infinity:

$$\Delta t_2 / t_0 = v_2^2 / (2 c^2) \qquad \text{(C-8)}$$

The time dilation of a clock in an orbiting GPS satellite relative to a clock at infinity:

$$\Delta t_3 / t_0 = v_3^2 / (2 c^2) \qquad \text{(C-9)}$$

At the beginning of this section, the frame of reference for velocities v_2 and v_3 was the center of Earth which itself was assumed to have a velocity v_1 relative to the TI field. Having set v_1 to zero, the frame of reference for the velocities of the satellite clock and surface clock is now the TI field. To calculate properly the difference in time dilation between two clocks I imposed the criterion that the time dilation of each clock be calculated based on the velocity of each clock relative to the TI field, not on the difference in velocity between the two clocks. That criterion has been met in Eq (C-7). The difference in the squares of velocities of Eq (C-7) may be summed algebraically because v_2 and v_3 are each reckoned relative to the TI field.

C.2.0 Behavior of the TI Field Affirmed by the Twin Clock Non-Paradox and the Function of the Global Positioning System

The TI field mediates all gravitational interactions between matter objects and between the putative dark matter field and matter objects. Accordingly, the acceleration and velocity of particles of the TI field depend on their proximity to gravitational bodies and their location within the dark matter field. Acceleration of the TI field in response to the gravitational fields of these sources applies the same acceleration to matter particles and objects comprising matter particles (e.g. planets, stars and galaxies). Having identified the principle gravitational sources affecting motion of the TI field, I'll simplify the summary of behaviors of the TI field, by discussing the response of the TI field only to the gravitational influences of the Sun and Earth itself.

Table C.2 Behaviors of the TI Field Affirmed by the Twin Clock Non-Paradox and the Function of the Global Positioning System
If Earth is at rest relative to the TI field, then the orbits of Earth and the TI field about the Sun must be coincident.
Consequently, the TI field is subject to gravity and orbits the Sun in its response to the gravitational field of the Sun.
The TI field is responsible for the inertial force. The acceleration of matter particles relative to the TI field produces the familiar inertial reaction force.
The TI field mediates the gravitational force. The acceleration of the TI field toward the Sun produces the same acceleration of objects (e.g. Earth) within the field. Any deviation between the acceleration of a matter object and the TI field produces an inertial reaction force to eliminate that difference in acceleration. This behavior is the only way that the orbits of Earth and the TI field about the Sun can be exactly coincident. (If the reader has any doubts that the TI field has the strength to move a planet in its orbit, see Reference [3].)
The coincidence of the orbits about the Sun of the TI field and Earth demands that there can be no gravitational force acting directly on Earth. Thus matter particles and objects comprising matter particles are not subject directly to gravity, but respond to gravity only through the mediation of the TI field.
Colloquially, the TI field is not dragged around in Earth's orbit by Earth; Earth is dragged around by the TI field!
In the proximity (undefined) of a gravitational body (GB), the TI field flows directly toward the center of mass of the body. This does not contradict the assertion that at Earth's distance from the Sun the TI field orbits the Sun. The two behaviors coexist and both support the function of the GPS.
As the TI field flows toward a gravitational body the magnitude of its velocity at any radius from the body equals the escape velocity of matter particles at that radius. This follows from the fact that matter objects are not directly subject to gravity, hence the acceleration of the TI field toward the GB must account in full for the response of matter objects to gravity.
The acceleration of the TI field toward a gravitational body must accelerate matter objects within the field at the same rate. See Appendix A.

Table C.2 Behaviors of the TI Field Affirmed by the Twin Clock Non-Paradox and the Function of the Global Positioning System
The acceleration of the TI field relative to a GB at the surface of the GB applies the inertial reaction force to a matter object at the surface. This force must be equal to the weight of the object at the surface of the GB.

C.3.0 Inferences from the Thought Experiment

As described in the introduction to this Appendix, time dilation of a process is a function of the velocity of that process (say a ticking clock) relative to the Temporal-Inertial (TI) field. The widely accepted phenomenon of gravitational time dilation is the second means of causing time dilation. One wonders why nature would have two means of causing time dilation, but that's a philosophical question, not a scientific one. But there's a hitch in the gravitational explanation, so here's an alternative:

We've just described that the TI field flows toward the center of mass of a gravitational body, reaching the escape velocity at any given radius from the body. We've shown that the velocity of a process relative to the TI field causes time dilation. Accordingly, we can infer the following items shown in Table C.3.

Table C.3 Inferences re Gravitational Time Dilation
A process (e.g. our ticking clock) experiences time dilation that is a function of its velocity relative to the TI field.
The infalling TI field near a gravitational body (GB) must then cause time dilation for any object within the field that is not moving at the same velocity as the field.
The escape velocity at a given radius from the GB is a function of the value of the *standard gravitational parameter* GM and the radius from the center of mass of the GB as shown in Eq (B-26).
The magnitude of the escape velocity of a body at rest relative to the GB is the velocity of the infalling TI field. The time dilation of a process at rest relative to the GB caused by this velocity is the same value as that presumably caused directly by gravity.
I show in the section to follow, that the time dilation seen by the process at rest relative to the GB is fully accounted for by the difference in velocity between the process and the TI field, hence there can be no additional time dilation caused directly by gravity!

C.4.0 Gravitational Time Dilation Reformulated

A process is an event or sequence of events that takes time. In our discussions, a process is represented by a ticking clock.

Gravitational time dilation of a clock near a spherically symmetric gravitational body (GB) is defined by Eq (B-23) repeated below as Eq (C-10).

$$t_2 / t_0 = 1 / [(1 - 2GM / (r c^2)]^{1/2} \qquad \text{(C-10)}$$

where

t_2 is the period of a clock located a distance r from the center of mass of a gravitational body (GB) of mass M.

t_0 is the period of an identical clock located at such a great distance from any GB that its tick rate is unaffected.

GM is the standard gravitational parameter.

r is the distance of the clock from the center of mass of the GB.

c is the velocity of light in vacuo.

Now I will reconcile Eq (C-10), that expresses time dilation in terms of the strength of the gravitational field at the process with the statements repeated ad nauseam in previous sections that time dilation is caused by the velocity of a process relative to the TI field. The escape velocity at a distance r from a GB is given by Eq (B-26) repeated here as Eq (C-11).

$$v = (2 GM / r)^{1/2} \qquad \text{(C-11)}$$

The term $2 GM / r$ in Eq (C-11) is the square of the escape velocity. Substitute this into Eq (C-10) and we have the expression for gravitational time dilation in terms of the velocity of the clock relative to the TI field, or, if you prefer, the velocity of the infalling TI field relative to the clock:

$$t_2 / t_0 = 1 / (1 - v^2 / c^2)^{1/2} \qquad \text{(C-12)}$$

where now

t_2 is the period of a clock located within the gravitational field of a GB.

t_0 is the period of an identical clock located at such a great distance from any GB that its tick rate is unaffected.

v is the infall velocity of the TI field relative to the clock.

The form of Eq (C-12) emphasizes the cause of gravitational time dilation, but is not useful in calculating the effect. We still have to use the gravitational form of Eq (C-11) to calculate the infall velocity of the TI field at the location of the clock.

The manipulation of equations to yield Eq (C-12) may seem an artifice, but it is in accord with the premise that the TI field, subject to gravity, is accelerated toward the center of mass of the GB. Recall an earlier quote from reference [8]:

> '… the escape velocity at a point in space is equal to the speed that an object would have if it started at rest from an infinite distance and was pulled by gravity to that point.'

Acceleration of the TI field relative to a matter object accounts in full for the gravitational force exerted (via the mediation of the TI field) on the object. Thus the infall velocity of the TI field at any given radius from the GB is equal in magnitude to the escape velocity of matter particles at that radius.

Appendix D

Properties of the Temporal-Inertial (TI) Field [1]

D.1.0 Characterization of the TI Field

We can now characterize certain behaviors of the TI field that must follow from our thought experiments in which four primary conclusions have been reached:

- The acceleration of matter particles relative to the TI field produces the familiar inertial reaction force.
- The TI field is subject to gravity.
- Time dilation is a function of the velocity of a process relative to the TI field.
- Earth must be at rest relative to the TI field.

D.1.1 The Particle Flux of the TI Field and the Inertial Reaction Force

Consider first that the TI field is transparent to the velocity of an object, but resists the acceleration of an object through the field. Relativistic effects aside, a matter object may move at high velocity through the TI field without resistance, but the TI field resists the slightest acceleration of the object. Apparently, a constant flux of particles of the TI field on an object moving through the field produces no reaction from the field, but a change in flux does. This has profound consequences for the characterization of the TI field.

How might the particle flux encountered by an object moving through the TI field change? Again, relativistic effects aside, I can think of only two ways:

- An object will encounter an increase in the flux of particles of the TI field when it accelerates in the direction of its velocity through the TI field and a decrease in the flux of particles of the TI field when it accelerates in the direction opposite to its velocity through the TI field. In either case, the TI field resists the acceleration of the object.
- An object would encounter a change in flux of particles of the TI field if it entered a region where the particle density changed.

The particle flux of the TI field encountered by an object moving through the TI field is proportional to the velocity of the object through the field and to the particle density of the field. Acceleration is the rate of change of velocity and causes a rate of change of particle flux of the TI field encountered by an object accelerating through the field. The inertial reaction force on an object accelerating through the TI field is proportional to the acceleration of the object through the field and thus is proportional to the rate of change of particle flux of the TI field, whether increasing or decreasing.

D.1.2 The Particle Density of the TI Field Is Constant

We have seen that in the vicinity (undefined) of a gravitational body (GB) particles of the TI field flow toward the center of mass of the GB. As a rule we would expect the density of the TI particle field to vary inversely as the cube of the radius from the center of the GB as the field flows toward the GB. The effect of this variation in particle density of the TI field is obvious: the resistance to a given acceleration of an object near the GB would be greater than the same acceleration at a greater distance from the GB. Clearly, this behavior does not happen. The only way to explain this null effect is for the particle density of the TI field to remain constant even as the particles of the field flow toward a gravitational body. Determining how this null effect might happen is far beyond the scope of this paper. Perhaps particles of the TI field are transformed into other particles. Nature seems to have no trouble changing particles from one form to another. Again, this conjecture is beyond the scope of this paper.

A corollary to this question is the change in particle density of the TI field as the Universe expands. Again, it is clear that this change in particle density does not occur.

D.1.3. What Happens to Particles of the TI Field that Descend into a Gravitational Body?

I pondered for some time why the particles of the TI field that flowed into the center of Earth didn't just keep on going and flow out the other side thus negating any effect on their mediation of gravity. The conclusion reached in the section above that the particle density of the TI field must remain constant answers that question. As particles of the TI field descend toward a gravitational body and occupy a smaller volume of space they can retain the same particle density only by transforming into other particles. The nature of these 'other particles' is, of course, unknown. This answer must seem to be a contrivance and the wildest of speculations and it is.

D.2.0 Time Dilation of a Process is a Function of the Velocity of that Process Relative to the TI Field

Appendix A. The Twin Clock Non-Paradox showed that the time dilation of a process is a function of the velocity of that process relative to the TI field, not relative to an arbitrary frame of reference. A process is defined as a transaction, or a transition or a sequence of actions or events that takes time. Time dilation is not the slowing of time, but the slowing of the pace of the process itself. If a process moves through the TI field at high speed the process takes more time than the same process would take if moving at a slower speed. A process can be subatomic, atomic, chemical, mechanical or biological.

D.3.0 Earth Must be at Rest Relative to the TI Field

Appendix C. Time Dilation in the Global Positioning System (GPS) showed that time dilation in the satellite clocks had two causes: the orbital velocity of the satellite clocks and the effects of gravity. Time dilation in clocks on the surface of Earth had two causes: the surface velocity of Earth in its rotation about its own axis and the effects of gravity. It was argued that gravity does not act directly to cause time dilation but acts indirectly through the acceleration of the TI field so that, again, time dilation is caused only by the velocity of the clock (in orbit or on the ground) relative to the TI field.

The motion of Earth in its orbit about the Sun in combination with motions of the Solar System about the galaxy and motion of the galaxy itself was shown not to contribute to the time dilation of either the orbital clocks or the clocks on the ground. The only way to account for these null effects is for Earth to be at rest relative to the TI field. This can occur only if the TI field itself is subject to gravity and carries Earth about the Sun, the Sun about the galaxy and the galaxy in its motion relative to the fundamental reference for motion, the CMB.

The gravitational effects of the oblateness of Earth were not covered in the appendix.

D.4.0 Summary of the Properties of the TI Field

Table D.1 Summary of the Properties of the TI Field
The TI field is a field of particles that participates in the inertial and gravitational interactions.
When a matter particle or an object composed of matter particles is accelerated by an external force, its motion is resisted by its acceleration relative to the TI field. This reactive force of the TI field is the familiar inertial force.
The TI field is subject to gravity.
Particles of the TI field are accelerated by gravity directly toward the center of each gravitational body (GB) just as a test particle would be in the Newtonian model and reaches the escape velocity of such a particle at the distance of that particle from the gravitational center of the GB.
The gravitational acceleration of the TI field relative to a matter particle or an object composed of matter particles applies a force to that matter particle or object. This force is the familiar gravitational force applied indirectly through the intermediary of the acceleration of the TI field of space.
The TI field accelerates massive particles at the same rate as its own acceleration.
Acceleration of the TI field in its own response to gravity is the sole accelerator of massive particles in response to gravity. Accordingly, massive particles are not directly subject to the gravitational force.
The TI field supports the propagation of nature’s force particles.
The particle density of the TI field is constant even as particles of the field flow toward the center of mass of a gravitational body.