Highlights

Uncovering Relativity's Mechanistic Counterpart:
Discovering Time Dilation's Cause via Mill's Method

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- Mechanistic Counterpart to Relativity: Proposes a mechanistic model for time dilation and gravity, challenging the geometric perspective of general relativity.
- Specific Internal Energy Model: Derives a specific energy model to explain kinetic and gravitational time dilation, showing gravity as a result of a specific internal energy gradient.
- Innovative Experimental Design: Describes a novel experiment using gravimeters to measure gravitational acceleration and infer the preferred frame.
- Simulation and Validation: Provides simulations to demonstrate the feasibility of detecting the preferred frame and discusses implications for future experiments.

Uncovering Relativity's Mechanistic Counterpart: Discovering Time Dilation's Cause via Mill's Method

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ABSTRACT

This paper introduces a mechanistic counterpart to Einstein's theory of relativity, derived using Mill's Method—a valid method of induction rooted in the law of causality. Unlike geometric or mathematical models, which often lack causal explanations, this study provides a causal framework for understanding relativistic effects within a paradigm where the present is omnipresent, and only current entities exist.

The investigation begins by critically examining the foundational assumptions of relativity, including the isotropic nature of the speed of light. It then addresses limitations in the relativistic framework, particularly the reciprocity principle in special relativity, which hinders causal analysis. By reevaluating time as a measure of change to things rather than as a dimension of the Universe, the study identifies a preferred frame for light speed, crucial for causal coherence.

The cause of kinetic time dilation is pinpointed as specific work done with respect to this preferred frame, reducing the average effective speed of light with respect to a moving object. This reduction slows the speed of causality, increasing the duration of changes to the object, resulting in time dilation. Additionally, this framework unifies all forms of time dilation under a common cause: a reduction in the average effective speed of light—the speed of causality.

From this causal understanding, a new relationship between specific energy and time dilation emerges. This model explains gravity as emerging from a gradient in specific internal energy, corresponding to time dilation gradients. The paper concludes with an experimental proposal to validate this new paradigm, suggesting a fundamental shift in our understanding of relativistic effects.

1. Introduction

In the history of scientific progress, many models have emerged that describe natural phenomena with remarkable precision. However, not all of these models provide a causal explanation for the mechanisms they describe. A distinction can be made between geometric or mathematical models, which predict outcomes without offering a causal narrative, and mechanistic models, which attempt to elucidate the underlying causes of observed phenomena. This paper explores this distinction within the context of Einstein's theory of relativity, proposing a mechanistic counterpart that challenges the conventional understanding of time, space, energy, and gravity.

Historically, scientific advancements have often involved the transition from geometric models to mechanistic ones. For instance, Ptolemy's model of epicycles, while mathematically accurate in predicting the movements of celestial bodies, was eventually supplanted by Kepler's laws, which offered a causal explanation grounded in the influence of the sun on planetary motion. Similarly, Newton's law of gravitation provided a mechanistic account of gravitational forces, while later developments, such as the Newton-Cartan theory (1), abstracted these forces into a purely geometric framework. Despite the predictive success of these geometric models, the absence of a causal mechanism has often been a point of contention (2; 3; 4).

Einstein's general relativity, a geometric model par excellence, describes the curvature of spacetime as the cause of gravitational effects. While mathematically elegant, this model leaves open questions about the underlying mechanisms governing relativistic phenomena. This paper seeks to address these gaps by proposing a causal framework that offers a mechanistic interpretation of time dilation and gravity, derived through Mill's Method of induction.

Mill's Method, grounded in the law of causality, provides a rigorous approach to identifying the causes of observed phenomena. Causality, rooted in the law of identity, asserts that a thing must act in accordance with its nature. However,

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the relativistic framework, particularly the reciprocity principle in special relativity, complicates the application of Mill's Method by making it difficult to determine specific causes of observed effects. This obstacle led to a critical reassessment of the assumptions underpinning relativity, culminating in a fundamental reevaluation of time and space.

This paper argues that time is not an independent dimension of the Universe but rather a measure of the interval over which change occurs to things within the Universe, aligning with an absolute framework of time and space. By reinterpreting time in this way and considering a preferred frame for the speed of light, a new causal understanding of time dilation emerges. Specifically, kinetic time dilation is posited to result from specific work done with respect to the preferred frame, leading to a reduction in the average effective speed of light relative to the moving object. This reduction slows the speed of causality, thereby increasing the duration of changes—an effect known as time dilation.

Building on this causal insight, this paper develops a new specific energy model, which integrates time dilation as a reduction in an object's specific internal energy. This model not only unifies different forms of time dilation under a common cause but also provides a mechanistic explanation for gravity as an emergent force arising from a gradient in the specific internal energy of objects.

The implications of this new framework are profound, suggesting that the phenomena traditionally explained by relativity can be reinterpreted through a mechanistic lens. Furthermore, this paper outlines a simple experiment designed to test this new paradigm against the predictions of relativity, potentially paving the way for a significant shift in our understanding of the physical Universe.

2. Background

2.1. What is Mill's Method and Why it Works

Mill's Method works because it is based on an intimate understanding of the law of causality, which itself derives from the law of identity. Both laws make fundamental statements about existence. The law of identity asserts that each thing is identical to itself, meaning that an object or concept has a specific nature and set of characteristics that define what it is. In other words, something is what it is and cannot be something else at the same time and in the same respect. The law of causality asserts that each thing must act in accordance with its identity or nature. The nature of an action is caused and determined by the nature of the entities involved; a thing cannot act in contradiction to its nature. In this sense, the law of causality is the law of identity applied to action (5).

The validity of the law of identity rests on the fact that it is an axiomatic concept. Axiomatic concepts are the starting points of cognition, upon which all proofs depend, and they are validated by the fact that any attempt to disprove them requires their acceptance. This means that any argument against the law of identity must possess an identity, thereby nullifying the argument. We directly observe that things are what they are. Even if we cannot determine what things are, we can at least know *that* they are (6).

Mill's Method exploits these laws by recognizing that, given the same essential conditions, a thing must act the same way every time. Any deviation from a past action suggests that at least one essential condition has changed. This studied action is often called the *effect*. The antecedent factors that comprise the essential conditions determining the effect are termed the *cause*. To summarize, every effect has a cause, and no effect occurs without one, meaning no entity acts against its nature.

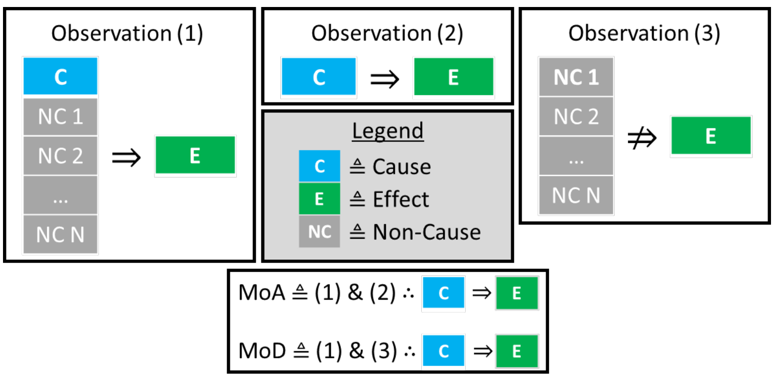


Figure 1: **Mill's method of agreement and method of difference.**

Mill's Method establishes a means of controlling conditions—known as the *controlled experiment*—to isolate cause-effect relationships. Mill's two basic methods for discovering these relationships are illustrated in Figure 1 and summarized as follows (7):

- **Method of Agreement (MoA)**: A controlled experiment in which plausible causes are removed/changed, yet the effect remains the same. This proves that the cause is contained in the remaining set of unchanged plausible causes.

- **Method of Difference (MoD)**: A controlled experiment in which plausible causes are removed/changed, and the effect is different. This proves that the cause is contained in the removed/changed set of plausible causes.

2.2. Peikoff's Refinement to Induction

Peikoff refines the inductive approach outlined by Mill. This refinement becomes evident when we observe that a controlled experiment is not chosen at random, and interpreting the results does not originate from a blank slate of understanding. A solid conceptual framework is necessary to intelligently select useful controlled experiments and to interpret the observations (8; 9; 10).

For example, without the concept of velocity, which includes both speed and direction, Newton would be left with the old generalization that a change in speed is caused by acceleration, instead of the wider generalization that a change in velocity is caused by acceleration. Without the concept of motion broken into component directions, what we now call vectors, Newton would have been lost when studying the circular motion of planets. It did not occur to the ancients that uniform circular motion was accelerated motion, even though the speed was not changing. Like the ancients, Newton would not have been able to discover that planets are accelerating toward the Sun, nor realize that a force acts upon them in accordance with $\vec{F} = m\vec{a}$ and $\vec{a} = -\hat{r}GM/\vec{r}^2$. Integrating the concept of velocity into one's conceptual framework is necessary to make sense of uniform circular motion as accelerated motion.

Thus, a valid method of induction requires a valid theory of concepts, and Objectivism provides such a theory. Given a valid conceptual framework, the refined causal discovery method is to observe the causal action via Mill's Method, identify the causal relationship at play, quantize the action in precise mathematical terms, and integrate the new generalization into one's conceptual framework (8; 10; 11).

2.3. Contrast With Hypothetico-Deductive Method

Throughout history, philosophers have attempted to validate[1] induction by reducing it to deduction (8). The Hypothetico-Deductive Method is one such approach (12).

The challenge of induction is finding a valid method for generalizing from specific instances. This is crucial because deductions rely on premises, at least one of which must be a generalization. The relationship between induction and deduction can be summarized as follows: induction arrives at general principles from specific instances, while deduction applies general principles to specific instances (as shown in Figure 2).

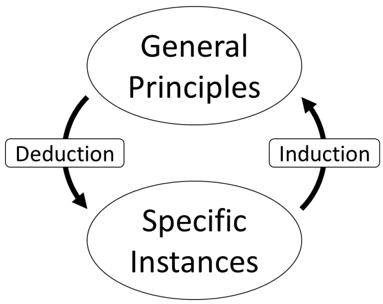


Figure 2: **Induction versus deduction.**

Logic—whether inductive or deductive—serves as the primary means of validating non-trivial concepts and knowledge,[2] implying that all non-trivial knowledge depends on a valid method of induction. Without valid generalizations, deductions lack sound premises (8; 11; 10).

The Hypothetico-Deductive Method tries to short-circuit induction by replacing it with guessing. It involves making observations, hypothesizing a general principle, deducing unobserved but verifiable consequences, and testing them. If enough previously unobserved consequences are confirmed, the hypothesis is accepted as true (12). However, certainty is impossible with this method because it amounts to simple enumeration, a form of induction that Francis Bacon considered childish (13), as he puts it:

> "For the induction which proceeds by simple enumeration is childish; its conclusions are precarious and exposed to peril from a contradictory instance; and it generally decides on too small a number of facts, and on those only which are at hand." (13)

The major flaw with the Hypothetico-Deductive Method is that a single counterexample can invalidate the generalization, and, in principle, generalizations can never be validated with this method. Many proponents of this method acknowledge its limitations, leading to the belief that knowledge can never be fully validated (12).

[1] Validate means to demonstrate something is true.

[2] Trivial knowledge refers to ostensive facts directly perceived through the senses, like "this thing (pointing) is green," or "this thing (pointing) smells good." The knowledge of these facts forms the basis for non-trivial knowledge, but to arrive at non-trivial knowledge requires logic. Trivial knowledge is self-evident and is the fuel for logical inference (10).

Perhaps unsurprisingly, the Hypothetico-Deductive Method is based on itself. That is, the method rests on the following guessed generalization: the only way to achieve a generalization is to guess. Of course, by their own method, they can never be certain of their self-induced skepticism because a single counterexample, such as Peikoff's theory of induction (8), would demonstrate that a valid method of discovering generalizations is possible.

This Hypothetico-Deductive Method is particularly relevant to this paper because relativity was derived through this method. Relativity is based on postulates (generalized assumptions), and while relativity's verifiable predictions align with observations, its unverifiable predictions often conflict with fundamental principles like the laws of identity and causality.

3. Relativity's Tenuous Foundation

History teaches us that geometric models can predict observations with great accuracy and still be false. The fact that a model is false does not render it useless, as accurate predictions from a false model can help derive a correct causal model.

For example, before discovering the elliptical nature of planetary motion, Kepler sought the quantitative causal relationship between the Sun and planets. Even though he knew his initial model was causally lacking and therefore false, he needed a more accurate model. He famously said:

> "Who would have thought it possible? This hypothesis, so closely in agreement with the acronychal [opposition] observations, is nonetheless false." (3)

Many regard relativity as above reproach, refusing to consider that it too might be an interim step toward a causal model. However, a brief survey of its foundation reveals its tenuous nature.

3.1. Light Postulate

The special theory of relativity (SR) rests on two postulates, and from these postulates, the entire body of special relativity is deduced[3] (14):

SR1) Principle of Relativity: The laws of physics take the same form in every frame in uniform motion.

SR2) Light Model: The speed of light is constant in a vacuum and independent of the relative motion of the source.

An universal specificity theory (US), resting on different postulates, can predict the same verifiable observations as relativity (14). Such a model resembles Lorentz Ether Theory but reduces its foundation to these postulates:

US1) Principle of Specificity: The laws of physics take a specific form in a preferred frame.

US2) Light Model: The speed of light is constant only in a preferred frame and independent of the relative motion of the source.

Both theories agree that the laws of physics appear to take the same form and that the speed of light appears to be constant in every uniformly moving frame, but they disagree on why. Relativity claims they are the same, while specificity argues they only appear the same due to the miscalibration of instruments, as time and space measurements deviate from absolute values.

An intuitive way to understand specificity is to imagine that, among the infinitely many inertial frames with the "right" to claim they are stationary, only one frame is truly stationary. In this preferred frame, the speed of light is isotropic. In specificity, an observer in any inertial frame who assumes they are stationary will experience miscalibration of instrumentation, making it impossible to prove otherwise.

Though both theories make the same verifiable predictions, the key difference lies in which postulates align with reality. Despite evidence levied in favor of relativity's light postulate, alternative postulates should not be dismissed lightly.

One commonly cited piece of evidence in favor of relativity is that the speed of light has been measured as constant, regardless of the Earth's motion around the Sun. The Earth's velocity changes by up to 60×10^3 $[m/s]$ throughout its orbit, so if the speed of light were not constant, this difference should have been detected (15). However, when

[3] Postulates are used in the Hypothetico-Deductive Method to reason the following: if these postulates are true, then the rest follows.

investigating how the speed of light is measured, it becomes clear that either (1) the average two-way speed of light was measured, or (2) the one-way speed was measured using a clock synchronization scheme that assumes SR2 is true (16; 17; 18; 19).

Of course, a measured average two-way speed might result from averaging the same speed in both directions or from averaging a faster speed in one direction with a slower speed in the other. Less obviously, a one-way speed of light measurement using a clock synchronization scheme that assumes **US2** to be true would find the speed of light to be anisotropic—i.e., all events and experimental results compatible with the Lorentz transformation and the isotropic one-way speed of light must also be compatible with the Lorentz transformation and the anisotropic one-way speed of light (17; 18; 19). Therefore, no current measurement of the speed of light proves one postulate over the other.

Another piece of evidence often cited in favor of relativity is that Maxwell's equations suggest the speed of light equals the square root of the inverse product of the permeability (ε_0) and permittivity (μ_0) of free space, as shown in Equation (1).

$$c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}} \tag{1}$$

The argument is that since Maxwell did not specify which frame his equations apply to, they must apply to all inertial frames. However, this falls short because Maxwell's original work is built on the assumption that a preferred frame exists (20). Therefore, his equations work equally well in a preferred frame.

Since both theories (relativity and specificity) make the same verifiable predictions, any confirmed prediction of relativity is also a confirmed prediction of specificity (14).

3.2. Equivalence Principle

General relativity (GR) builds upon SR by extending **SR1** into the equivalence principle (14):

GR1) Equivalence Principle: The laws of physics in free-falling frames are the same as in uniformly moving frames. Additionally, a frame undergoing uniform acceleration can be treated as stationary in a uniform gravitational field.

An universal specificity theory could also predict the same observations as GR but would reject the equivalence principle. Specificity attributes the appearance of equivalence to measurement errors rather than true physical equivalence.

The equivalence principle may seem intuitive—experiments in a free-falling lab resemble those in a lab moving uniformly through space—but it disregards a key distinction. "Equivalent" means identical in all essential respects, implying that their differences are inessential. However, one key difference is the change in relative motion between two frames—in free-fall, it can change, while it remains constant when floating in empty space. This distinction is why Newton was certain that gravity was a force: the relative motions between planets, moons, satellites, and free-falling objects changed, and his laws of motion showed that a change in motion is caused by a force, $F = ma$.

Why is this distinction inessential, as the equivalence principle tacitly assumes? In my experience, no satisfactory answer has ever been given, and as we shall see later in Section 8, no answer can be given. We will see that the equivalence principle should be renamed the "similarity principle," as there are many similarities between the situations taken as equivalent, and a lot can be learned from this similarity, but they are not truly equivalent when examined closely.

3.3. Relativity versus More fundamental Principles

Relativity's assumptions face scrutiny not only due to plausible contrary assumptions but also because they hinder the discovery of causes for relativistic phenomena. Questions about what causes differences in time and length intervals between frames prove impossible to answer. More generally, integrating the most fundamental principles of human knowledge, such as the law of identity and the law of causality, with relativity's framework proves impossible due to the absurdities associated with unverifiable predictions.

Special relativity has a reciprocity principle, stemming from the fact that any frame in uniform motion has the "right" to claim it is at rest (14). It is simply a matter of translating measurements from one frame to another using the Lorentz Transformation, shown in Equation (2) as a specific case when relative velocity, v, lies solely on the x-axis (14).

$$\begin{aligned} t' &= \gamma_K(t - \frac{v}{c^2}x) \\ x' &= \gamma_K(x - vt) \\ y' &= y \\ z' &= z \end{aligned} \tag{2}$$

Where :

$$\gamma_K = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$x, y, z, t \in \mathbb{R}$ are spatial and time measurements from frame taken to be at rest.

$x', y', z', t' \in \mathbb{R}$ are spatial and time measurements from frame taken to be in motion relative to rest frame.

v is the relative velocity between both frames.

c is the speed of light.

From this system of equations, the time dilation differential, dt'/dt, which is a ratio of infinitesimal time intervals between two frames, can be determined directly by evaluating an interval of time:

$$\begin{aligned} &\text{Let } : dt' = t'_2 - t'_1 \\ &\text{Let } : dt = t_2 - t_1 \\ &t'_1 = \gamma_K(t_1 - \frac{v}{c^2}x_1) \\ &t'_2 = \gamma_K(t_2 - \frac{v}{c^2}x_2) \\ &dt' = \gamma_K(dt - \frac{v}{c^2}dx) \\ &\quad = \gamma_K(dt - \frac{v}{c^2}vdt) \\ &\quad = dt\gamma_K\gamma_K^{-2} \\ &\therefore \frac{dt'}{dt} = \gamma_K^{-1} \ \in \mathbb{R} \leq 1 \blacksquare \end{aligned} \tag{3}$$

In a similar manner, the length contraction differential, dx'/dx, which is a ratio of infinitesimal length intervals between two frames, can be determined directly by evaluating an interval of length at an instant of time:

$$\begin{aligned} &\text{Let } : dx' = x'_2 - x'_1 \ @ \ t' \\ &\text{Let } : dx = x_2 - x_1 \ @ \ t \\ &x'_1 = \gamma_K(x_1 - vt) \\ &x'_2 = \gamma_K(x_2 - vt) \\ &dx' = \gamma_K(x_2 - vt) - \gamma_K(x_1 - vt) \\ &dx' = \gamma_K(dx) \\ &\therefore \frac{dx'}{dx} = \gamma_K \ \in \mathbb{R} \geq 1 \blacksquare \end{aligned} \tag{4}$$

From studying Equation (3), we can see the only adjustable parameter is the relative velocity, v, between the two frames. Applying Mill's MoD and MoA to this relationship leads to logical havoc. For example, since either frame can "rightly" conclude it is at rest under the relativity framework, each evaluates the other's time dilation differential to be less than one. This means each evaluates the other frame as taking longer to complete experiments than their own.

For example, if one frame measures two hours for a coffee to reach room temperature, then the predicted time it took for the other frame is longer than two hours. Logically speaking, it makes no sense for both frames to simultaneously predict that the other frame took longer for the same changes to complete.

This realization was likely the motivation behind the genesis of the twins paradox, in which one twin travels quickly to a distant star and back, aging less than the twin who stayed on Earth. Relativity addresses this by selecting one frame as stationary, but this arbitrary resolution fails to address the underlying contradiction.

A resolution to the twins paradox does not eliminate the absurdity of unverifiable predictions, such as both frames predicting that the other experiences time dilation. While relativity can make accurate predictions at the end of the round trip, it cannot be trusted to describe the reality of any leg of the journey.

Depending on the reference frame used, the results can vary significantly. For instance, in one frame taken as stationary, the traveling twin might age more on the way to the star and less on the return trip, balancing the aging from the first leg. In contrast, another frame might predict the opposite sequence. Yet another frame could predict that the traveling twin ages less on both legs. Infinitely many frames exist predicting results in between. They all agree on the return trip's outcome but differ on what happens during the journey (14).

Relativity, by definition, is currently secure from evidence contradicting its verifiable predictions, as the only evidence produced is the conclusion at the end of the round trip. However, the unverifiable contradictory predictions, which are accepted within relativity's framework, remain absurd. This makes it impossible to integrate relativity with the law of identity and, therefore, impossible to evaluate the cause of time dilation using this framework.

Given that relativity accepts this chaos of contradictory unverifiable predictions as correct, how can one establish a controlled experiment to evaluate why a duration of change lengthens with relative velocity? If one uses the frame in motion, such as the traveling twin's frame during one leg, as at rest, then according to the MoD, a change in local motion causes all objects in other frames to experience length contraction[4] and time dilation, even for objects infinitely far away. This conclusion is clearly wrong as it violates local causality.

In addition to the logical havoc created when evaluating the causes of relativistic phenomena under the framework of relativity, the relativity of simultaneity also adds to the chaos and violates more fundamental principles. For example, we know that things are what they are. Some things have the potential to become something else; it is part of their nature. For instance, seeds have the potential to become flowers, and flowers have the potential to turn to ash. Causality dictates that a thing changes from what it is to its potential, but it is never simultaneously changed and unchanged. A thing is never a seed, a flower, and ash simultaneously. Under relativity's framework, which holds the relativity of simultaneity, a thing can be a seed, flower, and ash simultaneously.

If you are familiar with the Andromeda paradox (21), we can concretely evaluate a slight modification to it using the context of flowers. Suppose three scientists, A, B, and C, set up an experiment such that they will be seated in a conference room at the moment a seed grows into a mature flower on a spaceship far away, about 82.137×10^6 $[ly]$, and traveling at $v = 0$ with respect to the conference room.

Once the conference meeting ends, at $t = 0$, Scientist A remains seated in the conference room, Scientist B begins walking away at 1 $[m/s]$ toward the flower, and Scientist C begins walking away at 1 $[m/s]$ away from the flower. Let's see what each scientist would predict for the state of the living organism so far away.

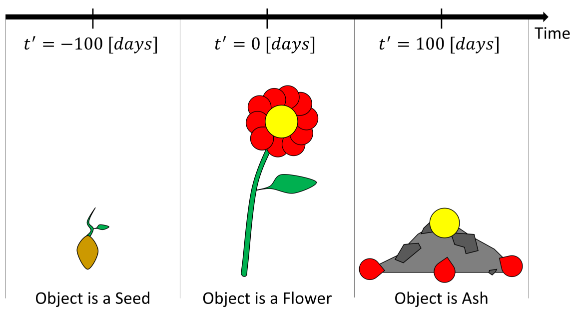


Figure 3: **Flower life cycle.**

Assume it takes 100 days for the seed to turn into a flower after being planted, and another 100 days for the flower to turn to dust, as illustrated in Figure 3, where the proper time for the flower is t'.

We can use Equation (2) to determine t' for each of the scientists. Since $\gamma_K \approx 1$ when $|v| \leq 1$ $[m/s]$, t' simplifies to:

$$t' = \gamma_K (t - \frac{v}{c^2} x)$$
$$t' = -\frac{v}{c^2} x$$

[4] The same argument applies to length contraction. Both frames predict that the other experiences contraction, leading to logical inconsistencies.

$$\begin{aligned}
&\text{When}: x \approx 82.137 \times 10^6\ [ly] \\
&\qquad t' = -\frac{v}{c^2}(82.136 \times 10^6\ [ly]) = -v(100 \times 24 \times 60 \times 60\ [m^{-1} \cdot s^2) \approx -v(100\ [m^{-1} \cdot s \cdot days])
\end{aligned} \tag{5}$$

For Scientist A, $v = 0\ [m/s]$ and $t' = 0\ [days]$, meaning the scientist seated in the conference room predicts the object is still a flower. For Scientist B, $v = -1\ [m/s]$ and $t' = 100\ [days]$, meaning they predict the object has turned to ash. For Scientist C, $v = 1\ [m/s]$ and $t' = -100\ [days]$, meaning they predict the object has returned to a seed.

At $t = 0$, we get three contradictory predictions about the flower from each scientist—one predicts it is a seed, another predicts it is a flower, and the third predicts it is ash. According to relativity, all are correct due to the relativity of simultaneity, even though moments before $t = 0$, when all scientists were seated in the conference room, they all agreed that the object was a flower. Under relativity, objects do not adhere to the law of identity, indicating that relativity does not integrate with this fundamental law.

Even more absurd is what happens when, moments after $t = 0$, Scientist B turns around and joins Scientist C. According to relativity, this simple act transforms a past event for Scientist B into a future event—the object was just a flower in the past at $t = 0$, and now the object will be a flower at $t > 0$.

Equally absurd is the perspective of Scientist D, who is sitting with the flower on the spaceship far away. The inverse Lorentz Transformation, used by Scientist D, is derived by substituting the primed values for unprimed values and vice versa in Equation (2) and solving for primed values, as shown in Equation (6).

$$\begin{aligned}
t &= \gamma_K(t' - \frac{v}{c^2}x') \\
x &= \gamma_K(x' - vt') \\
y &= y' \\
z &= z' \\
&\therefore \\
t' &= \gamma_K(t + \frac{v}{c^2}x') \\
x' &= \gamma_K(x + vt') \\
y' &= y \\
z' &= z
\end{aligned} \tag{6}$$

We can use Equation (6) to determine t' for each scientist on Earth as predicted by Scientist D with the flower. Again, $\gamma_K \approx 1$ when $|v| \leq 1\ [m/s]$, and by letting $t = 0$, t' simplifies to:

$$\begin{aligned}
&t' = \gamma_K(t + \frac{v}{c^2}x) \\
&t' = \frac{v}{c^2}x \\
&\text{When}: x \approx -82.137 \times 10^6\ [ly] \\
&\qquad t' = -\frac{v}{c^2}(82.136 \times 10^6\ [ly]) = -v(100 \times 24 \times 60 \times 60\ [m^{-1} \cdot s^2) \approx -v(100\ [m^{-1} \cdot s \cdot days])
\end{aligned} \tag{7}$$

Moments before $t = 0$, when Scientists A, B, and C were all sitting in the conference room, Scientist D predicts that all three (A, B, and C) were sitting in the conference room simultaneously. At $t = 0$, everything changes drastically. For Scientist A, $v = 0\ [m/s]$ and $t' = 0\ [days]$, meaning Scientist D predicts that Scientist A is still seated in the conference room. For Scientist B, $v = 1\ [m/s]$ and $t' = -100\ [days]$, meaning Scientist D predicts that Scientist B has transported into the future by 100 days; thus, the negative result for t' corresponds to Scientist D being in Scientist B's past. For Scientist C, $v = -1\ [m/s]$ and $t' = 100\ [days]$, meaning Scientist D predicts that Scientist C has transported into the past by 100 days; thus, the positive result for t' corresponds to Scientist D being in Scientist C's future. Moments after $t = 0$, when Scientist B turns around to catch up with Scientist C, Scientist B travels from Scientist D's future to his past. Relativity predicts a confusing series of events out of chronological order, contradicting the fact that Scientists A, B, and C all agree they existed simultaneously together in that conference room at those moments.

Why do all these absurdities arise from relativity? They all stem from its assumed speed-of-light model, **SR2**. These absurdities ultimately reflect a conflict between the law of identity and **SR2**, i.e., between the most fundamental principle and the foundations of relativity. When faced with a contradiction between a verified axiom and an assumed generalization, the decision should be straightforward: uphold the axiom and reject the assumed generalization.

3.4. Integrating Relativistic Effects with Identity

If the preferred frame model, **US2**, were used for predictions instead, all the absurd predictions of relativity would be explained as using the wrong light model to make calculations. Using the preferred frame would involve the preferred frame velocity, v_p, or velocity with respect to the preferred frame, rather than the relative velocity between objects. The Lorentz Transformation for a preferred frame would then be:

$$
\begin{aligned}
t' &= \gamma_K (t - \frac{v_p}{c^2} x) \\
x' &= \gamma_K (x - v_p t) \\
y' &= y \\
z' &= z
\end{aligned}
\tag{8}
$$

Where :

$$\gamma_K = \frac{1}{\sqrt{1 - \frac{v_p^2}{c^2}}}$$

$x, y, z, t \in \mathbb{R}$ are spatial and time measurements from preferred frame.
$x', y', z', t' \in \mathbb{R}$ are spatial and time measurements from frame in motion relative to the preferred frame.
v_p the velocity relative to preferred frame.
c is the speed of light.

We can use Equation (8) to determine t' for the flower as predicted by the scientists on Earth. If the flower were stationary with respect to the preferred frame, then $v_p = 0$, and at $t = 0$, $t' = 0$ for all scientists. If the flower were moving with respect to the preferred frame, then $|v_p| > 0$ for all scientists, and the predicted t' would deviate from t, but it would be the same for all scientists on Earth, with its deviation from t explained as a miscalibration. The same applies from the perspective of the flower (Scientist D). t' might change because of a miscalibration, but t remains invariant.

No absurdities arise with the preferred frame because it integrates with the law of identity and, therefore, with causality (as identity applied to action)—even for unverifiable cases. On this basis, the cause of time dilation can be found. Let us proceed to investigate this cause.

4. Investigation 1: Conceptual Housekeeping

With the plausibility of relativity in question, we are free to begin anew from a different foundation—a foundation based on a preferred frame. However, we must be cautious to avoid the fallacy of concept stealing (9). This fallacy occurs when a concept, whose base has been invalidated or is otherwise incompatible with the new foundation, is used. Any concept derived from relativity must be reevaluated to ensure a valid conceptual framework, which is critical for any scientific investigations seeking to make causal discoveries, as shown by Peikoff's refinement of Mill's method (8).

The concepts that require reevaluation are: *time*, *measurement*, *time dilation*, and *spacetime*.

4.1. Time

Understanding the concept of time correctly is as crucial for scientific progress as understanding Earth's place in the solar system was in the past. As will be shown, our current conception of time, much like the belief that the Earth was the center of celestial motion or that it was flat, is holding us back from further discovery.

Today, time is often thought to be an illusion—something wrongly perceived by the senses. As Einstein put it:

> "The motion of clocks is also influenced by gravitational fields, and in such a way that a physical definition of time which is made directly with the aid of clocks has by no means the same degree of plausibility as in the special theory of relativity." (14)

It is said that Newtonian mechanics assumes time to be absolute, whereas relativity assumes that time is relative, as in the relativity of simultaneity (4; 14). Both of these perspectives rely on conceptions of time that cannot be reduced to verifiable observations.

When discussing time, it is important to ask what exactly is meant by "time." Seeking a more informative definition is critical. A quick online search defines time as "the indefinite continued progress of existence and events in the past, present, and future regarded as a whole." This definition is circular since "past," "present," and "future" are concepts that depend on a conception of time. Thus, the definition effectively states: time is the continued progress of existence and events in time. This is not helpful for gaining insight into what time is.

If Wikipedia represents a common understanding, then time is often viewed as "what a clock reads" (22), which reflects Einstein's implied definition in the earlier quote (14). But this, too, is circular. Clocks are tools that measure time, so defining time as what a clock measures translates to: time is what is measured when measuring time—another unhelpful definition.

The best, and my preferred, definition of time is: *time* is the interval over which change occurs (23). This definition provides a clearer and more actionable understanding of time. To validate this conception, one must ask: what facts about reality give rise to the need for this concept?[5]

The facts that give rise to this concept are twofold. First, changes to existents from one state to another are never instantaneous. Despite what quantum physicists might say (4), the law of non-contradiction dictates that both states (the before and after) cannot exist at the same instant in the same respect. Consequently, this transition from one state to another lasts for some duration (a series of instances).

Second, given the same essential conditions, the same changes will last for the same duration, as dictated by the law of causality. Changes in duration (the effect) imply changes in essential conditions (the cause). For example, the time it takes for your coffee to reach room temperature might vary depending on the temperature of the room, the initial temperature of your coffee, and the cup it is in. However, if all essential conditions remain unchanged, the coffee will take the same amount of time to cool as before.

These two facts—that change is not instantaneous and that its duration is repeatable under the same circumstances—give rise to the concept of time as a way to quantify causal relationships. Without this concept, certain causal relationships would remain unknowable and uncontrollable. For instance, this conception of time allows us to cook meals with the reasonable certainty that they will complete after a predictable duration. Additionally, it provides a framework for figuring out why an expected outcome does not occur—e.g., if a change in altitude caused your cooking times to be off. Similarly, this conception allows us to coordinate future events, like meeting people at a specific time and place.

The primary need for this conception of time is to gain better control over reality by improving our understanding of causality. Thus, defining time as "the interval over which change occurs" captures the essence of this concept.

Implicit in this conception of time is the notion that there is no existing past or future—only the eternal present is omnipresent. Things that exist, exist now, and only now. The past is simply the conceptualization that things in existence now had a previous configuration. The future is the conceptualization that things in existence now will have a new configuration. If the configuration of things stopped changing, then time would cease, as there would no longer be any change, and therefore, no interval of change.

This conception also implies the practical impossibility of time travel. Even if every existent were mechanically reversible[6], time travel would require omnipresence, omnipotence, and omniscience to apply the right mechanism

[5] If one's conception of time is not based on any facts, then the concept itself becomes arbitrary, meaning it is outside reality and, therefore, useless in helping us understand reality (9).

[6] What would one do with something as simple as a diode?

everywhere to reverse all things, even the mechanisms used to reverse everything—an impossible feat to achieve on purpose. Moreover, once the reversal process begins, how could one stop it?

4.2. Measurement

All measurements involve the relationship between the thing being measured and the unit serving as the standard of measurement. Like all measurements, time also needs a standard. The best standards for time, depending on the required precision, are changes that occur at regular intervals, meaning their essential conditions are easily maintained as invariant, leading to consistent measurements. Examples include the arc length traversed by a sundial's shadow, sand falling in an hourglass, pendulum swings in a clock, or light traveling a known distance. These standards can then be compared to other changes to measure their duration. For instance, if it takes two turns of an hourglass for coffee to cool, we say it took two hours. Tomorrow it might take three hours, and because of this standard, we can quantify the difference.

Understanding this next point is **critical** for fully grasping the essential difference between universal specificity and the theory of relativity. Different methods of measuring time can be placed in situations where essential conditions change, resulting in varying durations being measured. For example, a sundial at a different latitude or an hourglass at a different altitude will measure a different duration than in their original context. Similarly, a light clock that undergoes a change in specific energy measures a different duration than before (see Section 6). This does not mean that time itself sped up or slowed down—it only means that the base unit of measurement has changed. For instance, an hourglass at a different altitude measures something other than an hour—i.e., the standard unit of time for that measuring device has changed. The same goes for light clocks.

4.3. Time Dilation

Time dilation is commonly defined as the lengthening of the time interval between two events (24). However, with the refined conceptions of time and measurement in mind, we can improve this understanding. Time dilation is best conceptualized as the change in the interval over which change occurs *to things*.

To clarify this concept, let's modify the twin paradox slightly. The twin paradox showcases time dilation, in which one twin travels to a distant star and back, aging less than the twin who remains on Earth (14). Suppose for this modification the twins each plant identical seeds. Each twin follows an identical regimen of care (e.g., water, nutrients, light exposure, etc.). The expectation is that, given this regimen, the seed will grow into a flower after 100 days and turn to ash after another 100 days, as shown in Figure 4.

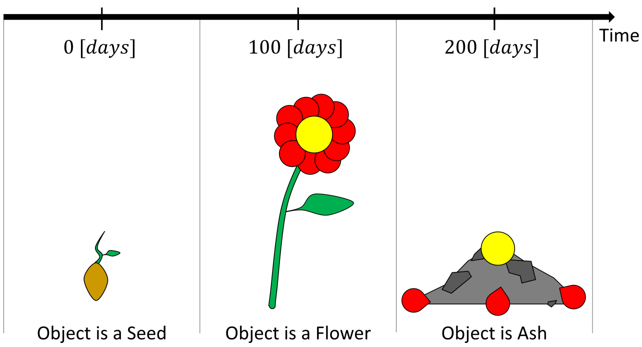


Figure 4: **Flower 200 day life cycle.**

After planting the seeds, the traveling twin departs for a round trip. Upon returning, they find that the Earth twin's flower has turned to ash, while the traveling twin's flower is still in bloom. The Earth twin recorded exactly 200 days, while the traveling twin recorded only 100 days with an identical clock. So, did 100 days pass, or 200?

Given our conception of time and measurement, the solution is simple. The interval over which change occurred remained the same for the Earth twin, via the MoA, and lengthened for the traveling twin, via the MoD. The traveling twin's entire system experienced a lengthened interval for the seed's growth, as evidenced at the end of the trip.

Any argument over which twin correctly measured the duration is missing the point. The measuring instrument of time for the traveling twin changed such that the standard unit of time being measured was no longer a day. The "day" being measured by the traveling twin's clock was something more than a day on average. Thus, the key takeaway is both twins measured different durations because the measuring standards themselves have changed, which aligns with the improved conceptualization of time dilation above.

4.4. Spacetime

This refined conception of time and time dilation challenges the common notion that time is a property of the Universe or is tied to space (as in spacetime), apart from the duration of any changes taking place (23). Identical clocks measuring different durations under different conditions do not suggest that time is a property of the Universe or tied to space; they only suggest that changes in conditions caused a change in the base units being measured. In other words, the difference in conditions caused the duration of state changes to speed up or slow down—not time itself. There is no "time itself." Time, being only a measure of change (to things), has no meaning apart from that. To generalize that time is everywhere, simply because things could exist and undergo change anywhere, suffers from the fallacy of hasty generalization.

Applying Mill's method to a simple thought experiment based on relativity rules out space as being tied to how duration is measured. In this thought experiment, suppose the origins of two inertial frames occupy the same point in space at the same time.

Since the velocity of these reference frames differs from each other, special relativity tells us that they measure different intervals over which the same physical changes occur. For example, one clock in one frame might measure two hours for a cup of coffee to cool to room temperature, while an identical clock in the other frame might measure three hours. This means that two different measures of time occur at the same instant in time and space, according to special relativity.

What limits us to consider only two overlapping reference frames? Why not all possible reference frames at the same instant in time and point in space? What limits us to considering just a single point in space? Why not consider all possible frames overlapping at the same instant in time and at all points in space? What limits us to a single instance of time? Why not consider all frames at every point in time and space?

Invoking Mill's MoD, we see that different effects—i.e., different time intervals measured by identical clocks—occur at the same instant in time and place. This proves that instances in time and points in space do not affect how time is measured. In other words, how time is measured is independent of where (and when) time is measured. The key takeaway is this: time is a property of things in the Universe—the interval over which change occurs to things—not a property of the Universe itself, nor an aspect of spacetime.

4.5. Blazing a New Trail

Assuming that time is a property of the Universe or an aspect of spacetime prevents us from addressing important questions, hindering scientific progress. Some of these questions include: What causes time dilation? What, then, causes gravity if not the bending of spacetime? Which frame is preferred? Addressing these questions, given this revised conceptual framework, is the focus of the remaining investigations into universal specificity contained in this paper.

5. Investigation 2: Why Does c Appear to be Isotropic Given a Preferred Frame?

All observations are beyond reproach, but interpretations of those observations are not—they may be riddled with conceptual errors. Universal specificity makes all the same verifiable predictions (potential observations) as relativity. However, specificity rejects the interpretations and causes of those predictions made by relativity. This is akin to accepting Ptolemy's planetary model for its accurate predictions of the relative motion of planets but not accepting the conclusion that planets actually orbit around nothing (i.e., epicycles) (25).

As an example of such disagreement, specificity adheres to the law of identity and asserts that distant events occur at specific instances in time and space. Specificity holds that the sequence of distant events only appears relative due to a model error in relativity—namely, the incorrect premise that light is constant in all directions for all inertial frames. In reality, light is only constant in the preferred frame. This implies that events at a distance occur in a definite sequence, and their simultaneity is not relative but only appears so when using miscalibrated instruments. The one frame that predicts the true sequence, by assuming that light is constant in all directions, is the preferred frame we seek.

This implies the following:

- The speed of light is constant only in the preferred frame, while light's relative speed may be more or less than that in other frames, depending on direction (26).

- The speed of light appears constant in any other frame due to the miscalibration of measuring instruments, caused by time dilation and length contraction.

This section investigates how this could be the case.

5.1. Rotating Preferred Frame

To see these implications, consider an object traveling at any speed less than c with respect to the preferred frame, in any arbitrary direction. The preferred frame's x-axis can easily be rotated such that the object's velocity aligns with it, as shown in Figure 5 for two dimensions.

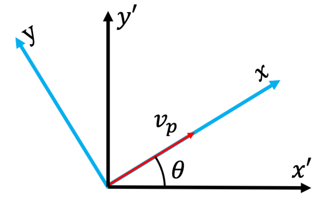


Figure 5: **Aligning velocity with preferred frame.**

The equation for this rotation is the traditional rotation of axes, and its 2D formulation is presented in matrix form in Equation (9).

$$\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} x' \\ y' \end{bmatrix} \tag{9}$$

Where :

$x', y' \in \mathbb{R}$ are preferred frame coordinates misaligned with velocity.

$x, y \in \mathbb{R}$ are preferred frame coordinates aligned with velocity.

5.2. The Null Result of the Michelson–Morley Experiment

Now consider the Michelson–Morley experiment (15), whose apparatus is illustrated in Figure 6. In this experiment, light arrives from one direction, splits into two orthogonal directions with respect to the apparatus's reference frame (ARF), reflects off mirrors, and recombines. Any interference in the combined rays, caused by differing arrival times, can be detected. The length of both paths is made identical, as measured in the ARF without calibration, producing identical lengths when the ARF is stationary with respect to the preferred frame.

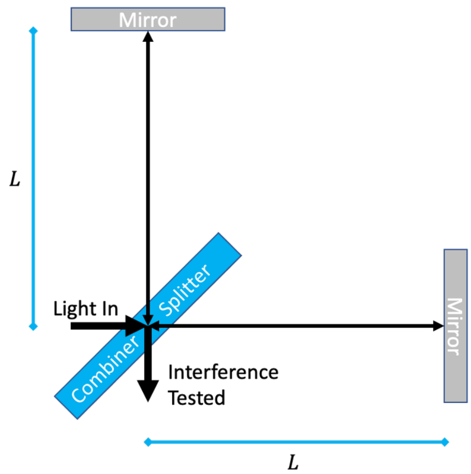


Figure 6: **Michelson–Morley experiment schematic.**

It was hypothesized that, if light traveled at a constant c only in the preferred frame, this instrument would detect interference patterns if the ARF had some velocity relative to the preferred frame. To ensure some velocity, the experiment was conducted at various points in Earth's orbit. However, it failed to detect interference patterns, leading many to conclude that the speed of light is constant in all directions for all reference frames, a belief that became orthodox. Since a preferred frame implies that light's speed is constant only in that frame, many took the null results as evidence that no preferred frame exists.

If a preferred frame does exist, we must reconcile this experiment with it. The first thing to consider is what the average (to the mirror and back) speed of light was expected to be.

5.3. Quantifying the Average speed of Light

Specificity quantifies the average speed of light in the ARF consistent with classical mechanics, i.e., Galilean relativity. Consider two cases: (1) the ARF is not moving with respect to the preferred frame, $v_p = 0$, as shown in Figure 7(a); and (2) the ARF is moving, $v_p > 0$, as shown in Figure 7(b). The dashed lines represent the path each light beam takes to the mirror and back.

In the trivial case where the ARF is the preferred frame, the speed of light is c in all directions, so the average speed is c.

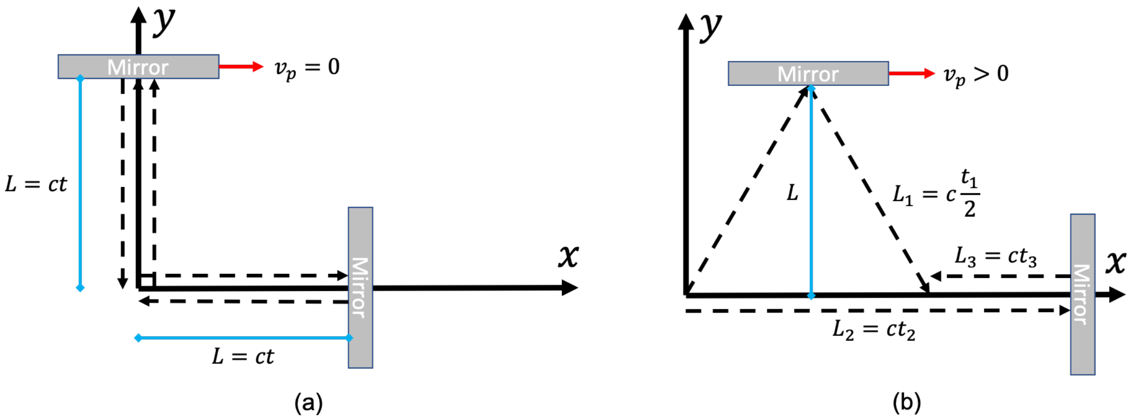


Figure 7: Apparatus is (a) Stationary (b) Moving with respect to the preferred frame

In the case where the ARF is moving, deriving the average speed of light is more complex. Observers in the preferred frame see light reflecting off the y-axis mirror following a "sawtooth" path, as shown in Figure 7(a); however, observers in the ARF see only the y-component of this path. To them, the light appears to travel straight up and down along the ARF's y-axis. The average speed of light along this axis, c_y, can be derived using trigonometric laws (Figure 8):

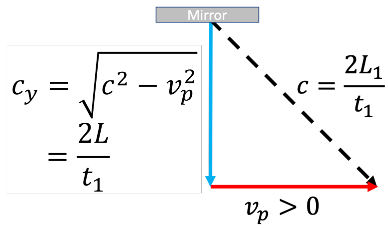


Figure 8: **Trigonometric derivation of c_y.**

$$c_y = \sqrt{c^2 - v_p^2} \tag{10}$$

Deriving the average speed of light along the x-axis in the ARF is more complex, as shown in Equation (11):

$$\begin{aligned}
&L_2 = ct_2 = L + v_p t_2 \implies t_2 = \frac{L}{c - v_p}\\
&L_3 = ct_3 = L - v_p t_3 \implies t_3 = \frac{L}{c + v_p}\\
&\therefore c_x = \overline{v} = \frac{2L}{t_2 + t_3} = \frac{2L}{\frac{L}{c-v_p} + \frac{L}{c+v_p}} = \frac{2(c+v_p)(c-v_p)}{(c+v_p)+(c-v_p)} = \frac{2(c^2 - v_p^2)}{2c} = c\left(1 - \frac{v_p^2}{c^2}\right)\\
&\text{Let : } \gamma_K = \frac{1}{\sqrt{1 - \frac{v_p^2}{c^2}}}\\
&\therefore c_x = \gamma_K^{-2} c \;\blacksquare
\end{aligned} \tag{11}$$

Comparing c_x to c_y yields:

$$\begin{aligned}
&c_x = \gamma_K^{-2} c\\
&c_y = \sqrt{c^2 - v_p^2} = c\sqrt{1 - \frac{v_p^2}{c^2}} = \gamma_K^{-1} c\\
&\therefore c_x = \gamma_K^{-1} c_y \;\blacksquare
\end{aligned} \tag{12}$$

In the ARF, the average speed of light along the x-axis is slower than along the y-axis by a factor of γ_K^{-1}. Thus, interference was expected in the Michelson–Morley experiment, but none was observed.

5.4. The Average Effective Speed of Light

Given the existence of a preferred frame, the only way to reconcile the Michelson–Morley experiment is for the light to arrive at the combiner simultaneously. Since $c_x = \gamma_K^{-1} c_y$, the distance along the x-axis must contract by a factor of γ_K^{-1}, as shown in Equation (13), for the light beams to arrive at the combiner at the same time.

$$\begin{aligned}
t_1 &= t_2 + t_3 \\
\frac{2L}{c_y} &= \frac{L_x}{c - v_p} + \frac{L_x}{c + v_p} \\
\frac{2L}{\gamma_K^{-1} c} &= \frac{L_x(c + v_p) + L_x(c - v_p)}{c^2 - v_p^2} \\
\frac{\gamma_K 2L}{c} &= \frac{2L_x c}{c^2 - v_p^2} = \frac{2L_x}{c}\frac{1}{1 - \frac{v_p^2}{c^2}} = \frac{\gamma_K^2 2L_x}{c} \\
\therefore L_x &= \gamma_K^{-1} L \ \blacksquare
\end{aligned} \tag{13}$$

This is the exact value given to length contraction, originally derived by Lorentz in his Lorentz Ether Theory (27; 28). Length contraction counteracts the average directional speed of light difference, making the average *effective* speed of light, c_0, isotropic for all frames in uniform motion. c_0 is quantified in Equation (14).

$$c_0 = \gamma_K^{-1} c \tag{14}$$

5.5. Apparent Average Speed of Light is c

We must reconcile the fact that $c_0 < c$ in any frame in uniform motion with respect to the preferred frame, yet measurements within those frames still show $c_0 = c$. This apparent inconsistency is due to the miscalibration of all time-measuring instruments. While it truly takes longer for light to travel "there and back," the duration for all changes also lengthens in the moving frame (ARF). This lengthened duration makes the measured time appear shorter by the same factor. The net effect is that the recorded duration appears the same, even though it is longer in reality. This miscalibration of time is known as time dilation, which affects not only clocks but also the intervals over which all changes occur to objects in the moving frame.

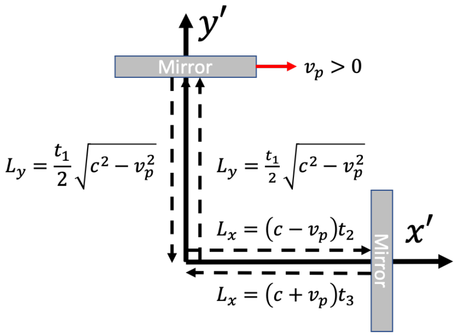


Figure 9: **Moving apparatus in ARF.**

The miscalibrated time and length measurements are described by the Lorentz Transformation (see Equation (8)). The time dilation differential, dt'/dt, a ratio of uncalibrated-to-calibrated infinitesimal time intervals, can be derived by evaluating an interval of time described by the Lorentz Transformation:

$$\begin{aligned}
\text{Let } &: dt' = t_2' - t_1' \\
\text{Let } &: dt = t_2 - t_1 \\
t_1' &= \gamma_K(t_1 - \frac{v_p}{c^2}x_1) \\
t_2' &= \gamma_K(t_2 - \frac{v_p}{c^2}x_2)
\end{aligned}$$

$$
\begin{aligned}
dt' &= \gamma_K(dt - \frac{v_p}{c^2}dx) \\
&= \gamma_K(dt - \frac{v_p}{c^2}v dt) \\
&= dt\gamma_K\gamma_K^{-2} \\
\therefore \frac{dt'}{dt} &= \gamma_K^{-1} \ \in \mathbb{R} \leq 1 \blacksquare
\end{aligned} \tag{15}
$$

Similarly, the length contraction differential, dx'/dx, a ratio of uncalibrated-to-calibrated infinitesimal length intervals, can be derived by evaluating an interval of length at an instant of time:

$$
\begin{aligned}
\text{Let } &: dx' = x_2' - x_1' \ @ \ t' \\
\text{Let } &: dx = x_2 - x_1 \ @ \ t \\
x_1' &= \gamma_K(x_1 - v_p t) \\
x_2' &= \gamma_K(x_2 - v_p t) \\
dx' &= \gamma_K(x_2 - v_p t) - \gamma_K(x_1 - v_p t) \\
dx' &= \gamma_K(dx) \\
\therefore \frac{dx'}{dx} &= \gamma_K \ \in \mathbb{R} \geq 1 \blacksquare
\end{aligned} \tag{16}
$$

To understand why miscalibrated instruments in the ARF measure the average speed of light as c, consider first what calibrated instruments measure in the ARF, as shown in Figure 9, and then convert these to miscalibrated measures.

For the y-axis in Figure 9, applying Equation (15) converts calibrated time, t_1, to miscalibrated time, t_1', while length remains calibrated $L_y = L_y'$ (according to Equation (8)):

$$
L_y = \frac{t_1}{2}\sqrt{c^2 - v_p^2} = L_y' = \frac{\gamma_K t_1'}{2}\sqrt{c^2 - v_p^2} \tag{17}
$$

From this, we can derive the apparent average speed of light along the y-axis, c_y', as shown in Equation (18):

$$
c_y' = \overline{v}_y' = \frac{2L_y'}{t_1'} = \frac{2}{t_1'}\frac{\gamma_K t_1'}{2}\sqrt{c^2 - v_p^2} = \gamma_K\sqrt{c^2 - v_p^2} = \gamma_K c\sqrt{1 - \frac{v_p^2}{c^2}} = \gamma_K c \gamma_K^{-1} = c \blacksquare \tag{18}
$$

Similarly, for the x-axis, we apply Equation (15) to convert calibrated times, t_2 and t_3, to miscalibrated times, t_2' and t_3', and apply Equation (16) to convert calibrated length, L_x, to miscalibrated length, L_x':

$$
\begin{aligned}
L_x &= t_2(c - v_p) = \gamma_K^{-1} L_x' = \gamma_K t_2'(c - v_p) \implies t_2' = \frac{L_x'}{\gamma_K^2(c - v_p)} \\
L_x &= t_3(c + v_p) = \gamma_K^{-1} L_x' = \gamma_K t_3'(c + v_p) \implies t_3' = \frac{L_x'}{\gamma_K^2(c + v_p)}
\end{aligned} \tag{19}
$$

From this, we can now derive the apparent average speed of light along the x-axis, c_x', as shown in Equation (20):

$$
c_x' = \overline{v}_x' = \frac{2L_x'}{t_2' + t_3'} = \frac{2L_x'}{\frac{L_x'}{\gamma_K^2(c-v_p)} + \frac{L_x'}{\gamma_K^2(c+v_p)}} = \frac{2(\gamma_K^2(c + v_p))(\gamma_K^2(c - v_p))}{\gamma_K^2(c + v_p) + \gamma_K^2(c - v_p)}
$$

$$= \frac{2\gamma_K^2(c^2 - v_p^2)}{2c} = \gamma_K^2 c \left(1 - \frac{v_p^2}{c^2}\right) = \gamma_K^2 c \gamma_K^{-2} = c \ \blacksquare \tag{20}$$

Thus, despite the actual directional differences in light speed, the combined effects of time dilation and length contraction cause the measured average speed of light to always appear as c in all directions in any inertial frame. This explains why no interference patterns were observed in the Michelson–Morley experiment, despite the actual variations in light speed along different axes relative to the preferred frame.

5.6. Conclusion

In conclusion, the existence of a preferred frame has significant implications: the actual average speed of light in a moving frame is not isotropic; it varies most along the x- and y-axes (parallel and perpendicular to the velocity, respectively). Length contraction allows light to travel a shorter distance along the x-axis, compensating for its slower speed in that direction. This results in identical round-trip travel times for light in the Michelson–Morley experiment, regardless of the apparatus's velocity relative to the preferred frame. Consequently, the average effective speed of light, c_0, appears the same in all directions for any inertial reference frame.

The fact that the average effective speed of light is slower than c means that the actual travel time for light over a given distance in a moving frame takes longer. However, this longer duration goes undetected due to time dilation, which causes the measured duration to appear shorter by the same factor. This miscalculation due to miscalibration makes the average speed of light always appear to be c, even though it is slower in reality. In the next investigation, we will use Mill's method to discover the cause of time dilation.

6. Investigation 3: What Causes Kinetic Time Dilation?

Prior investigations established that time, when properly conceptualized, is the interval over which change occurs to *things*, and is not a separate property of the Universe. This understanding led to the conceptualization of time dilation as a change in the interval over which objects change. Furthermore, it was found that a preferred frame must exist, leading to the discovery that the average effective speed of light, c_0, with respect to a uniformly moving object is isotropic and depends on the object's velocity with respect to the preferred frame, v_p, as shown in Equation (21).

$$c_0 = c\sqrt{1 - \frac{v_p^2}{c^2}} = \gamma_K^{-1} c \tag{21}$$

Since c_0 is less than c, light's travel duration takes longer. This longer duration is undetected due to time dilation, which makes the apparent average speed of light c in any direction for any inertial frame.

The form of kinetic time dilation most suitable for studying its cause is expressed as the ratio of uncalibrated-to-calibrated infinitesimal intervals over which identical changes occur:

$$\frac{dt'}{dt} = \sqrt{1 - \frac{v_p^2}{c^2}} \tag{22}$$

Here, dt' is the uncalibrated infinitesimal time interval for a change, and dt is the calibrated interval for that change, where v_p is the velocity of the thing that is changing with respect to the preferred frame and c is the speed of light with respect to the preferred frame. This formulation allows us to focus on *why* this differential (the ratio of infinitesimals) becomes less than one.[7]

Orthodox interpretations hold that Equation (22) applies to any inertial frame, not just the preferred frame (see Subsection 3.3). In this context, v_p can be replaced by v, the relative velocity between any two frames in uniform motion, making time dilation applicable to any frame moving relative to another. This form will be referred to as orthodox Equation (22).

[7] It takes the least amount of time for change to occur in the preferred frame, as this differential is always less than or equal to one.

6.1. List of Plausible Causes

I have identified three plausible causes proposed by others and one stance that abdicates the need for a cause. The abdication involves relying on the Lorentz Transform to predict time dilation measurements, which it does precisely. However, I aim to discover *why* we observe these effects.

In addition to the three posited causes, I have added two of my own—work done and specific work done. The compiled list of plausible causes is:

- **Frame-Wise Relative Velocity**: $dt'/dt < 1$ is observed only when two frames exhibit relative velocity.
- **Velocity with Respect to Preferred Frame**: v_p appears to be the only controllable parameter in Equation (22).
- **Acceleration**: Acceleration is often thought to resolve the twin paradox.
- **Work Done**: Velocity and acceleration result from work done on an object.
- **Specific Work Done**: The same reasoning as work done but requires work to scale by the inertia of an object.

6.2. Ruling out Velocity

Frame-wise relative velocity refers to the velocity between any two frames in relative motion, not just between the preferred frame and another. It might seem reasonable to consider velocity as the cause of time dilation due to its presence in orthodox Equation (22), but this is not necessarily the case.

For example, consider modifying the twin paradox such that both twins travel with the same speed profile but in opposite directions in the preferred frame. Upon their reunion, despite their relative velocity, no difference is observed in the interval over which changes occur in their respective frames, dt'_1/dt'_2, as shown in Figure 10.

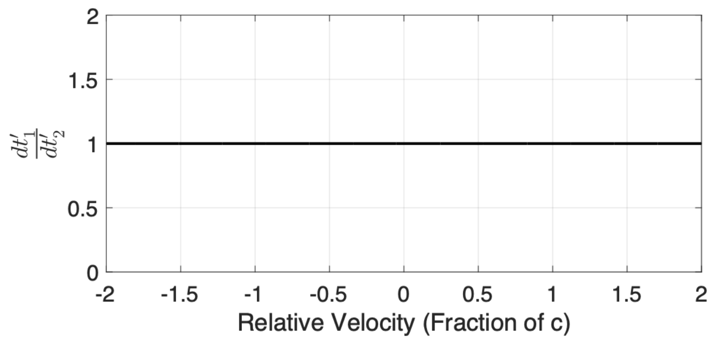


Figure 10: **Time dilation differential versus velocity.**

Using the MoA, where the effect remains invariant despite changes in the plausible causal factor, demonstrates that changes in v do not cause changes in the time dilation differential between two reference frames.

In addition, this thought experiment disproves v_p as the cause since the effect remained the same when v_p changed (e.g., $-v_p$ and v_p produce the same value despite $-vp \neq v_p$). Thus, using MoA proves inductively that v_p does not cause $dt'/dt$to change.

While v_p is the only parameter in the time dilation differential equation that can be manipulated, it is a squared term, equivalent to a vector dot product with itself ($v^2 = \vec{v} \cdot \vec{v}$). This implies that only the magnitude of v_p matters, not its direction, since v_p and $-v_p$ produce the same results.

Thus, although changes in speed with respect to the preferred frame, $|v_p|$, may cause changes in time dilation, a more fundamental cause exists. A change in an object's $|v_p|$ results from specific work done on the object. In other words, an object's speed cannot change with respect to the preferred frame without specific work being done on it, w_K, as shown below:

$$w_K = \int f(s)ds = \int a(s)ds = \int \frac{dv_p}{dt}ds = \int \frac{ds}{dt}dv_p = \int v_p dv_p = \frac{1}{2}v_p^2 \tag{23}$$

$$\therefore |v_p| = \sqrt{2w_K} \tag{24}$$

To make the relationship between a cause and a more fundamental cause clearer, consider the following analogy: Career advice to increase net income can either suggest (a) gaining more money or (b) becoming more productive. Gaining more money does not provide actionable steps, while becoming more productive does. Similarly, specific work done is the more fundamental cause of time dilation, as it involves an actionable process that changes an object's speed with respect to the preferred frame.

6.3. Ruling out acceleration

In the twin paradox, one twin accelerates while the other does not, and the accelerated twin's clock slows down compared to the stationary twin's clock on Earth. Acceleration, therefore, seems to be the factor that causes time dilation. Einstein even attempted to resolve the twin paradox by attributing the kinetic time dilation differential to gravity during acceleration. However, this plausible factor has been disproved in many sources (29; 30; 31; 32).

To add further evidence, consider a twin paradox-type experiment where acceleration is removed from measurements entirely. This could involve two spacecraft traveling in opposite directions. The first ship passes Earth, synchronizing its clock with an Earth clock. Then, as the outbound and return ships coast past each other, the outbound ship's clock sets the return ship's clock. As the return ship passes Earth, its clock is compared to the Earth clock, showing that time dilation has occurred without any acceleration.

Using MoA, where the time dilation effect occurs regardless of acceleration, demonstrates that acceleration does not cause changes in the time dilation differential.

6.4. Ruling out Work and Inducing Specific Work

Work and specific work is similar to the acceleration argument. The key difference is that time dilation remains constant until work (or specific work) is done, implying that time dilation has "inertia," where the differential remains constant until acted upon by an external force. This concept is termed *Inertial Time Differential* (ITD).

Let's test the remaining two factors through two thought experiments that reveal specific work as the precise cause. Proof:

1. Consider the effects of work done on two objects initially at rest in the preferred frame: a planet and a marble. The planet barely accelerates compared to the marble, which reaches a much higher velocity with the same work done. Using the Lorentz Transformation, the marble experiences more time dilation than the planet, proving that work done is not the precise cause since different effects occur with the same amount of work.
2. Now, consider the effects of specific work done. The same two objects receive the same specific work. Using the Lorentz Transformation reveals the same change in their ITD. By invoking MoA, where the same effect occurs with the same specific work done, we can inductively prove that specific work done causes the change in ITD $\blacksquare$.

It has been proven that changes in specific work done cause changes in the ITD. Relevant properties of specific work are detailed in Appendix A.

As a final reflection on the use of controlled experiments to induce the cause of time dilation, we can note that considering the specific work done on objects in the thought experiments used earlier explains the observed experimental results. In other words, the net specific work done on the objects in those experiments is consistent with the time dilation effects observed.

6.5. Deriving The Causal Math Model

To derive a precise mathematical model that captures the relationship between kinetic time dilation and specific work done, we can relate Equation (22) to specific work via Equation (23), as shown in Equation (25).

$$\frac{dt'}{dt} = \sqrt{1 - \frac{v_p^2}{c^2}} = \sqrt{1 - \frac{2\frac{1}{2}v_p^2}{c^2}} = \sqrt{1 - \frac{2\int a(s)ds}{c^2}} = \sqrt{1 - \frac{2w_K}{c^2}} \blacksquare \tag{25}$$

This equation demonstrates that kinetic time dilation is fundamentally linked to the specific work done on an object. As specific work increases, the ratio dt'/dt decreases, indicating a greater time dilation effect.

6.6. Conclusion

In summary, the investigation into the fundamental cause of kinetic time dilation reveals that it is specific work done on an object that causes the time dilation effect. The derived mathematical model, given by Equation (25), encapsulates this relationship by linking time dilation to the specific work done. This discovery not only deepens our understanding of time dilation but also opens new avenues for exploring how specific energy, which is transferred via specific work, relates to relativistic effects.

This understanding sets the stage for subsequent investigations, where we will explore the broader implications of this relationship for other relativistic phenomena, including gravity.

7. Investigation 4: How Does Specific Energy Relate to Time Dilation?

Prior investigations established that time, when properly conceptualized, is the interval over which change occurs to *things*, and is not a separate property of the Universe. This understanding led to the conceptualization of time dilation as a change in the interval over which objects change. Furthermore, it was determined that a preferred frame of reference must exist, leading to the discovery that the average effective speed of light, c_0, with respect to a uniformly moving object is isotropic and depends on the object's velocity with respect to the preferred frame, v_p, as shown in Equation (26). Consequently, it was found that the cause of kinetic time dilation is specific work done on the object with respect to the preferred frame, as indicated in Equation (27).

$$c_0 = c\sqrt{1 - \frac{v_p^2}{c^2}} = \gamma_K^{-1} c \tag{26}$$

$$\frac{dt'}{dt} = \sqrt{1 - \frac{v_p^2}{c^2}} = \sqrt{1 - \frac{2\frac{1}{2}v_p^2}{c^2}} = \sqrt{1 - \frac{2\int a(s)ds}{c^2}} = \sqrt{1 - \frac{2w_K}{c^2}} \tag{27}$$

Definition of terms:

- dt' is the uncalibrated measured interval over which an object changes.
- dt is the calibrated measured interval over which an object changes.
- The ratio of time derivatives, dt'/dt, termed the *inertial time differential* (ITD), remains constant for any object until the net specific work done on an object changes. Specific work done is conservative (see Appendix A).
- c_0 is the average effective speed of light with respect to an object (see Subsection 5.4).
- c is the speed of light in a vacuum with respect to the preferred frame, unaffected by gravitational potentials.
- w_K is the net specific kinetic work done on an object with respect to the preferred frame.

Relating specific energy to time dilation introduces an intriguing new relationship, leading to a new specific energy model, which is the focus of this investigation.

7.1. Relating Specific Kinetic Energy to Time Dilation

Energy is the ability to do work, so it is proper to think of energy as stored work. Conversely, work done on an object changes its energy. The relationship between specific kinetic energy and specific work is given by Equation (28).

$$\Delta e_K = w_K \tag{28}$$

Therefore, specific kinetic energy relates to time dilation in the following way:

$$\frac{dt'}{dt} = \sqrt{1 - \frac{2w_K}{c^2}} = \sqrt{1 - \frac{2\Delta e_K}{c^2}} \tag{29}$$

This equation connects time dilation to specific energy, leading to an intriguing inquiry: if studying relativistic effects on energy led to a new energy model, then can we do the same for a specific energy model? We can explore this by looking at how the total energy model was first derived.

7.2. Total Energy Model Derivation

Relativistic kinetic energy was first introduced in a thought experiment devised by Einstein, which derived a relationship between an object's mass and internal energy. In this thought experiment, Einstein considered an object at rest emitting energy in the form of radiation in two opposite directions in equal amounts. He then considered the same object with the same emission but viewed from a different inertial reference frame moving with respect to the object along an arbitrary axis. Figure 11 illustrates this thought experiment (33).

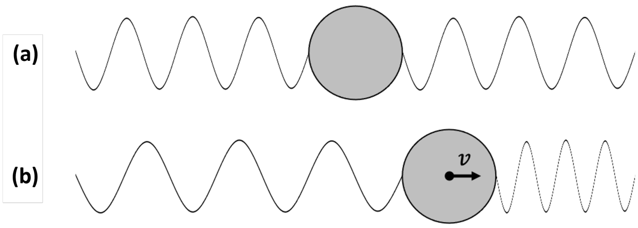


Figure 11: **(a) Object at rest. (b) Object in motion.**

Einstein compared the total energies measured by the two reference frames. Let E represent the total energy of the object as measured from its own inertial reference frame, and H represent the total energy of the object as measured from the reference frame in relative motion. Einstein noted, "It is clear that the difference $H - E$ can differ from the kinetic energy [ΔE_K] of the body, with respect to the other [reference frame with relative motion], only by an additive constant C..." The resulting model is: $H - E = \Delta E_K + C$ (33).

Feynman derives the total energy relation to kinetic energy from the relativistic mass model that conserves momentum (34), as shown in Equation (30).

$$\begin{aligned} m &= \gamma_K m_0 = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}} = m_0\left(1-\frac{v^2}{c^2}\right)^{-1/2} = m_0\left(1+\frac{1}{2}\frac{v^2}{c^2}+\frac{3}{8}\frac{v^4}{c^4}+\dots\right) \\ m &\approx m_0 + \frac{1}{2}m_0\frac{v^2}{c^2} \\ mc^2 &\approx m_0c^2 + \frac{1}{2}m_0v^2 \; \blacksquare \end{aligned} \tag{30}$$

According to this energy model, the total energy, mc^2, of an object is its internal energy[8], m_0c^2, plus a change in its kinetic energy, $(\gamma_K - 1)m_0c^2$. This aligns with $H - E = \Delta E_K + C$, discussed earlier as follows:

$$H = mc^2 \tag{31a}$$

$$E = m_0c^2 \tag{31b}$$

$$\Delta E_K = H - E = mc^2 - m_0c^2 = (\gamma_K - 1)m_0c^2 \tag{31c}$$

$$\therefore C = 0 \text{ in this case} \tag{31d}$$

This energy model depends on the relativistic mass model representing an object's inertia. To see this dependency, one can derive the kinetic energy model in Equation (31c) from first principles, as shown in Equation (32).[9]

$$\begin{aligned} m &= \gamma_K m_0 = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}} \\ \Delta E_K &= W_K = \int F(s)ds = \int \frac{dp}{dt}ds = \int \frac{ds}{dt}dp = \int v d(mv) = \int v d(\gamma_K m_0 v) = m_0 \int v d(\gamma_K v) \\ &= (\gamma_K - 1)m_0c^2 \; \blacksquare \end{aligned} \tag{32}$$

This analysis used to derive the total energy model can be used to inform the analysis required to derive a specific energy model, as shown in the next subsection.

[8] Traditionally called rest energy, but in the context of a preferred frame, internal energy is more appropriate.

[9] The full derivation is detailed here (35).

7.3. Deriving A New Specific Energy Model

Energy can be viewed as the result of integrating both a motion component and an inertia component. A specific kinetic energy model, which abstracts away inertia, cannot simply be derived from Equation (32) by factoring out m_0. To isolate and abstract away inertia, we remove inertia before integration. Thus, a specific kinetic energy model can be derived from first principles by integrating a specific force applied over some distance, as shown in Equation (33).

$$\Delta e_K = w_K = \int f(s)ds = \int \frac{d\left(\frac{p}{m}\right)}{dt}ds = \int \frac{d\left(\frac{mv}{m}\right)}{dt}ds = \int \frac{dv}{dt}ds = \int \frac{ds}{dt}dv = \int v dv = \frac{1}{2}v^2 \blacksquare \quad (33)$$

Thus, the relativistic specific kinetic energy model matches the Newtonian specific kinetic energy model. Since the preferred frame model makes the same verifiable predictions as relativity (14), this is also specificity's specific kinetic energy model when v is replaced with v_p.

Additionally, this implies that simply factoring out m_0 from internal energy, in Equation (31b), is also not sufficient to derive a specific internal energy model. What is required to derive a specific internal energy model is to learn from Feynman's approach to deriving the total energy model. A slight modification to Feynman's method used to derive the total energy equation can be used to derive the total specific energy equation, which includes the specific internal energy component, as shown in Equation (34).

$$\begin{aligned}
m = \gamma_K m_0 &= \frac{m_0}{\sqrt{1-\frac{v_p^2}{c^2}}} \\
m^2\left(1-\frac{v_p^2}{c^2}\right) &= m_0^2 \\
m^2 &= m_0^2 + m^2\frac{v_p^2}{c^2} \\
c^2 &= \frac{m_0^2}{m^2}c^2 + v_p^2 \\
\frac{1}{2}c^2 &= \gamma_K^{-2}\frac{1}{2}c^2 + \frac{1}{2}v_p^2 \\
e_{T|K} &= e_I + \Delta e_K \blacksquare
\end{aligned} \quad (34)$$

According to this model, an object's total specific energy[10], $c^2/2$, is its specific internal energy, $\gamma_K^{-2}c^2/2$, plus a change in its specific kinetic energy, $v_p^2/2$. Why $e_I = \gamma_K^{-2}c^2/2$ will be covered in a moment, but this model is analogous to Einstein's total energy model[11], where an object's total energy is its internal energy plus a change in its kinetic energy. Unlike Einstein's model, however, the specific internal energy of an object diminishes as it gains specific kinetic energy, while its total specific energy remains conserved.

This conservation implies that when an object is at rest with respect to the preferred frame, its total specific energy is fully attributed to its specific internal energy—there is no motion with respect to the preferred frame and all durations of change happen the fastest. Conversely, as an object's velocity with respect to the preferred frame increases, its specific internal energy decreases correspondingly, and specific kinetic energy increases. At the limit where an object's velocity approaches c, its specific internal energy approaches zero, and its total specific energy is wholly kinetic—there is no motion within the object because the duration of any change to the object becomes infinite.

This result holds even for older concepts of mass, such as longitudinal mass, where $m = \gamma^3 m_0$, as shown in the following derivation:

$$m = \gamma_K^3 m_0$$

[10] Ignoring gravitational potential energy, which will be taken into consideration in Section 9.
[11] Which also ignored gravitational potential energy.

$$
\begin{aligned}
m\gamma_K^{-2} &= m\left(1 - \frac{v_p^2}{c^2}\right) = m - m\frac{v_p^2}{c^2} = \gamma_K m_0 \\
m &= \gamma_K m_0 + m\frac{v_p^2}{c^2} \\
c^2 &= \gamma_K \frac{m_0}{m} c^2 + v_p^2 = \gamma_K \gamma_K^{-3} c^2 + v_p^2 \\
\frac{1}{2}c^2 &= \gamma_K^{-2} \frac{1}{2} c^2 + \frac{1}{2} v_p^2 \\
e_{T|K} &= e_I + \Delta e_K \ \blacksquare
\end{aligned} \tag{35}
$$

Integrating this discovery back into Equation (27), we find that the $2/c^2$ term is indeed the inverse of the total specific energy, $e_{T|K}^{-1}$, as shown in Equation (36).

$$
\frac{dt'}{dt} = \sqrt{1 - \frac{2\Delta e_K}{c^2}} = \sqrt{1 - \frac{\Delta e_K}{e_{T|K}}} = \sqrt{1 - \frac{\int a(s)ds}{e_{T|K}}} = \sqrt{1 - \frac{w}{e_{T|K}}} \ \blacksquare \tag{36}
$$

This implies that time dilation is a function of the ratio between the change in an object's specific kinetic energy and its total specific energy. Additionally, another connection arises between time dilation and the ratio of an object's specific internal energy to its total specific energy, as shown in Equation (37).

$$
\frac{dt'}{dt} = \sqrt{1 - \frac{\Delta e_K}{e_{T|K}}} = \sqrt{1 - \frac{e_{T|K} - e_I}{e_{T|K}}} = \sqrt{\frac{e_I}{e_{T|K}}} \ \blacksquare \tag{37}
$$

While this relationship does not represent that changes in e_I directly cause time dilation, it highlights the connection between an increase in the time interval over which change occurs and the reduction in specific internal energy. It is more accurate to say that a reduction in an object's specific internal energy manifests as increased time dilation—both are aspects of the same phenomenon.

The reason why $e_I = \gamma^{-2} e_{T|K}$, as suggested by Equation (34), is now addressed. The relationship between e_I and $e_{T|K}$ can be further explored by considering that e_I may depend on c_0. Indeed, if we revisit the relationship between c_0 and c, shown in Equation (26), while examining the e_I term in Equation (34), we see that c_0 has been present all along, as shown in Equation (38).

$$
\begin{aligned}
e_{T|K} = \frac{1}{2}c^2 = \gamma_K^{-2}\frac{1}{2}c^2 + \frac{1}{2}v_p^2 &= \frac{1}{2}c_0^2 + \frac{1}{2}v_p^2 \\
&= e_I + \Delta e_K
\end{aligned} \tag{38}
$$

Since e_I depends on c_0, this introduces a new perspective on the relationship between e_I and $e_{T|K}$. Just as $e_{T|K}$ is determined by c, e_I is determined by c_0. In this sense, e_I can be viewed as the total specific rest energy. When an object's velocity with respect to the preferred frame becomes zero, $c_0 = c$, and therefore, $e_I = e_{T|K}$. In this sense $e_{T|K}$ can be rightfully considered the maximum specific internal energy value, $e_{\max\{I\}}$, an object can achieve.

Thus, the relationship between time dilation and e_I in Equation (37), combined with the relationship between e_I and c_0 in Equation (38), leads to a connection between time dilation and c_0:

$$
\frac{dt'}{dt} = \sqrt{\frac{e_I}{e_{T|K}}} = \sqrt{\frac{\frac{1}{2}c_0^2}{\frac{1}{2}c^2}} = \frac{c_0}{c} \ \blacksquare \tag{39}
$$

It has been said that the maximum speed linking two events causally (where event A affects event B) is the speed of light, i.e., the speed of causality (36). In this context, Equation (39) suggests that the change in the interval over which an object changes is directly tied to a change in c_0, as c_0 represents the speed of causality for that object. This effectively makes c_0 a fundamental parameter in the causal dynamics of the Universe—the metronome of the Universe.

7.4. Conclusion

In conclusion, the complete causal chain for kinetic time dilation is this: a change in net specific work done to an object with respect to the preferred frame, which is the prime cause, causes a change in an object's speed with respect to the preferred frame; which causes a change in c_0 with respect to the object; which causes a change in the object's speed of causality; which finally causes a change in the interval over which the object changes, which also manifests as a change in the object's specific internal energy. Specific work done can still properly be said to cause kinetic time dilation, but only because of all the intermediary (and simultaneous) steps in between this primary cause and the final effect.

This refined understanding of the causal chain—specific work leading to changes in speed, affecting c_0, and subsequently influencing time dilation—offers a comprehensive perspective on how kinetic time dilation arises. It highlights how the fundamental principles of specific energy and motion interplay to produce observable relativistic phenomena.

Furthermore, this new understanding provides the foundation to address a crucial question: What causes gravity if not the bending of spacetime? The next investigation will demonstrate how time dilation gradients around massed objects, caused by a spatially variable c_0, imply a specific gravitational force between objects, $\vec{g}(r)$, caused by a specific internal energy gradient, $\nabla e_I > 0$.

8. Investigation 5: Do Time Dilation Gradients Imply Specific Energy Gradients?

In previous investigations, we established that time, when correctly conceptualized, represents the interval over which change occurs to *things* rather than a separate property of the Universe. This understanding led to the conclusion that time dilation is a change in the interval over which objects change. Furthermore, the existence of a preferred frame was established, allowing us to discover the cause of kinetic time dilation (Equation (40)), and derive a specific energy model (Equation (41)).

$$\frac{dt'}{dt} = \frac{c_0}{c} = \sqrt{\frac{e_I}{e_{T|K}}} = \sqrt{1 - \frac{w_K}{e_{T|K}}} = \sqrt{1 - \frac{\Delta e_K}{e_{T|K}}} = \gamma_K^{-1} \tag{40}$$

$$\begin{aligned} e_{T|K} = \frac{1}{2}c^2 &= e_I + \Delta e_K \\ &= \frac{1}{2}c_0^2 + \frac{1}{2}v_p^2 \end{aligned} \tag{41}$$

Definition of terms:

- dt' is the uncalibrated measured interval over which an object changes.
- dt is the calibrated measured interval over which an object changes.
- The ratio of time derivatives, dt'/dt, termed the *inertial time differential* (ITD), remains constant for any object until the net specific work done on an object changes. Specific work done is conservative (see Appendix A).
- c_0 is the average effective speed of light with respect to an object (see Subsection 5.4).
- c is the speed of light in a vacuum with respect to the preferred frame, unaffected by gravitational potentials.
- Δe_K is an object's change in specific kinetic energy with respect to the preferred frame.
- w_K is the net specific kinetic work done on an object with respect to the preferred frame, resulting in Δe_K.
- $e_{T|K}$ is an object's total specific energy, $c^2/2$, ignoring gravitational effects.
- e_I is an object's specific internal energy, $c_0^2/2$.

We have seen that time dilation relates to an object's specific internal energy, Equation (40). With this foundation, we can now investigate the implications of time dilation gradients (TDGs) and how they connect to gravitational effects through specific internal energy gradients.

8.1. Gravitational Time Dilation

According to the Schwarzschild Metric (1), given in Equation (42), which can be used to describe time dilation within a gravitational field for a spherical body at rest in the preferred frame, the ITD measured within this field (for zero coordinate velocity) is given Equation (43).

$$c^2 dt'^2 = ds^2 = g_{\mu\nu} dX^\mu dX^\nu \tag{42}$$

Where :

$$g_{\mu\nu} = \begin{bmatrix} c^2\left(1-\frac{r_s}{r}\right) & 0 & 0 & 0 \\ 0 & -\left(1-\frac{r_s}{r}\right)^{-1} & 0 & 0 \\ 0 & 0 & -r^2 & 0 \\ 0 & 0 & 0 & -r^2\sin^2(\theta) \end{bmatrix}$$

$$dX^\mu = [dt, dr, d\theta, d\phi]$$

$$r_s = \frac{GM}{e_{T|K}}$$

$$\frac{dt'}{dt} = \sqrt{1 - \frac{GM/r}{e_{T|K}}} \tag{43}$$

Here, $-GM/r$ represents the Newtonian gravitational potential. The relationship between ITDs and specific work done extends beyond kinetic time dilation. Specifically, GM/r represents the specific work done by the gravitational field, w_P, on an object as it travels from infinity to a distance r from the center of mass, expressed as $\int_\infty^r g(r)dr$. The change is specific potential energy relates to work done by the gravitational field the following way as potential energy is lost as the gravitational field does work:

$$w_P = -\Delta e_P \tag{44}$$

Rewriting the Newtonian potential in Equation (43) in terms of this specific gravitational work, and change in specific potential energy:

$$\frac{dt'}{dt} = \sqrt{1 - \frac{\int_\infty^r g(r)dr}{e_{T|K}}} = \sqrt{1 - \frac{w_P}{e_{T|K}}} = \sqrt{1 + \frac{\Delta e_P}{e_{T|K}}} = \gamma_P^{-1} \tag{45}$$

This formulation bears a striking resemblance to the form of kinetic time dilation, implying a similar underlying relationship between gravitational time dilation and specific work. Since kinetic time dilation is influenced by changes in the effective speed of light, c_0, the same logic may apply to gravitational time dilation.

As noted by prior work, according to the Schwarzschild metric, the radial coordinate speed of light, c_r, is $\gamma_P^{-2}c$, while the transverse speed, c_t, is $\gamma_P^{-1}c$ (1). This is analogous to the kinetic case (see Section 5), where the calibrated two-way average speed of light with respect to a moving object along its velocity dimension, c'_x, is $\gamma_K^{-2}c$, and the two-way average speed perpendicular to that dimension, c'_y, is $\gamma_K^{-1}c$. In both cases, the dimensional difference in the speed of light is offset by length contraction, meaning the average effective speed of light, c_0, becomes $\gamma_P^{-1}c$ in all directions for the gravitational case, just as it does in the kinetic case (1).

This fact suggests that refraction could play a role in gravitational effects. Prior work showed that "the equations of motion for [refracted] light are formally identical to those predicted by general relativity" (37). Moreover, the correspondence between TDGs and a gradient in c_0 leads to an important connection to specific energy gradients.

8.2. Implications of Time Dilation Gradients

Observations of gravitational ITDs confirm that a time dilation gradient (TDG), $\nabla\left(dt'/dt\right)$, exists around massed objects. This gradient is defined as:

$$\nabla\frac{dt'}{dt} \triangleq \frac{d\left(\frac{dt'}{dt}\right)}{dr}\hat{r} = \frac{d\left(\sqrt{1-\frac{\int_{\infty}^{r} g(r)dr}{e_{T|K}}}\right)}{dr}\hat{r} = -\frac{\gamma_P}{2e_{T|K}}\vec{g}(r) \tag{46}$$

We immediately see a relationship between TDG and the specific force of gravity, $g(r)$, but, this correlation is not causal. However, TDGs do imply a specific internal energy gradient, ∇e_I, within objects that exist within TDGs, which does causally relate to the specific force applied to that object due to the conservative nature of specific work (38). This is derived as follows:

$$\begin{aligned}
&\text{given}: \frac{dt'}{dt} = \sqrt{\frac{e_I}{e_{T|K}}} = \sqrt{1-\frac{\int_{\infty}^{r}\vec{g}(r)dr}{e_{T|K}}}\\
&\quad\therefore \vec{f}(r) = -\nabla e_I = -e_{T|K}\nabla\frac{e_I}{e_{T|K}} = -e_{T|K}\nabla\frac{dt'^2}{dt^2} = -e_{T|K}\frac{d\left(\frac{dt'}{dt}\right)^2}{dr}\hat{r} = -e_{T|K}2\frac{dt'}{dt}\frac{d\left(\frac{dt'}{dt}\right)}{dr}\hat{r}\\
&\qquad = -\frac{2e_{T|K}}{\gamma_P}\nabla\frac{dt'}{dt}
\end{aligned} \tag{47}$$

Substituting Equation (46) in for $\nabla\frac{dt'}{dt}$ yeilds:

$$\vec{f}(r) = -\nabla e_I = -\frac{\cancel{2e_{T|K}}}{\cancel{\gamma_P}}\left(-\frac{\cancel{\gamma_P}}{\cancel{2e_{T|K}}}\vec{g}(r)\right)\hat{r} = \vec{g}(r)\ \blacksquare \tag{48}$$

This result holds for any stationary object within a generic gravitational field, not just those described by the Schwarzschild metric. In this model, gravitational effects are measured as specific forces acting on objects due to their specific internal energy gradient, ∇e_I.

8.3. Relating Gravitational Specific Force to Relativity

Consider a test particle in Schwarzschild coordinates (t, r, θ, ϕ) near a gravitational object of mass M. Suppose the particle's worldline is described by $Y^\mu = (t, r, 0, 0)$ and is at the apex of its free-fall trajectory. We aim to show that Equation (48) represents the particle's coordinate radial acceleration in proper time, as given in Equation (49):

$$\frac{d^2r}{dt'^2}\hat{r} = \vec{f}(r) = -\nabla e_I = -\frac{GM}{r^2}\hat{r} \tag{49}$$

The next subsections will provide the detailed mathematical proof.

8.3.1. Proper Acceleration

Begin by deriving the particle's proper acceleration relative to a point, P, collocated but stationary relative to the massive object. The worldline of point P is described by $X^\mu = (t, r_0, 0, 0)$. First, calculate the four-velocity V^μ of point P in Schwarzschild coordinates:

$$\begin{aligned}
&\text{Recall}: r_s = \frac{GM}{e_{T|K}}\\
&\text{Given}: cdt' = ds = \sqrt{1-\frac{r_s}{r}}cdt
\end{aligned}$$

$$
\begin{aligned}
V^{\mu} &= \frac{dX^{\mu}}{dt'} = c\frac{dX^{\mu}}{ds} = c\frac{dX^{\mu}}{dt}\frac{dt}{ds} = c\left(\frac{dt}{dt}, \frac{dr_0}{dt}, \frac{d0}{dt}, \frac{d0}{dt}\right)\left(1-\frac{r_s}{r}\right)^{-\frac{1}{2}} c^{-1} \\
&= \left(\left(1-\frac{r_s}{r}\right)^{-\frac{1}{2}}, 0, 0, 0\right)
\end{aligned} \tag{50}
$$

Next, calculate the proper acceleration A^{μ}:

$$
A^{\mu} = \frac{DV^{\mu}}{dt'} = \frac{dV^{\mu}}{dt'} + \Gamma^{\mu}_{\nu\lambda}V^{\nu}V^{\lambda} \tag{51a}
$$

$$
\frac{dV^{\mu}}{dt'} = c\frac{dV^{\mu}}{ds} = c\frac{dV^{\mu}}{dt}\frac{ds}{dt} = c\left(\frac{dr}{dt}\frac{d\left(1-\frac{r_s}{r}\right)^{-\frac{1}{2}}}{dr}, \frac{d0}{dt}, \frac{d0}{dt}, \frac{d0}{dt}\right)\left(1-\frac{r_s}{r}\right)^{-\frac{1}{2}} c^{-1} = (0,0,0,0) \tag{51b}
$$

$$
\begin{aligned}
\Gamma^{\mu}_{\nu\lambda} &= \frac{1}{2}g^{\mu\sigma}\left(\frac{\partial g_{\lambda\sigma}}{\partial X^{\nu}} + \frac{\partial g_{\sigma\nu}}{\partial X^{\lambda}} - \frac{\partial g_{\nu\lambda}}{\partial X^{\sigma}}\right) \\
&= \begin{bmatrix}
(\Gamma^{t}_{tt},\Gamma^{t}_{tr},\Gamma^{t}_{t\theta},\Gamma^{t}_{t\phi}) & (\Gamma^{t}_{rt},\Gamma^{t}_{rr},\Gamma^{t}_{r\theta},\Gamma^{t}_{r\phi}) & (\Gamma^{t}_{\theta t},\Gamma^{t}_{\theta r},\Gamma^{t}_{\theta\theta},\Gamma^{t}_{\theta\phi}) & (\Gamma^{t}_{\phi t},\Gamma^{t}_{\phi r},\Gamma^{t}_{\phi\theta},\Gamma^{t}_{\phi\phi}) \\
(\Gamma^{r}_{tt},\Gamma^{r}_{tr},\Gamma^{r}_{t\theta},\Gamma^{r}_{t\phi}) & (\Gamma^{r}_{rt},\Gamma^{r}_{rr},\Gamma^{r}_{r\theta},\Gamma^{r}_{r\phi}) & (\Gamma^{r}_{\theta t},\Gamma^{r}_{\theta r},\Gamma^{r}_{\theta\theta},\Gamma^{r}_{\theta\phi}) & (\Gamma^{r}_{\phi t},\Gamma^{r}_{\phi r},\Gamma^{r}_{\phi\theta},\Gamma^{r}_{\phi\phi}) \\
(\Gamma^{\theta}_{tt},\Gamma^{\theta}_{tr},\Gamma^{\theta}_{t\theta},\Gamma^{\theta}_{t\phi}) & (\Gamma^{\theta}_{rt},\Gamma^{\theta}_{rr},\Gamma^{\theta}_{r\theta},\Gamma^{\theta}_{r\phi}) & (\Gamma^{\theta}_{\theta t},\Gamma^{\theta}_{\theta r},\Gamma^{\theta}_{\theta\theta},\Gamma^{\theta}_{\theta\phi}) & (\Gamma^{\theta}_{\phi t},\Gamma^{\theta}_{\phi r},\Gamma^{\theta}_{\phi\theta},\Gamma^{\theta}_{\phi\phi}) \\
(\Gamma^{\phi}_{tt},\Gamma^{\phi}_{tr},\Gamma^{\phi}_{t\theta},\Gamma^{\phi}_{t\phi}) & (\Gamma^{\phi}_{rt},\Gamma^{\phi}_{rr},\Gamma^{\phi}_{r\theta},\Gamma^{\phi}_{r\phi}) & (\Gamma^{\phi}_{\theta t},\Gamma^{\phi}_{\theta r},\Gamma^{\phi}_{\theta\theta},\Gamma^{\phi}_{\theta\phi}) & (\Gamma^{\phi}_{\phi t},\Gamma^{\phi}_{\phi r},\Gamma^{\phi}_{\phi\theta},\Gamma^{\phi}_{\phi\phi})
\end{bmatrix} \\
&= \begin{bmatrix}
(0, \frac{r_s}{2r^2-2rr_s}, 0, 0) & (\frac{r_s}{2r^2-2rr_s}, 0, 0, 0) & (0,0,0,0) & (0,0,0,0) \\
(\frac{c^2(r-r_s)r_s}{2r^3}, 0, 0, 0) & (0, -\frac{r_s}{2r^2-2rr_s}, 0, 0) & (0, 0, r_s - r, 0) & (0, 0, 0, (r_s - r)\sin^2(\theta)) \\
(0,0,0,0) & (0, 0, \frac{1}{r}, 0) & (0, \frac{1}{r}, 0, 0) & (0, 0, 0, -\cos(\theta)\sin(\theta) \\
(0,0,0,0) & (0, 0, 0, \frac{1}{r}) & (0, 0, 0, \cot(\theta) & (0, \frac{1}{r}, \cot(\theta), 0)
\end{bmatrix}
\end{aligned} \tag{51c}
$$

$$
\Gamma^{\mu}_{\nu\lambda}V^{\nu}V^{\lambda} = \Gamma^{r}_{tt}V^{t}V^{t} = \left(\frac{c^2(r-r_s)r_s}{2r^3}\right)\left(1-\frac{r_s}{r}\right)^{-1} = \frac{GM}{r^2} \tag{51d}
$$

$$
\therefore A^{\mu} = \left(0, \frac{GM}{r^2}, 0, 0\right) \tag{51e}
$$

The magnitude of this proper acceleration is thus:

$$
-||A^{\mu}||^2 = -A_{\mu}A^{\mu} = -g_{\mu\nu}A^{\nu}A^{\mu} = -g_{rr}A^{r}A^{r} = \left(1-\frac{r_s}{r}\right)^{-1}\left(\frac{GM}{r^2}\right)^2 \tag{52}
$$

Hence, the proper acceleration of the test particle relative to a point P is:

$$
\frac{d^2r'}{dt'^2}\hat{r} = -\frac{GM}{r^2}\gamma_P\hat{r} \tag{53}
$$

8.3.2. Coordinate Acceleration

Next, derive the coordinate acceleration in Schwarzschild coordinates. The first step is to calculate the four velocity of the test particle, U^{μ}, in Schwarzschild coordinates.

$$
\text{Given}: cdt' = ds = \sqrt{\left(1-\frac{r_s}{r}\right)c^2dt^2 + \left(1-\frac{r_s}{r}\right)^{-1}dr^2}
$$

$$
U^{\mu} = \frac{dY^{\mu}}{dt'} = c\frac{dY^{\mu}}{ds} = c\frac{dY^{\mu}}{dt}\frac{dt}{ds} = c\left(\frac{dt}{dt}, \frac{dr}{dt}, \frac{d0}{dt}, \frac{d0}{dt}\right)\left(\left(1-\frac{r_s}{r}\right)c^2 + \left(1-\frac{r_s}{r}\right)^{-1}\frac{dr^2}{dt^2}\right)^{-\frac{1}{2}}
$$

$$= \left(\frac{c}{\sqrt{-\frac{c^2 r_s}{r} + c^2 + \frac{r}{r_s - r}\frac{dr^2}{dt^2}}}, \frac{c\frac{dr}{dt}}{\sqrt{-\frac{c^2 r_s}{r} + c^2 + \frac{r}{r_s - r}\frac{dr^2}{dt^2}}}, 0, 0 \right) \tag{54}$$

The next step is to derive the four acceleration, A^μ, of the test particle using the same process as before:

$$A^\mu = \frac{DU^\mu}{dt'} = \frac{dU^\mu}{dt'} + \Gamma^\mu_{\nu\lambda} U^\nu U^\lambda = \left(c^2 \dot{r} k, c^4 (r_s - r)^2 k, 0, 0\right) \tag{55}$$

Where :

$$k = \frac{c^2 r_s (r_s - r)^2 + 2r^3 (r - r_s)\ddot{r} - 3r^2 r_s \dot{r}^2}{2\left(c^2 (r_s - r)^2 - r^2 \dot{r}^2\right)^2}$$

The particle's coordinate acceleration, $\ddot{r}$, is found by setting $A^\mu = (0, 0, 0, 0)$, which provides the geodesic equation describing the test particle in free-fall along the radial direction, and solving for $\ddot{r}$:

$$\ddot{r} = \frac{c^2 r_s (r_s - r)^2 - 3r^2 r_s \dot{r}^2}{2r^3 (r_s - r)} = -\frac{GM}{r^2}\left(1 - \frac{r_s}{r}\right) + 3\frac{GM}{r^2}\left(1 - \frac{r_s}{r}\right)^{-1}\frac{\dot{r}^2}{c^2} \tag{56}$$

Recalling that the particle is momentarily stationary, where $\dot{r} = 0$, and factoring in direction yields the particles coordinate acceleration:

$$\frac{d^2 r}{dt^2}\hat{r} = \ddot{r}\hat{r} = -\frac{GM}{r^2}\left(1 - \frac{r_s}{r}\right)\hat{r} = -\frac{GM}{r^2}\gamma_P^{-2}\hat{r} \tag{57}$$

8.3.3. Relating Know Terms Using the Chain Rule

Now that we have derived the coordinate acceleration of the test particle (Equation (57)) and its proper acceleration relative to the stationary point P(Equation (53)), we can verify Equation (49) using the chain rule. The chain rule for first and second derivatives is given by: j

$$\frac{dy}{dz} = \frac{dy}{dx}\frac{dx}{dz} \tag{58}$$

$$\frac{d^2 y}{dz^2} = \frac{d\left(\frac{dy}{dx}\frac{dx}{dz}\right)}{dz} = \frac{d\left(\frac{dy}{dx}\right)}{dz}\frac{dx}{dz} + \frac{dy}{dx}\frac{d\left(\frac{dx}{dz}\right)}{dz} = \frac{dx}{dz}\frac{d\left(\frac{dy}{dx}\right)}{dx}\frac{dx}{dz} + \frac{dy}{dx}\frac{d^2 x}{dz^2} = \frac{d^2 y}{dx^2}\left(\frac{dx}{dz}\right)^2 + \frac{dy}{dx}\frac{d^2 x}{dz^2} \tag{59}$$

Using Equation (59) and setting $z = t'$, $y = r$, and $x = r'$, the particle's coordinate acceleration in proper time (Equation (49)) can be related to its proper acceleration (Equation (53)) as follows:

$$\frac{d^2 r}{dt'^2}\hat{r} = \frac{d^2 r}{dr'^2}\left(\frac{dr'}{dt'}\right)^2 + \frac{dr}{dr'}\frac{d^2 r'}{dt'^2}\hat{r} = \frac{d^2 r}{dr'^2}(0)^2 + \cancel{\gamma_P^{-1}}\left(-\frac{GM}{r^2}\cancel{\gamma_P}\hat{r}\right) = -\frac{GM}{r^2}\hat{r} \blacksquare \tag{60}$$

Similarly, setting $z = t'$, $y = r$, and $x = t$, we can relate the particle's coordinate acceleration in proper time (Equation (49)) to its coordinate acceleration (Equation (57)):

$$\frac{d^2 r}{dt'^2}\hat{r} = \frac{d^2 r}{dt^2}\left(\frac{dt}{dt'}\right)^2 + \frac{dr}{dt}\frac{d^2 t}{dt'^2} = \left(-\frac{GM}{r^2}\cancel{\gamma_P^{-2}}\hat{r}\right)\cancel{\gamma_P^2} + (0)\frac{d^2 t}{dt'^2} = -\frac{GM}{r^2}\hat{r} \blacksquare \tag{61}$$

It naturally follows that the coordinate acceleration can be similarly related to the proper acceleration relative to point P using this method.

8.3.4. A More General Treatment

The previous derivations hold for a test particle momentarily at rest relative to the gravitational mass. A more general approach, accounting for all components of the Schwarzschild metric, involves:

$$c^2dt'^2 = ds^2 = \left(1 - \frac{r_s}{r}\right)c^2dt^2 - \left(1 - \frac{r_s}{r}\right)^{-1}dr^2 - r^2d\theta^2 - r^2\sin^2(\theta)d\phi^2 \tag{62}$$

$$\frac{dt'^2}{dt^2} = \left(1 - \frac{r_s}{r}\right) - \left(1 - \frac{r_s}{r}\right)^{-1}\frac{\dot{r}^2}{c^2} - \frac{r^2\dot{\theta}^2}{c^2} - \frac{r^2\sin^2(\theta)\dot{\phi}^2}{c^2} \tag{63}$$

$$\therefore \vec{f} = -\nabla e_I = -e_{T|K}\nabla\frac{dt'^2}{dt^2} \blacksquare \tag{64}$$

While using the Schwarzschild metric directly relies on specific assumptions, Equation (64) remains generally valid according to specificity, independent of how the squared ITD is described.

8.4. Challenging the Equivalence Principle

Figure 12 illustrates the causal relationship captured by Equation (48) for massed bodies where the TDG is defined by the Schwarzschild metric for a stationary object. Distance is expressed in units of the Schwarzschild Radius, r_s, and $\nabla\left(e_I/e_{T|K}\right)$ is in units of $1/r_s$. This makes evident that a non-zero gradient in specific internal energy plays a critical role in gravitational dynamics.

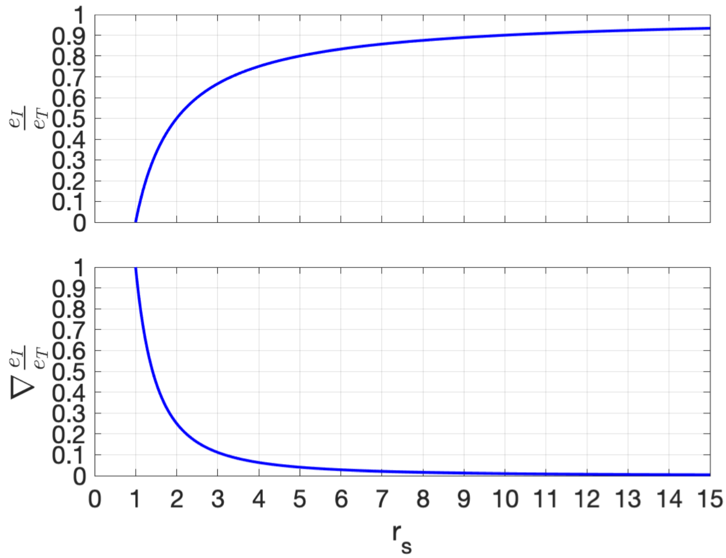


Figure 12: $e_I/e_{T|K}$ and its gradient versus r_s.

Because TDGs imply ∇e_I, the equivalence principle is falsifiable under this paradigm. Free-falling toward Earth is not equivalent to floating in empty space, nor is sitting on Earth equivalent to accelerating in empty space. The key distinction is that ∇e_I exists in a gravitational field but not in empty space. Traditional reasoning about vanishing tidal forces (39) does not apply to ∇e_I, as Figure 12 demonstrates that $\nabla(e_I/e_{T|K})$ remains non-zero at infinitesimal scales, highlighting the persistence of a specific internal energy gradient, invalidating the equivalence principle.

Indeed, in this framework, the principle is reversed for c_0: free-falling toward Earth resembles accelerating in empty space (i.e., e_I decreases), while sitting on Earth resembles floating in empty space (i.e., e_I remains constant). Specific work done to objects drives changes in c_0 in the kinetic case, while gradients in c_0 cause specific wor k done on objects in the gravitational case, making the two reciprocal phenomena.

In summary, TDGs arise from gradients in c_0, which correspond to ∇e_I, producing the gravitational effects we observe.

8.5. Historical Context

The idea of a spatially variable speed of light (spatially-VSL) has been explored by several theorists (40; 41; 42; 43). Einstein himself considered this possibility in multiple works leading up to general relativity (44; 45; 46; 47; 48; 49; 50), and even after the development of general relativity (51; 52). The formalization of spatially-VSL in a manner consistent with general relativity's predictive power was first accomplished by Dicke, who took into account the length contraction implied by the Schwarzschild metric (41). Dicke's work demonstrated how the speed of light varies around massed objects and offered insights into phenomena such as the time delay of light signals, later confirmed by Shapiro (53; 54).

While the spatially-VSL model successfully explains the motion of light in gravitational fields through refraction, it previously lacked a causal mechanism to explain the motion of massed objects. Dicke correlated spatially-VSL with gravitational potential, which accurately described gravitational motion as predicted by general relativity, but did not provide a causal explanation for this correlation.

The present investigation fills this gap by identifying the gradient in specific internal energy, ∇e_I, as the underlying cause of observed gravitational effects. This new insight bridges the spatially-VSL model and the gravitational phenomena it sought to explain, providing a more complete understanding of the relationship between gravity and light. Additionally, this investigation offers a novel perspective on gravity and opens new research avenues into the interplay between light, gravity, time dilation, specific energy, and the permeability and permittivity of free space, along with Newton's Laws.

8.6. New Avenues of Research

8.6.1. Spatially Variable Permittivity and Permeability of Free Space

The discovery that a gradient in specific internal energy (∇e_I) causes the specific force of gravity represents a significant advancement in understanding gravitational phenomena. This approach shifts the concept of gravity from Newton's action at a distance to a localized effect resulting from an object's internal energy gradient, which is itself induced by a spatially variable c_0.

Although this provides a more localized view of gravity, it raises further questions about the underlying causes of changes in the permittivity and/or permeability of free space around objects. To address this, future investigations might explore the role of neutrinos and their potential impact on time dilation (55). Or perhaps future experiments can be conducted to determine whether there is an aether flow into massed objects that affects c_0 (56).

8.6.2. Electromagneticgravitism

Interestingly, gravity, once considered a force independent of light, is now seen as involving light, which governs the electromagnetic force. Electromagnetism (EM) operates orthogonally to light's velocity (perpendicular to the direction of light propagation), while gravity appears to act parallel to light's velocity. Thus, each of the three spatial dimensions seems to have a distinct force related to light: electrical, magnetic, and gravitational.

This suggests a potential unification of gravity and electromagnetism into a single theoretical framework, termed *electromagneticgravitism* (EMG). Unlike *gravitoelectromagnetism* (GEM), which draws analogies between gravity and EM (57), EMG would aim to integrate these forces into a coherent model.

One interesting aspect of GEM is that the only known solution that resolves its scaling issues and historical asymmetries uses complex numbers to enforce gravitational and electromagnetic orthogonality, successfully integrating both fields into a single set of equations (58). The detailed derivation of this solution is provided in Appendix B.

Einstein pursued a unified field theory that coupled gravity with electromagnetism (59; 60; 61; 62; 63; 64), but he lacked the conceptual tools and causal connections between gravity and EM that we now possess. Investigating whether EMG is a true force coupling presents an intriguing future research direction.

If future studies confirm EMG as a true coupling, it might prompt a reconsideration of the fundamental forces. A grand unified theory could emerge, in which light is the only force carrier, and the strong and weak nuclear forces could be interpreted as aspects of EMG. In this model, EMG would be the only force in existence, with the strong and weak nuclear forces representing forms of magneticgravitism (MG) and electrogravitism (EG), respectively. MG would involve gravity and magnetism, with the electric component neutralized, and EG would involve gravity and electricity, with the magnetic component neutralized, just like EM is a form of EMG with the gravitational component neutralized.

8.6.3. Newtonian Kinematics Predicts Schwarzschild Coordinate Acceleration

If light is the sole force carrier in the universe, intriguing questions arise, such as: "What if everything were made of light?" Suppose light formed unique structures corresponding to the most fundamental particles, looping onto themselves as light circuits—the simplest example depicted in Figure 13. This figure illustrates two photons emitted simultaneously from a single point at time t_0, traveling in opposite directions, reflecting, and reuniting at time t_2, restarting the circuit from the new meetup location.

An intriguing implication of this concept is that gravitational motion could be explained by Newtonian kinematics applied to these light circuits. Figure 13(a) depicts the scenario when the system has no velocity relative to the preferred frame and is not under gravity's influence—each photon travels equal distances at identical speeds, reuniting exactly at their midpoint. Figure 13(b) depicts the scenario when the system has no initial velocity relative to the preferred frame but *is* under gravity's influence—the "blue" photon travels a shorter distance and at a slower speed compared to the "red" photon, preventing them from reuniting at their original location. By the time the "red" photon reaches the starting point, at t_1, the "blue" photon is $2\Delta h$ distance away.

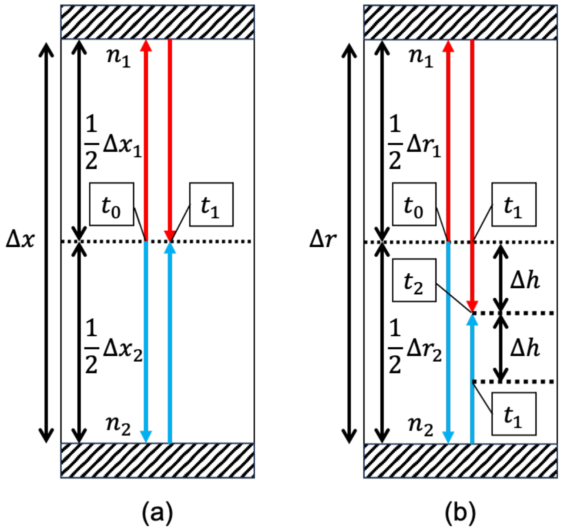


Figure 13: **(a)** $n_1 = n_2$, **(b)** $n_1 > n_2$.

Given a properly calibrated measurements, we can demonstrate that Newtonian kinematics predict the Schwarzschild coordinate acceleration (Equation (57)). Proper calibration and notation definitions are provided below:

$$n_i c = c_i \tag{65}$$

$$n_i = \gamma_P(r_i)^{-2} = \alpha_i^{-2} \tag{66}$$

$$c_i \alpha_i^2 = c \tag{67}$$

$$\Delta r_i \alpha_i = \Delta r' \tag{68}$$

$$\Delta t_i = t_i - t_0 \tag{69}$$

Where :

n_i is the index of refraction for the i$^{\text{th}}$ region

c_i is the calibrated speed of light for the i$^{\text{th}}$ region

$\gamma_P(r_i)$ is the gravitational lorentz factor for the i$^{\text{th}}$ region

Δr_i is the calibrated measurement of $\Delta r'$ if measured in the i$^{\text{th}}$ region

The first region is above the "midway" point, and the second region is below. The Newtonian kinematic equation for an accelerating system is:

$$s_f = s_0 + v_0 t + \frac{1}{2} a t^2 \tag{70}$$

Setting $s_f = s_0 - \Delta h$, $v_0 = 0$, and $t = \Delta t_2$, we solve for the acceleration of the light circuit system, a:

$$a = -2\frac{\Delta h}{\Delta t_2^2} \tag{71}$$

First, we express Δh in terms of $\Delta r'$ and α_i:

$$t_1 = \frac{2\frac{1}{2}\Delta r_1}{c_1} = \frac{\Delta r' \alpha_1^{-1}}{c\alpha_1^{-2}} = \frac{\Delta r'}{c}\alpha_1 \tag{72}$$

$$2\frac{1}{2}\Delta r_2 = \Delta r' \alpha_2^{-1} = 2\Delta h + t_1 c_2 = 2\Delta h + \left(\frac{\Delta r'}{\cancel{c}}\alpha_1\right)(\cancel{c}\alpha_2^{-}2) \tag{73}$$

$$\therefore \Delta h = \frac{1}{2}\left(\Delta r' \alpha_2^{-1} - \Delta r' \alpha_1 \alpha_2^{-2}\right) = \frac{1}{2}\Delta r' \frac{(\alpha_2 - \alpha_1)}{\alpha_2^2} \blacksquare \tag{74}$$

Next, we solve for Δt_2 in terms of $\Delta r'$, c, and α_i:

$$\Delta t_2 = \Delta t_1 + \frac{\Delta h}{c_2} = \frac{\Delta r'}{c}\alpha_1 + \frac{\frac{1}{2}\Delta r' \frac{(\alpha_2 - \alpha_1)}{\cancel{\alpha_2^2}}}{c\cancel{\alpha_2^{-}2}} = \frac{1}{2}\frac{\Delta r'}{c}\left(2\alpha_1 + \alpha_2 - \alpha_1\right) = \frac{1}{2}\frac{\Delta r'}{c}\left(\alpha_1 + \alpha_2\right) \blacksquare \tag{75}$$

Substituting these into Equation (71), we obtain:

$$a = -2\frac{\frac{1}{2}\Delta r' \frac{(\alpha_2 - \alpha_1)}{\alpha_2^2}}{\left(\frac{1}{2}\frac{\Delta r'}{c}\left(\alpha_1 + \alpha_2\right)\right)^2} = -\frac{4c^2}{\Delta r'}\frac{\alpha_1 \cancel{\alpha_2}\left(\frac{1}{\alpha_1} - \frac{1}{\alpha_2}\right)}{\alpha_2 \cancel{^2}(\alpha_1 + \alpha_2)^2} \tag{76}$$

Taking the limit $\Delta r' \to 0$, we have:

$$\Delta r' \to dr' = \gamma_P dr \tag{77}$$

$$\alpha_1 + \alpha_2 \to 2\gamma_P \tag{78}$$

$$\frac{\alpha_1}{\alpha_2} \to 1 \tag{79}$$

$$\frac{1}{\alpha_1} - \frac{1}{\alpha_2} \to d\left(\frac{dt'}{dt}\right) \tag{80}$$

$$\therefore a \to -\cancel{4}c^2 \frac{d\left(\frac{dt'}{dt}\right)}{\gamma_P dr}(\cancel{2}\gamma_P)^{-2} = \left[-\frac{2e_{T|K}}{\gamma_P}\nabla\frac{dt'}{dt}\right]\gamma_P^{-2} \tag{81}$$

From Equations (47) and (48), the term in brackets is recognized as $\vec{g}(r)$, confirming that the acceleration of the light circuit matches the Schwarzschild coordinate acceleration:

$$a = \vec{g}\gamma_P^{-2} = -\frac{GM}{r^2}\gamma_P^{-2}\hat{r} \blacksquare \tag{82}$$

This suggests that light circuit kinematics could represent a promising direction for future research.

8.6.4. *The Law of Action and Reaction and Inertia Explained by* ∇e_I

The discovery that ∇e_I causes a specific force explains why Newton's third law of motion holds in kinetic scenarios. Newton's third law states that for every action, there is an equal and opposite reaction. In the case of kinematic acceleration—such as a rocket accelerating uniformly in space—the similarity principle allows us to evaluate how much specific work an equivalent uniform gravitational field would do on an object falling from infinity to a point s (described by Equation (83)).

$$\frac{dt'}{dt} = \sqrt{1 - \frac{\int_\infty^s -\vec{a}ds}{e_{T|K}}} \tag{83}$$

This gives us a pseudo time dilation differential equation[12] to evaluate the specific reaction force $\vec{f}(s)$, as shown in Equation (84).

$$\begin{aligned}\vec{f}(s) = -\nabla e_I = -e_{T|K}\nabla\frac{e_I}{e_{T|K}} = -e_{T|K}\nabla\frac{dt'^2}{dt^2} = -e_{T|K}\frac{d\left(1-\frac{\int_\infty^s -\vec{a}ds}{e_{T|K}}\right)}{ds}\hat{s} = \frac{d(-e_{T|K})}{ds}\hat{s} + \frac{d\left(\int_\infty^s -\vec{a}ds\right)}{ds}\hat{s}\\ = -\vec{a}\ \blacksquare\end{aligned} \tag{84}$$

The parts of an accelerating object that are farther in the direction of the acceleration vector experience less time dilation than parts in the opposite direction, leading to an equal and opposite reaction force. This mechanism also explains inertia—an object's resistance to changes in motion. When an object accelerates, its internal energy distribution changes, causing it to push back against the applied force. Once the external force is removed, the object returns to equilibrium, where $\nabla e_I = 0$, and the object maintains uniform motion.

Future investigations could further explore how classical laws like Newton's action-reaction principle and inertia might be revisited through this causal framework that link light properties to specific force and energy.

8.7. Conclusion

This investigation into time dilation gradients (TDGs) reveals that gravitational time dilation follows the same principles as kinetic time dilation, both linked to specific work done within the preferred frame and reductions in c_0. The existence of TDGs shows that gravitational fields create specific internal energy gradients within objects, which, in turn, produce the specific forces experienced as gravity.

This new understanding shifts the conceptualization of gravity from a field-based force to one rooted in local variations of specific internal energy. The relationship between c_0 and gravity uncovered here opens the door to further theoretical development. For example, it suggests the possibility of a unified field theory that integrates gravity and electromagnetism into a coherent framework. Ultimately, this investigation highlights that both kinetic and gravitational time dilation share a common cause (i.e., $c_0 < c$) and result in the same effect: a reduced speed of causality, which lengthens the interval over which objects change. These two types of time dilation may be aspects of a broader, more general time dilation phenomenon. The next investigation will aim to integrate these two aspects into a comprehensive inertial time differential (ITD) model.

9. Investigation 6: What Causes Total Time Dilation?

Prior investigations established that time, when properly conceptualized, is the interval over which change occurs to *things*, and is not a separate property of the Universe. This understanding led to the conceptualization of time dilation as a change in the interval over which objects change. It was also established that a preferred frame must exist, leading to the discovery of the cause of kinetic time dilation (Equation (85)), and the development of a specific energy model (Equation (86)). This, in turn, revealed that gravity arises from a specific internal energy gradient (Equation (88)), and helped explain gravitational time dilation (Equation (87)).

$$\frac{dt'}{dt} = \frac{c_0}{c} = \sqrt{1-\frac{w_K}{e_{T|K}}} = \sqrt{1-\frac{\Delta e_K}{e_{T|K}}} = \gamma_K^{-1} \tag{85}$$

$$\begin{aligned}e_{T|K} = \frac{1}{2}c^2 = e_I + \Delta e_K\\ = \frac{1}{2}c_0^2 + \frac{1}{2}v_p^2\end{aligned} \tag{86}$$

$$\frac{dt'}{dt} = \frac{c_0}{c} = \sqrt{1-\frac{w_P}{e_{T|K}}} = \sqrt{1+\frac{\Delta e_P}{e_{T|K}}} = \gamma_P^{-1}$$

[12] Equation (83) is called "pseudo" because the work done by a uniform gravitational field on an object starting at infinity is infinite, leading to an unreal, imaginary time dilation value. This further highlights the limitations of the equivalence principle in these cases.

$$= \sqrt{1 - \frac{\int_{\infty}^{r} \vec{g}(r)dr}{e_{T|K}}} = \sqrt{1 - \frac{\int_{\infty}^{r} -\nabla e_I dr}{e_{T|K}}} \tag{87}$$

$$\vec{g}(r) = -\nabla e_I = -\frac{d(e_I)}{dr}\hat{r} \tag{88}$$

Definition of terms:

- dt' is the uncalibrated measured interval over which an object changes.
- dt is the calibrated measured interval over which an object changes.
- The ratio of time derivatives, dt'/dt, termed the *inertial time differential* (ITD), remains constant for any object until the net specific work, w_K or w_P, done on an object changes. Specific work done is conservative (see Appendix A).
- c_0 is the average effective speed of light with respect to an object (see Subsection 5.4).
- c is the speed of light in a vacuum with respect to the preferred frame, unaffected by gravitational potentials.
- Δe_K is an object's change in specific kinetic energy with respect to the preferred frame.
- w_K is the net specific kinetic work done on an object with respect to the preferred frame, resulting in Δe_K.
- Δe_P is the change in specific potential energy of the object.
- w_P is the net specific work done by gravity on the object, resulting in Δe_P.
- $e_{T|K}$ is an object's total specific energy, $c^2/2$, ignoring gravitational effects.
- e_I is an object's specific internal energy, $c_0^2/2$.
- $\vec{g}(r)$ is the specific gravitational force acting on an object.
- ∇e_I is the gradient of an object's specific internal energy.

This investigation examines how to integrate gravitational and kinetic ITDs into a total ITD by relating ITDs to total work done, w_t. This is accomplished by allowing changes to w_t components, i.e., w_K and w_P, while holding e_I constant.

9.1. Time Dilation Equivalence

Specific word done in kinetic or gravitational contexts affect ITDs, but neither factor alone is sufficient for a complete explanation. To refine our understanding, we must explore cases where these variables vary while the ITDs remain unchanged. Equations (85) and (87) suggest that some ammount of gravitational specific work done, w_P, creates an equal ITD effect as the same amount of kinetic specific work done, w_K. Equation (89) demonstrates that the ITDs in each state are the same.

$$\begin{aligned}
&\text{Let } \Delta e_P > 0.\\
&\text{Let } \gamma^{-1} = \frac{dt'}{dt}\\
&\gamma_P^{-2} = 1 + \frac{\Delta e_P}{e_{T|K}}\\
&-\Delta e_P = e_{T|K}\left(1 - \gamma_P^{-2}\right)\\
&-\Delta e_P \implies \Delta e_K\\
&\therefore \Delta e_K = e_{T|K}\left(1 - \gamma_P^{-2}\right)
\end{aligned}$$

$$1 - \frac{\Delta e_K}{e_{T|K}} = \gamma_P^{-2}$$
$$\gamma_K^{-2} = \gamma_P^{-2} \blacksquare \tag{89}$$

Using the MoA: the amount of gravitational and kinetic specific work done differ (the antecedent factors) without changes in the ITD (the effect), proves inductively that neither factor alone is the fundamental cause of changes in ITDs—each factor contributes partially. It turns out that the total specific work done, w_t, produces the same change in ITDs. Inductively, via the MoA, this implies that changes in ITD are caused by w_t.

9.2. Deriving the Causal Math Model

We can now derive the total time dilation model, beginning with the ITD of an object stationary in a gravitational field. Then, we analyze how specific kinetic work done affects the overall ITD when measured from this stationary position using miscalibrated instruments. This scenario is illustrated in Figure 14.

The overall ITD, dt'_2/dt, for a moving object within a gravitational field is calculated by using the chain rule to combine the measurements dt'_1/dt and dt'_2/dt'_1, as shown in Equation (90).

$$\frac{dt'_2}{dt'_1} = \sqrt{1 - \frac{w_{K2|P1}}{e_{T|K}}}$$
$$\frac{dt'_1}{dt} = \sqrt{1 - \frac{w_{P1}}{e_{T|K}}}$$
$$\frac{dt'_2}{dt} = \frac{dt'_2}{dt'_1}\frac{dt'_1}{dt} = \sqrt{1 - \frac{w_{K2|P1}}{e_{T|K}}}\sqrt{1 - \frac{w_{P1}}{e_{T|K}}} \tag{90}$$

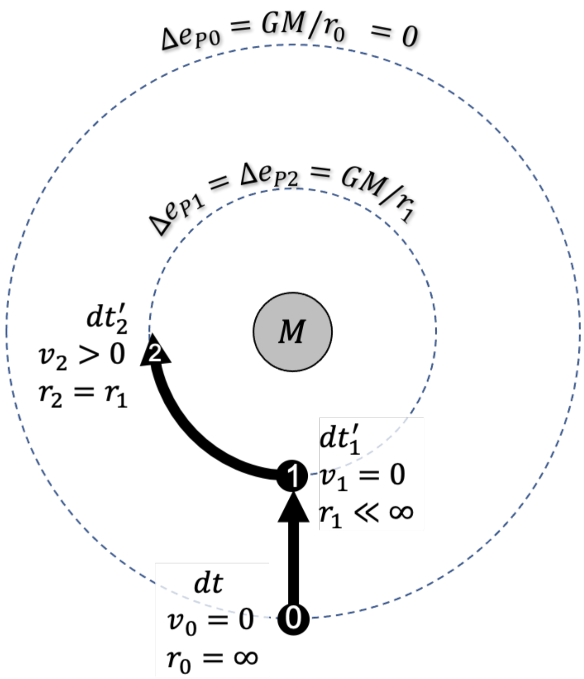


Figure 14: **Total time dilation example.**

This applies to any scenario where an object with kinetic energy is within a stationary gravitational field, leading to the general form in Equation (92).

$$\text{Let}: \frac{dt'_T}{dt'_P} = \sqrt{1 - \frac{w_{K|P}}{e_{T|K}}} \text{ and } \frac{dt'_P}{dt} = \sqrt{1 - \frac{w_P}{e_{T|K}}} = \gamma_P^{-1}$$

$$\gamma_T^{-1} = \frac{dt'_T}{dt} = \frac{dt'_T}{dt'_P}\frac{dt'_P}{dt} = \sqrt{1 - \frac{w_{K|P}}{e_{T|K}}}\sqrt{1 - \frac{w_P}{e_{T|K}}} \tag{92a}$$
$$= \sqrt{1 - \frac{\gamma_P^{-2} w_{K|P} + w_P}{e_{T|K}}} \tag{92b}$$
$$= \sqrt{1 - \frac{w_K + w_P}{e_{T|K}}} = \sqrt{1 - \frac{w_t}{e_{T|K}}} \blacksquare \tag{92c}$$

Equation (92b) shows that the object's effective speed slows by the same factor that c_0 is reduced—by a factor of γ_P^{-1}. Additionally, its actual speed in the radial direction slows by an additional factor of γ_P^{-1}, because length contraction along the velocity dimension is abstracted out in the effective speed concept (see Subsection 5.4).

For completeness, let's now consider another scenario where the gravitational potential is moving rather than stationary. The model is described in Equation (93). The thought experiment illustrating this is found in Appendix C.

$$\text{Let}: \frac{dt'_T}{dt'_K} = \sqrt{1 - \frac{w_{P|K}}{e_{T|K}}} \text{ and } \frac{dt'_K}{dt} = \sqrt{1 - \frac{w_K}{e_{T|K}}} = \gamma_K^{-1}$$

$$\gamma_T^{-1} = \frac{dt'_T}{dt} = \frac{dt'_T}{dt'_K}\frac{dt'_K}{dt} = \sqrt{1 - \frac{w_{P|K}}{e_{T|K}}}\sqrt{1 - \frac{w_K}{e_{T|K}}} \tag{93a}$$

$$= \sqrt{1 - \frac{\gamma_K^{-2} w_{P|K} + w_K}{e_{T|K}}} \tag{93b}$$

$$= \sqrt{1 - \frac{w_P + w_K}{e_{T|K}}} = \sqrt{1 - \frac{w_t}{e_{T|K}}} \blacksquare \tag{93c}$$

Equation (93b) demonstrates that observed gravitational effects in the moving frame are effectively miscalibrated by a factor of γ_K^2, which aligns with the results of the thought experiment in Appendix C.

Thus, for any number of N combinations of gravitational or kinetic specific work done, where $N \in \mathbb{Z} \geq 0$, and for all $i = \{0..N\}$, the overall ITD, dt'_N/dt, is given by:

$$\text{Let}: dt'_0 = dt \text{ and } w_{1|0} = w_1$$

$$\gamma_{T,i}^{-1} = \frac{dt'_i}{dt} = \prod_{j=1}^{i} \frac{dt'_j}{dt'_{j-1}} = \prod_{j=1}^{i} \sqrt{1 - \frac{w_{j|j-1}}{e_{T|K}}} = \sqrt{1 - \frac{\sum_{j=1}^{i} \gamma_{T,j-1}^{-2} w_{j|j-1}}{e_{T|K}}}$$

$$= \sqrt{1 - \frac{w_K + w_P}{e_{T|K}}} = \sqrt{1 - \frac{w_t}{e_{T|K}}} \blacksquare \tag{94}$$

9.3. Relating Total Time Dilation Model to Relativity

Given the assumptions required for the Schwarzschild metric hold, the total time dilation model derived in the previous section can be related to relativity through this metric as follows.

$$c^2 dt'^2 = ds^2 = \left(1 - \frac{GM/r}{e_{T|K}}\right) c^2 dt^2 - \left(1 - \frac{GM/r}{e_{T|K}}\right)^{-1} dr^2 - r^2 d\theta^2 - r^2 \sin^2(\theta) d\phi^2 \tag{95}$$

$$\gamma_T^{-1} = \frac{dt'}{dt} = \sqrt{\left(1 - \frac{w_P}{e_{T|K}}\right) - \left(1 - \frac{w_P}{e_{T|K}}\right)^{-1} \frac{w_{K,r}}{e_{T|K}} - \frac{w_{K,\theta}}{e_{T|K}} - \frac{w_{K,\phi}}{e_{T|K}}}$$

$$= \sqrt{1 - \frac{w_P + \gamma_P^2 w_{K,r} + w_{K,\theta} + w_{K,\phi}}{e_{T|K}}} = \sqrt{1 - \frac{w_t}{e_{T|K}}} \blacksquare \tag{96}$$

The γ_P^2 term next to the radial specific work term, $w_{K,r}$, puts radial specific work in terms of "effective" work done—i.e., abstracting out gravitational length contraction—thus, validating our emphasis on thinking in terms of the average *effective* speed of light.

9.4. Updating the Specific Internal Energy Model

We can now incorporate these findings to update the specific internal energy model from Equation (86) that includes Δe_P along with Δe_K. First, we need to solve for e_I in Equation (94).

$$\begin{aligned} \frac{dt'}{dt} &= \gamma_T^{-1} = \sqrt{1 - \frac{w_t}{e_{T|K}}} \\ \gamma_T^{-2} &= 1 - \frac{w_t}{e_{T|K}} \\ \gamma_T^{-2} e_{T|K} &= e_{T|K} - w_t \\ e_I &= e_{T|K} - w_t \end{aligned} \tag{97}$$

Recalling from Subsection 7.3, $e_{T|K}$ can properly be conceptualized as the maximum specific internal energy value, $e_{\max\{I\}}$ or $e_{\max}$ for short, an object can achieve—and substituting back in specific energy terms—yields:

$$e_I = e_{\max} - w_t = e_{\max} - \left(\Delta e_K - \Delta e_P\right) \tag{98}$$

By selecting $e_K = 0$ when $v_p = 0$, $e_K = e_{\max}$ when $v_p = c$, $e_p = 0$ when $r = r_s$, and $e_p = e_{\max}$ when $r = \infty$ as the convention for absolute specific energy values yields:

$$\begin{aligned} e_I &= e_{\max} - \left(\Delta e_K - \Delta e_P\right) = -\Delta e_K + e_{\max} + \Delta e_P = -\frac{1}{2}v_p^2 + \left(\frac{1}{2}c^2 - \int_\infty^r g(r)dr\right) \\ &= -e_K + e_P = -(e_K - e_P) = -l \end{aligned} \tag{99}$$

Specific internal energy is revealed as the specific Lagrangian in the context of the principle of least action. This is the connecting point between universal specificity and the principle of least action. Further exploration beyond this point is an intriguing future research direction.

Solving Equation (99) for c_0/c leads to Equation (100). This equation shows a recurring pattern: c_0/c is equivalent to total time dilation, dt'/dt, as expected.

$$\frac{c_0}{c} = \sqrt{1 - \frac{\Delta e_t}{e_{\max}}} = \frac{dt'}{dt} \tag{100}$$

As discussed in prior sections, a change in total time dilation is a direct consequence of a change in c_0. The speed of light represents the speed of causality (36), so a change in c_0 signifies a shift in the speed of causality, thereby altering the interval over which an object changes—the effect known as time dilation. Under this broader context, c_0 remains a key parameter in the Universe's causal structure—the metronome of the Universe.

The causal chain for time dilation, in this general sense, is: a change in c_0 causes a change in the ITD of an object, regardless of whether that change originates from specific kinetic or potential work. Specifically, for kinetic cases, a change in net w_K causes a change in c_0, while for gravitational cases, the existing c_0 gradient causes a specific force which acts on objects to do specific work, w_P, assuming other factors remain constant.

9.5. Conclusion

In summary, this investigation has demonstrated that changes in the interval over which an object undergoes change (time dilation) are fundamentally caused by variations in c_0, which is tied to the specific internal energy of the object. The key insights include:

1. Kinetic and Gravitational Time Dilation: These two effects stem from the same underlying cause—a reduction in c_0, the speed of causality.
2. Specific Internal Energy: A complete specific internal energy model must account for losses in specific potential energy alongside gains in specific kinetic energy.

With the development of these tools and models, we are now prepared to address the final question posed in this investigative series: is there an objective method for determining the preferred frame of reference? This will be the subject of the next and final investigation.

10. Investigation 8: How is the Preferred Frame Determined?

Prior investigations established that time, when properly conceptualized, is the interval over which change occurs to *things*, and is not a separate property of the Universe. This understanding led to the conceptualization of time dilation as a change in the interval over which objects change. It was also determined that a preferred frame must exist, which led to the discovery that gravity results from a specific internal energy gradient (Equation (101)). This understanding culminated in the causal discovery of total time dilation (Equation (102)) and a complete specific internal energy model incorporating specific kinetic energy and specific potential energy (Equation (103)).

$$\vec{g}(r) = -\nabla e_I = -\frac{d(e_I)}{dr}\hat{r} \tag{101}$$

$$\frac{dt'}{dt} = \frac{c_0}{c} = \sqrt{1 - \frac{w_t}{e_{\max}}} = \sqrt{1 - \frac{w_K + w_P}{e_{\max}}} = \sqrt{1 - \frac{\Delta e_K - \Delta e_P}{e_{\max}}} \tag{102}$$

$$e_I = \frac{1}{2}c_0^2 = -l = -\left(e_K - e_P\right) = -\Delta e_K + \left(e_{\max} + \Delta e_P\right) = -\frac{1}{2}v_p^2 + \left(\frac{1}{2}c^2 - \int_{\infty}^{r} -\nabla e_I dr\right) \tag{103}$$

Definition of terms:

- dt' is the uncalibrated measured interval over which an object changes.
- dt is the calibrated measured interval over which an object changes.
- The ratio of time derivatives, dt'/dt, termed the *inertial time differential* (ITD), remains constant for any object until the net w_t changes. Specific work done is conservative (see Appendix A).
- c_0 is the average effective speed of light with respect to an object (see Subsection 5.4).
- c is the speed of light in a vacuum with respect to the preferred frame, unaffected by gravitational potentials.
- $e_{\max}$ is the maximum value of e_I that any object can achieve, $c^2/2$.
- w_t is the net specific total work done on an object.
- Δe_K is an object's change in specific kinetic energy with respect to the preferred frame.
- e_K is an object's absolute specific kinetic energy given a convention described in Subsection 9.4.
- w_K is the net specific kinetic work done on an object with respect to the preferred frame, resulting in Δe_K.
- Δe_P is the change in specific potential energy of the object.
- e_K is an object's absolute specific potential energy given a convention described in Subsection 9.4.
- w_P is the net specific work done by gravity on the object, resulting in Δe_P.
- e_I is an object's specific internal energy, $c_0^2/2$.
- l is the specific Lagrangian of the object.
- $\vec{g}(r)$ is the specific gravitational force acting on an object.
- ∇e_I is the gradient of an object's specific internal energy.

The next task is to revisit an original and final question from this investigative series: is there a way to objectively determine which frame is the preferred frame of reference?

10.1. Defining a Preferred Frame

A preferred frame is the only inertial reference frame that can be considered “still" (no velocity) in the Universe. This frame is defined as the frame where the speed of light (in the absence of gravity) is constant in all directions.

The existence of a preferred frame becomes obvious in rotational contexts, where it is easy to identify a frame with no angular velocity, $\omega_p = 0$. For instance, a simple bucket of water experiment can reveal if the bucket's reference frame is rotating. If the bucket rotates, the water's surface forms a bowl shape; otherwise, it remains flat (see Figure 15) (65).

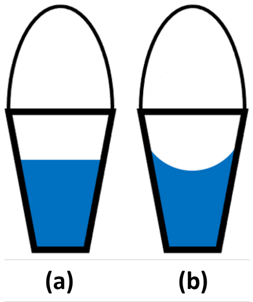


Figure 15: **Water bucket (a)** $\omega_p = 0$**. (b)** $\omega_p \neq 0$**.**

In contrast, detecting translational velocity with respect to the preferred frame is far more difficult (see Figure 16). Michelson and Morley's famous experiment attempted to determine Earth's motion with respect to the preferred frame by measuring the speed of light at different points in Earth's orbit (15). The results, however, suggested that the speed of light appears constant in all directions for any inertial frame (see sections 3 and 5). This underscores the difference between rotational and translational velocity, where the latter appears undetectable in typical experiments.

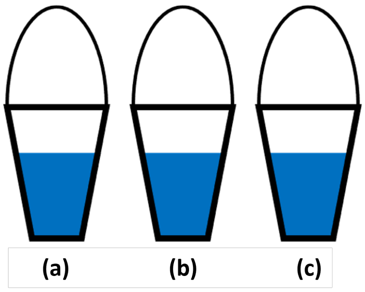


Figure 16: **(a)** $|v_p| = 0$ **(b)** $|v_p| = 0.5c$ **(c)** $|v_p| = 0.\overline{9}c$

Our goal is to design an experiment that can objectively measure motion with respect to the preferred frame. Although several experiments have been proposed to detect motion relative to the preferred frame (66), they have failed to detect it. These methods rely on known theories, such as those incorporating a preferred frame (26), but the challenge lies in the fact that, despite changes in calibrated instruments, all pairs of reference frames agree on their relative velocities. Thus, any effects of miscalibration seem to cancel out.

10.2. Do Miscalibration Effects Cancel when Measuring Translational Velocity?

All pairs of observers in any inertial frames agree on their relative velocity (67), even though units of measurement for space and time change when specific kinetic work is done. This invariance is expressed in Equation (104).

$$\begin{aligned} |v| &= |v'| \\ \frac{dx}{dt} &= \frac{dx'}{dt'} \\ \frac{dt'}{dt} &= \frac{dx'}{dx} \end{aligned} \tag{104}$$

In this equation, dx'/dx is not length contraction, but instead represents the ratio of uncalibrated-to-calibrated distances traveled by a single point over time. We will explore two common methods for measuring velocity—Doppler velocity estimation and measuring velocity as distance over time—to show how miscalibration effects cancel out.

10.2.1. Doppler Velocity Estimation

For light in a preferred frame, the classical Doppler equation applies, shown in Equation (105), which makes use of the coordinate system depicted in Figure 17:

$$f_r = f_s \frac{1 + \frac{v_r}{c}}{1 + \frac{v_s}{c}} \tag{105}$$

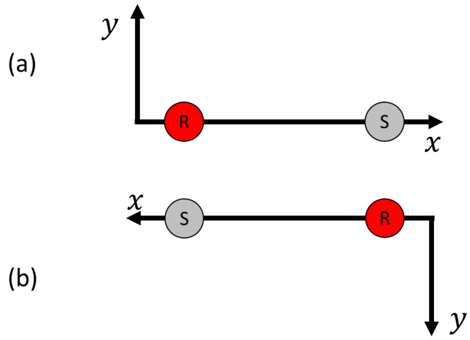


Figure 17: (a) Source is in positive direction with respect to receiver. (b) Source made to be in positive direction.

Where :

f_r is the frequency recieved at the reciever.

f_s is the emitted frequency at the source.

v_r is the velocity of the reciever with respect to the preferred frame.

v_s is the velocity of the source with respect to the preferred frame.

c is the speed of light in the preferred frame.

Equation (105) can be used to measure the velocity of distant stars by observing frequency shifts in spectral absorption lines (Figure 18) (68). However, relativity provides its own Doppler equation (Equation (106)):

$$f_r' = f_s' \frac{\sqrt{1 + \frac{v'}{c}}}{\sqrt{1 - \frac{v'}{c}}} \tag{106}$$

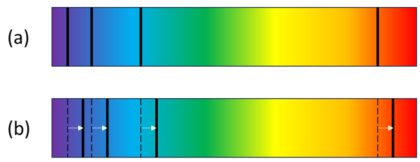


Figure 18: **(a) Expected Values. (b) Shifted Values.**

Where :

f_r' is the uncalibrated frequency recieved at the reciever.

f_s' is the uncalibrated emitted frequency at the source.

v' is the uncalibrated relative velocity between the reciever and the source.

c is the speed of light with respect to the preferred frame.

When one considers the proper transformation between uncalibrated and calibrated values the relativistic Doppler equation (Equation (106)) falls out from the classical Doppler equation (Equation (105)). Thus, the effects of miscalibration cancel out, making it impossible to detect the preferred frame using this method.

Equation (107) relates uncalibrated-to-calibrated frequencies, and shows that uncalibrated frequency scales with time dilation, which stands to reason given the units of frequency is inverse time units.

$$\frac{f}{f'} = \sqrt{1 - \frac{v_p^2}{c^2}} = \frac{dt'}{dt} \tag{107}$$

Where :

f is the calibrated frequency being measured.

f' is the uncalibrated frequency being measured.

v_p is the velocity of measurement location with respect to the preferred frame.
c is the speed of light with respect to the preferred frame.

Equation (108) is the familiar relativistic velocity addition formula applied to this case, which relates uncalibrated-to-calibrated velocities.

$$v' = \frac{v_r - v_s}{1 - \frac{v_r v_s}{c^2}} \tag{108}$$

Where :
v' is the uncalibrated relative velocity between the reciever and the source.
v_r is the velocity of the reciever with respect to the preferred frame.
v_s is the velocity of the source with respect to the preferred frame.
c is the speed of light in the preferred frame.

Given the above relationships between the calibrated and uncalibrated values, the proof that the relativistic Doppler equation (Equation (106)) falls out from the classical Doppler equation (Equation (105)) is demonstrated in Equation (109).

$$\begin{aligned}
f_r &= f_s \frac{1+\frac{v_r}{c}}{1+\frac{v_s}{c}} \\
f_r \frac{f'_r}{f'_r} &= f_s \frac{f'_s}{f'_s} \frac{1+\frac{v_r}{c}}{1+\frac{v_s}{c}} \\
f'_r \frac{f_r}{f'_r} &= f'_s \frac{f_s}{f'_s} \frac{1+\frac{v_r}{c}}{1+\frac{v_s}{c}} \\
f'_r \sqrt{1-\frac{v_r^2}{c^2}} &= f'_s \sqrt{1-\frac{v_s^2}{c^2}} \frac{1+\frac{v_r}{c}}{1+\frac{v_s}{c}} \\
f'_r &= f'_s \frac{\sqrt{1-\frac{v_s^2}{c^2}}}{\sqrt{1-\frac{v_r^2}{c^2}}} \frac{1+\frac{v_r}{c}}{1+\frac{v_s}{c}} = f'_s \frac{\sqrt{1-\frac{v_s}{c}}\sqrt{1+\frac{v_s}{c}}}{\sqrt{1-\frac{v_r}{c}}\sqrt{1+\frac{v_r}{c}}} \frac{1+\frac{v_r}{c}}{1+\frac{v_s}{c}} = f'_s \frac{\sqrt{1-\frac{v_s}{c}}}{\sqrt{1-\frac{v_r}{c}}} \frac{\sqrt{1+\frac{v_r}{c}}}{\sqrt{1+\frac{v_s}{c}}} \\
&= f'_s \frac{\sqrt{1-\frac{v_s}{c}+\frac{v_r}{c}-\frac{v_r v_s}{c^2}}}{\sqrt{1-\frac{v_r}{c}+\frac{v_s}{c}-\frac{v_r v_s}{c^2}}} = f'_s \frac{\sqrt{\left(1-\frac{v_r v_s}{c^2}\right)\left(1+\frac{1}{c}\frac{v_r - v_s}{1-\frac{v_r v_s}{c^2}}\right)}}{\sqrt{\left(1-\frac{v_r v_s}{c^2}\right)\left(1-\frac{1}{c}\frac{v_r - v_s}{1-\frac{v_r v_s}{c^2}}\right)}} = f'_s \frac{\sqrt{1+\frac{v'}{c}}}{\sqrt{1-\frac{v'}{c}}} \blacksquare
\end{aligned} \tag{109}$$

The above proof shows that mapping from calibrated values to miscalibrated is surjective and not bijective—i.e., many different calibrated frequency values lead to the same uncalibrated frequency measurements. The effects of miscalibration that might distinguish one frame from another cancels out. For this reason, it becomes impossible, by this method, to determine which frame is preferred when starting with uncalibrated values. This hurdle extends to a slightly different method that reflects signals off targets and measures the difference between the emitted and return frequency, e.g., police radar speed guns.

10.2.2. Velocity as Distance Over Time

The process of measuring velocity using the round-trip time of a laser pulse also suffers from a miscalibration calcelation issue. In this method, an object estimates the distance to another object by sending a laser pulse and measuring the time it takes for the pulse to return. The round-trip time is used to compute the distance, s_1, based on the elapsed time between the emission and return of the pulse (Equation (110)).

$$s_1 = \frac{1}{2}(t_1 - t_0)c \tag{110}$$

Given that Galilean geometry holds for a preferred frame, the red object (if it sent the laser signal at $t0$ as well) experiences a round trip time of of $t_1 - t_0$ as well, but due to time dilation, its measure of t_1 and t_0 are off, represented by the primed symbols, t'_1 and t'_0 respectively. Their relationship is as expected, $t'_1 = \gamma_K^{-1} t_1$ and $t'_0 = \gamma_K^{-1} t_0$; therefore, the red object, with miscalibrated instruments, measures an elapsed time of $\gamma_K^{-1}(t_1 - t_0)$, which is less than what the blue object measures. Assuming the one-way speed of the laser pulse is c for there and back with respect to the red object's frame,[13] then the ping 1 is measured at a distance, s'_1 given by:

$$s'_1 = \gamma_K^{-1} \frac{1}{2}(t_1 - t_0)c = \gamma_K^{-1} s_1 \tag{111}$$

This process is repeated for the next return:

$$s_2 = \frac{1}{2}(t_2 - t_1)c \tag{112}$$

$$s'_2 = \gamma_K^{-1} \frac{1}{2}(t_2 - t_1)c = \gamma_K^{-1} s_2 \tag{113}$$

$$\tag{114}$$

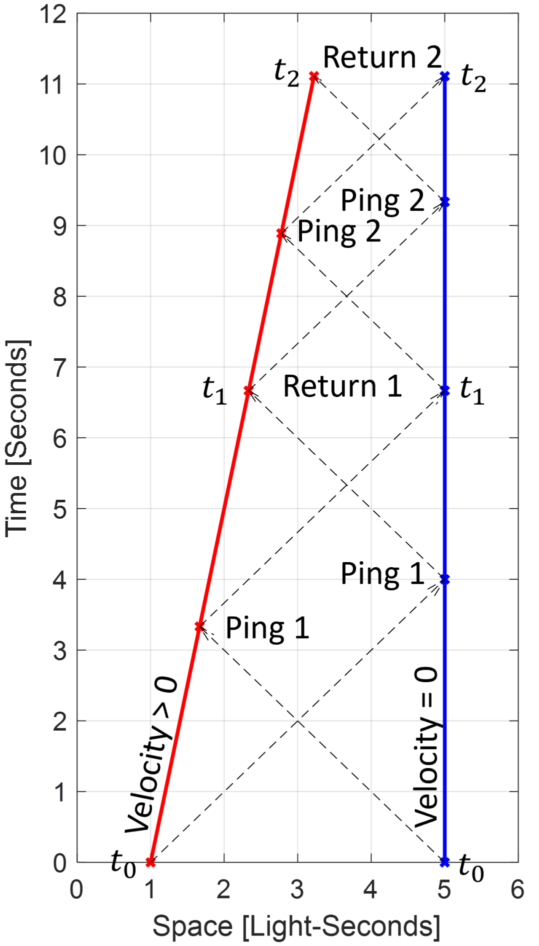


Figure 19: **Estimating velocity using ping returns.**

The velocity is calculated as the change in distance divided by the change in time:

$$|v| = 2\frac{s_2 - s_1}{t_2 - t_0} \tag{115}$$

$$|v'| = 2\frac{s'_2 - s'_1}{t'_2 - t'_0} \tag{116}$$

However, the ratio of distance to time remains the same across both the uncalibrated and calibrated frames:

$$|v'| = 2\frac{\gamma_K^{-1}(s_2 - s_1)}{\gamma_K^{-1}(t_2 - t_0)} = |v| \blacksquare \tag{117}$$

Thus, the measured velocity remains invariant, regardless of the frames of reference. This demonstrates that, like with the Doppler method, miscalibration effects cancel out in the measurement of velocity over time, making it impossible to detect motion relative to the preferred frame using this technique.

[13] A false assumption, but, being ignorant as to which frame is preferred, it is assumed nonetheless.

Attempts to measure the motion with respect to a preferred frame typically involve measuring light's speed in various ways (66)(69). However, these methods have failed because any calibration errors are canceled out in velocity measurements. To determine the preferred frame, we need a measurement that does not eliminate the effects of being in a different reference frame. What is required is a way to observe the unit change in uncalibrated instruments caused by specific work done, allowing us to calculate an object's velocity within the preferred frame. Once achieved, that object's velocity relative to the preferred frame can be related to other objects using established methods.

10.3. Determining Which Frame is Preferred

To detect the preferred frame, experiments that involve acceleration are crucial, as pairs of observers do not agree on their relative acceleration (70), like they do on their relative velocity. In fact, a closer look at the bucket experiment reveals that rotational tests inherently involve acceleration.

However, we require a test based on translational acceleration. There are two forms of translational acceleration to consider: kinetic and gravitational. Of these, only gravitational acceleration is suitable for our purposes.

A kinetic acceleration experiment, such as accelerating a rocket to Alpha Centauri and back (akin to the twin paradox), is impractical. It relies on remote measurements using signals with a finite velocity, which interferes with the effects we seek to measure. Consequently, this experiment cannot detect the preferred frame.

In contrast, gravitational acceleration experiments, which rely solely on local measurements, offer a viable path forward. The proposed experiment involves using six identical gravimeters, each positioned to measure the gravitational acceleration in three orthogonal directions (two gravimeters per direction). By comparing the gravitational acceleration measurements from each gravimeter, it becomes possible to detect the effects of time dilation and length contraction due to motion relative to the preferred frame.

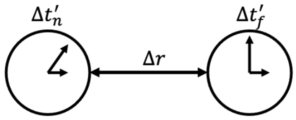


Figure 20: **Gravimeter.**

According to the gravitational model derived earlier (see Subsection 8.2), measurements of time dilation gradients are related to the specific force of gravity through the following equation (Equation (118)):

$$\vec{g}(r) = -2e_{\max}\gamma_P^{-1}\nabla\frac{dt'}{dt} \tag{118}$$

In practice, Equation (118) represents the theoretical value assuming infinitely precise instruments. The measured value, $\hat{g}(r)$, becomes:

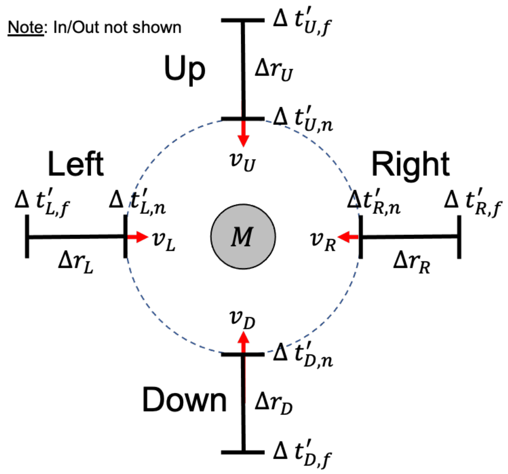
$$\hat{g}(r) = -2e_{\max}\frac{\Delta t'}{\Delta t}\frac{\frac{\Delta t'_f}{\Delta t} - \frac{\Delta t'_n}{\Delta t}}{\Delta r}\hat{r} \tag{119}$$

Assuming $\Delta t' \approx \Delta t'_n$ and $(\Delta t'_n/\Delta t)^2 \approx 1$, Equation (119) simplifies to:

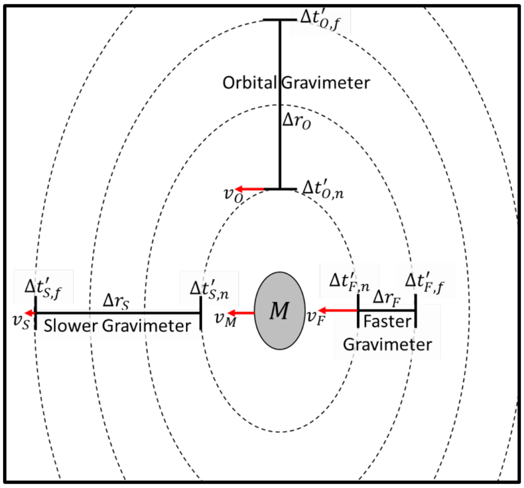
$$\begin{aligned}\hat{g}(r) &\approx -2e_{\max}\frac{\Delta t'_n}{\Delta t}\frac{\frac{\Delta t'_f}{\Delta t} - \frac{\Delta t'_n}{\Delta t}}{\Delta r}\hat{r} = -2e_{\max}\frac{\Delta t'_n}{\Delta t}\frac{\Delta t'_n}{\Delta t'_n}\frac{\frac{\Delta t'_f}{\Delta t} - \frac{\Delta t'_n}{\Delta t}}{\Delta r}\hat{r} = -2e_{\max}\left(\frac{\Delta t'_n}{\Delta t}\right)^2\frac{\frac{\Delta t'_f}{\Delta t'_n} - \frac{\Delta t'_n}{\Delta t'_n}}{\Delta r}\hat{r}\\ &\approx -2e_{\max}\frac{\frac{\Delta t'_f}{\Delta t'_n} - 1}{\Delta r}\hat{r}\end{aligned} \tag{120}$$

Using Equation (120), six gravimeters measuring gravitational acceleration, $\hat{g}(r)$, in three orthogonal dimensions (two per dimension) would allow for the determination of the preferred frame. Figure 21(a) illustrates the experimental setup.

In this experiment, identical light clocks count cycles, Δt, of light bouncing back and forth within each gravimeter. As the nearest end of the gravimeter reaches a marked threshold at radius r from a massive object, it tracks the counts from both clocks, stopping when it reaches another marked threshold closer to the object.



(a) Experimental setup.



(b) Experimental effects of Lorentz contraction.

Figure 21: Preferred frame gravimeter experiment.

Each gravimeter, calibrated to the same initial inertial frame, assumes Δr is consistent. Variations in $\Delta t'_f/\Delta t'_n$ due to kinetic time dilation are canceled out, leaving variations caused by kinetic length contraction. When Δr is greater for gravimeters moving slower with respect to the preferred frame, measures of $\Delta t'_f/\Delta t'_n$ deviate more from unity compared to when Δr is smaller for faster-moving gravimeters. This distinction enables estimation of the massive object's velocity relative to the preferred frame.

The gravitational acceleration measurements from the gravimeters would then be compared with simulated results to determine the massive object's velocity with respect to the preferred frame. The simulation, detailed in Appendix E, uses parameters such as:

- Uncalibrated mass of massive object, M, measured in its frame: 1000 [$Solar\ Masses$]
- Uncalibrated distance between clocks, Δr, measured in the gravimeter's frame: 1 [km]
- Uncalibrated distance from the object's center, r, measured in its frame: 0.5 [AU]
- Uncalibrated speed of gravimeters, $|v|$, measured relative to the object's frame: 0.1 [$fraction\ of\ c$]

Figure 22 displays the simulation results, showing how the massive object's speed with respect to the preferred frame affects gravimeter readings.

If the actual experiment produces gravitational acceleration measurements of 21.75 $\left[\mathrm{ms}^{-2}\right]$ and 24.05 $\left[\mathrm{ms}^{-2}\right]$ for two opposing gravimeters, it would indicate that the massive object has a velocity of $0.5c$ with respect to the preferred frame in the direction towards the gravimeter that measured 21.75 $\left[\mathrm{ms}^{-2}\right]$ relative to the massed object.

In a practical scenario, three probes in highly elliptical orbits around the Sun, with semi-major axes oriented orthogonally, could be used to determine the Sun's velocity relative to the preferred frame. Over time, integrating data from multiple passes in each of the six directions would reveal the preferred frame as the counts between near and far clocks diverge.

10.4. Conclusion

In conclusion, detecting the preferred frame is feasible through experiments utilizing gravitational acceleration and local measurements. The proposed gravimeter experiment near a massive object can effectively verify the existence of a preferred frame, supporting the validity of universal specificity over relativity.

11. Conclusion

This paper has explored the implications of a preferred frame of reference, particularly in the context of the speed of light, time dilation, specific energy, and gravitation. By applying Peikoff's method of induction and Mill's Method,

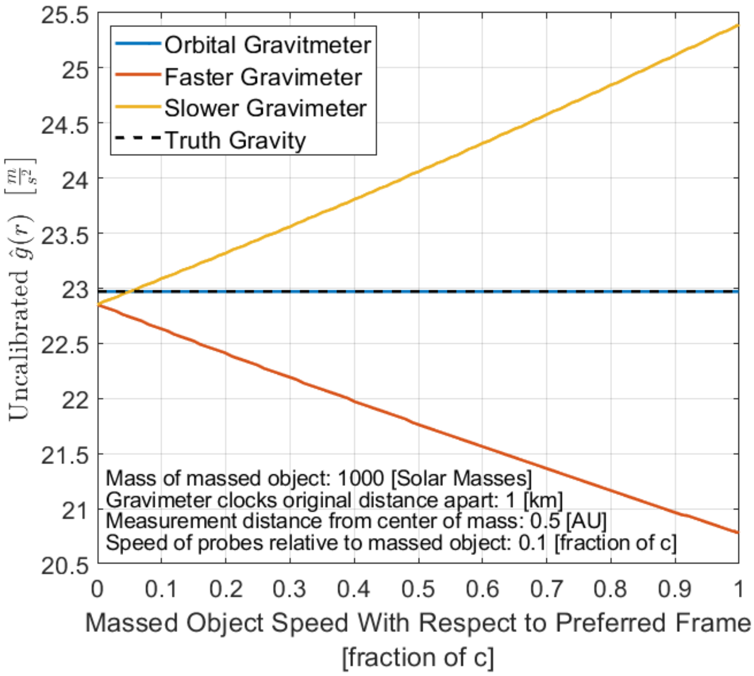


Figure 22: Simulated results.

we proposed a mechanistic counterpart to Einstein's theory of relativity, emphasizing the detection of a preferred frame through gravitational experiments.

We began by establishing that time should be understood as the interval over which change occurs to physical objects, rather than as an independent property of the universe. This led to a reconceptualization of time dilation as a change in the duration over which physical processes unfold. From this understanding, we inferred the necessity of a preferred frame of reference and identified the cause of kinetic time dilation, as expressed in Equation (85). This also allowed us to derive a comprehensive specific internal energy model, shown in Equation (99).

Further exploration revealed the cause of gravitational time dilation (Equation (87)), showing that gravity is driven by a gradient in an object's specific internal energy, described in Equation (88). This led to the discovery that kinetic and gravitational time dilation share a common cause, uniting them under the same theoretical framework, as summarized in Equation (102). These insights reinforce the existence of a preferred frame and provide a fresh perspective on the connections between time dilation, specific energy, and gravity.

Moreover, we demonstrated that gravitational acceleration experiments, such as those utilizing gravimeters, offer a practical approach for identifying the preferred frame. Simulations indicated that under specific conditions, measurements of gravitational acceleration can reveal the velocity of massive objects relative to the preferred frame. This result has significant implications for our understanding of the fundamental nature of time and space.

Our findings suggest that these experiments are feasible with current technology. Gravimeters positioned in highly elliptical orbits around massive celestial bodies, like the Sun, could yield data that challenge or validate existing theories, opening doors to new discoveries in physics.

11.1. Future Work

Several avenues for future research emerge from this study:

1. Experimental Verification: The next immediate step is to conduct real-world gravimeter experiments to test the theoretical predictions. Refining measurement techniques and mitigating potential sources of error will be critical to improving experimental accuracy.

2. Extended Simulations: Further simulations could explore a broader range of scenarios, including variations in the mass of the test objects, different orbital configurations, and additional parameters. This would help assess the robustness of the proposed methods and address any unexpected challenges.
3. New Investigations: Future studies into changes in the permeability and permittivity of free space could provide insights into unified field theory, potentially enabling breakthroughs in artificial gravity or neutralizing gravitational effects, which could transform transportation and propulsion technologies.
4. Broader Implications: Investigating how the preferred frame influences other physical phenomena and theories, such as space travel, cosmology, and high-energy physics, may offer deeper insights into the fundamental nature of reality.

By following these research directions, we can enhance our understanding of time dilation, specific energy, and the potential for detecting the preferred frame. This work lays the groundwork for future discoveries that could revolutionize our view of the universe and its governing principles.

12. Glossary

- Electromagneticgravitism: the physical coupling between gravitation and electromagnetism.
- Electrogravitism: electromagneticgravitism with the magnetic component neutralized.
- Gravitoelectromagnetism: the mathematical analogy between gravity and electromagnetism.
- Inertial Time Differential: is like a time dilation differential except it adds the constraint that this differential remains constant until the net specific total work done on an object changes.
- Magneticgravitism: electromagneticgravitism with the electrical component neutralized.
- Method of Agreement: A controlled experiment in which plausible causes are removed/changed, yet the effect remains the same. This proves that the cause is contained in the remaining set of unchanged plausible causes.
- Method of Difference: A controlled experiment in which plausible causes are removed/changed, and the effect is different. This proves that the cause is contained in the removed/changed set of plausible causes
- Time: the interval over which change occurs to things.
- Time Dilation: the lengthening of the interval over which objects change.
- Time Dilation Differential: The ratio of the uncalibrated infinitesimal time interval an object changes to the calibrated interval.
- Universal Specificity: the theoretical framework considered the mechanistic counterpart to relativity covered in this paper.

13. Abbreviations

- ARF: Apparatus' Reference Frame
- EG: Electrogravitism
- EM: Electromagnetism
- EMG: Electromagneticgravitism
- GEM: Gravitoelectromagnetism
- GR: General Relativity
- ITD: Inertial Time Differential
- MG: Magneticgravitism

- MoA: Method of Agreement
- MoD: Method of Difference
- SR: Special Relativity
- TDG: Time Dilation Gradient
- US: Universal Specificity
- VSL: Variable Speed of Light

14. Declaration of Generative AI and AI-assisted Technologies in the Writing Process

During the preparation of this work the author used ChatGPT in order to to improve the spelling, grammar, clarity and conciseness of the content within. After using this tool/service, the author reviewed and edited the content as needed and takes full responsibility for the content of the published article.

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A. Properties of Specific Work

This appendix outlines several key properties of specific work, essential for understanding its role in the context of reference frames and energy dynamics:

- Specific work done can be positive or negative.
- Specific work is the sum of its orthogonal components.
- Total specific work done is the sum of a set of isolated incidents of specific work done.
- Specific work done is conservative.

For any isolated incident, specific work is positive when an object accelerates relative to the preferred frame and negative when it decelerates. This outcome arises because specific work is calculated using vector quantities like net specific force and displacement, as shown in Equation (A1).

$$w = \mathbf{a} \cdot \mathbf{s} \tag{A1}$$

Furthermore, the total specific work done in any spatial dimension is the sum of each dimension's individual work, as demonstrated in Equation (A2).

$$w = \mathbf{a} \cdot \mathbf{s} = \mathbf{a_x} \cdot \mathbf{s_x} + \mathbf{a_y} \cdot \mathbf{s_y} + \mathbf{a_z} \cdot \mathbf{s_z} = w_x + w_y + w_z \blacksquare \tag{A2}$$

When combining multiple isolated incidents of work, the total specific work done is the sum of all these incidents. For example, in the twin paradox scenario where Earth's frame is considered the preferred frame, the twin accelerating away from Earth performs positive specific work. As the twin decelerates at the turnaround point, negative specific work is done. The net effect at this point results in the total specific work summing to zero, and this applies similarly for the return trip.

The net effect of all these properties is that specific work done is conservative to any inertial reference frame. This means when any object returns back to its original state (position and velocity), then the total specific work done is zero, regardless of the path taken. Additionally, when any object goes from one frame to another, the same amount of specific work is done, regardless of the path taken. This is why objects in the same frame are always synchronized with respect to their interval over which the same change occurs—e.g., it is impossible for one twin to "progress through time" slower than the other, when they are both in the same reference frame at the same time.

Because specific work is conservative, knowing the entire history of an object's work is unnecessary to evaluate the total specific work done. Only the amount of specific work required to transition between frames is needed.

B. Gravitoelectromagnetism Equations

This section explores how the use of complex numbers enables the combination of gravitational and electromagnetic (EM) fields into a unified framework. To achieve this, we begin by converting charge into a mass-equivalent term, M_e, using a scaling factor (58):

$$M_e \triangleq \frac{q}{\sqrt{4\pi\varepsilon_0 G}}, \frac{1C}{\sqrt{4\pi\varepsilon_0 G}} \approx 1.16042 \times 10^10\ kg \tag{B1}$$

This form fits into Newton's law of gravitation, except for the sign being positive instead of negative (58):

$$\vec{F}_e = \frac{1}{4\pi\varepsilon_0]} \frac{q_1 q_2}{r^2}\hat{r} = +G\frac{M_{e1}M_{e2}}{r^2}\hat{r} \tag{B2}$$

The positive sign is resolved by interpreting mass and charge as mutually orthogonal, following the property $-1 = i^2$. This orthogonal coupling aligns with the findings of this investigation, where gravitational fields act parallel to the velocity vector of light when c_0 changes, and EM fields act perpendicular to the light's velocity vector. Consequently, ordinary mass, $M_g = m$, relates to charge, $M_e = q/\sqrt{4\pi\varepsilon_0 G}$, as follows (58):

$$M = M_g + iM_e = m + i\frac{q}{\sqrt{4\pi\varepsilon_0 G}} \tag{B3}$$

This use of imaginary mass represents the orthogonal relationship between gravitation and EM fields, rather than a physical concept like tachyons (71; 72). The gravitoelectromagnetism (GEM) analogy is expressed as follows (58):

$$\begin{aligned}
&\nabla \cdot \vec{G}_g = -4\pi G\rho_g && \nabla \cdot \vec{E} = \frac{\rho'}{\varepsilon_0}\\
&\nabla \cdot \vec{B}_g = 0 && \nabla \cdot \vec{B} = 0\\
&\nabla \times \vec{G}_g = -\frac{\partial \vec{B}_g}{\partial t} && \nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}\\
&\nabla \times \vec{B}_g = -\frac{4\pi G}{c^2}\vec{J}_g + \frac{1}{c^2}\frac{\partial \vec{G}_g}{\partial t} && \nabla \times \vec{B} = -\frac{1}{\varepsilon_0 c^2}\vec{J}' + \frac{1}{c^2}\frac{\partial \vec{E}}{\partial t}
\end{aligned} \tag{B4}$$

Using the charge-to-mass conversions from Equation (B1), the following variable transformations eliminate the asymmetries between GEM and EM (58):

$$\begin{aligned}
&\rho_e \triangleq \frac{\rho'}{\sqrt{4\pi\varepsilon_0 G}} && \vec{J}_e \triangleq \frac{\vec{J}'}{\sqrt{4\pi\varepsilon_0 G}}\\
&\vec{G}_e \triangleq -\sqrt{4\pi\varepsilon_0 G}\vec{E} && \vec{B}_e \triangleq -\sqrt{4\pi\varepsilon_0 G}\vec{B}
\end{aligned} \tag{B5}$$

With these transformations, the asymmetries between the gravitational and electromagnetic field equations are removed:

$$\begin{aligned}
&\nabla \cdot \vec{G}_g = -4\pi G\rho_g && \nabla \cdot \vec{G}_e = -4\pi G\rho_e\\
&\nabla \cdot \vec{B}_g = 0 && \nabla \cdot \vec{B}_e = 0\\
&\nabla \times \vec{G}_g = -\frac{\partial \vec{B}_g}{\partial t} && \nabla \times \vec{G}_e = -\frac{\partial \vec{B}_e}{\partial t}\\
&\nabla \times \vec{B}_g = -\frac{4\pi G}{c^2}\vec{J}_g + \frac{1}{c^2}\frac{\partial \vec{G}_g}{\partial t} && \nabla \times \vec{B}_e = -\frac{4\pi G}{c^2}\vec{J}_e + \frac{1}{c^2}\frac{\partial \vec{G}_e}{\partial t}
\end{aligned} \tag{B6}$$

Multiplying Maxwell's equations by the imaginary unit i imposes the orthogonality between gravity and electromagnetism (58):

$$\begin{aligned}
&\rho = \rho_g + i\rho_e && \vec{J} = \vec{J}_g + i\vec{J}_e\\
&\vec{G} = \vec{G}_g + i\vec{G}_e && \vec{B} = \vec{B}_g + i\vec{B}_e
\end{aligned} \tag{B7}$$

Given the linear properties of divergence ($\nabla\cdot$) and curl ($\nabla\times$), we combine the gravitational and electromagnetic field equations into a single set by using these generalized quantities:

$$\begin{aligned}
&\nabla \cdot \vec{G} = -4\pi G\rho\\
&\nabla \cdot \vec{B} = 0
\end{aligned}$$

$$\nabla \times \vec{G} = -\frac{\partial \vec{B}}{\partial t}$$

$$\nabla \times \vec{B} = -\frac{4\pi G}{c^2}\vec{J} + \frac{1}{c^2}\frac{\partial \vec{G}}{\partial t} \blacksquare \tag{B8}$$

These equations provide a unified description of gravitational and electromagnetic fields. Whether this set of equations fully represents a theory of electromagneticgravitism (EMG) is an interesting question that merits further investigation. While these equations suggest a special case for the integration of gravitational and EM fields, a more general solution may need to account for variations in the permeability and permittivity of free space, rather than treating them as constants. Investigating this question will require future work.

C. Kinetic Effects on Gravity

This section examines the effects of kinetic time dilation on gravitational forces. To explore this, imagine constructing four identical orbs made from the element Osmium,[14] each with the same shape and size. If each orb has a radius of 0.1 $[m]$, their rest masses would each be approximately 92 $[kg]$. The first two orbs are initially stationary in the preferred frame and placed 100 $[m]$ apart from their centers. Gravitational attraction would cause them to move toward each other, and in about four months (according to the orbs' proper time), the two orbs would come into contact.

Now, suppose the other two orbs are sent away in a scenario resembling the twin paradox, while maintaining the same initial conditions.[15] When these traveling orbs return after the stationary orbs have made contact, the traveling orbs—due to experiencing less proper time (as a result of kinetic time dilation)—would still be separated, as shown in Figure 23.

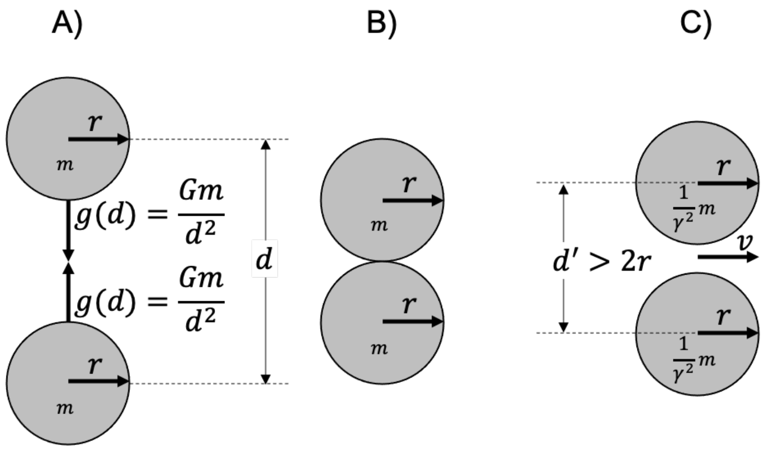

Figure 23: A) Initial conditions. B) Preferred orbs after four months. C) Traveling after four months.

These results suggest that the inertia of the traveling orbs increased (assuming the gravitational force remained constant), but the question remains: by how much? Through experimentation, it was found that the increase in inertia follows the relation $\gamma_K^2 m_0$. This result is intuitive because displacement due to gravitational acceleration is related to time squared, and the interval over which change occurs in the traveling frame is lengthened by a factor of γ_K compared to the preferred frame. This relationship is demonstrated in the analysis of displacement perpendicular to the system's velocity, s_y, as a function of gravitational acceleration, as shown in Equation (C1).

$$s_y = s'_y$$
$$t = \gamma_K t'$$

[14]Osmium has an atomic number of 76.

[15]The distance between their centers remains orthogonal to the direction of velocity.

$$
\begin{aligned}
s_y &= \frac{1}{2}g(r)t^2 \\
s'_y &= \frac{1}{2}g'(r)t'^2 \\
\therefore g(r) &= \gamma_K^{-2}g'(r) \blacksquare
\end{aligned} \tag{C1}
$$

Similarly, we can study displacement parallel to the system's velocity, s_x, as a function of gravitational acceleration, as shown in Equation (C2).

$$
\begin{aligned}
s_x &= \gamma_K^{-1}s'_x \\
t &= \gamma_K t' \\
s_x &= \frac{1}{2}g(r)t^2 \\
s'_x &= \frac{1}{2}g'(r)t'^2 \\
\therefore g(r) &= \gamma_K^{-3}g'(r) \blacksquare
\end{aligned} \tag{C2}
$$

If we focus solely on the time difference between when the two pairs of orbs touch, we can ignore $s_x = \gamma_K^{-1}s'_x$ in Equation (C2), yielding $g(r) = \gamma_K^{-2}g'(r)$, which aligns with the result obtained in Equation (C1).

Now, imagine another similar experiment where two new, smaller orbs are created. These new orbs have the same properties as the others but are reduced in radius to ensure their mass, m'_0, equals $\gamma_K^{-2}m_0$. If these new orbs replace the stationary orbs, and we conduct the same experiment, the distances traveled by both the traveling and stationary orbs would be the same upon the return of the traveling orbs.

Several trials of this experiment were simulated, numerically solving the dynamics within each reference frame. The code for these simulations is included in Appendix D. Each trial was conducted with the same velocity for the traveling orbs, but the return times varied. At the end of each trial, the distances traveled by both pairs of orbs were compared, with the results presented in Figure 24.

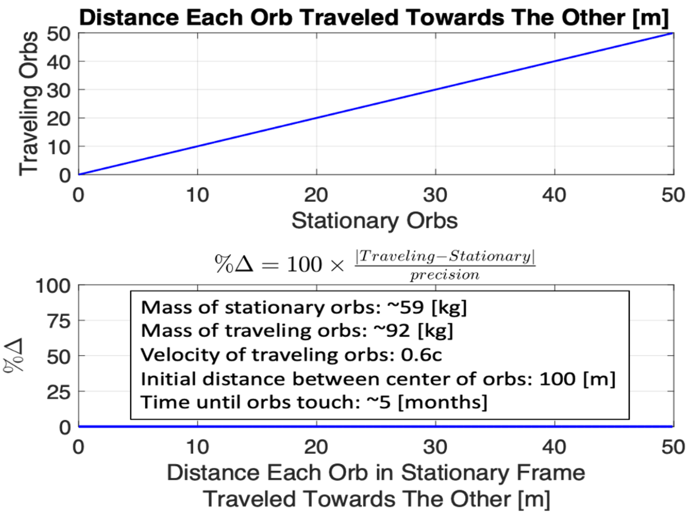

Figure 24: **Results of experiments.**

The experiments show that both pairs of orbs exhibited the same gravitational behavior, despite one pair being in motion. According to the Method of Agreement (MoA), the fact that the same gravitational effect occurred in both cases provides inductive proof that gravitational effects are reduced by a factor of γ_K^{-2} when the source of the gravitational potential is not stationary.

D. Matlab Code: Kinematic Effects on Gravitation

```
%% constants and functions
G                  = 6.6744e-11; % [m^3/(kg s)] gravitational constant
gamma              = @(v)  1./sqrt(1-v.^2);
seconds2months     = 12/60^2/24/365;

%% Traveling orbs
% initial conditions
rho      = 22000;      % [kg/m^3] density of osmium
r        = 1e-1;       % [m]      radius of each orb
vol      = 4*pi*r^3/3; % [m^3]    volume of each orb
m        = rho*vol;    % [kg]     mass of each orb
d        = 1e2;        % [m]      initial distance between orbs' surfaces
d_min    = 2*r;        % [m]      minimum distance between center mass of orbs
gd1      = 2*G*m/(d);  % [J/kg]   initial relative xspecific potential energy
v        = 0.6;        % [-]      fraction of the speed of light of orbs
gamma_v  = gamma(v);   % [-]      1/sqrt(1-v^2/c^2)

% initialize other variables
dy   = (d-d_min)/1e4;      % increment steps to numerical solution
ds   = d:-dy:d_min;        % all numerical steps
gds  = ones(size(ds))*gd1;% specific potential energy
vs   = zeros(size(ds));    % relative velocity of orbs
ts   = zeros(size(ds));    % proper time passed

% incremental solution of orb pairs relative velocity and time passed
for id = 2 : length(ds)
    % this relative specific potential energy for orbs
    gds(id) = 2*G*m/(ds(id));

    % delta relative specific potential energy for orbs
    delta_gd = gds(id)-gd1;

    % relative velocity between them
    vs(id) = sqrt(2*delta_gd);

    % time for distance to close by mean relative velocity
    ts(id) = ts(id-1) + dy/mean([vs(id),vs(id-1)]);
end

% total passage of proper time until orbs contact in years and months
total_time_months = max(ts)*seconds2months;

%% Stationary orbs
my       = m/gamma_v^2; % [kg]   mass of stationary orb is traveling orb's mass
gd1_my   = 2*G*my/(d);  % [J/kg] initial specific potential energy

% time passed, as measured by stationary orbs
ts_gamma = ts*gamma_v;

% total passage of proper time until orbs contact in years and months
total_time_months_my   = max(ts_gamma)*seconds2months;
```

```
% initialize stationary orbs with mass my distance steps
dy_my = dy;                % increment steps to numerical solution
ds_my = d:-dy_my:d_min; % all numerical steps

% initialize other variables
vs_my  = zeros(size(ds_my));
gds_my = ones(size(ds_my))*gd1_my;
ts_my  = zeros(size(ds_my));

% incremental solution of orb pairs relative velocity and time passed
for id = 2 : length(ds_my)
    % this relative specific potential energy
    gds_my(id) = 2*G*my/(ds_my(id));

    % delta relative specific potential energy
    delta_gd_my = gds_my(id)-gd1_my;

    % relative velocity between them
    vs_my(id) = sqrt(2*delta_gd_my);

    % time for distance to close by mean relative velocity
    ts_my(id) = ts_my(id-1) + dy_my/mean([vs_my(id),vs_my(id-1)]);
end

%% Plot Results
figure(1);
% plot the movement of each orb makes towards its pair
subplot(2,1,1)
plot((d-ds)/2,(d-interp1(ts_my,ds_my,ts_gamma))/2,'-b','LineWidth',1.5)
xlim([0 d/2]);
ylim([0 d/2]);
grid on
xlabel('Stationary Orbs','FontSize',20);
ylabel('Traveling Orbs','FontSize',20);
title({'Distance Each Orb Traveled Towards The Other [m]'},'fontsize',16);

% plot the percent difference in movement between pairs of orbs
percent_difference = 100*abs((d-interp1(ts_my,ds_my,ts_gamma))/2 - (d-ds)/2)
    ./(dy);
subplot(2,1,2)
plot((d-ds)/2,percent_difference,'-b','LineWidth',2)
xlim([0 d/2]);
ylim([0 100]);
grid on
xlabel({'Distance Each Orb in Stationary Frame'...
    ,'Traveled Towards The Other [m]'},'FontSize',20);
ylabel({'\%$\Delta$'},'FontSize',20,'Interpreter','latex');
title({'\%$\Delta=100\times\frac{|Traveling-Stationary|}{precision}$'}...
    ,'Interpreter','latex','fontsize',16);

% print ellapsed proper (AAK wall) time for each pair or orbs
```

```
fprintf('Elapsed Time for Traveling Orbs: %0.1f [months]\n',total_time_months)
    ;
fprintf('Elapsed Time for Stationary Orbs: %0.1f [months]\n',
    total_time_months_my);
```

E. Matlab Code: Detecting the Preferred Frame

```
% Code designed to demonstrate detection of preferred frame
function preferred_frame_detection_via_g()
%% initializations, constants and simple functions
% initialization
clear all
clc
close all

% constants
c     = 299792458;  % [m/s] speed of light
G     = 6.6744e-11; % [m^3/(kg s)] gravitational constant
Me    = 5.97219e24; % [kg] earth's mass
Ms    = 333000*Me;  % [kg] sun's mass
e_T   = 0.5*c^2;    % [m^2/s^2] specific total energy
AU    = 152.03e9;   % [m] distance from sun to earth

% simple functions
r_s           = @(M)  G*M/e_T;
gamma_inv_K   = @(v)  1./sqrt(1-v.^2);
add_vel       = @(v1_in,v2_in) (v1_in+v2_in)/(1 + v1_in*v2_in);
r_2_gravObj   = @(M,r) G*M/r^2;
gamma_inv_P   = @(M,r)  sqrt(1-r_s(M)./r);
gravimeter    = @(dtnear_dtfar,dr) (2*e_T/dr)*(1/dtnear_dtfar -1);
prop_dist     = @(M,r1,r2) (r2*gamma_inv_P(M,r2) + 0.5*r_s(M)*log(2*r2*(
    gamma_inv_P(M,r2)+1)-r_s(M)))  ...
     - (r1*gamma_inv_P(M,r1) + 0.5*r_s(M)*log(2*r1*(gamma_inv_P(M,r1)+1)-r_s(M)
        ));

%% experiement: travel two gravimeters (probes) towards center of massed
    object (MO)
% set conditions (in MO's frame)
M_MO          = 1e3*Ms; % [kg] mass of object at center of experiment
r_measure     = AU/2;    % [m] nearest clock distance from center of MO
probe_dv      = 0.1;     % [frac of c] speed of probes relative to MO
dr_orb_MO_0   = 1e3;     % [m] clocks distance apart when stationary in zero
    gravity

% initialize
gr_orbit_all  = [];
gr_probe1_all = [];
gr_probe2_all = [];

% loop through range of MO velocities
v_obj_all = [0:0.01:0.99 0.99:0.001:0.999]; % [frac of c] speed of MO (in
    preferred frame)
for ivo = 1 : length(v_obj_all)
```

```
    % (in preferred frame)
    v_obj           = v_obj_all(ivo);            % [frac of c] velocity of MO
    v_p1            = add_vel(v_obj,probe_dv);   % [frac of c] velocity of probe1
    v_p2            = add_vel(v_obj,-probe_dv);  % [frac of c] velocity of probe2
    drPF_drp_obj   = gamma_inv_K(v_obj);        % [-] kinetic differential for MO
    drPF_drp_p1    = gamma_inv_K(v_p1);         % [-] kinetic differential for probe1
    drPF_drp_p2    = gamma_inv_K(v_p2);         % [-] kinetic differential for probe2
    drp_p1_drp_obj = drPF_drp_obj/drPF_drp_p1; % [-] kinetic differential WRT MO
    drp_p2_drp_obj = drPF_drp_obj/drPF_drp_p2; % [-] kinetic differential WRT MO

    % determine miscalibration effects on grivimeters (in MO frame)
    r2          = solve_for_r2(M_MO,r_measure,dr_orb_MO_0);
    dr_orb_MO = (r2-r_measure);             % [m] clocks distance apart in gravity, no velocity
    dr_p1_MO  = dr_orb_MO*drp_p1_drp_obj; % [m] clocks distance apart in gravity with velocity
    dr_p2_MO  = dr_orb_MO*drp_p2_drp_obj; % [m] clocks distance apart in gravity with velocity

    % determine effects on gravimeter from orbit of MO (in  MO frame)
    r_f_orbit      = r_measure+dr_orb_MO;                        % [m] farthest clock distance to MO
    r_n_orbit      = r_measure;                                  % [m] nearest clock distance to MO
    dtn_dtf_orbit = frames_dtn_dtf(M_MO,r_f_orbit,r_n_orbit); % [-] clock differential
    g_m_orbit      = gravimeter(dtn_dtf_orbit,dr_orb_MO);      % [m/s^2] measured g

    % determine effects on gravimeter from probe 1 (in  MO frame)
    r_f_probe1      = r_measure+dr_p1_MO;                           % [m] farthest clock distance to MO
    r_n_probe1      = r_measure;                                    % [m] nearest clock distance to MO
    dtn_dtf_probe1 = frames_dtn_dtf(M_MO,r_f_probe1,r_n_probe1); % [-] clock differential
    g_m_probe1      = gravimeter(dtn_dtf_probe1,dr_orb_MO);       % [m/s^2] measured g

    % determine effects on gravimeter from probe 2 (in  MO frame)
    r_f_probe2      = r_measure+dr_p2_MO;                           % [m] farthest clock distance to MO
    r_n_probe2      = r_measure;                                    % [m] nearest clock distance to MO
    dtn_dtf_probe2 = frames_dtn_dtf(M_MO,r_f_probe2,r_n_probe2); % [-] clock differential
```

```
    g_m_probe2      = gravimeter(dtn_dtf_probe2,dr_orb_MO);       % [m/s^2] measured g

    % store results
    gr_orbit_all  = [gr_orbit_all g_m_orbit];
    gr_probe1_all = [gr_probe1_all g_m_probe1];
    gr_probe2_all = [gr_probe2_all g_m_probe2];
end

% plot results
fig = figure(1);
hold off
plot(v_obj_all, gr_orbit_all,'LineWidth',2);
hold on
plot(v_obj_all, gr_probe1_all,'LineWidth',2);
plot(v_obj_all, gr_probe2_all,'LineWidth',2);
plot([v_obj_all(1) v_obj_all(end)], [r_2_gravObj(M_MO,r_measure) r_2_gravObj(M_MO,r_measure)],'k--','LineWidth',2)

% clean up plot
legend('Orbital Gravitmeter','Faster Gravimeter','Slower Gravimeter','Truth Gravity','FontSize',16,'location','NW');
xlabel({'Massed Object Speed With Respect to Preferred Frame','[fraction of c]'},'FontSize',16);
ylabel('Uncalibrated $\hat{g}(r)~\left[\frac{m}{s^2}\right]$','FontSize',16,'Interpreter','latex');
grid on
xticks([0:.1:1]);
a = get(gca,'XTickLabel');
set(gca,'XTickLabel',a,'fontsize',16)
annotation(fig, 'textbox', [.13 .10 .8 .2], 'String'...
    ,sprintf('Mass of massed object: %d [Solar Masses]',M_MO/Ms)...
    ,'EdgeColor','none','FontSize',14);
annotation(fig, 'textbox', [.13 .07 .8 .2], 'String'...
    ,sprintf('Gravimeter clocks original distance apart: %d [km]',dr_orb_MO_0/1e3)...
    ,'EdgeColor','none','FontSize',14);
annotation(fig, 'textbox', [.13 .04 .8 .2], 'String'...
    ,sprintf('Measurement distance from center of mass: %0.1f [AU]',r_measure/AU)...
    ,'EdgeColor','none','FontSize',14);
annotation(fig, 'textbox', [.13 .01 .8 .2], 'String'...
    ,sprintf('Speed of probes relative to massed object: %0.1f [fraction of c]',probe_dv)...
    ,'EdgeColor','none','FontSize',14);

%% supporting function
    function dtn_dtf = frames_dtn_dtf(M,r_f,r_n)
        % (in MO frame)
        dt_f     = gamma_inv_P(M,r_f);    % time dilation of clock farthest from MO
        dt_n     = gamma_inv_P(M,r_n);    % time dilation of clock nearest to MO
```

```
        dtn_dtf    = dt_n/(dt_f);    % relative time differential between
            closest and farthest clock
    end

    function r2 = solve_for_r2(M,r1,dr)
        % initial guess
        r2_upper = r1 + 2*dr;
        r2_lower = r1;
        r2 = (r2_lower + r2_upper)/2;
        dr_guess = prop_dist(M,r1,r2);
        error = dr_guess - dr;
        while (1e-9 < abs(error) || dr/(2^25) > abs(r2_upper-r2_lower))
            if 0 < error
                r2_upper = r2;
            else
                r2_lower = r2;
            end
            r2 = (r2_lower + r2_upper)/2;
            dr_guess = prop_dist(M,r1,r2);
            error = dr_guess - dr;
        end
    end
end
```

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