Special Relativity Completed

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Abstract

Though Einstein explained time dilation without recourse to a universal frame of reference, he erred by abolishing universal present moments. Relative simultaneity is insufficiently relativistic insofar as it depends on the absolute equality of reference frames in the measurement of the timing of events. Yet any given set of events privileges the frame in which the events take place. Relative to those events, the privileged frame yields the correct measurement of their timing while all other frames yield an incorrect measurement. Instead of multiple frames occupying multiple times, one frame is correct and all others incorrect within a shared present moment. With the collapse of relative simultaneity, we may regard time as a succession of universal moments. Absolute simultaneity, in turn, explains why an accelerated inertial frame dilates in time rather than regressing to a prior moment relative to non-accelerated frames. In the context of flowing time, absolute simultaneity predicts time dilation while relative simultaneity predicts time regression. Einstein's explanation of time dilation is therefore incomplete.

Keywords: relativity of simultaneity, time dilation, duration-slowing, time travel, space-time

Introduction

With the advent of Albert Einstein’s principle of the relativity of simultaneity, physicists generally came to regard time as a static sequence of instants, any of which can be arbitrarily defined as the present. This view is in stark contrast to our innate sense of time as duration. Why, if time contains neither flow nor presence, does all human experience derive from present moments that recede into past moments?

At the core of the special theory of relativity is the recognition that the speed of light *in vacuo* must be invariant across frames of reference because all absolute properties of nature, including the speed of light, apply equally in all frames. However, while motion relative to c causes time dilation in the accelerated frame relative to non-accelerated frames, no measurable effect provides empirical basis for the relativity of simultaneity.

Einstein failed to demonstrate relative simultaneity as an objective phenomenon. His error lay in his unstated assumption that the equivalence of reference frames in relation to *c* also applies in relation to events. While this is true in the abstract, any actual set of events privileges a particular frame, which is preferred not in the absolute sense of the ether but only relative to the events themselves being timed. Einstein neglected to consider a relativistic alternative to Hendrik Lorentz's ether.

In contrast to time dilation, the apparent effect of relative simultaneity is symmetrical: observers in both frames conclude that the clock in the other frame is slow. Yet any actual situation involving two frames breaks this symmetry. Because one frame is moving closer to *c*, its clock really does run slow in relation to the clock in the other frame. Like the tacit assumption of the absolute equality of reference frames in relation to events, relative simultaneity is an abstraction divorced from actuality.

In no way implying absolute space or a universal frame of reference, absolute simultaneity simply expresses the absolute nature of temporal presence. Whereas each present moment, like acceleration and *c*, is the same in all frames of reference, the elapsed time of an accelerated inertial frame dilates relative to the elapsed time of non-accelerated frames, just as Einstein stipulated. We are not abandoning special relativity but completing it.

Absolute Simultaneity

Einstein's celebrated 1905 paper, "On the Electrodynamics of Moving Bodies," begins with an examination of electricity and magnetism (1952, 37). At the time, scientists thought the cause of an electric current in a conductor depended on whether the conductor or the magnet was in motion. If a magnet moves past a conductor, the current is stimulated by an electric field. In the case of the conductor moving past the magnet, the current is stimulated by an "electromotive" force. Einstein realized the motion of the magnet is purely relative to the conductor and vice versa, meaning neither one moves in relation to an absolute state of rest. The question of which object is in motion and which one at rest is frame-dependent. Regardless of which frame we chose -- that of the magnet or the conductor -- the current is generated through the same mechanism, namely an electromagnetic field.

The dismissal of an absolute state of rest, i.e. a fixed frame of reference spanning the universe, is among Einstein's greatest achievements. Disposing of the need for an ether, he inferred that all frames are equally valid regarding the timing of events. Yet this is true only in the abstract. In every actual instance, one frame is preferred, specifically the one at rest with respect to the events in question. If we wish to measure the timing of the electric current, for instance, the fact that the current takes place in the conductor privileges the conductor frame over the magnet frame in our measurement. Instead of equally valid frames occupying different times, we have one valid frame and one invalid frame sharing a present moment. Einstein's conjecture of a distinct time for each frame is unfounded.

Einstein illustrates the problem of simultaneity with a train traveling on an embankment (1961, 21-27). Lightning occurs at points A and B along the embankment. At point M, midway between A and B, the flashes of lightning register simultaneously. Point M' is also midway between A and B. However, M' is on the train and therefore in motion towards B and away from A. For this reason, at M' the flash that takes place at B appears to precede the flash at A. "Events which are simultaneous with reference to the embankment," writes Einstein, "are not simultaneous with respect to the train, and vice versa." He concludes that each frame of reference "has its own particular time" (1961, 26).

Einstein's mistake is to grant equal validity to both frames despite the fact that only one of them, the frame of the embankment, is at rest with respect to the lightning. In motion relative to the lightning, M' registers the timing of the flashes incorrectly. Since the frames must occupy different times only if both are equally valid in their measurement of the timing of the flashes, the relativity of simultaneity collapses.

To fully appreciate this point, consider an alternative scenario. Let's say a light flashes within one of the cars comprising the train. The train frame is at rest with respect to the light since the light flashes in the train itself. If the source of light is fixed to the center of the car, the light reaches the front and back of the car simultaneously. When viewed from the embankment, however, the forward motion of the train causes the light to appear to reach the back of the car prior to the front. Rejecting the extraordinary claim that each frame has a distinct time, we conclude that the view from the train yields the correct measurement while the view from the embankment yields a mistaken measurement.

In the absence of an absolute frame of reference, all frames seem equally valid. In practice, however, any given set of events privileges whichever frame is at rest with respect to those events. In Einstein's lightning scenario, the frame of the embankment is preferred. In the alternative scenario of a light flashing within the train, the train is the preferred frame in which to measure the timing of events. A given frame is preferred not in the absolute sense of the ether but only relative to a particular set of events. By assuming the equality of all frames in every instance, Einstein was insufficiently relativistic in his analysis.

No frame of reference is always preferred in relation to other frames. What Einstein overlooked is that the inverse is also true: *all frames of reference are always preferred in relation to themselves*. Because the measurement of the timing of events is correct for the frame in which the events take place and incorrect for other frames, we have no need to posit different times for different frames. We simply recognize that the limitation of c distorts measurement in the context of relative motion.

The fact that mechanical clocks register different times in different inertial frames provides a sheen of objectivity to the relativity of simultaneity. Yet this means only that the limitation of c fools clocks as readily as subjective observers. Since the mistaken measurement in the non-preferred frame follows from a property of light, relative simultaneity is a special case of optical illusion. Whereas ordinary optical illusions depend on organic processing in the human visual system, the mirage of relative simultaneity arises from the transmission of light itself.

Rather than time itself, what differs from one frame to another is only the readings of clocks. This is why philosopher Mario Bacelar Valente refers to the apparent relativity of simultaneity as the relativity of synchronization (8).

A single present moment encompassing both reference frames is in fact implicit in Einstein's thought experiment. At the exact moment an observer on the train registers the lightning flash at B, an observer on the embankment has not seen either flash. At the moment the passenger registers the lightning at A, the embankment observer claims both lightning flashes have already occurred. In order for the observers to disagree on what is happening at any given moment, both must occupy that moment. Einstein highlighted the discord across reference frames while neglecting the underlying accord.

If an event happens at different times in different frames of reference, different events must be happening at the same time in those frames. To deny this claim is to assume from the outset that the phrase "at the same time" cannot apply to different frames. Yet this is precisely what Einstein ostensibly demonstrates in his discussion of simultaneity. We cannot assume at the outset the very thing we seek to prove.

If different frames actually occupied different times, that is, if the present moment of one frame differed from the present moment of another frame, they could not detect each other at all, as we perceive only what is present to us. This is not to deny that by observing a galaxy two million light years away, for instance, we see its state two million years prior. Nonetheless, we see only what was present, not past, at that point in time. While we cannot know what is happening now in a distant star system, we have no reason to doubt that the present moment on Earth is also the present moment at that remote location.

In his thought experiment involving a space fleet launched from the Andromeda galaxy, Roger Penrose explains the effect of two pedestrians passing each other in terms of their differing perspectives on events occurring in Andromeda (260). From one perspective, the space fleet has already set sail for Earth. From the perspective of the person walking the other direction, the decision to launch has yet to be made. Rather than negate a shared present between Earth and Andromeda, however, this conflict only highlights the inaccuracy of one or both perspectives. If we know that one perspective is indeed correct, we must ascertain which pedestrian's frame of reference is equivalent to the space fleet's frame. Even at a distance of two million light years, velocities that match up constitute a single frame. Of course, if neither pedestrian occupies the same frame as the Andromedeans, both are mistaken about the timing of the launch. Either way the paradox of multiple times dissolves.

Einstein rejected absolute time without considering the possibility that time is absolute only in presence and not, as Newton believed, in both presence and flow. Regardless of how fast or slow the clock runs, the time is now. Presence is implacable.

Objections

1) A “shared present moment” implies a third reference frame in addition to the train and the embankment.

A reference frame designates an area of space in motion relative to other areas. Time is not a reference frame. We cannot pluck out a moment of time and call that a reference frame. Fortunately this is not what I'm claiming. Instead I argue that the measurement of the timing of events is correct in whichever (spatial) frame is at rest with respect to those events and incorrect in all other frames, thus validating our intuitive sense that the same present moment applies regardless of motion across space.

2) Events cannot be localized to one frame or another but belong equally to both.

If a light appears in a moving train, clearly the light comes on in the train frame. To deny this is to separate the frame from the object whose motion defines it. In Einstein's thought experiment, lightning takes place in the embankment frame, while the train is in motion relative to the flashes. We know this because at point M, which is equidistant from the flashes, they are simultaneous. This is the point of invoking paired lightning strikes: we can all agree that they seem simultaneous. What Einstein fails to grasp is that they actually are simultaneous when measured correctly, that is, from their own frame of reference.

3) Events cannot occupy a frame of reference because they are simply points in space-time.

The implication here is that an event is instantaneous in the sense of occupying no duration. If this were the case, however, the view from the train would not differ from the view from the embankment. Only if the flashes of lightning occupy a certain interval is the motion of the train relevant, since only during the interval of the flashes does the train's motion distinguish its measurement of the timing of the flashes from the embankment's measurement.

Moreover, points in space-time do exist in frames. As Einstein put it, "Let M' be the midpoint of the distance A [to] B on the travelling train. Just when the flashes of lightning occur, this point M' naturally coincides with the point M, but it moves… with the velocity of the train" (1961, 26). Here Einstein assigns space-time point M to the embankment frame and M' to the train frame. This procedure is to be expected, for any points that do not adhere to a reference frame would therefore constitute the fabled ether, a space of absolute rest.

4) The apparent simultaneity of disagreement between frames can be resolved by assigning a third frame whose occupant notes disagreement between the first two frames.

A third frame of reference could provide a measurement of the discrepancy between the frame in which the measurement of timing is correct and a frame in which the measurement is incorrect. However, the fact that these two frames cannot instantaneously determine their exact discrepancy in no way negates the fact of that discrepancy. Ernst Mach's positivistic musings aside, physical theory does not end at the limits of human data-collection but says something about the world itself, even if that finding cannot be verified precisely at any given moment. In this regard, relativity resembles quantum mechanics.

5) In the case of a set of events extending across more than one frame of reference, no single frame would provide the correct measurement of the timing of events.

Multiple frames occupy multiple times only if more than one frame provides the correct measurement of the timing of events. In this case, the number of correct frames would be zero.

Time Dilation and Time Travel

Einstein's investigation of relativity famously began with a question: what happens to our perception of light when we travel alongside it? This question, as he discovered, has no answer. No matter how fast the fastest rocket soars, radiant waves of electromagnetism still outrun it by the speed of light.

In order for this to be the case, time must slow for the object accelerating across space. Indeed, the measurable phenomenon that demonstrates time dilation is clock-slowing within accelerated frames and clock-gain relative to accelerated frames (Hafele and Keating, 168). Yet the slowing of time appears nowhere in Einstein's formulation of time dilation.

Given the uniformity of physical law across all frames of reference, the speed of light must always be measured at c. If my frame accelerates to one-half the value of c, the speed of light should appear to drop to one-half c. The simplest way to keep my perception of the speed of light at c is for my half-second to stretch or "dilate" so as to equal a complete second of time outside my frame. As far as light is concerned, I am now as motionless as I was prior to accelerating to one-half c, and I naturally perceive the speed of light as c.

By borrowing the term "time dilation" from his ether-reliant predecessors, Einstein inherited their confusion of time with space. Instead of conceptualizing time as a line and then stretching that line, we accept the reality of temporal flow, and surmise that the rate of flow drops in the accelerated frame relative to non-accelerated frames. But slowed time should cause the accelerated frame to regress to a past moment relative to non-accelerated frames. If I undergo five seconds and you undergo ten seconds, I should wind up five seconds in your past. This is, after all, the nature of time.

In a universe without flowing time, Einstein's account is perfectly suitable. Motion relative to *c* stretches or "dilates" the interval of the journey of the accelerated frame relative to non-accelerated frames, thereby preserving the measurement of the speed of light at *c* in the accelerated frame. In a universe where time is real, however, Einstein's account breaks down. Motion relative to *c* reduces the rate of temporal flow of the accelerated frame, causing it to regress to a relative past, thereby negating the correction of the measured speed of light. Preserving the speed of light at *c* requires not only that the accelerated frame undergo duration-slowing but that it remain in the same present as all other frames.

If time flows, just as it seems, time dilation is duration-slowing in the context of absolute simultaneity. Because all frames must share the same present moment, no frame can regress to a previous moment relative to other frames. The only possible outcome for a frame that slows in time yet remains present to other frames is interval-stretching, i.e. time dilation.

Absolute simultaneity guarantees that time slows only in the weak sense that its rate of flow differs between equally present frames, not in the strong sense that an accelerated frame regresses to a relative past. The clock in the accelerated frame remains present to other frames while displaying an earlier time. Under the rule of relative simultaneity, however, acceleration would cause time regression. Instead of displaying an earlier time, the clock, along with its entire frame, would regress to that earlier time. This appears to be the reasoning behind Kip Thorne's misguided model of time travel via wormhole.

According to Thorne, a wormhole can in theory be harnessed as a portal to the past by introducing a time differential between its two openings (483). This can be accomplished by accelerating one opening of the wormhole (or bringing it near a massive object) but not the other opening. By entering the normal opening and exiting the accelerated opening, the traveler is deposited into a moment prior to entering the wormhole. The only way for this to work, however, is if time dilation is somehow transmuted, in the context of a wormhole, into time regression. In reality, accelerating one opening of the wormhole but not the other would create a clock differential, not a time differential. To arrive at a time differential, the wormhole would have to inhabit a universe in which time does indeed flow but simultaneity is relative. Thorne's error is to revert to an intuitive sense of time while adhering to Einstein's principle of relative simultaneity.

Conclusion

In a universe in which time flows, an accelerated inertial frame ought to undergo duration-slowing relative to non-accelerated frames, causing relativistic time regression of the accelerated frame. In the context of absolute simultaneity, however, duration-slowing resolves into time dilation.

An explanation of time dilation that acknowledges the reality of presence and passage is inherently preferable to a model that assumes away the very qualities that make time temporal. Time is not only experienced but appears to constitute the substrate of experience. Though our understanding of it is imperfect, what we call "time" seems to correspond to something real. An argument against the intrinsic nature of time must therefore be compelling. The burden of proof is on the Parmenidean, the one who denies becoming and restricts actuality to static being.

The fact that motion relative to c produces length contraction as well as time dilation tells us that time and space are related but says nothing of the nature of this relation. That time and space relate does not render time into an appendage of space. Since time dilation can be explained according to duration-slowing in the context of absolute simultaneity, evidence for time dilation in no way demotes flowing time to space-time. To do that we need the relativity of simultaneity, the expulsion of presence and the substitution of lived duration with static intervals in a fourth dimension.

Yet we’ve seen that Einstein’s argument for relative simultaneity is vacuous. Simultaneity is relative only if all frames are equally valid in their measurement of the timing of events. Relative to any actual set of events, however, the frame in which the events take place is privileged regarding their timing. If every frame but one is invalid, all can comfortably co-exist in the same present moment.

The absolute equality of frames makes sense only in a temporal vacuum. Einstein arrives at the substitution of intrinsic time with abstract time simply by failing to take into account the effect of actual events, i.e. time, on frames of reference. His argument on simultaneity proves only that if reality is subsumed to abstraction in the first place, duration is abstracted into after-the-fact interval. While this streamlines special relativity, it applies only in a universe that literally never happens.

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