# Resolving Paradoxes Through Presentist Fragmentalism: Eight Key Thought Experiments

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## Abstract

Einstein's special and general relativity emerged from his systematic analysis of three seminal thought experiments: chasing a light beam, the train-platform scenario, and the equivalence principle. Following this tradition of using Gedankenexperiments as core theoretical tools, we examine eight fundamental thought experiments through the lens of Presentist Fragmentalism - a framework positing that reality consists of fragments with independent A-series temporal flows connected by B-series relations. Our analysis spans both relativistic scenarios (Einstein's train) and quantum phenomena (EPR correlations, delayed choice eraser, Schrodinger's Cat), demonstrating how this interpretation naturally resolves apparent paradoxes without sacrificing causality or introducing faster-than-light signaling. The framework's success in systematically resolving these diverse thought experiments, while preserving both relativistic and quantum principles, suggests it captures fundamental features of physical reality. Just as Einstein's resolution of three key paradoxes led to relativity, we argue that the consistent resolution of these eight Gedankenexperiments provides compelling support for Presentist Fragmentalism as a unified framework for understanding quantum and relativistic phenomena.

**Keywords** Gedankenexperiment, Presentist Fragmentalism, Einstein's Train, Schrodinger's Cat

## 1. Introduction

Einstein's path to Special Relativity was guided by two key thought experiments: the pursuit of a light beam and the train-platform scenario with lightning strikes [1, 2]. Later, he developed General Relativity through a third crucial thought experiment involving an elevator and gravitational fields [3]. Following this tradition of using thought experiments to probe fundamental physics, we examine eight key scenarios through the lens of Presentist Fragmentalism (PF), an interpretation of quantum mechanics developed in [4] and [5].

While detailed accounts of PF can be found in [4] and [5], our focus here is on demonstrating how this framework illuminates eight fundamental thought experiments. Through these examples, we show how

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PF naturally resolves apparent paradoxes in both quantum mechanics and relativity while preserving causality and avoiding faster-than-light signaling.

Briefly, PF has three tenets. First, it adopts an A-theory of time, which incorporates both an A-series (the progression from future to present to past) and a B-series (the fixed relations of "earlier than," "simultaneous with," and "later than"). As time flows, events that were in the future become present and then move into the past via the A-series, while maintaining their B-series relationships.

Second, PF proposes that each quantum system possesses both an A-series and a B-series, forming a distinct fragment of reality. These fragments are distinguished by having independent A-series flows of time. Finally, measurement between two fragments occurs if and only if their respective A-series synchronize and merge into a single unified A-series.

The point is that when they have different A-series they do not share a ‘now’ so *there is no time at which* they can have classical properties relative to each other. When they have observed and collapsed the statefunction the have the same A-series again, they share the same ‘now’. Since they share a ‘now’ *there is a time at which* they can both have classical properties relative to each other.

## 2. Gedankenexperiments

**2.1.** The first Gedankenexperiment, or in this case scenario, is lunch and dinner. Suppose dinner tonight is 6 hours later than lunch today. With respect to our present both lunch and dinner are in our future, then (consecutively) in our present, then (consecutively) in our past. The number of hours that dinner is later than lunch does not change as it is a B-series. But the future/present/past status changes 'relative' to’ or ‘in relation to’ our present as it is an A-series.

Where does relativity come in? We will assume that lunch and dinner are in the same place, so they are time-like separated. For time-like separated events their temporal order does not change, but the 'duration' between them might change. So, depending on the (relative) motion of Bob, in his frame of reference our dinner might be 7 hours (of his hours) later than our lunch, or 8 hours later. But the fact remains that dinner is later than lunch, and, importantly, the fact remains that both are in our future, then our present, and then our past. This is also true in Bob's frame of reference. The ordering is a B-series and the changing state is an A-series.

**2.2** The second Gedankenexperiment is Alice-in-the-sun. Consider the common observation that "if the sun went out right now, we wouldn't feel it for 8 minutes.” Suppose we say, in our present, 'now' at 12:00 PM on Earth, and the sun suddenly goes out. Due to the finite speed of light, *c*, we would receive this information only at 12:08 PM. The changes in light (and gravitation) would not get out to us until 8 minutes later than ‘now’. This exemplifies the B-series notion of time, constrained by relativity.

Now consider quantum entanglement in this context. This non-local behavior is implicit in the EPR paper. If Alice is at the sun's center and measures one of an entangled pair of particles at 12:00 PM (Earth time), her choice of measurement orientation instantaneously affects the outcomes of experiments done on the other entangled particle here on Earth, despite the 8-minute light travel time (this is the content of Bell's theorem). This exemplifies A-series time.

The A-series has a 'now' or 'present moment' that extends throughout space. But this is compatible with the relativity of simultaneity because each quantum system forms a 'fragment' of reality and, crucially, does not include the information of another fragment's A-series. Thus for each fragment there is an A-series 'now' and a spacetime which encodes the information of relative simultaneity as usual. But there is no contradiction because there are not multiple 'nows' in a single fragment.

In the example above we on Earth form one fragment. Alice in the sun forms another fragment. And the (non-local) entangled pair forms another fragment. When the experiment is done, by either Alice or us, this combines the disparate A-series into one A-series, giving a single 'now' for the combined system. Before the measurement there is no time at which—no single 'now' in which—all three fragments have a definite classical state relative to each other. Thus the two-particle entangled pair does not decide, so to speak, which orientation they are in *until* actual measurement. This is what accounts for the greater-than-classical correlations that happen in quantum mechanics, in the Presentist Fragmentalist realist interpretation. This also resolves the mystery of why the whole non-local wavefunction collapses upon observation even though a particle is found to be in only one place.

The effect only shows up in a comparison of the statistics of Alice and us, in retrospect as it were, because the information of which orientation Alice had her measurement apparatus in is constrained by the speed of light exactly because that is B-series information.

**2.3.** The third Gedankenexperiment is Bob-in-Andromeda. A common scenario investigated is when we are here, on Earth, and Bob is orbiting a star in the Andromeda galaxy. It is asked what are the implications about time for Bob's events, in our frame of reference, given relativity. But this can be turned on its head. We can ask what are the implications for our time, here on Earth, in Bob's frame of reference, given relativity, and quantum mechanics.

Consider Bob orbiting a star in Andromeda. His A-series 'now' extends throughout the universe instantaneously for his fragment of reality. However, for most orientations events that are simultaneous in his relativistic frame of references are not simultaneous in our frame of reference. A consequence is that some events in our frame of reference, say, a clock reading 2:00 pm, will cycle through being earlier then, simultaneous with, and later than, a clock reading (say, 3:00 pm) in Bob's 'now' in his frame of reference. But here's the point. What does *not* happen is that as Bob orbits his star we cycle through magically being transported into our own past, our 'now', and our own future. The temporal ontologies of the A-series and the B-series are different, though can be combined into one account in fragmentalism. So no paradox arises.

This apparent paradox is resolved by recognizing that each fragment has its own A-series, and there is no fact of the matter about the synchronization between different fragments' A-series values. This allows for both instantaneous non-local quantum effects and the relativity of simultaneity.

**2.4.** The fourth Gedankenexperiment is Einstein’s Train [6]. Alice is standing on a platform of a train station. Bob is in a train that is moving relative to the station on a track that is next to and parallel with the platform. Two lightening bolts strike the beginning and end of the train at the same ‘time’ in Alice’s frame of reference. Perhaps she learned of what time the lightening struck by records written on two pieces of paper carried to her after the strikes. In Bob’s frame of reference the lightening strikes are not simultaneous. Thus, simultaneity is relative in some sense.

Yet when Alice did her experiment, it was ‘now’ for her. If we asked her what time it is as she performs her experiment (to see what time the bolts strike) she will say ‘‘now,’ obviously,’ as there is no other possible time to do it, and, further, the station clock only happens to read 12:00 noon. As I am taking the action to call my sister I am doing it ‘now’ regardless of what time of day it is. There is no other time than ‘now’ to perform the experiment. And there is no other time than one’s ‘now’ to perform *any* scientific experiment whatsoever. But notice an issue will arise when she makes the mundane observation that as she performs her measurement in her ‘now,’ there is, at that exact time, also some state Bob is in, even though he is in the moving train.

Bob’s experiment is exactly the same except he is in the (relatively) moving train, and that the outcome of his experiment is that the lightening strikes are not simultaneous. Nevertheless, just like Alice, Bob performed and had no choice but to perform his experiment in his ‘now’.

The issue that arises comes from this:

(1) ‘now’ is simultaneous with itself

The consequence is that since both Alice and Bob have ‘now’s, and they must be simultaneous with themselves, but their planes of simultaneity are different, their ‘now’s must be different.

The issue then is that when it is ‘now’ for either one of them it is ‘now’ throughout the universe. Alice’s ‘now’ spatially encompasses Bob and Bob’s ‘now’ spatially encompasses Alice. But this is exactly where quantum mechanics comes in. In Alice’s ‘now’ there is no fact of the matter as to the relative or relational time of Bob’s ‘now,’ and *vice versa*. When Alice performs her experiment in her ‘now’ there is no fact of the matter about when Bob’s ‘now’ is, even though they can calculate relative B-series information. That uncertainty in the relative states (times) of the two ‘now’s is exactly the origin of quantum mechanical behavior. For Alice in her ‘now’ the evolution of the time of Bob’s ‘now’ is stochastic. And it is ontologically stochastic because there is no fact of the relevant matter.

**2.5.** The fifth Gedankenexperiment is Einstein's Elevator [7]. Consider Alice in a uniform gravitational field on Earth. She observes objects falling with constant acceleration. In her 'now', she experiences a succession of B-series states as objects fall through fixed spacetime trajectories. The fixed earlier/later relations between these positions form B-series events that pass through her A-series present moment.

Now consider Alice in an elevator accelerating uniformly through space, far from any gravitational sources. She observes objects appearing to "fall" with the same acceleration relative to her. Just as in the gravitational case, her 'now' experiences a succession of B-series states as objects trace out their spacetime trajectories. The B-series relations between positions flow through her A-series present exactly as they did in the gravitational case.

The equivalence between these situations extends naturally to both temporal series. In each case, Alice and her local environment constitute a single fragment of reality with its own A-series, while the trajectories of objects form fixed B-series relations. The fact that objects fall identically (follow the same B-series trajectories) through her A-series 'now' in both cases demonstrates that Einstein's equivalence principle holds just as well for A-series time as it does for B-series time. This provides additional support for the compatibility of A-theory with fundamental physical principles.

This Gedankenexperiment illustrates how our theory naturally accommodates one of physics' most profound principles - the equivalence of gravity and acceleration - while preserving the essential distinction between A-series and B-series time. The identical flow of B-series states through the A-series present in both cases suggests that the equivalence principle may be even more fundamental than previously recognized, operating at the level of basic temporal structure itself.

**2.6.** The sixth Gedankenexperiment explores the Einstein-Podolsky-Rosen setup [8]. Consider two quantum particles prepared in an entangled state with zero total momentum and fixed relative position. In Alice's reference fragment, she sees the joint system in the state:

$$|\Psi\rangle = \int dx1dx2\ \psi(x1-x2)|x1\rangle|x2\rangle$$

where $\psi(x1-x2)$ enforces their fixed separation. Due to momentum conservation, measuring momentum $p$ for one particle determines momentum $-p$ for the other. Similarly, measuring position $x$ for one determines position $x \pm d$ for the other, where $d$ is their separation.

The EPR paradox emerges because Alice can seemingly determine either the position or momentum of particle 2 "without disturbing it" by measuring particle 1. This appears to give both properties simultaneous reality, contradicting quantum mechanics.

However, in A-theory, these particles form an object fragment distinct from Alice's reference fragment. This object fragment has its own A-series temporal flow independent of Alice's A-series. When Alice measures particle 1's position, her measuring apparatus's A-series merges with the object fragment's A-series specifically through a position-type interaction. This merger makes position definite for both particles in their now-shared present moment.

If Alice instead measures momentum, a different kind of merger occurs - one that makes momentum definite. But crucially, before measurement, there is no fact of the matter about whether the object fragment has definite position or momentum relative to Alice's fragment, because their A-series flows are independent. The particles exist in a state of indefinite properties relative to Alice until her measurement establishes a specific type of A-series merger.

This resolves the EPR paradox - it's not that both properties simultaneously have definite values which quantum mechanics fails to describe. Rather, the object fragment maintains its quantum properties relative to Alice's fragment until a specific type of measurement establishes an A-series merger that makes one property definite. The other property remains indefinite due to complementarity. EPR's "elements of reality" emerge through A-series mergers, not through pre-existing hidden variables.

This interpretation is non-local because the A-series ‘now’ extends throughout space. Merger affects both particles simultaneously in their shared present moment, while maintaining consistency with quantum mechanics' predictions. The key insight is that quantum correlations arise not from faster-than-light signaling, but from how fragments with independent A-series become synchronized through measurement.

**2.7.** The seventh Gedankenexperiment examines the delayed choice quantum eraser [9]. Consider a photon passing through a double-slit apparatus followed by a crystal that produces an entangled pair through parametric down-conversion. The signal photon travels a shorter path to detector D0, while its entangled partner (the idler photon) travels a longer path through beamsplitters to detectors D1-D4. The idler photon's path length ensures it reaches its detectors after the signal photon hits D0. When the data is later analyzed, signal photons whose partners hit D3 or D4 (erasing which-path information) show interference patterns, while those whose partners hit D1 or D2 (preserving which-path information) do not.

The apparent paradox is that the signal photon's behavior at D0 seems to depend on a future measurement of the idler photon. However, in A-theory, this dissolves naturally. The initial photon forms an object fragment with its own A-series. When it interacts with the crystal, the resulting entangled pair maintains a single unified object fragment with a shared A-series independent of the laboratory reference fragment.

At any moment in the laboratory's A-series, let the state be:

$|\Psi\rangle = (|s1\rangle|i1\rangle + |s2\rangle|i2\rangle)/\sqrt{2}$

where $|s1,2\rangle$ represent signal photon paths and $|i1,2\rangle$ represent corresponding idler paths. When the signal photon reaches D0, this begins but does not complete an A-series merger between the detector and photon fragments. The merger's nature - whether it preserves or erases path information - depends on how the idler photon's measurement completes the process.

For D1/D2 measurements, the completed merger preserves which-path information:

$|\Psi\rangle \rightarrow |s1\rangle|i1\rangle$ or $|s2\rangle|i2\rangle$

For D3/D4 measurements, the completed merger puts the signal photon in a superposition:

$|\Psi\rangle \rightarrow (|s1\rangle \pm |s2\rangle)|i\pm\rangle$

The key insight is that there is no backwards causation. Rather, the signal photon's quantum properties relative to D0 remain indeterminate until both parts of the measurement complete the A-series merger. The interference pattern emerges from how the fragments' A-series ultimately synchronize, not from future measurements affecting the past.

This provides an explanation that preserves causality while accounting for the observed correlations. The delayed choice quantum eraser demonstrates how quantum behavior arises from the interplay between A-series and B-series time - with B-series governing the fixed spatiotemporal relationships between measurements, which are generally local, while A-series mergers determine their outcomes, which can be non-local.

## 2.8. Schrodinger’s Cat [10]

Alice and the cat share one A-series before the beginning of the experiment, have two different A-series during the experiment, and share one A-series again after Alice opens the box. QED.

More precisely, in the A-theory Alice’s time is given by a pair $T_1 = (\tau_1, t_1)$ where $\tau_1$ is the A-series and $t_1$ is the B-series. There is a corresponding pair for the cat $T_2 = (\tau_2, t_2)$. Before measurement, according to Alice, her A-series $\tau_1$ has a definite value (or range of values) and it is consistent with such for $\tau_2$. The point is then that, during the experiment, according to Alice, there is no fact of the matter about the value(s) of $\tau_2$. Since Alice and the cat do not share a ‘now’ there is *no time at which* there is a fact of the matter about their respective values. So until $\tau_1 = \tau_2$ the cat is (‘is’ in the sense of the A-series) literally not ‘alive’ and literally not ‘dead’ in Alice’s fragment. When she opens the box and $\tau_1 = \tau_2$, they have the same A-series again, they share the same ‘now’, so *there is a time at which* they can both have classical properties. And *vice versa*.

## 3. Conclusion

We have shown how Presentist Fragmentalism systematically resolves eight fundamental Gedankenexperiments spanning both relativistic and quantum phenomena. Just as Einstein's resolution of three thought experiments - chasing a light beam, the train-platform scenario, and the elevator experiment - led to relativity theory, our resolution of eight key paradoxes suggests Presentist Fragmentalism captures fundamental features of physical reality.

The power of this approach lies in its consistency. Each resolution emerges naturally from the same core principles: the distinction between B-series relations (governing fixed spatiotemporal relationships between events, modified by relativity) and A-series "now" moments that can merge through measurement interactions. From simple temporal relations to delayed choice quantum erasure, the same mechanism resolves each paradox without additional assumptions.

Most significantly, this interpretation accomplishes what has long been sought in physics - a natural accommodation of both relativistic frame-dependence and quantum non-locality. By distinguishing between B-series relations (which respect relativistic locality) and A-series synchronization (which allows quantum correlations), Presentist Fragmentalism offers a promising path toward reconciling quantum mechanics with relativity. The fact that it does so while resolving eight historic paradoxes suggests we may have uncovered not just an interpretation, but a deeper understanding of the temporal structure underlying physical reality.

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