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Reevaluating Relativistic Length Contraction Via Thought Experiments

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ABSTRACT

Special Relativity (SR) incorporates the concept of length contraction as a coordinate-dependent and symmetrical effect. According to SR, two observers in relative motion, each equipped with identical measuring rods, can both validly assert that the other's rod appears contracted. This paper challenges the *physical* interpretation of this principle by presenting a series of simplified thought experiments. These experiments reveal contradictions within SR, suggesting that the theory predicts two fundamentally different types of length contraction when applied to real-world scenarios. The results call for a critical reassessment of the role of length contraction in SR and invite further exploration of its theoretical consistency and implications for modern physics.

Keywords: special relativity, length contraction, symmetry

INTRODUCTION

The concept of physical length contraction was introduced by FitzGerald (1889) and H. A. Lorentz (1892) to account for the null result of the Michelson–Morley experiment and to preserve the hypothesis of a stationary ether. In contrast, Albert Einstein did not interpret this contraction as a physical deformation, but rather as a coordinate-dependent effect.

In Special Relativity (SR), length contraction refers to the reduction in the measured length of an object relative to its proper length when observed from a reference frame moving with respect to the object. According to SR, a moving object's length appears shorter than its proper length the length measured in the object's rest frame. For an observer in relative motion, the length is determined by simultaneously measuring the positions of the object's front and rear ends. The principle of relativity states that the laws of physics are the same in all inertial frames of reference. Consequently, SR demands that length contraction be a symmetrical phenomenon: each observer perceives the other's measuring rod as contracted, despite identical proper lengths.

Since the publication of Special Relativity in 1905, there has been ongoing debate among physicists regarding certain aspects of length contraction. Notably, in 1909, Paul Ehrenfest published a note in *Physikalische Zeitschrift* (Ehrenfest, 1909; Wilhelm, 1990), arguing that a Born-rigid cylinder could not be set into rotation without generating internal stresses due to relativistic effects. This sparked intense discussions, including contributions by Einstein himself.

After the year 2000, the topic has continued to attract attention, resulting in numerous papers such as *Einstein's Uniformly Rotating Disk and the Hole Argument* (Weinstein, 2015), and *Appearance and Reality: Einstein and the Early Debate on the Reality of Length Contraction* (Giovanelli, 2023).

In my view, many of these discussions rely on unnecessarily complex thought experiments particularly those involving rotating cylinders or disks where the predicted effects of SR and General Relativity (GR) are difficult to calculate due to the variation in contraction at different radii and the absence of radial contraction.

This inevitably leads to internal stresses in the rotating body. In contrast, my thought experiments begin from scenarios that are as simple and straightforward as possible. The objective is to make it easier to reach consensus on whether a given setup reveals serious conceptual issues in SR.

In several papers, I have argued that relativistic length contraction is not consistently applied. One such example appears in *Fundamental Inconsistencies in the Theory of Relativity* (Jensen, 2022), and is presented as follows: "Let's imagine that we conduct the following experiment: In an inertial frame, IF-1, we have two transparent tubes, as shown in the illustration below.

At the beginning of the experiment, both tubes are completely filled with identical measuring rods, all at rest relative to their respective tubes. Then, the rods in tube 2 are accelerated to a relative speed of approximately 260,000 km/s, such that the Lorentz factor γ equals 2."

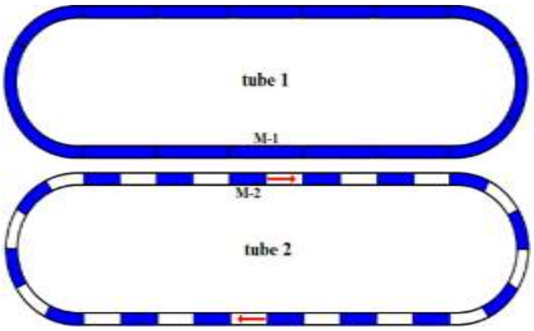

Fig. 1 Two closed tubes with measuring rods.

We assume that the rest lengths of the "moving" rods are preserved throughout the experiment. According to the theory of relativity, these rods will appear shorter when measured in the inertial frame IF-1.

Since the physical length of tube 2 remains unchanged in this frame, it is inevitable that gaps will appear between the rods inside tube 2. At the given relative speed where the Lorentz factor is 2 these gaps will be approximately the same size as the rods themselves. This implies that the rods have undergone physical contraction, not merely a coordinate effect.

From this, we may deduce that Special Relativity must predict physical contraction of all bodies and particles when they are transferred from one inertial frame to another, assuming their rest lengths remain constant.

As illustrated, one of the rods in tube 1 is labeled M-1, and one in tube 2 is labeled M-2.

In the situation shown, M-2 is at rest relative to a different inertial frame, which we refer to as IF-2. Now, if we compare the length of M-2 as measured in IF-1 to the length of M-1 as measured in IF-2, SR tells us this is a "symmetrical situation" according to the principle of relativity.

An observer in IF-1 would measure M-2 to be shorter than M-1, while an observer in IF-2 would measure M-1 to be shorter than M-2. (We assume both observers make their measurements while M-2 is located within a straight segment of tube 2.).

However, this leads to a critical question: How can the situation be symmetrical when M-2 has clearly undergone physical contraction? For example, if there is room for *x* rods of the same physical length as M-1 arranged sequentially between the Earth and the Moon, then there must be space for *2x* rods of the same physical length as the moving M-2, according to SR. In this view, M-2 is contracted relative to *space*, whereas M-1 is only *coordinate-dependently* contracted along with space. But can we be absolutely certain that M-2 is physically shorter than M-1, as predicted by SR in the situation illustrated? Can this be demonstrated convincingly?

Yes, it can be shown using the following thought experiment, adapted in part from the paper *Questions Concerning the Foundation of the Theory of Relativity* (Jensen, 2018): "Imagine two identical ring-shaped tubes, A and B, each with a total length of approximately 1000 meters. Both are initially at rest relative to an inertial frame, IF-1. The rings, which are perfectly circular, are composed of one-meter segments that effectively function as measuring rods. We select one segment from each ring A1 and B1 for comparison under different conditions."

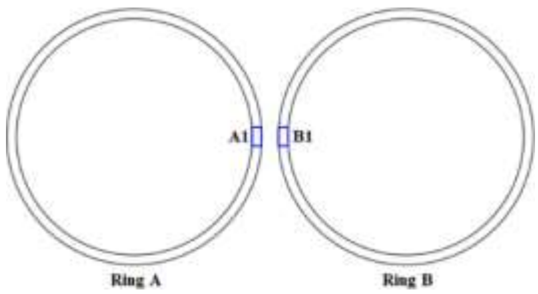

Fig. 2 Rings A and B, with segments A1 and B1.

Next, we set ring B into rotation in such a way that the *proper lengths* of its individual segments are preserved (**Fig. 3**). According to the predictions of Special and General Relativity, the ring's material will undergo contraction in the direction of motion. As a result, ring B will become physically smaller than ring A.

At sufficiently high rotational speeds, it is theoretically possible for ring B to fit entirely within the central hole of ring A.

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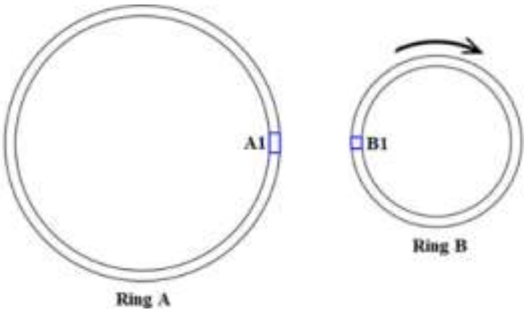

Fig. 3 Ring B in rotation, becoming physically smaller than ring A.

This provides clear evidence that ring B has become physically smaller, and that the circular tube forming the ring has also become physically shorter. However, the argument can be made even stronger. At an even higher rotational speed, ring B may shrink to the point that it fits entirely within the measuring rod A1 itself, as shown in **Fig. 4**. Naturally, this would require that the tube used for ring B is significantly thinner than that of ring A. Still, this physical difference in thickness does not affect the central question: Are A1 and B1 physically equal in length or not? In other words, does the symmetry required by the special principle of relativity actually hold under these conditions?

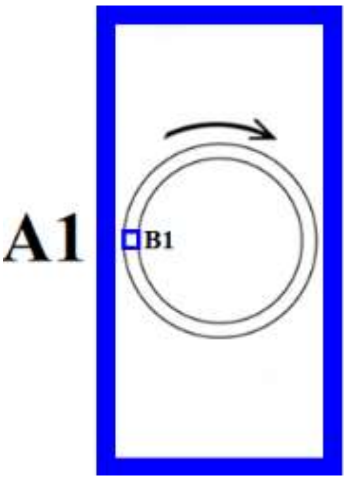

Fig. 4 Ring B enclosed within segment A1

An observer at rest relative to segment A1 can justifiably claim that B1 is shorter than A1 in the configuration shown. However, an observer at rest relative to B1 cannot validly assert that A1 is shorter than B1. This is physically impossible in a situation where B1 is completely enclosed within the A1 measuring rod.

It is important to emphasize that I am not arguing that relativistic length contraction is mathematically inconsistent only that it is physically inconsistent. The mathematical formalism of Special Relativity does not differentiate between coordinate-dependent and physically real contractions when rest lengths are preserved. However, because this mathematics is used to predict physical scenarios (which, in principle, are testable under SR), it becomes essential to distinguish between these two types of contraction.

Failure to do so inevitably leads to inconsistent physical predictions, and undermines the symmetry that the principle of relativity requires, as I have illustrated.

That the shortening of B1 is not due to acceleration is clear from analyzing the scenario shown in Figure 1, where the rods are physically contracted regardless of whether they are located in a curved or straight section of the system. These effects are entirely determined by the relative speed, not the acceleration process.

In support of the claim that some contractions must be physical, I presented an alternative argument in *Questions Concerning the Foundation of the Theory of Relativity* (Jensen, 2018). Consider the following thought experiment:

"Imagine a train that is 4.4 × 10^{29} kilometers long, stationary alongside a perfectly straight railway platform, both at rest in an inertial frame. The train and the platform have precisely the same length, such that the ends of the train align exactly with the ends of the platform. Now, all parts of the train are simultaneously accelerated (as measured in the 'rail frame') to a constant speed of 10 km/h. Let's suppose the train travels 2 meters before reaching this velocity. Since all sections of the train have moved equally far in the same direction (in the rail frame), its overall length, measured in that frame, remains unchanged."

However, under SR, the rest length of the train L_0 has increased, according to the Lorentz contraction formula $L = L_0/\gamma$. Based on my calculation, the new rest length of the train would be approximately 1.9×10^{13} kilometers longer roughly equivalent to two light-years.

The rest length of the train could be restored i.e., brought back to its original value if the train were shortened by approximately 1.9×10^{13} kilometers, as measured in the rail frame. However, this would require a significant period of time: at least one year in the rail frame, even if the two ends of the train were moved toward the center at nearly the speed of light, following extremely brief but intense bursts of acceleration (which I refer to as contraction-accelerations).

Alternatively, this process could occur much more rapidly if the train were instead composed of short, uncoupled, self-propelled railcars (e.g., 10 meters in length). In that case, only relatively weak and short-lived contraction-accelerations would be needed to produce the same overall contraction effect.

Assuming that there are no gaps between the wagons before the acceleration, then if their rest lengths are preserved gaps must necessarily emerge after the acceleration. Even though these gaps would be very small for a modest speed increase (from 0 to 10 km/h), they must exist because the length of each wagon, as measured in the rail frame, becomes shorter than in its rest frame, in accordance with Special Relativity. The total sum of these gaps directly reflects how much the entire train has become physically contracted.

Without such gaps, there could be no contraction of the wagons (as measured in the rail frame) if the front and rear railcars moved equally far, in the same direction, under the assumption that the lengths of all railcars remain identical throughout.

Therefore, this setup demonstrates that the contraction of the wagons is a physical effect when it results from the actual acceleration of material objects between inertial frames. By contrast, if the contraction were solely due to the acceleration of an observer (from 0 to 10 km/h relative to the stationary wagons and the rail frame), then no gaps would appear. This clearly illustrates a fundamental difference between physical contraction and coordinate (observer-dependent) contraction.

Furthermore, there is an important distinction in speed limits: coordinate-dependent contraction is not constrained by the vacuum speed of light. The moment an observer enters a new inertial frame, a given measuring rod is assigned the length that would be measured in that frame, according to SR. However, the minimum time required for an object to undergo *physical* contraction depends on the maximum speed at which physical changes (e.g., molecular or atomic rearrangements) can occur bounded by the speed of light.

This distinction becomes especially significant for extremely long objects, which are theoretically possible. According to SR, if an object is accelerated into a new inertial frame and its rest length is preserved, then it must necessarily be physically contracted even if it is completely non-accelerating both before and after the transition, relative to its local inertial frames.

Thus, we find a compelling case where an object's proper length does not determine how much space it occupies physically. Instead, its space-filling capacity becomes dependent on its speed. For instance, if the Sun were accelerated to an inertial frame moving sufficiently fast relative to the Earth, then according to SR it would occupy less physical space in the universe than the Earth.

An extension of the previous thought experiment further highlights this idea: Suppose the continuous (non-segmented) train had its natural length (based on its physical properties at a given temperature) before being accelerated to 10 km/h. After the acceleration, this would no longer be the case. To regain its natural length, nearly all parts of the train would need to accelerate physically that is, relative to the local inertial frames. The inertial forces generated during this adjustment would, in principle, be measurable.

Now, imagine that there is no friction at all: under such idealized conditions, the train would naturally become shorter and shorter until it returned to its natural length. This behavior would be governed by molecular and atomic forces, showing that such a contraction is fundamentally different from one caused solely by an observer changing inertial frames.

DISCUSSION

Some may defend Special Relativity (SR) as follows: Suppose two observers, A and B, each possess an identical measuring rod. Initially, they are at rest with respect to one another within a shared inertial frame. Upon precise measurement, it is confirmed that both rods are exactly the same length. Subsequently, observer B and his measuring rod are accelerated into another inertial frame. Afterward, observer A measures B's rod and finds that it appears contracted. Likewise, observer B measures A’s rod and observes an identical degree of contraction.

They both agree on the extent of each other's measured contraction. In this view, the effects are completely symmetrical so what, then, is the issue?

The problem is that this symmetry is only apparent, not physical. What is overlooked in such reasoning is that the rod which underwent acceleration must have experienced physical contraction, provided its rest length remains constant as I have demonstrated throughout this paper. This contraction must be treated as a real physical effect, comparable to physically removing a portion of the rod. There would be space for more rods of the same physical length within the same region of space (e.g., within the solar system or the universe).

Another possible objection to my argument is the claim that the mathematics of SR is completely consistent, and therefore relativistic length contraction must also be consistent.

In my own long-term study of SR, which began in 1982, I have not found any mathematical inconsistencies in the formalism of the theory but this is under the assumption that no distinction is made between coordinate-dependent and physically real length (or time) contractions. As I argued in *Fundamental Inconsistencies in the Theory of Relativity* (Jensen, 2022), the time dilation effect in SR suffers from a similar issue.

For example, if a clock is accelerated from one inertial frame to another while preserving its rest length then, from the SR perspective, the clock becomes physically deformed and also ticks more slowly than before.

This contradicts the principle of relativity, which asserts that no inertial frame is privileged and that the same physical laws apply in all such frames. It is worth mentioning that many years ago I concluded that Lorentz ether theory aligns more closely with physical reality than Special Relativity, despite the fact that both theories are often said to predict identical experimental outcomes(Goldberg, 1984).

However, I (Jensen, 2023), along with several other physicists such as (Atkins, 1980), (Winterberg, 1986), and (Sherwin, 1987) have argued that there are exceptions. In fact, it is entirely plausible that future physical experiments will be capable of distinguishing between the two theories. If relativistic length contraction is better explained by Lorentz’s framework, then this effect should eventually be demonstrable through real-world observation and measurement.

CONCLUSION

Relativistic length contraction, as presented in Special Relativity, is not physically consistent. This predicted effect is a direct consequence of Einstein's assertion that simultaneity is relative that different inertial frames yield different results when measuring simultaneous events. This, in turn, stems from the assumption that the speed of light is constant and isotropic in all inertial frames.

Based on the arguments presented throughout this paper, I conclude that it is highly probable the speed of light is **not** truly constant in the way Einstein proposed. If this conclusion can be independently confirmed by experts, it would provide strong justification for a critical re-evaluation of the foundations of Special Relativity. I have previously presented additional arguments challenging the constancy of the speed of light (Jensen, 2022, 2024).

While Einstein maintained that the Michelson–Morley experiment and similar tests supported the constancy of light speed, I believe there are compelling reasons to suspect that natural laws may have so far prevented scientists from accurately measuring the one-way speed of light. Further arguments against relativistic length contraction can be found in my paper *Thought Experiments that Critically Explore the Theory of Relativity* (Jensen, 2024). See also *Note on Lorentz Contractions and the Space Geometry of the Rotating Disc* (Kraus, 1970), which offers additional perspectives on the geometry and physical interpretation of relativistic effects.

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