SRYAHWA PUBLICATIONS

Open Access Journal of Physics
ISSN: 2637-5826 | Volume 7, Issue 2, 2025
https://doi.org/10.22259/2637-5826.0702003

RESEARCH ARTICLE

A Logical Critique of Length Contraction in Special Relativity

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Received: 24 July 2025 Accepted: 8 August 2025 Published: 12 August 2025

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Abstract

This article presents a logical critique of the concept of length contraction within the framework of Special Relativity. Through a simple thought experiment involving a bus and two moving observers, we highlight the logical tension between the objective length of a physical object and the observer-dependent lengths predicted by the Lorentz transformation. The analysis raises fundamental questions regarding the nature of reality and the interpretation of relativistic effects.

1. Introduction

Length contraction is one of the cornerstone predictions of Special Relativity (SR). According to SR, the length of an object moving relative to an observer is contracted along the direction of motion. In this article, we present a thought experiment (gedankenexperiment) to highlight a logical inconsistency in Special Relativity.

This article focuses on the logical coherence of Special Relativity rather than its empirical predictions.

The magnitude of this contraction is governed by the Lorentz factor.

$$\gamma(v) = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} \tag{1}$$

The contracted length L is given by

$$L = L_0/\gamma(v) \tag{2}$$

where L_0 is the proper length (the length in the object's rest frame).

2. The Thought Experiment

Consider a bus at rest at a bus stop. The proper length of the bus is.

$$L_0 = 10 \text{ m} \tag{3}$$

Two cars drive past the bus at different velocities, v_1 and v_2, relative to the bus. The velocities are

$$v_1 = 100,000 \text{ km/s} \tag{4}$$

$$v_2 = 200,000 \text{ km/s} \tag{5}$$

Each observer (each car) calculates the length of the bus using equation (2). The results are

$$L_1 = 9.43 \text{ m} \tag{6}$$

$$L_2 = 7.45 \text{ m} \tag{7}$$

This leads to a logical contradiction: the same physical object is attributed three different lengths — 10 m, 9.43 m, and 7.45 m — depending on the observer.

3. Logical Analysis and Critique

The core issue presented by this thought experiment is the logical conflict between objective reality and observer-dependent phenomena. The bus exists as a physical object with a proper length of 10 m, yet Special Relativity assigns it different lengths depending on the relative velocity of observers.

This brings into focus a central question: can a single object have multiple, simultaneously valid lengths? If length is a property of the object itself, then allowing it to change with observation implies that length is not an intrinsic property but rather a relational one. This undermines the classical notion of objective physical reality.

Citation: Jan Slowak. A Logical Critique of Length Contraction in Special Relativity. Open Access Journal of Physics. 2025; 7(2): 10-11.

A single object cannot possess multiple, simultaneously valid lengths in a logically consistent physical theroy.

4. Discussion

The interpretation of length contraction is often debated within the physics community. There are two primary viewpoints:

1. **Physical Effect:** Length contraction represents a real physical shortening of objects due to motion.
2. **Coordinate Effect:** Length contraction is merely a consequence of using different coordinate systems and does not reflect any physical change.

Some proponents of Special Relativity might argue that length contraction is a coordinate effect rather than a physical property. However, this interpretation does not resolve the logical contradiction highlighted in the thought experiment, as it leaves the objective physical properties of the object ambiguous.

In either case, the logical tension remains the bus either physically changes length depending on who observes it, or the concept of ”length” becomes entirely dependent on the choice of coordinate system, leaving the objective physical properties of the bus ambiguous.

This article’s thought experiment highlights that Special Relativity’s handling of length conflicts with the logical principle of identity — a single object should have a single length at any given moment in time.

5. Conclusion

Through this simple example, we have shown that Special Relativity’s length contraction leads to a logical contradiction when interpreted as a physical property of objects. Either length ceases to be a fundamental property of physical reality, or the theory requires re-examination to reconcile these contradictions.

The analysis presented here complements previous critiques of Special Relativity, including the author’s prior works [1, 2, 3], and invites further discussion on the logical foundations of modern physics.

Future research could explore alternative formulations of space and time that avoid such contradictions, possibly by re-examining the foundational assumptions of Special Relativity.

6. References

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