Einstein's Principle of Relativity

and

Cosmic-Ray Muon Decay

Stephan J. G. Gift

Department of Electrical and Computer Engineering
Faculty of Engineering
The University of the West Indies
St. Augustine, Trinidad, West Indies
Email: Stephan.Gift@sta.uwi.edu

Abstract. This paper shows that the famous cosmic-ray muon time dilation experiment of B. Rossi and D.B. Hall contains an inertial frame asymmetry that is inconsistent with Einstein's Principle of Relativity.

Keywords: special theory of relativity, Einstein's Principle of Relativity, muons, light speed invariance postulate.

1. Introduction

The principle underpinning Special Relativity is Einstein's Principle of Relativity [Ref.1p25]: The laws of nature are in concordance for all inertial systems. Rindler [Ref.2,p7] referred to Einstein as advancing "his famous *relativity principle*" that "all inertial frames are totally equivalent for the performance of all physical experiments." Rindler [Ref.2p23] pointed out that this principle requires "perfect symmetry between inertial frames" thereby emphasizing the reciprocal nature of the theory. This must be so if inertial frames are to be indistinguishable.

Elaborating elsewhere (p41)on this he said, "By the relativity principle, it is a priori evident that if two observers A and B compare yardsticks along their common line of motion, and if A considers B's stick to be shorter than his own, then B considers A's stick to be shorter. Further (p43), "Time dilation like length contraction, must a priori be symmetric: if one inertial observer considers the clocks of a second inertial observer to run slow, the second must also consider the clocks of the first to run slow." An example of this symmetry is the source-observer reciprocity present in the relativistic Doppler formula for an observed frequency f' given by

$$f' = f\sqrt{\frac{1-v/c}{1+v/c}} \tag{1}$$

for the case of a light source and an observer moving apart at relative speed ***v***. This result is dependent only on relative velocity and is unaffected by whether the source or observer is "fixed" or "moving".[1] This requirement of "perfect symmetry" therefore places extreme demands on the theory and has resulted in several "paradoxes" which sometimes require bizarre methods of resolution. Kaku has presented a most extraordinary example of this in his tiger-in-the cage example [Ref.3p81].

There have not been many direct tests of the relativity principle [4], particularly its symmetry requirements and this has been a long-standing criticism of the theory. Because of its critical importance to special relativity, we explore a test of this key principle. We do so by considering the decay of muons generated in the upper atmosphere as they travel to earth. This well-known experiment is one of the main grounds for the claim of time dilation in special relativity and it is widely reported in the scientific literature. We subject this experiment to the stringent demands of the principle of relativity i.e. the requirement of perfect symmetry between inertial frames.

2. The Relativity Principle and Muon Decay

Consider the classic time dilation experiment performed by B. Rossi and D.B. Hall and described in French [Ref.5p102-105]. Cosmic rays entering the earth's atmosphere from outer space produce muons, many of which travel downward through the earth's atmosphere at speeds close to ***c***. Muons are unstable and decay into electrons. At an altitude of 2000m, counting apparatus recorded the arrival on average of 563 muons per hour. Travelling at the speed approximately equal to that of light, these muons take approximately $\tau = 6.5\mu\text{sec}$ to reach sea level from this altitude. The expected arrival rate based on laboratory decay rates was 25 muons per hour. An actual sea level measurement recorded an arrival rate of 400 muons per hour, which corresponds to elapsed time of only $\tau_o = 0.7\mu\text{sec}$. The interpretation of this result is that the time in the frame of the travelling muons has slowed down in accordance with the special theory of relativity thereby resulting in fewer muon decays. According to French, the time dilation factor is $\tau / \tau_o = 9$ where τ is the elapsed time in the "fixed" frame and τ_o is the elapsed time in the "moving" frame and since from special relativity

$$\tau_o = \tau\sqrt{1 - \frac{v^2}{c^2}} \qquad (2)$$

this results in

$$1 - \frac{v^2}{c^2} = (\frac{\tau_o}{\tau})^2 \approx \frac{1}{81} \qquad (3)$$

which gives $v/c \approx 0.994$. This analysis was done from the perspective of the "fixed" inertial frame at sea level and the result is interpreted as time in the "moving" inertial frame of the muon slowing down.

French considered what in the context of the relativity principle is an equivalent situation i.e. the situation according to which measurements are taken in an inertial frame that moves with the muon. In this frame the muons are decaying at rest and it is the earth, which is moving at almost the speed ***c*** to meet the muons. Says French, "if frames in uniform relative motion are equivalent, the decay data for muons at rest in the laboratory must be applicable to muons at rest in our new frame. But we cannot change the result of the experiment, which is that about 75% (rather than 5%) of the [muons] survive the journey from the mountaintop to sea level. How is this apparent inconsistency resolved? The answer is that, from the point of view of the moving [muons], the distance between mountaintop and sea level is strongly contracted" and this is the manner in which French and others resolve "this apparent inconsistency". With the shorter distance, the muons in the new frame travel for a shorter time and therefore about 75% rather than just 5% survive the journey in the new frame.

However, the relativity principle demands "perfect symmetry between inertial frames". This symmetry is an essential requirement in special relativity since otherwise inertial frames would be distinguishable, contrary to the relativity principle. Therefore not only must the decay data for muons at rest in the laboratory be applicable to muons at rest in our new frame as French points out, but in applying the data the operative conditions in both frames must be the same. As a result there can be no appeal to length contraction in the new frame since none was invoked in the laboratory frame. Thus, there is no basis in the theory for invoking distance shortening as done by French. This application of distance shortening to one frame and not the other enables the two inertial frames to be distinguished from each other, contrary to the requirements of the relativity principle. Distance shortening in the new frame only is thus an illegitimate step that is employed solely to realize the observed 75% rather than the much smaller 5% muon survival rate that would otherwise be obtained. Since length contraction applied only to the new frame violates the relativity principle, it must be excluded and therefore the inconsistency in the data remains i.e. according to special relativity in the new frame only 5% and not 75% of the muons will survive the journey to earth. Since 75% is what is actually observed, this inconsistency invalidates the theory.

Even if French's asymmetrical length-shortening procedure were allowed thereby enabling special relativity to correctly predict the result of the muon experiment from the perspective of both frames, violation of the relativity principle still occurs. This violation results from the asymmetry inherit in the single experimental result which is that starting with 563 muons, a laboratory observer records 400 muons coming from the upper atmosphere and only 25 muons for muons at rest in the laboratory frame, while an observer in the new frame records does not record 400 muons coming from the laboratory and only 25 muons for muons at rest in the new frame. The muon decay result, like stellar aberration [6-8] and unlike the relativistic Doppler formula (1), is asymmetrical and this asymmetry allows the two inertial frames to be distinguishable thereby violating the relativity principle which demands the equivalence of all inertial frames. The relativity principle is therefore falsified.

This falsification of the relativity principle means that special relativity is invalid and this is evident from the following incorrect prediction of the theory: The relativistic velocity composition formula of special relativity predicts a constant light speed c in all inertial frames while Gift has demonstrated light speed variation relative to a moving observer in the Roemer and Doppler experiments [9, 10].

3. Conclusion

In this paper we have pointed out that the results of the famous muon decay experiment conducted by B. Rossi and D.B. Hall in 1941 are asymmetrical and therefore contradict Einstein's principle of relativity. Moreover the attempt by French and others to accommodate this asymmetry within special relativity by a length-shortening procedure applied to one inertial frame only is illegitimate as it too violates the relativity principle. This principle requires perfect symmetry between inertial frames if one frame is not to be distinguishable from the other. This condition has given rise to several "paradoxes" in special relativity requiring convoluted and unconvincing explanations. Apart from the tiger-in-the-cage case discussed by Kaku [3], other examples have been described by Rindler [2]. It is now clear that these "paradoxes" are indications that special relativity is flawed. Fortunately, a semi-classical replacement theory in which none of these "paradoxes" occur is available [11-12].

Endnote

1. I have recently shown that even the symmetry of the relativistic Doppler formula breaks down under close examination [13].

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