The Problem of Faster-than-Light Speeds

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Abstract

If we allow that 'particles' of some exotic nature are capable of traveling at speeds greater than the speed of light (a superluminal frame), we arrive at the conclusion that such a particle would be judged to be moving backward in time with respect to some ordinary reference frame (a subluminal frame). We will prove this result by constructing a frame in which it's true. Some knowledge of special relativistic kinematics and Minkowski (spacetime) diagrams would be useful. What the reader won't need for this discussion is the Lorentz transformation (at least not explicitly).

1 The setup

When we create these fanciful thought experiments in special relativity, we must accept that these imagined situations are needed to 'measure' times and distances according to various reference frames, yet, they could probably never be performed in real life. For example, we imagine abstractions in which ordinary wind-up clocks (say) can move at high (constant) speeds in straight lines, which we refer to as 'inertial motion'. And that the clock times can be 'read off' by moving observers when they are 'close to the clock event'.

We begin by drawing a Minkowski (spacetime) diagram for a 'rest frame' that we, the readers, will inhabit, as in Fig. 1 below. In this frame, we'll establish the light cones (rays) and take it from there.

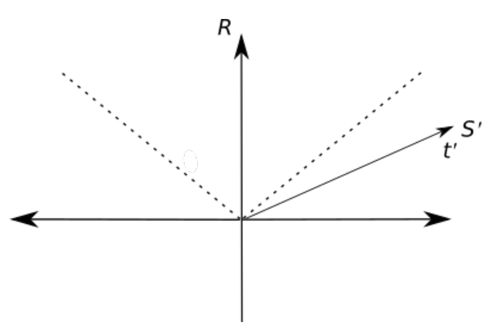

Figure 1. The frame labeled R is the rest frame. The dashed lines represent the paths of light beams. The primed frame is superluminal. The frames are labeled on their time axes.

The 'rest frame' R is our frame. In this frame, we first construct the light cone and then we construct two other frames for the analysis of superluminal (faster-than-light speed) motion, specifically, as it affects moving clocks.

S' in Fig. 1 is the time axis of the superluminal frame. For this analysis to make any sense at all, we must assume that a clock at rest in the S' frame will progress to an observer at rest with respect to that clock to be advancing in the 'positive direction', meaning that the clock appears to move 'forward in time'. It would make no sense at all to be sitting at rest to a clock in your own frame that 'runs backwards'.

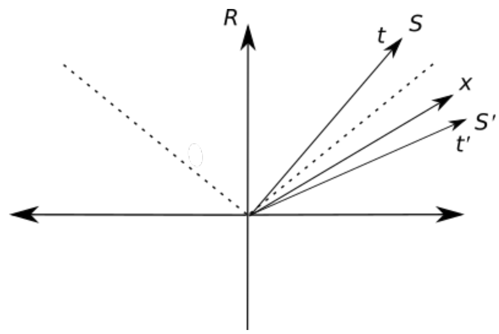

Figure 2. The unprimed frame is constructed so that its x' axis is between the S' time axis and the light cone. Now that we have that, we can put in the unprimed time axis.

Fig. 2 shows the construction of the unprimed frame. Its time and space axes have to be constructed so that they make the same angle (in absolute value) to the light ray (dashed line).

In special relativity, the spatial axis has the same time as the clock time at the point where it intersects the time line. In other words, the spacial axis is a 'line of simultaneity' ' in a given inertial frame. How does this happen? It's part of the procedure of making clocks at rest in one's frame synchronized.

2 The payoff

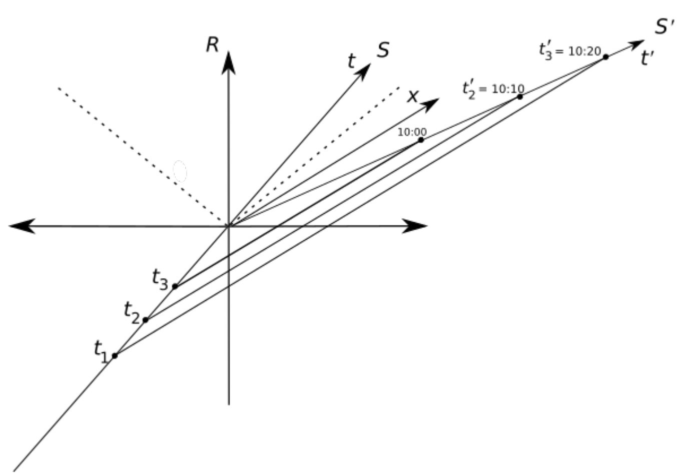

Figure 3. In both the primed and unprimed frames time advances 'in the positive direction' by design. Thus, in the unprimed frame, $t_1 < t_2 < t_3$. And in the primed frame, $t'_1 < t'_2 < t'_3$, which I have arbitrarily assigned the values, respectively, as 10:00, 10:10, and 10:20.

After some careful analysis of Fig. 3, we see that the observer in the unprimed frame will record the primed clock time at his time t_1 as 10:20 (in the primed frame), and at his time t_2 as 10:10 (in the primed frame), and at his time t_3 as 10:00 (in the primed frame). In other words, as the clock time in the unprimed system advances, the corresponding clock times in the primed system appear to be running backwards as viewed by the unprimed observer.

Okay, one could object that this odd result is an effect of the method by which one has synchronized clocks in one's frame, particularly in the unprimed frame. To this I would reply, Correct. But my counter to this objection is simply this, What else are we to do? The clocks distributed in one's physical space have to be synchronized somehow, because they aren't going to spontaneously synchronize themselves.

3 Conclusion

Is the natural process of superluminal motion possible? I don't know. Maybe time is nonexistent for superluminal particles, in which case our analysis above falls apart. And even if the assumptions we've made in this paper are valid, and even if we assume that the assumptions we've made in this paper to analyze superluminal motion makes superluminal particles appear to go backwards in time, can we live with that in an extended form of special relativity? I don't know.

4 Afterthoughts

After completing this paper, I checked on the Internet for some analysis similar to what I had done with tachyons in spacetime diagrams, but I did not find anything. However, I did find one attempt to demonstrate that time goes backward for a tachyon by the tachyon communicating with a subluminal inertial frame. I didn't bother to look at the details. I don't see anything wrong with that approach accept that it assumes a bit more structure to the tachyon than merely carrying around some notion of a clock in its rest frame, which is all I needed for the analysis in this paper.