DISTANCE AND THE CONVENTIONALITY OF SIMULTANEITY IN SPECIAL RELATIVITY

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The conventionality of simultaneity within inertial frames is presented in a general formalism that clarifies the relationship of spatial measures to the choice of simultaneity. A number of claims that such measures undermine the conventional nature of simultaneity are presented and shown to be unfounded. In particular, a recent claim by Coleman and Korte [9] that such measures empirically establish a unique simultaneity relationship is shown to be in error. In addition, the general formalism enables the empirical status of simultaneity within an inertial frame to be clarified by presenting the choice of simultaneity as a gauge choice.

Key words: special relativity, conventionality, gauge transformation.

1. INTRODUCTION

The precise status of the simultaneity relation within a given inertial frame remains a disputed issue within recent writings on the foundations of spacetime theories. In the position developed by Reichenbach [36, 37], Grünbaum [16-19], and others, the relation is taken to be conventional, and moreover, associated with a conventionality in the speed of light in a given direction. The basis for the
position is the absence of any means of instantaneous communication in the special theory of relativity (STR) and the special nature of light as a "first signal." In order to synchronize spatially separated clocks, signals must be sent between them and the time of passage of such signals must be known. A maximum specification will only arise through the use of light signals by virtue of their property of being first signals. But we are caught in a circle here, as the time of passage for first signals can only be obtained by prior knowledge of the synchronization of clocks. The essence of the "conventionalist" position is that this circularity is inescapable and that no fact of nature permits a unique determination of either the simultaneity relation within an inertial frame or the speed of light in a given direction. The round-trip speed of light, however, is free from this sort of underdetermination since the time for a round-trip passage of a light signal is measured on a single clock. The *locus classicus* of the conventionalist position has been Einstein's remark in his 1905 paper [12, § 1] that a common time throughout a frame can be established by a "definition that the 'time' required by light to travel" in a given direction between two points is the same as that in the reverse direction.

Thus, if events $e_i$ and $e_f$ represent the emission and reception of a pulse of light on the worldline of an inertial observer equipped with a clock, and $t_i$ and $t_f$ the respective times of the events, and if event $e_r$ represents the reflection of the light pulse from another worldline, then the conventionality of simultaneity is a statement that we are free to choose the time of event $e_r$, to be anywhere between $t_i$ and $t_f$. If $t_r$ represents the time of $e_r$, then this freedom may be parameterized by $\kappa$ in the following manner:

$$t_r = t_i + \frac{1 - \kappa}{2} (t_f - t_i).$$ (1)

In order to ensure $t_i < t_r < t_f$, we require $|\kappa| < 1$. In addition, if we assume that the spatial distances can be assigned independently of the clock synchronization and take $\kappa$ to be a constant along the direction between the worldlines on which the events lie, then the one-way speeds of the light associated with the out and return paths are given by

$$c_\pm = \frac{c}{1 \pm \kappa}.$$ (2)

The Einstein choice of synchronization entailing equal speeds in opposite directions corresponds to $\kappa = 0$. Without the possibility of an independent spatial measure the type of association between simultaneity and the one-way speed of light presented in Eqs. (1) and (2) can not exist. And, indeed, the debate on the conventionality of simultaneity is almost always posed as one of establishing a time coordination throughout a frame independent of the establishment...