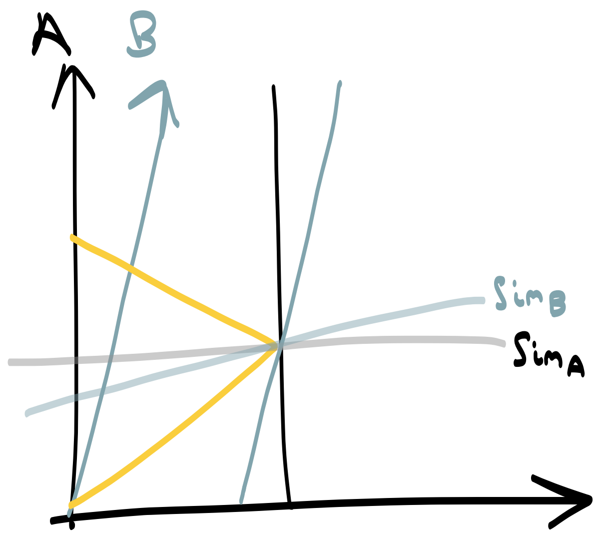
Philosophy of Space and Time: Week 5

Relativity *vs.* Conventionality of Simultaneity



Conventionality of Simultaneity

- While there is evidently a fact of the matter about the two-way speed of light since to measure this speed relies on only one clock (A), there is no such fact about the one-way speed of light—indeed, there could not be without a prior method of clock synchrony.
  - The only restrictions are plausible *a priori* principles based upon e.g. causality.
- It was for this reason that Einstein *stipulated* that the time on the worldline of A midway between A_1 and A_3 is simultaneous with B_2, in which case we obtain the following equation for clock synchrony:

$$t_B\left(B_2\right) = t_A\left(A_1\right) + \frac{1}{2}\left(t_A\left(A_3\right) - t_A\left(A_1\right)\right).$$

- However (Reichenbach), this is just one *convention*; in general we have

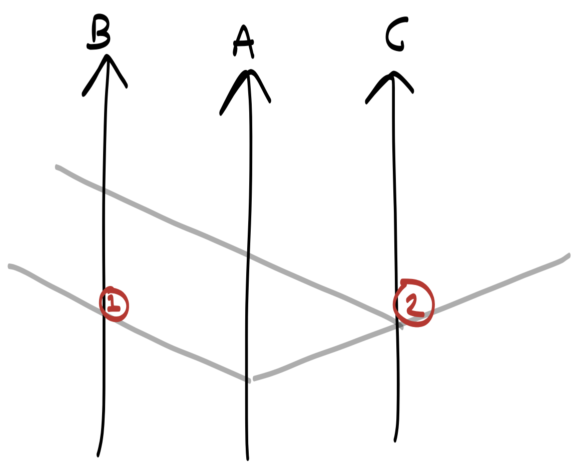
$$t_B\left(B_2\right) = t_A\left(A_1\right) + \epsilon\left(t_A\left(A_3\right) - t_A\left(A_1\right)\right) \qquad , \qquad 0 < \epsilon < 1.$$

Relativity of Simultaneity

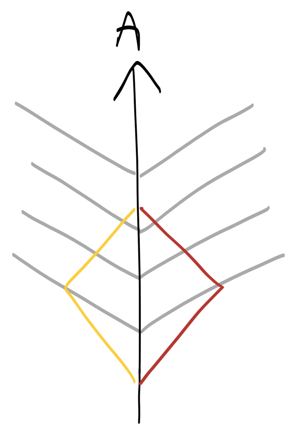
- Suppose $\epsilon = 1/2$. Then we can demonstrate *relativity of simultaneity* as per the diagram above.
- What if we chose e.g. $\epsilon = 1/4$? We would still have the relativity of simultaneity.

Reichenbach Synchrony Conventions

Reichenbach-I Convention

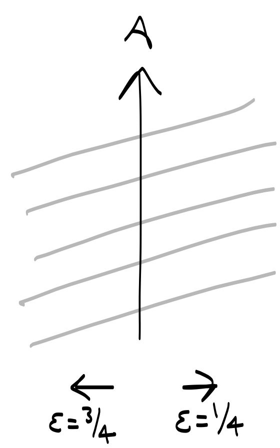


- Suppose we send a light ray out in both directions, with an $\epsilon = 1/4$ convention.
- Sim. surfaces won't be flat, and there will be a preferred position in the reference frame.
- (1) and (2) are sim. from the point of view of A but not from the point of view of C.
- About A, description of the one-way speed of light is isotropic but highly non-homogeneous due to the preferred point.
- Objection (Toretti): The resulting assignment of temporal coordinates does not define an *inertial* timescale.
  - Definition: A timescale (i.e. an assignment of time coordinates to spacetime points) is *inertial* iff, relative to that timescale, free particles have (or would have) constant velocity.



Reichenbach-II Convention

- If we set $\epsilon = 1/4$ on one side, we set $\epsilon = 1 - 1/4$ on the other side. This will give us flat simultaneity surfaces.
- A uniform anisotropy but homogeneous: light travels faster in the $\rightarrow$ direction.



Some Consequences of Non-Standard Synchrony Conventions

The derivations of the Lorentz transformations assumes standard ($\epsilon = 1/2$) synchrony. Adopting non-standard synchrony would require changing:

- The form of the Lorentz transformations.
- Length contraction and distance measurements (typically a rod will contract different when moving in different directions.)
- Time dilation.
- How fast something moves relative to a reference frame.

Of course, some invariant things will have to stay the same (otherwise our synchrony convention would make an observable difference!). For example, the time read by two clocks when reunited after a 'twin paradox' journey will have to be the same.

Arguments Against the Conventionality of Simultaneity

Debs and Redhead: two styles of argument against the conventionality of simultaneity:

1. Empirical arguments: There exist phenomenological methods for establishing distant simultaneity which confine our choice of ϵ.
2. Malament-style arguments: Technical arguments based on the structure of spacetime and the notion of causality in SR.

Empirical Arguments

Slow clock transportation:

- Claim: We may establish distant simultaneity by physically moving two clocks together, synchronising them, then moving one away from the other at an infinitesimal velocity.
- In this case, time dilation will not slow the rate of this clock (in the rest frame of the other clock), so they should agree, even when spatially separated.

- If this method of synchrony is used, then it will be found that $\epsilon = 1/2$, in accordance with Einstein synchrony.

Problems for this approach:

- Synchrony by slow clock transportation is just another synchrony convention (one which happens to coincide with Einstein synchrony in the limit $v_r \to 0$, where v_r is the relative velocity between the clocks).
- The reasoning above presupposes that such a method of clock synchronisation is 'the one true way of synchronising clocks', and this too is a matter of convention.

In conclusion, we cannot rely on these phenomenological methods in order to determine that $\epsilon = 1/2$ and so establish the non-conventionality of simultaneity.

Malament's Argument

- Malament claims that the simultaneity relation $S(\cdot,\cdot)$ picked out by the standard ($\epsilon = 1/2$) convention is the only such relation:
  (a) Which is invariant under all *O-causal automorphisms* (i.e. maps from Minkowski spacetime to itself preserving the lightcone structure and mapping the worldline of some observer O to itself).
  (b) Which is an equivalence relation (i.e. symmetric, transitive, and reflexive).
  (c) For which there exist world points p and q, one of which is on O's worldline and one of which is not, such that $S(p,q)$.
  (d) Which is not the universal relation.
- But: Are all of (a)-(d) truly required in order to define a simultaneity relation?
  - There appear to be synchrony conventions which violate (a) (see Read).

– Problem with (b): "If the same non-standard synchrony [i.e. the same ϵ value for $\epsilon \neq 1/2$] is used to synchronise a clock B from a clock A, and a clock C from B, then the C-clock will not be in synchrony with A. Thus non-standard synchrony is in fact intransitive, and so cannot be an equivalence relation. By stipulating that the relation must be an equivalence relation, Malament is effectively eliminating by decree all non-standard synchrony conventions, which seems to be rather begging the question."