

Asynchronous Equivalence Principle of Special Relativity

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2022-10-17.10:55 EDT Mon
Email Excerpt

Date: Mon, 17 Oct 2022 10:55:10 -0400

Dear Lorenzo,

Your mention of the well-known use of relativistic non-simultaneity in, for example, twin paradoxes clarified why I never interpreted your use of the phrase that way. Of course, examples of the importance of non-simultaneity in special relativity go back to Einstein.

The difference is that Einstein's examples focused on *independent* clocks that do nothing more than compare notes. Comparing notes from the isolated clocks then shows that different observer frames get different, non-simultaneous readings from the clocks. Nothing new there! Alas, isolated point-like entities with *no* causal interdependence provide an overly simplified view of the problem. In particular, clock isolation lends itself too readily to mystical statements of the form *No One Knows!* when addressing the issue of relative causality and whose view is "correct." Einstein himself was not immune to the temptation of who-knows mysticism.

That's *not* what you are doing in your papers. You are looking at systems such as wave functions that are not amenable to reduction into isolated, independent, and thus entirely classical points. Thus, at least implicitly, you are looking at how non-simultaneity applies within a *single* system. That single system could be quantum *or* classical.

Even though viewer-dependent simultaneity is the central theme of special relativity, it's surprisingly easy to take it less seriously than it should be. In practice, folks almost always switch their point of view when considering how special relativity operates at one of the moving points, e.g., within an elevator or a spaceship. Switching point of view by imagining yourself *inside* a moving object restores the simultaneity of that frame. Our strong tendency to switch is not surprising since our brains are constructed at the neural level to operate in simultaneous space locations. (Incidentally, none of that works the way one might expect. Rather than something like a map, multi-scale grids of specialized location-aware neurons implement the biological version of location awareness.)

The distinguishing element of your papers is that you *refuse* to switch point-of-view. Instead, you look at the dynamics of a hyperplane region precisely as sliced by the observer's definition of simultaneous space. To distinguish from traditional non-simultaneous terminology in special relativity, I like calling the observer-frame contents of such hyperplane slices *asynchronous* systems. Asynchronous dynamics require that despite the time differences visible across the system, it is still *one* system that must behave equivalently to a fully synchronous system. Notably, this distinction of asynchronous dynamics applies equally to classical and quantum systems.

The defining feature of this *asynchronous equivalence principle* is that a system can exhibit physics identical to that of a synchronous system even if its parts display *different* times. Asynchronous equivalence requires the asynchrony of the system to follow the age gradient rule along the observer axis of relative motion:

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

Furthermore, to keep points with diverse time labels "asynchronized," the effective internal light velocities must vary by direction. Photons travel slowest in the forward gradient direction and fastest in the backward direction. If $\theta=0$ is forward, the set of all possible 3-space light-velocity vectors is:

$$c_\theta = c \exp(-w \cos \theta) \quad (2)$$

... where w is rapidity. Rapidity here is defined here in terms of the geometric forward-light-path-distance-ratio-to-rest R :

$$w = \ln R \quad (3)$$

In terms of $\beta = v/c$, the forward-light-path-distance-ratio-to-rest is:

$$R = \sqrt{\frac{1+\beta}{1-\beta}} \quad (4)$$

The bottom line is that your papers use a non-trivial definition of simultaneity and non-simultaneity. By doing so, they highlight an equivalence principle that is as foundational for special relativity as the free-fall equivalence principle is for general relativity.

Cheers,
Terry

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2022-10-17.10:55 EDT Mon
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