

1.3: Non-simultaneity and Maximum Speed of Cause and Effect

We've seen that time flows at different rates for different observers. Suppose that Alice and Betty repeat their Hafele-Keating-style experiment, but this time they are allowed to communicate during the trip. Once Betty's ship completes its initial acceleration away from Betty, she cruises at constant speed, and each girl has her own equally valid inertial frame of reference. Each twin considers herself to be at rest, and says that the other is the one who is moving. Each one says that the other's clock is the one that is slow. If they could pull out their phones and communicate instantaneously, with no time lag for the propagation of the signals, they could resolve the controversy. Alice could ask Betty, "What time does your clock read right *now*?" and get an immediate answer back.

By the symmetry of their frames of reference, however, it seems that Alice and Betty should *not* be able to resolve the controversy *during* Betty's trip. If they could, then they could release two radar beacons that would permanently establish two inertial frames of reference, A and B, such that time flowed, say, more slowly in B than in A. This would violate the principle that motion is relative, and that all inertial frames of reference are equally valid. The best that they can do is to compare clocks once Betty returns, and verify that the net result of the trip was to make Betty's clock run more slowly *on the average*.

Alice and Betty can never satisfy their curiosity about exactly when during Betty's voyage the discrepancies accumulated or at what rate. This is information that they can never obtain, but they could obtain it if they had a system for communicating instantaneously. We conclude that instantaneous communication is impossible. There must be some maximum speed at which signals can propagate — or, more generally, a maximum speed at which cause and effect can propagate — and this speed must for example be greater than or equal to the speed at which radio waves propagate. It is also evident from these considerations that simultaneity itself cannot be a meaningful concept in relativity.

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