Twin Paradox

Two twin sisters A and B

( If we can think of Earth as an inertial frame)

A stays in a spacecraft that moves at constant speed
( an inertial reference frame),

while

B hops on a spacecraft that travels at a very high
speed to another star and then returns to A's spacecraft.

Suppose B moves away from A at speed \( \nu = 0.8c \) and then returns
at \( \nu = 0.8c \)

1. From the point of view of A

   - Suppose also that for (A) \( \Delta t = 10 \text{ y} \)

2. Since (B) has the proper time, she says her trip actually took

   \[ \Delta t = \Delta t = \frac{10 \text{ y}}{5} = 2 \text{ y} \]

So when (B) returns, (A) is older than her traveling sister

3. From the point of view of B

   The paradox is the following: B could say that it was A who traveled
   and so B should be older than A.

   This is wrong! This symmetry does not exist, because B was not always
   in an inertial frame. She accelerated away, decelerated when arriving
   at the star, accelerated again away from the star, and then decelerated
   again to get to A's spacecraft.

   Acceleration is not relative. B feels it and A does not. The problem
   from the point of view of B needs to be solved with general relativity
   and when we do so, we arrive at the same conclusion.

   (A is 4 years older than B at the end of the trip)
**The Pole and Barn Paradox**

3. A runner carries a pole 10 m long toward a small barn 5 m long.

5. A farmer stays close to the barn and sees its front and back doors.

Pole: \( L_{Po} = 10 \text{ m} \) is the proper length for the runner (5).

Barn: \( L_{b} = 5 \text{ m} \) is the proper length for the farmer (5).

4) From the point of view of the farmer (5), for an instant he sees the whole pole inside the barn. How is this possible? Length contraction.

For him, the pole is actually \( \underline{5 \text{ m}} \).

\[
\frac{L_{Po}}{\delta} = 5 \text{ m} \quad \Rightarrow \quad \delta = \frac{L_{Po}}{L_{Po}} = \frac{10}{5} = 2
\]

because the runner moves at \( v = 0.866c \).

6) From the point of view of the runner (5),

the barn will contract and actually be

\[
L_{b} = \frac{L_{b}}{\delta} = \underline{2.5 \text{ m}}
\]

and thus is the paradox: how can he fit the 10 m pole into the 2.5 m barn?

He cannot!

The two fronts from and end of pole coinciding with front and end of barn are simultaneous only for the farmer (5), but not for the runner (5).
Causality

Speed faster than light would violate causality.

Quantum Mechanics

Entanglement

$|\psi>| + |\psi>|$

Czachor: "spooky action at a distance."