Twin Paradox

Two twin sisters A and B

(A) stays in a spacecraft that moves at constant speed (Earth – if we can think of Earth as an inertial frame)
(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 $v = 0.8c$ and then returns at $v = -0.8c$

$$\gamma = \frac{1}{\sqrt{1 - v^2/c^2}} = \frac{5}{3}$$

a) From the point of view of A

→) Suppose also that for (A) [reference frame S] ——— (B)'s whole trip took $\boxed{\Delta t = 10\ y}$ //

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

$$\Delta t' = \frac{\Delta t}{\gamma} = \frac{10}{5} \times 3 = \boxed{6\ y}$$ //

So when (B) returns, (A) is <u>older</u> than her traveling sister

b) From the point of view of B

The <u>paradox</u> 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 <u>NOT</u> 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 spaceship.
<u>Acceleration</u> is <u>NOT</u> relative. B feels it and A does not. The problem from the point of view of B needs to be solved with <u>general relativity</u> 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

(S') A runner carries a pole 10m long toward a small barn 5m long

(S) A farmer stays close to the barn and sees its front and back door

POLE: $L'_{po} = 10\,m$ is the proper length for the runner (S')

BARN: $L_{ba} = 5\,m$ is the proper length for the farmer (S)

a) From the point of view of the farmer (S), for an instant he sees the whole pole inside the barn. How is this possible? Length contraction
For him, the pole is actually 5m

$$L_{po} = \frac{L'_{po}}{\delta} = 5\,m \Rightarrow \delta = \frac{L'_{po}}{L_{po}} = \frac{10}{5}$$

because the runner moves at $v = 0.866c$

b) From the point of view of the runner (S')
the barn will contract and actually be

$$L'_{ba} = \frac{L_{ba}}{\delta} = 2.5\,m$$

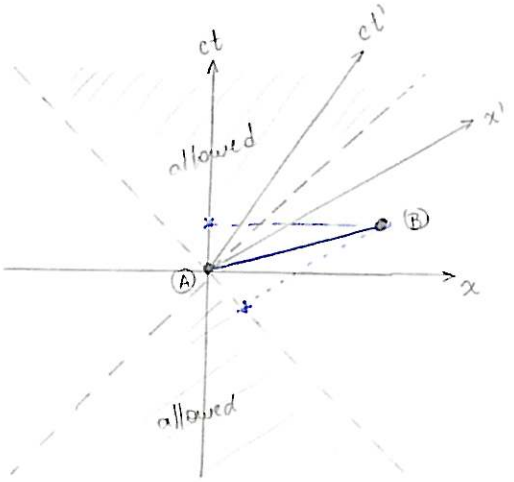
and this is the paradox: how can he fit the 10m-pole into the 2.5m barn?

He cannot!

The two events front and end of pole coinciding with front and end of barn are simultaneous only for the farmer (S), but not for the runner (S').

Causality

Speed faster than light would violate causality



B happens after A for (S)

BUT

B happens before A for (S') !!

Quantum Mechanics

Entanglement

$$|01\rangle + |10\rangle$$

Einstein: "spooky action at a distance"