

## The Twin Paradox and Their Universes

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Special relativity (SR) defines the time of an object traveling with a speed  $v$  by

$$t = t_0 / \sqrt{1 - v^2/c^2} \quad \dots (1)$$

where  $t_0$  is the rest time of the moving object and  $c$  is the speed of light about  $3 \times 10^8$  m sec<sup>-1</sup>. It means that an object in motion experiences time dilation, meaning that when an object is moving it experiences time more slowly than when it is at rest. This dilation is probably the most intriguing aspect of this theory.

Perhaps the most peculiar thought experiment in physics, and particularly in the SR theory, is the paradox twin experiment involving identical twins. One twin stays on the Earth while the other travels at relativistic speed. When he later returns to the Earth, he finds that the one who stayed on Earth is older than him.

Let us assume that the name of the twins are Luke and John and they are 22 years old. Suppose John makes this year 2024 a journey outside our galaxy, in the intergalactic space, to avoid any gravitational interaction. He travels in a spaceship at a relativistic speed  $v = 0.87c$  and returns to Earth 20 years later or in 2044. Plugging into eqn. (1) the given value for  $v$ , we find, after a bit of algebra and calculation, that Luke who remained on Earth is 42 years old but John is 10 years younger. John would be very surprised at first because he would soon realize that his spaceship was outdated and that the artificial intelligence on Earth had advanced significantly, about which he knew almost nothing.

John during his relativistic journey was all the time in the past in respect to Luke and Luke is in the future in respect to John. In other words, John's universe during his flight was different than Luke's. Actually, Luke's universe is our Universe and John's universe is our Universe in the past. The time difference between these two universes [derived from eqn. (1)] is

$$\Delta t = t - t_0 = t_0 [1/\sqrt{1 - v^2/c^2} - 1] \quad \dots (2)$$

This equation implies that Luke and John are in different, in respect of time, universes even if John travels at a “non-relativistic” speed during his spaceflight. The faster John travels he is further into the past in reference to Luke or Luke is further into the future in reference to John.

We know that Luke and John communicated with each other during John's spaceflight using radio waves even though they were in different universes. (Even John could send the necessary photos to Luke this way). So, these waves, like any other electromagnetic radiation (for example light), can span from a physics point of view this insurmountable time (past/future) barrier between Luke's universe (or our Universe) and John's universe (or our Universe in the past).