

THE TWIN PARADOX

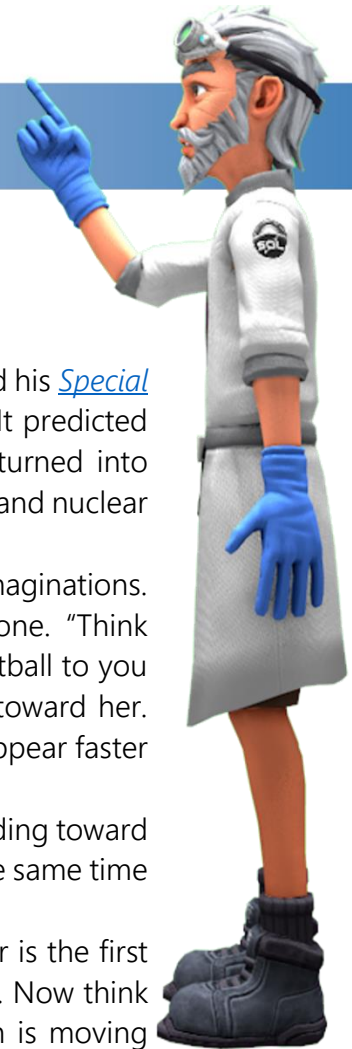
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GRANDPA'S STORIES

THE TWIN PARADOX

(AS TOLD BY JGRANDPA)



Here's our fantastic story. It starts in 1905, the year Albert Einstein published his [Special Theory of Relativity](#). His famous equation $E=Mc^2$ came from that theory. It predicted that mass, like a chunk of uranium or a cloud of hydrogen, could be turned into energy. That is the basis for the energy from the sun, atomic power plants, and nuclear weapons.

But there were other strange predictions that stretched our imaginations. Einstein said that the speed of light was always a constant. Lizzy liked that one. "Think of this experiment," proposed Lizzy. "Neddy, have a pitcher throw her fastball to you as you stand in a speeding convertible. Do it when your car is moving toward her. Then do the same thing when your car is moving away. Which pitch will appear faster to you?"

"That's easy," answered Neddy. "The pitch when you are speeding toward her will appear faster. Just imagine it: you are moving toward the ball at the same time as the ball is moving toward you. It's a no-brainer."

"Right," said Lizzy. "The pitch speed *plus* the speed of the car is the first measurement. The pitch speed *minus* the speed of the car is the second. Now think about the speed of light that is coming to you from a star as the Earth is moving *toward* the star. How does that compare to the speed of light from the same star as the Earth is moving *away* from the star? You'd think the lightspeed measurements would be different by twice the speed of the Earth moving through space."

"But that's not true," I corrected. "The speed of light is the same no matter where the light comes from or how fast you are moving toward or away from it."

"And then there was this weird thing about the mass or weight of an object," Lizzy continued. "Imagine you cranked the speed of a spaceship up to nearly the speed of light. The mass of the ship would become larger and larger as it approached lightspeed. It would become infinitely large at the speed of light. Based on that, Einstein made another hypothesis: objects cannot go faster than the speed of light."

"Time clocks also get weird when they're in motion," added Neddy. "If that speeding spaceship had a clock onboard that you could see from the ground, it would look like the clock was going slower than your clock on the ground that was standing still. That is what the *Twin Paradox* is all about. If I am on the ground and my twin is in the spaceship, my twin wouldn't be getting older as fast as me because her clock is going slower."

Neddy and Lizzy decided to test that strange prediction.

"We'll use the [Virtual World](#) and the *Cosmic Egg* time-, space-, and size-change- travel ship," suggested Neddy. "You take a trip to the nearest star. Do it at nine-tenths the speed of light. You circle the star and then come back to Earth."

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"OK," agreed Lizzy. "I just looked it up. The nearest star to Earth is Proxima Centauri. It is 4.25 light years away. If I go at 0.9 times the speed of light, the round trip is going to take me nine and a half years."

"What are you going to do while I'm gone?" asked Lizzy.

"I plan to hang out in the *Virtual World* doing fun stuff," said Neddy. "First, I am going to New York City to shop for clothes and see a Broadway musical. Then I'll go to school and work on getting into college. By the time you get back, I'll be almost 10 years older. Maybe I'll get married.

"Oh," Neddy continued, "while you are at Proxima Centauri, check around to see if you see any planets with lights on them at night. See if you detect any radio signals that might be coming from intelligent life. That will help confirm whether Earth really is unusual. Let's plan for half a year for you to explore the Proxima Centauri star system, so 10 years total. Let's meet back at the *Mystery Museum* on August 1, 2030.

"The most important thing is this," continued Neddy. "If Einstein was correct, and the *Virtual World* has the physics programmed correctly, I will be the older sister when you come back. Your clock will be slower because you accelerated to nearly the speed of light and then slowed down when you got home. I'd so love being the older sister for once."

"That sounds crazy," said Lizzy, "but if this works, it will certainly be one of the *Five Most Unusual Things in the Universe*."

They checked with me and the rest of the team. We approved their plan. They were good to go.

Lizzy and Neddy logged on to the *Virtual World*. They could see the *Mystery Museum* through the trees at the end of the road where they had spawned in. They ran to the entrance and went inside.

"OK, Neddy," said Lizzy, "have a nice life while I am gone." Lizzy did something she almost never does; she gave Neddy a sisterly hug. Neddy looked at her with total shock as Lizzy teleported to the *Cosmic Egg*.



The girls kept their *Virtual World* session going with their avatars each doing their thing. We got ready for the next part of the plan, where I, who had come to their house, was going to join them. I logged into the same *Virtual World* session that the girls had started, and Neddy and Lizzy logged on for a second time. We all walked to the *Mystery Museum* and went to the large meeting room. We were in the present time, August 1, 2020, so the girls' first avatars were not there.

"OK," said Lizzy, "I hope this works." We all teleported to a second time-, space-, and size-change travel ship called *The Beamer*. Neddy programmed a time jump for exactly 10 years and changed our size to something small to reduce time-travel duration. She hit go.

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We teleported back to the Mystery Museum and went to the meeting room. No one was there. Lizzy said, "I'm a little worried. Maybe our plan didn't work."

"Hey," called Neddy, looking out the window, "there's someone coming up the path. It's a woman I don't recognize."

A short time later, the woman came into the meeting room. Before we had a chance to find out who she was, we saw the *Cosmic Egg* approaching and heard it coming to a stop overhead. Then an older-looking Lizzy walked into the room.

"Hi, sister," the woman said to old Lizzy.

"Oh, wow," said young Neddy, "that's not a woman. It's me."



The first Neddy avatar had been living in the *Virtual World* for 10 years. She was now 22 years old and the tallest person in the room—even taller than me.

Lizzy reported, "Because of my slow clock after accelerating to 0.9 times the speed of light, my time travel to Proxima Centauri and back was only 4.4 years. So I am only 18 years old. Neddy, you're now four years older than me. And, wow, you got really tall."

"I so love this," said the tall Neddy, patting adult me on the top of the head.

"I wish we could have done this for real," said the young Neddy.

I took pictures of us, and we made a screenshot of our reunion. Then I added some relevant news. "They actually did a measurement to prove the paradox. They flew one clock around the Earth and compared it to an identical clock on the ground. They were different by the amount of time predicted by the [General Theory of Relativity](#)."

We all agreed. The *Twin Paradox* is one of the *Five Most Unusual Things in the Universe*.

GRANDPA'S GLOSSARY

[Special Theory of Relativity](#): Albert Einstein's theory of special relativity was published in 1905. It explains how space and time are linked for objects that are moving at a consistent speed in a straight line. One prediction of the theory is that as an object approaches the speed of light, its observed mass approaches an infinite value. This is the basis for Einstein's prediction that objects cannot go faster than the speed of light. Another famous prediction is the relationship $E=mc^2$ between mass (m) and energy (E), where c is the speed of light.

[Virtual World](#): Virtual worlds, also known as virtual environments, use computer technology to create a simulated world that a user can explore and interact with, while creating a feeling as if he or she were in that world. The representation of the user in that world is called an [avatar](#). The user can even wear goggles to make it appear that he or she is surrounded by the 3-D virtual world. That is called virtual reality.

[General Theory of Relativity](#): General relativity is the geometrical theory of gravitation published by Albert Einstein in 1915. When Einstein became aware that feeling weightless in the absence of gravity, or in free fall acceleration because of it, were equivalent and something extremely fundamental, he called it the "happiest thought of my life." This observation guided him in the development of the theory in which gravity is a geometric property of space. In Einstein's theory, mass tells space how to curve, and the curvature of space tells mass how to move. The General Theory of relativity has important predictions. Georges Lemaître's solution of Einstein's equations for an expanding universe led to his Big Bang theory. The bending of light by gravity can lead to the phenomenon of gravitational lensing, in which multiple images of the same distant astronomical object are visible in the sky. The attraction of light by mass leads to the prediction of black holes, whose mass is so large that no light can escape. The theory predicts that cosmic events can produce gravitational wave distortions of space itself that travel at the speed of light. The first observation of gravitational waves was made by LIGO in 2015. The theory predicts the Twin Paradox described in chapter 18. The predictions of general relativity have been confirmed in all observations and experiments to date.

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