Time Dilation Re-visualized

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Abstract**: Albert Einstein's explanation of Time Dilation* [1]*, along with "The Twin Paradox" explained by Paul Langevin* [2]*, are re-visualized for the layman, using a pulsar as a natural clock that can be seen by both the traveling twin and the stationary twin. This eliminates the need to magically see ordinary clocks instantly across vast distances. It also assists in providing additional explanations for what Time is and* ***why *Time slows down significantly when an object moves at near-light speeds.*

Most explanations of Time Dilation seem to just make the subject more confusing. Albert Einstein supposedly once said, "You do not really understand something unless you can explain it to your grandmother [3]." This is an attempt to explain Time Dilation relatively simply.

First, it is very important to understand that, in this paper, Time Dilation has only to do with the movement of a person or object relative to the speed of light or relative to a stationary object. It has absolutely nothing to do with the movement of one person or object relative to the movement of a different person or object (i.e., Special Relativistic Time Dilation).

Second, instead of two people using different clocks that the other person cannot possibly see, this re-visualization uses a single ***natural*** clock - a pulsar. There's some dispute over how close we are to the nearest pulsar, but whether it is 400 light years away [4] or 280 light years away [5], the key point is that it is very far away and it can literally be seen from astronomical distances. We just need to pick one that pulses at an easy-to-use rate -- say one pulse every 10 seconds. Using such a "clock,"

1 pulse every 10 seconds = 6 pulses per minute.
6 pulses per minute = 360 pulses per hour, or
8,640 pulses per day, or
3,153,600 pulses per year, or
31,536,000 pulses in TEN years, or
31,553,280 pulses when you include 2 leap year days.

Next, let's assume that, on January 1, in the year 2500, a pair of astronomers who also happen to be 25-year-old twins, decide to perform two slightly different Time Dilation experiments. The two astronomer's names are Homebody Jones and Traveler Jones.

The first experiment will involve Traveler Jones and his wife taking a space ship on a journey to Alpa Centauri. Alpha Centauri is 4.3 light years away from Earth, and it is one of the nearest stars to our Solar System. Homebody Jones will wait back home on Earth.

Since there is no way for either party to see what is happening with the other party via some magical TV signal, Time Dilation will be measured by counting pulses from that distant pulsar. On Earth, Homebody Jones can use sensors around the globe to record the pulsar's pulses occurring at the rate of 1 pulse every 10 seconds as described above.

The planned route to and back from Alpha Centauri is within the plane of the rotating beam from the pulsar, and the route will be at a right angle to the oncoming beam from the pulsar, so there will be no effect on pulse counts caused by the speed of light.

Time Dilation route

The experiment is expected to take 10 years, Earth time. From the point of view of the two people traveling on the space ship, however, things are soon very different. They have determined that, aboard the space ship, Traveler Jones will have to travel very close to the speed of light before the effects of Time Dilation will enable him to observe the same pulsar pulsing at an average of 1 pulse every 1 second.

As the space ship begins to accelerate, the number of pulses per minute from the pulsar increases due to Time Dilation. Traveler and his wife record the pulses as arriving more and more quickly until the ship reaches its cruising speed where the pulses are recorded as arriving at a rate of slightly more than 1 pulse per second (to compensate for the time spent accelerating).

Life and time aboard the space ship, however, will seem to be ticking along normally. The two passengers feel no effects from the slowing down of time aboard the ship. They still go to bed at 11 p.m. as measured by the clock aboard the space ship, they still get up at 7 a.m., Traveler Jones still has to shave every morning, they eat breakfast at 7:45 a.m., etc. To them, it doesn't seem like time is slowing down, it appears that everything outside of their space ship is going faster. They can see that the pulses from the pulsar are coming at a faster rate. They can also see that planets orbiting distant stars are orbiting at a faster rate.

One month into their voyage, as measured by clocks aboard the space ship, Mrs. Traveler Jones unexpectedly (or maybe according to plan) becomes pregnant.

When they reach a point in the vicinity of Alpha Centauri where they calculated they would need to turn around, they decelerate down to a stop. When they've done that, they also see that the pulses from the pulsar have slowed down and are once again arriving at 1 every 10 seconds. Then they accelerate again to return to earth. Very soon, the pulses from the pulsar are again reaching the space ship at the rate of just slightly more than one per second (in order to compensate for the acceleration and deceleration).

On the voyage home, Mrs. Traveler Jones has a baby boy right on schedule, at the end of a nine month gestation period as measured by her "body clock" and by the various kinds of clocks aboard the space ship.

Then, on January 1, 2501, according to the clocks aboard the space ship, they arrive back on Earth. Traveler is now 26 years old and his son is 2 months old.

They meet Homebody Jones and find that on Earth it is January 1, 2510. From Traveler's point of view, he and his wife traveled forward in time nine years. Or, to put it another way, time outside of their space ship went faster. Only one year passed for them while, from Homebody's point of view, Traveler and wife were gone for ten years. During that time, Homebody aged 10 years. He is now 35 years old -- nine years older than his twin brother.

They compare the results of counting pulses from the pulsar, and both counts are exactly the same. From Traveler Jones's point of view:

1 pulse (on average) every second = 60 pulses per minute.
60 pulses per minute = 3,600 pulses per hour, or
86,400 pulses per day for 365 days, plus
17,280 pulses to compensate for 2 leap year days equals
31,553,280 pulses counted during the ONE year trip.

There were 31,553,280 pulses measured by both devices during the experiment. From his perspective, it took Traveler just 1 year to record that number of pulses. From Homebody's point of view, it took 10 years to record the same number of pulses. Neither twin counted more pulses than the other. And that means,

Neither twin was ever ahead of or behind the other in time.

The experiment confirmed "time dilation." Time slows down for a person who is traveling very fast. But it has no visible effect on the person or ship doing the traveling. To people on Earth, it would appear that time had slowed down for the traveler. It took 90 months for them to have a baby. For Traveler Jones, it would appear that time had sped up on Earth and in the rest of the universe, as evidenced by the increase in the rate the pulses from the pulsar were received.

Trip #2

The Jones twins immediately embark on the second of their two experiments. For the second experiment, Homebody Jones will travel alone aboard the space ship while Traveler, his wife and son remain on earth.

There will be only one small difference in the second experiment: Homebody will travel toward the pulsar and back again, not at a right angle to it. So, he will see the effects of the speed of light on his pulse counts.

When Homebody returns after what seemed to him to be a one year voyage out and back again, he is 1 year older. He is 36 years old. And, as expected, instead of it being the year 2511 on Earth, it is the year 2520.

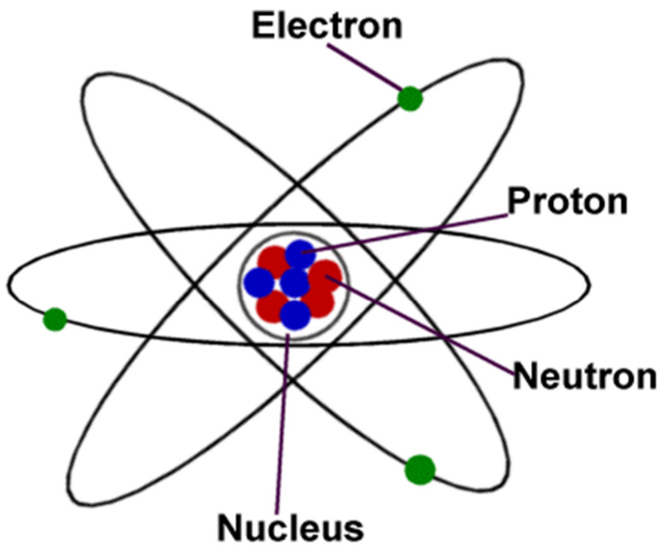
On Earth, Traveler Jones waited 10 years for his brother to return. Traveler is now also 36 years old. The twins are once again the same age. (Traveler Jr. is 10 years and 2 months old.)

The only thing that was measured differently during Homebody's voyage was that, while traveling toward the pulsar, the pulses from the pulsar arrived at an average rate of 2 per second. And while traveling on the return trip, the pulses arrived at an average rate of one every 2 seconds. However, once again there were exactly 31,553,280 pulses measured by both the device on earth and the device on the space ship during the experiment.

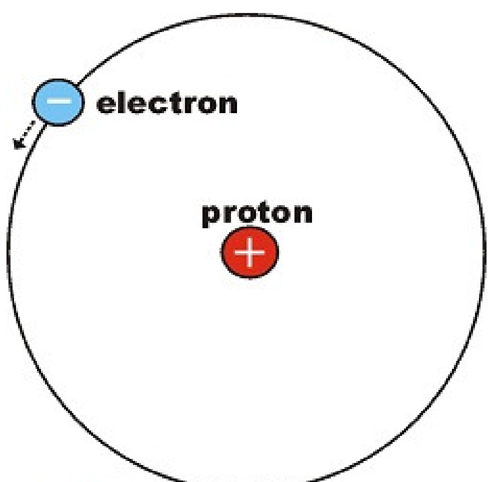
What causes Time Dilation? My understanding could be totally different from what physicists believe. But, here it is:

Are atoms the “Clocks” that control Time?

Why does time slow down? As I understand and visualize it, it's because the atoms that comprise everything around us are like tiny clocks measuring time. Each atom has one or more electrons that whirl around the neutrons and protons in the nucleus at a fixed speed.



However, for purposes of this explanation and to avoid the complications of multiple electrons in different orbits moving at different speeds, it is better to use a far simpler atom than the one shown above. The simplest atom is the hydrogen atom, which has a nucleus consisting of only one proton, and it has only one electron orbiting the nucleus:



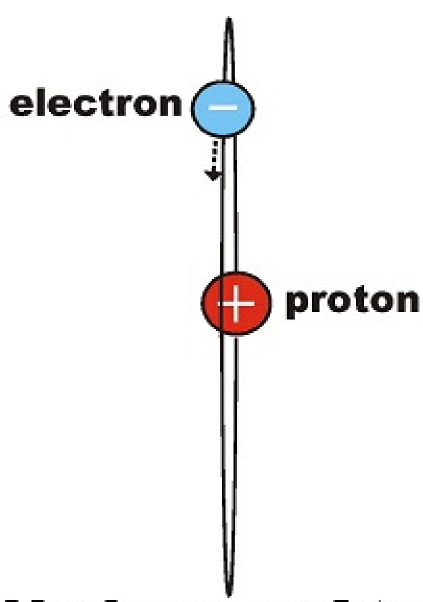
Hydrogen Atom

The single electron orbits the proton at a fixed speed, very much like the tip of the minute hand of a clock moves around the center of a clock at a fixed speed. If the clock is working properly, the fixed speed for the minute hand on the clock is one orbit per hour. Of course, the electron in the hydrogen atom orbits the proton at a much faster fixed speed.   As far as I know, there is no name for period of time it takes an electron to make one orbit of the proton, but for the purposes of this explanation, I'm going to call it one "moment." It doesn't matter how long a "moment" is, it's only necessary to understand that it is a very short period of time - probably shorter than a trillionth of a second. So the "clock" that is a hydrogen atom can be viewed as measuring time as:

One orbit of the electron at its fixed speed equals one "moment of time."

As everyone knows, our bodies are composed of different kinds of atoms. We just need to think of each atom as being a tiny clock measuring off time for us. And, if we were in a space ship, the space ship would also be made up of tiny-clock atoms of various kinds all measuring off time in tiny increments.

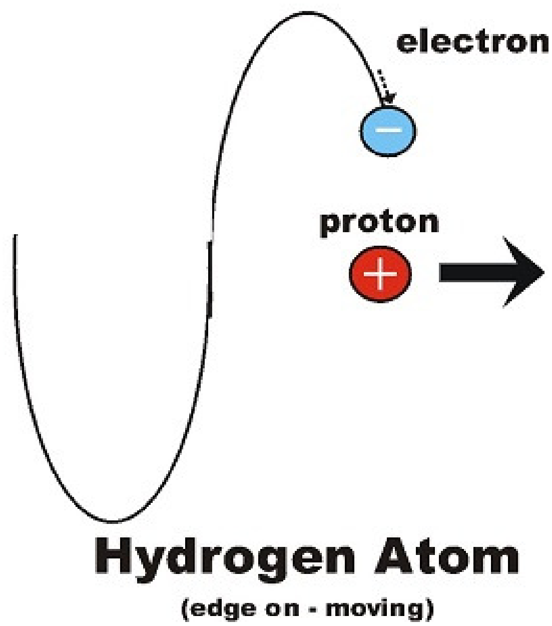
Everything we see around us is made up of atoms, and those little clock-like atoms measure and determine how fast time passes for us. When we are going about are normal business, the electrons are spinning normally and measuring time normally. But, when we start moving very fast, things change. That's because the electron in an atom is moving at a fixed speed to complete each orbit, but the distance the electron needs to travel to complete the orbit is slightly different when the entire atom is moving. It's an exceedingly small, nearly unmeasurable difference, but it is a different distance. To visualize the reason for the difference, it is easier if the hydrogen atom is viewed edge on:



Hydrogen Atom

(edge on)

When the atom is next to us on earth, its orbit is like the orbit shown above. But, in order to complete one orbit when the atom is moving, the electron has to travel the distance of its normal orbit PLUS the lateral distance traveled. So, when viewed edge on, the electron is making a corkscrew pattern through space:



If the proton moved laterally the same distance it takes to complete one orbit of the electron, time as measured by this atom "clock" will have slowed to half its normal rate. I.e., it would take the electron twice as long to complete one orbit at its fixed rate of speed. If the lateral speed is ten times greater, it will take the electron ten times as long to complete one orbit. Time, as measured by the atom "clocks" in the object, will have slowed down to one-tenth the normal rate.

So, on the trips across space, all the atom "clocks" that were part of the space ship and its contents slowed down because of their high-speed lateral movement.

Gravitational Time Dilation

If the atom is part of a person traveling at relatively high speeds, like an astronaut aboard a space station in orbit around the earth, time will slow down for that astronaut. Using speeds available with today's rocket technology, it's not a big difference - perhaps just 7 microseconds per day -- but it *is* a measurable difference, so it has been proven to happen.

Interestingly, there is also a similar effect on time that is caused by atoms moving closer to a massive gravity source.

When atoms get closer and closer to a massive gravity source (such as the earth or a black hole), the orbits of the electrons are elongated by the pull of gravity. Since the electrons must still move at the same fixed speed, the elongated orbits require more time to complete. Time slows down. For example, time moves slower on Earth than it does aboard a satellite in orbit around the earth, because the satellite is farther away from the Earth's mass. Again, the difference is small. It's about 45 microseconds per day.

That means that clocks aboard satellites in certain orbits above Earth have to be periodically reset by 38 microseconds per day, subtracting 7 microseconds to compensate for the motion of the satellite and adding 45 microseconds to compensate for the difference in distance from the center of the earth (45-7=38).

Time and space are interconnected and can be referred to as "spacetime[6]." The faster matter moves through space, the slower matter moves through time. When matter reaches the speed of light, atoms stop being atoms and the various parts of the atom all become waves of energy. It's Einstein's $E=MC^2$ equation. When matter reaches the speed of light, matter is no longer an object, it has become tightly packed waves of pure energy. Time will appear to have stopped. And that's why nothing can go faster than the speed of light.

And of course, just as time stops when an object is traveling at the speed of light, time also stops when a hydrogen atom is crushed down to the point where the electron and proton are merged into a "singularity." When it is part of a "singularity, time not only stops, it ceases to exist. A new Big Bang is needed to get all the atom "clocks" working to measure time again.

Relativity

One major problem scientists and mathematicians have with "spacetime" is trying to explain to others what "now" means when everything and everybody is already moving very fast. We are on a planet that is rotating once per day, and it is 24,860 miles in diameter. That means we are all moving at roughly a thousand miles an hour as we rotate with the earth. And we are all moving at roughly 66,000 miles per hour as the earth orbits around the sun. And we are all moving at roughly 483,000 mile per hour as the sun moves in its orbit around the center of the Milky Way Galaxy. And no one knows how fast we're moving away from the point where the Big Bang occurred.

Most people seem to understand that such large scale movements are not noticeable to us because we are all moving at roughly the same rates and in the same direction. If we were in a jet airliner having a conversation while traveling at 500 miles per hour, our speed wouldn't be noticeable unless we looked out the window. Relative to the person we are talking with, we are not moving. Relative to the earth below, we are moving very fast at 500 miles per hour.

But what is "now"? Scientists and mathematicians seem to argue that "now" has a different meaning for you than it has for someone else. That may be true if they're talking about what is going on "now" around us. Each person sees events taking place at slightly different times because of the different times it takes for light to travel from the "event" to their eyes.

However, another way to visualize and understand "now" is that it is the moment where we currently exist in relation to the Big Bang. It's the same for everyone, regardless of where you are in the universe. We are all the same distance in time from the Big Bang. Behind us is the past. Ahead of us is the void into which the universe is expanding. We are all in the moving moment called "now," moving from the past into the void.

Another way to look at it is to view "Time" as a "Fourth Dimension[7]." The universe is a debris-filled balloon of the Big Bang explosion expanding into the void. The "balloon" and all the debris in it have three spatial dimensions: length, width and height. But all the atoms within the "balloon" are also in a Fourth Dimension, the dimension measured from the beginning of Time, i.e., the Big Bang, to "now." We may all be in different locations as measured by the first three dimensions, but we are all in the same location as measured by the Fourth Dimension. That location is called "now." And there is no way to travel into the future (which does not yet exist) or into the past (which would require reversing Time and all the tiny "clocks" that measure Time). So,

What is Time?

Time is the fourth dimensional distance from the Big Bang to another point.

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