Understanding Time Dilation

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Abstract: *Even though Time Dilation has been repeatedly confirmed to be a real, natural phenomenon which can be easily demonstrated and verified in any laboratory which can obtain two sufficiently accurate atomic clocks, many scientists and physicists insist on viewing Time Dilation as nothing more than an "illusion" resulting from "Relativity," and no different than momentarily believing that when you look out the window of a train, the train station is moving, not the train car you just boarded. Understanding Time Dilation could be the "key" to understanding and resolving some of the greatest mysteries in science, while at the same time correcting some of the greatest misunderstandings in science.*

According to Albert Einstein's Special and General Theories of Relativity,[1][2] all time is local. Time will pass at different rates for different objects depending upon how fast the object is moving, and depending upon how close the object is to a large gravitational mass. The faster the object moves, the slower Time will pass for that object. The closer an object is to the center of a large gravitational mass, the slower Time will pass for that object. To simplify matters, Einstein used clocks as the objects in his thought experiments, since the primary function of a clock is to measure the passage of Time.

The "dilation" of Time is the expansion or slowing of time. The fastest or maximum rate at which Time can pass is when it is theoretically measured for a stationary object in an otherwise empty universe. In a universe which is not empty (such as ours), and in a universe where virtually all objects are moving (such as ours), time for all objects will be dilated – slower than the maximum. Until we can find a point in our universe that is stationary, and where all effects of gravity are in equal balance, we may have no way to determine the actual difference between our Time and the maximum Time. We can only compare the dilated Time being experienced by one specific object to the dilated Time being experienced by another specific object.

Measuring Time

Humans have probably always been measuring Time. At first it was just a matter of counting the days and seasons of their lives.   As cultural societies became more complex, days had to be divided into hours so people would know when shops would be open for business. Then hours had to be divided into minutes to schedule employee tasks within those businesses. Eventually, minutes had to be divided into seconds when it became necessary to measure tasks more precisely.   Today, a standard "second" is defined as "the duration of 9,192,631,770 cycles of microwave light absorbed or emitted by the hyperfine transition of cesium-133 atoms in their ground state undisturbed by external fields."**[3]**   In other words, a standard "second" is 9,192,631,770 "ticks" of a cesium-based atomic clock.   And, if you need to be more precise than that, you can measure fractions of a "tick."

Unfortunately, they do not usually make a point of stating ***where*** a specific cesium-based atomic clock was located when the "standard" was determined. It appears the first instance of measuring a "standard second" via a cesium-based atomic clock was accomplished in 1955 at the National Physical Laboratory (NPL) in Teddington, England, which is near London. What is not mentioned is that, even though they established a "standard second," that specific atomic clock ticked at a **local** rate that was different from the **local** rate of virtually every other atomic clock in the world. Moreover, if that same clock could be moved to any other point on Earth and it would tick at a different rate.

So, if an atomic clock in Teddington, England, ticks at the rate of 9,192,631,770 ticks per **local** second, and some other clock elsewhere also ticks at 9,192,631,770 per **local** second, any comparison of the two tick rates will almost certainly show one is ticking faster than the other.

But it is very rare to make such comparisons, since the only reason to do so would be to confirm Time Dilation, which has already been repeatedly confirmed in many ways.

Interestingly, in this 1905 paper "*On the Electrodynamics of Moving Bodies*" Albert Einstein wrote that "a balance-clock at the equator must go more slowly, by a very small amount, than a precisely similar clock situated at one of the poles under otherwise identical conditions." That is because a clock at the North Pole is essentially stationary and just slowly turning in place, compared to a clock at the equator, which is moving with the Earth's surface at 1,674 kilometers per hour around the Earth's axis.   Of course, that also means that an atomic clock in Teddington, England, will tick more slowly than an identical atomic clock in Oslo, Norway, and it will tick faster than an identical atomic clock in Madrid, Spain, even though all the clocks may be ticking at the rate of 9,1192,631,770 ticks per their **local** second.

There are organizations which keep track of the time as measured by different atomic clocks, i.e., the "International Atomic Time" or TAI, from the French name *Temps Atomique International*. Most notably, the *Bureau International des Poids et Mesures* (BIPM) in Sèvres, France, keeps track of data produced from 391 atomic clocks distributed all over the world in 69 different institutes (as of October 2010).[4] Most of the clocks are located at National Metrology (weights and measures) Institutes. And, of course, the BIPM has to cope with Time Dilation as they work to produce the "Coordinated Universal Time" or UTC (*Temps universel coordonné*), which is the primary time standard by which the world regulates clocks and time.

In the 1970s, it became clear that the clocks participating in TAI were ticking at different rates due to gravitational time dilation.[5] The NIST's clocks in Boulder, Colorado, were at least 5,430 feet above sea level, while an atomic clock in Teddington, England, would likely be less than 100 feet above sea level. Today's TAI scale therefore corresponds to an **average** of the altitudes of the various clocks. Starting from Julian Date 2443144.5 (1 January 1977 00:00:00), corrections were applied to the output of all participating clocks, so that TAI would correspond to proper time at mean sea level ("the geoid"). Because the participating clocks had been on average well above sea level, this meant that the official TAI second slowed down by about one part in a trillion, i.e., the official second became about one picosecond longer.

Measuring Time Dilation

There have been many experiments to confirm Time Dilation by putting atomic clocks on airplanes and flying them around the world,[6] or by comparing the passage of time for an atomic clock at the bottom of a mountain and again at the top of a mountain.[7] And every day the atomic clocks aboard GPS satellites have to be adjusted by 38 microseconds to correspond with clocks on Earth. Due to the satellite's velocity, time runs slower by 7 microseconds per day at the satellite's location than it does on Earth, and due to the satellite's altitude, time runs faster by 45 microseconds per day. (45 – 7 = 38) If the adjustments weren't made, errors in global positions would accumulate at a rate of about 10 kilometers each day.[8]

But no demonstration of Time Dilation was ever so potentially meaningful as a 2010 experiment performed by the National Institute for Standards and Technology (NIST) in Boulder, Colorado. The experiment confirmed that gravitational Time Dilation can now be measured at differences in altitude of as little as just one foot. The NIST set two atomic clocks side by side, they confirmed that the two clocks were synchronous, then they raised one of the clocks 33 centimeters (just over 1 foot) and confirmed that the raised clock did indeed tick faster than the lower clock. They reported their results in a paper titled "*Optical Clocks and Relativity*."[9]

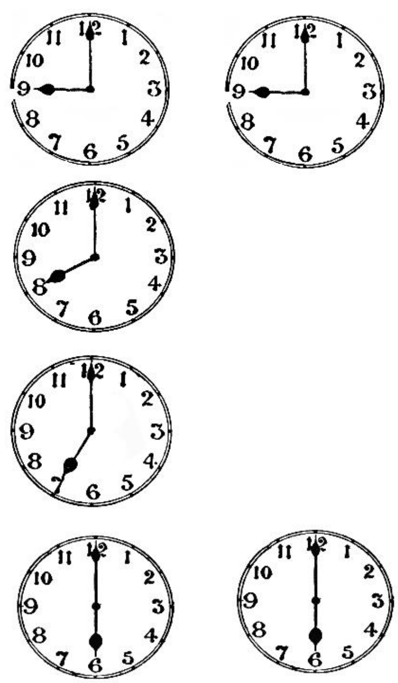
Of course, the difference in time was so small that it is almost as difficult to imagine as it is to describe. They used this explanation:

> *For example, if two identical clocks are separated vertically by 1 km near the surface of Earth, the higher clock emits about three more second-ticks than the lower one in a million years.*

In other words, if you have two atomic clocks, with one positioned at the surface of the Earth and the other positioned 1 kilometer above the surface, after one million years of ticking, the higher clock will have measured the passing of three more seconds than the identical clock on the surface.   In the actual NIST experiment, the clocks indicated a time difference measured in picoseconds (trillionths of a second).

What makes the NIST experiment so meaningful is that it clearly and undeniably demonstrated that Time was ticking at different rates at different altitudes before a single observer. A single observer could see and measure the difference.

So, while I cannot be absolutely certain how fast I am moving as the earth spins on its axis beneath my feet, and as the Earth orbits the Sun, and as the Sun orbits the center of the Milky Way Galaxy, I **can** be absolutely certain that the two clocks right in front of me are ticking at different rates due to Time Dilation, and I can confidently measure the difference. And if I had a half dozen atomic clocks arranged as in the illustration below, I could predict the differences in tick rates between the various clocks.



Time Dilation Verification Test

While the time difference between the six clocks in the illustration above would be just trillionths and billionths of a second and not easily visible by directly viewing the clocks themselves, there are devices which can show the time **difference** between two atomic clocks in billionths of a second. Therefore, if all six clocks are started at the same moment, the differences in time between the clocks would gradually accumulate on the display devices. The extra clocks at the bottom and top would further verify that the experiment isn't some kind of fluke. Those two clocks should measure time at the same rate as the clocks beside them.

The key point being made once again is that Time Dilation is real. With a set of atomic clocks like that illustrated above, we can see time ticking at different rates. And what we can also see is that even though time moves slower for the lower clocks, those clocks do not somehow fade away into the past. Nor do the higher clocks somehow move off into the future. All six clocks are simply ticking at different rates, much like different parts of a wheel moving at different velocities around a common axis called "now." The six clocks show that "now" is the same at all six locations regardless of how fast time is moving at each location.

And that says that no one can ever move ahead of or fall behind anyone else in Time. "Now" is the same for all of us, regardless of how fast we are moving in Time.

Another key point being made here is that Time Dilation has been repeatedly confirmed to be a **REAL** physical phenomenon. That means it is time to move on to the next question: What ***is*** Time if it can tick by at different rates in front of a single observer?

Time certainly isn't just a "concept." Concepts do not slow down when they get closer to the center of the Earth or when they travel very fast. Time certainly isn't a "process," since we can see that Time controls processes, not the other way around. Paul Langevin's so-called "Twin Paradox"[10] takes on new importance by illustrating how different life processes function at different rates under different conditions of Time.

The Twin Paradox Re-Visualized

"The Twin Paradox" involves twin scientists who will perform a Time Dilation experiment where the one twin travels to a nearby star and back while his brother stays at home on Earth. In this version, while each twin will possess various clocks to show their local time, they will also use a common "clock" that they can both see at the same time. They will use a pulsar which, when viewed from Earth, pulses at 1 pulse every ten seconds.

When the astronaut twin travels at 99.5% of the speed of light on his journey to a nearby star, time for him will pass at $1/10^{th}$ the rate experience by his brother on Earth. That means his electrically driven thought processes and cognitive powers will slow down at the same rate as the electrical and mechanical clocks aboard his space ship slow down. When he looks out the window, he will see the pulsar pulsing once per second according to the clocks on his ship, while his twin on Earth will still see the pulsar pulsing once every ten seconds.

Their brains and bodies will operate at the speed of Time at each location. It will take the astronaut twin ten times longer to blink. The stay-at-home twin's **normal** heart rate will be 10 times faster than that of his twin. The astronaut twin can look out his window and see the Earth orbiting the Sun once every 36.5 days. The stay-at-home twin can watch a 2 hour movie while it takes 20 Earth hours for the astronaut to watch the same movie.

Growth and digestive processes operate at local time. The Earth-bound twin will need to shave ten times as often as the astronaut twin. The astronaut will eat and digest 3 meals for every 30 meals eaten and digested by his twin on Earth.

When the astronaut twin returns to Earth after spending 1 year of his Time traveling to the nearby star and back, his Earth-bound brother will have aged 10 years, but they will both have counted the same number of pulses from the pulsar. They can argue that the Earth went around the Sun ten times for both of them, so they both experienced the passing of ten years by that system of measurement, but all biological processes for the two twins operated at the rates appropriate for their personal local time. That means that Time is not a process. They manipulated Time to slow it down for the astronaut twin, which had the effect of slowing down all of his biological processes. Meanwhile, the stay-at-home twin experienced the same biological processes operating at their normal rates.

Conclusion

We can all theorize about how Time works, but it's better if someone performs experiments to **demonstrate** how time works. The muon experiments,[11] for example, indicate that Time operates on a sub-atomic level, since a fast moving muon will "live" or exist longer than a slow moving or stationary muon. What other atomic or sub-atomic processes occur very quickly with rate differences that can be measured at different altitudes or velocities by atomic clocks? Is there any way to demonstrate that Time does not exist in a vacuum? Don't the atomic clocks themselves demonstrate that Time is a property of matter? Do we already have enough data available to confirm how Time works, but no one has asked the right questions? That might be the subject for another paper.

The key points being made in this paper are

1) Time Dilation is a real, it is a natural phenomenon that operates independent of all the measurement complexities related to simultaneity and Relativity;

2) although Time may move at different rates for virtually everything and everyone, we all exist in the same "now;"

3) there is much we do not yet understand about how Time works, and

4) it is difficult to imagine anything more important to science than figuring out how Time works.

References

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