EINSTEIN'S SPECIAL THEORY OF RELATIVITY
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Albert Einstein published his Special Theory of Relativity in 1905. This was a radical advance on the concepts of classical physics. The Special Theory describes how the world looks to an observer moving at constant speed. It contradicts our 'commonsense' notions. Because the speed of light is constant for all such observers, moving rulers shrink, moving masses grow in mass, and moving clocks run slow. In this article I will try to briefly explain the main features of Einstein's Special Theory of Relativity.

Prior to Einstein, science accepted that observers moving at a steady velocity relative to each other each find the laws of mechanics to be the same. However, mechanical experiments are affected by movements of the earth so that experimental results never perfectly match theory. The laws of mechanics work perfectly only in a frame of reference that is at absolute rest. But what part of the universe is at absolute rest? This greatly puzzled physicists. It was postulated that absolute rest is represented by the ether, a ghostly substance that permeates the entire universe, and to which matter is as porous as a sponge is to water.

The ether also conveniently explained the movement of light through a vacuum. James Clerk Maxwell had shown that light is an electrical-magnetic wave that travels through a vacuum at a speed (C) of 186,000 miles per second. But if light is a wave, something must be waving - presumably the ether. According to Maxwell's equations, light moves at only one velocity - C. Maxwell assumed that this velocity was relative to the stationery ether.

In 1887, Albert Michelson and Edward Morley performed an experiment to measure the motion of the earth through the ether. A beam of light was split into two parts, one part aimed along the direction of the earth's path through space and the other part aimed at right angles to this direction. It was reasoned that the light aimed along the earth's path would be heading straight into the 'ether wind' and would be slowed relative to the speed of the light moving across the wind (every sailor knows that you travel faster across the wind than into the wind). Surprisingly, the experiment showed that light moved at the same speed regardless of its direction of movement. In other words, there was no evidence for the existence of the ether.

Measurements of the speed of light always gave the same answer, regardless of the motion of the observer. This finding was puzzling and contradicted the commonsense of classical physics. For example, if you stand opposite a friend, say at a hundred yards distance, and he throws a ball towards you at a speed of ten miles per hour, you will observe the ball moving, relative to you, at ten miles per hour. On the other hand, if you run towards your friend at a speed of ten miles per hour, and he again propels the ball towards you with the same energy as before, you now observe the ball moving at twenty miles per hour relative to yourself. However, if you repeat this experiment and substitute a source of light for the ball you will always measure the velocity of light at 186,000 miles per second!

Einstein looked afresh at the situation and decided that, (a) the ether didn't exist, and (b) he transformed the puzzle of the constant speed of light into the principle of the constant speed of light. In abolishing the ether Einstein also abolished the primacy of the idea of absolute non-motion. He declared that all the laws of nature are identical in all frames of reference that move uniformly relative to each other and, therefore, there is no way to distinguish absolutely uniform motion from non-motion. In a railway carriage from which you cannot see out, moving perfectly smoothly at steady speed in a straight line, there is no experiment you can perform which will tell you whether the carriage is moving or is stationary. The other foundation-stone of the Special Theory of Relativity is that the velocity of light is the same in all frames of reference moving uniformly relative to each other.

How do we explain the constant speed of light regardless of the motion of the observer? In order to measure speed one must use a ruler and a clock. Einstein reasoned that these measuring instruments change, depending on their motion, in such a way that the speed of light always appears the same. The changes in the moving ruler and clock are apparent to an observer at relative rest, but not to an observer travelling along with them. Therefore both observers measure the same speed of light and neither detects anything unusual in the measurement or in the apparatus.

Einstein introduced the labels 'proper' and 'relative'. If we are 'stationery' and observe our stationery rods and clocks, we see their proper lengths and time. If we observe a rod and clock travelling very fast relative to us we see their relative length and time. Relative length is always shorter than the proper length and relative time is always slower than the proper time. A moving object is observed to contract in its direction of motion as its velocity increases, until it disappears altogether at the speed of light. A moving clock ticks more slowly than a clock at rest (time-dilation) and this trend continues until, at the speed of light, it stops altogether.

This time-dilation effect is the basis for the well-known twins paradox. In this scenario, an astronaut twin leaves earth and spends a year of earth-time travelling through space at high speed. Because time passes more slowly for him than for his earth-bound brother, he finds when he returns to earth that he is younger than his brother. This is not science fiction and has been confirmed experimentally. For example, in 1972 four atomic clocks were flown around the world by aircraft. At the end of the trip they were found to be slightly behind the earth bound twin clocks with which they were synchronised before the flight. Time-dilation has also been verified by observations on high energy particles, e.g. cosmic rays.

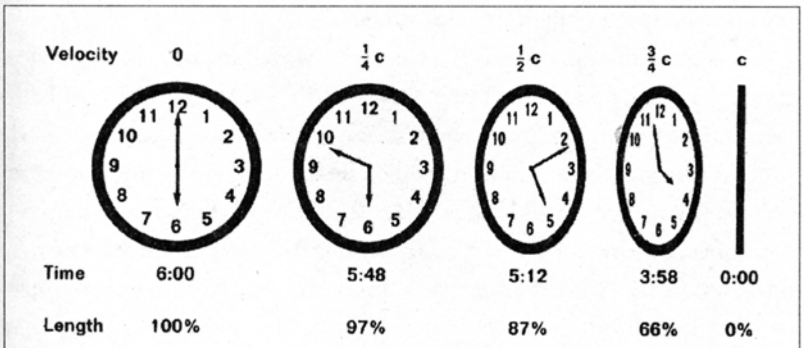
The speed of light is the fastest speed allowed in the universe. The carriers of light energy are called photons. They can travel at the speed of light because they have no mass. But no material body can ever be accelerated to the speed of light because this would require an infinite amount of energy. This is because mass is measured to increase with speed, rising to infinite mass at the speed of light. This effect has often been verified experimentally, e.g. noting the increased mass of the electron moving at high velocities.

The length-contraction, increasing mass and time-dilation consequences of moving at speed become really significant only at velocities close to the speed of light. Measurements made by the methods of classical physics are fine for the speeds of our everyday world. However, measurements made of events moving close to the speed of light can only be made accurately by taking Einstein's theory into account. For example, for Concorde travelling at Mach 2, the length contraction is only two parts in a trillion - less than the width of an atom. However, if Concorde travelled at half the speed of light it would be seen to contract 15% and its mass would increase correspondingly. In other words, as you approach the speed of light, energy added to make an object move yet faster is largely converted into an increase in mass of the object. There is an equivalence between energy and mass. Einstein expressed this relationship in his famous formula, $E=MC^2$. This equation has been verified experimentally on countless occasions, not the least of which was the explosion of the first atomic weapon.

Classical physics considered time and space to be separate -space is continuous but time moves in a two dimensional line from the past to the present to the future. However, arising from the Special Theory of Relativity, time and space were seen to form a four dimensional (3 space dimensions and a dimension of time) space-time continuum. There are no breaks in a continuum. In the traditional picture, events develop with the passage of time. The space-time continuum is more of a static picture where events do not develop, they just are. If we could view the world of the space-time continuum, we would see events that now seem to develop before us as time passes, already existing in total, etched on the fabric of space-time.

The space-time interval between two events is an absolute, but it can appear different to observers in different states of motion. For example, imagine two observers A and B. A is sitting in the centre of a steadily moving train carriage and B is standing on the platform as the train passes. A light bulb is switched on in the centre of the carriage as the train passes B. Observer A sees the light hit both end walls of the carriage simultaneously, but B sees the light hit the rear wall of the carriage before it hits the front wall, because the rear wall is moving forward to meet the light. In other words observers A and B disagree on the timing of these two events. However, if observers A and B each feeds his time and distance measurements into the formula for calculating space-time interval they will both get the same result.

The Special Theory of Relativity is called special because it applies only to frames of reference that move uniformly with respect to each other. Einstein later developed a theory that is valid for frames of reference that move with non-uniform motion (acceleration and deceleration) relative to each other, as well as those moving uniformly. This is the General Theory of Relativity, published in 1915. I will describe this theory in the next article.



If a set of five clocks in relative motion are synchronised at twelve o' clock, six hours later (by the clock at rest relative to us) they will read differently and have different linear dimensions, depending on their relative velocities. C is the speed of light.

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