Relativistic Effects

There are four effects of motion through the background which become significant as we approach the speed of light. They are:

- contraction in length
- increase in mass
- slowing of time dependant processes which affects clocks
- problems in synchronising clocks

Our unified theory follows the relativity of Lorentz and Poincaré in which there exists a background through which matter moves producing these real physical effects. The theory of relativity taught in schools and universities is Einstein's theory of relativity in which these effects are not thought to be real.

They affect everything including our rulers and clocks. This makes them virtually impossible to measure. If nature did not provide us with electrons and other sub-atomic particles travelling at nearly the speed of light, they would probably have gone undetected.

Electrons emitted by radioactive atoms were identified by deflecting them with electric and magnetic fields to measure their mass, charge and velocity and these experiments revealed the increase in mass. Other sub-atomic particles were discovered with different masses. Most lived for only a very very short time. The tracks they left could be measured revealing mass, velocity, charge and lifetime showing that at near light speed, they lived longer.

Maxwell had proved that the laws of electricity and magnetism predict the existence of electromagnetic waves which travel at the speed of light. But waves need something to wave and Maxwell called it the æther making use of an old Greek term. Sound travels through air and the speed of sound is affected by the wind. Experiments were performed to see if the earth's motion through the supposed æther affected the speed of light, but all of these failed. Fitzgerald suggested that these null-results could be explained if matter contracted in the direction of motion.

In our unified theory, matter is made of electrons and quarks. They consist of energy in the form of their electric flux which extends outwards from a tiny ball of electric charge. The motion of their electric flux generates a magnetic field which contains their kinetic energy. The motion of magnetic flux also generates an electric field. Radio waves and photons consist of electric and magnetic flux moving at the speed of light. The motion of their electric flux generates the magnetic field and the motion of the magnetic flux generates the electric field. This same process is at work within matter. The motion of the magnetic flux which contains their kinetic energy generates an effect which modifies their electric fields.

The primary effect is to cause matter to contract in the direction of motion. This has a secondary effect that mass increases. This in turn produces a third effect slowing clocks and all other time dependant processes. There is a fourth effect on the synchronization of clocks. Nature works through processes of cause and effect. These four effects of motion form a series. Motion causes contraction in length, which causes increase in mass, which causes a slowing of clocks, which causes synchronization problems.

Lorentz contraction

Fitzgerald first proposed the idea because it would explain why the Michelson Morley experiment failed to detect any variation in the speed of light. It is properly named after Lorentz who discovered its cause and proved its existence based on the assumption that there is a background through which light travels at a constant speed. Light travels through space because it consists of electric and fields. The motion of the electric fields generate magnetic fields and their motion in tern generates the electric field. This process requires a background. Maxwell and Lorentz called it the æther. No satisfactory theory of the æther was ever developed and this left an opening for Einstein's new theory which declared the æther to be "superfluous". The term is used in Einstein's theory to refer to the observed effects caused by the relative velocity between object and observer. Without a background, there can be no real Lorentz contraction, but Einstein's theory still has a Lorentz contraction which is correctly attributed to the relative motion of observer and object.

When two observers moving at near light speed pass one another, whatever their speeds through the background and whatever the real Lorentz contraction they suffer, each will see the other's space craft appear to be Lorentz contracted. Although the apparent Lorentz contraction caused by their relative velocity is exactly the same as the real Lorentz contraction due to travelling at the same velocity through the background, the two are quite different. One is a real physical effect, the other "an artefact of observation". If the observation is made by taking a photograph, we could say that the apparent Lorentz contraction is manufactured by the act of taking a photograph.

While we cannot measure it directly, Lorentz has provided the mathematical proof that the contraction occurs. We know that radio waves and photons are described by Maxwell's equations. Lorentz identified two of the fundamental equations of electricity and magnetism as being special cases of the same equation:

Maxwell's wave equation $$\nabla^2\phi - \frac{1}{c^2}\frac{\partial^2}{\partial t^2}\phi = 0$$ and Poisson's equation $$\nabla^2\phi = \frac{\rho}{\varepsilon_0}$$

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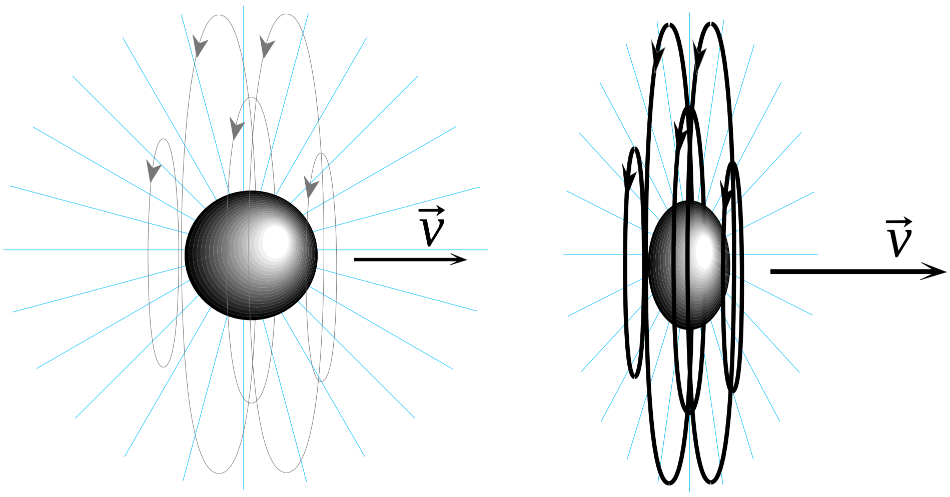
Maxwell's wave equation determines how radio waves and photons travel through space and Poisson's's equation determines how atoms arrange themselves to form matter.

Without worrying too much about what the symbols mean, we can see that if nothing varies with time, the term $\frac{1}{c^2}\frac{\partial^2}{\partial t^2}\phi$ becomes zero leaving Poisson's equation and if there is no electric charge, $\frac{\rho}{\varepsilon_0}$ becomes zero leaving Maxwell's wave equation. Lorentz showed that by changing the the co-ordinates form (x,y,z) to (x',y',z',) where:

$$x = \sqrt{1 - \tfrac{v^2}{c^2}}\,x' \qquad y = y' \qquad z = z'$$

The equation reduces to Poisson's equation. So the new co-ordinates (x,y,z) give the dimensions of the moving object in terms of the co-ordinates (x',y',z') which gave its dimensions when it was stationary.



The real Lorentz contraction affects the surface of the electron, its electric field and its magnetic field.

The amount of flux in the magnetic field is proportional to the velocity of the electron, but as its speed gets near the speed of light, the electric field generated by the motion of the magnetic field becomes significant and starts to affect the electron's electric field. The amount of electric flux is fixed because electric flux is quantised. The electric field generated by the motion of the magnetic field has no flux, just electric intensity which distorts the existing electric field and with it the surface of the electron.

Unfortunately, even if we on a space ship travelling at near light speed, there is no way of directly measuring the Lorentz contraction because all rulers, tape measures, ultrasonic and laser devices on board the space ship are affected by the contraction and show everything to be the same size as it was. Neither is it possible to measure the contraction of objects in relative motion to us because any object big enough to measure cannot be accelerated to even a small fraction of the speed of light.

Relativity is full of what Einstein called "thought experiments". In that tradition, we must imagine that God has given us rulers, clocks and other scientific instruments which are immune to the effects we wish to measure. Our god-given rulers will allow us to measure the Lorentz contraction.

The Lorentz contraction is described by the fraction $\sqrt{1 - \frac{v^2}{c^2}}$ where v is the velocity through the background and c the speed of light. The expression is mathematically related to Pythagoras Theorem, so the same numbers fit. At $\frac{3}{5}$ the speed of light, a star ship would be contracted to $\frac{4}{5}$ of its original length. The usual practice is to turn the fraction upside down and define the factor "gamma" which describes the effect on mass which is increased to $\frac{5}{4}$ of its original mass:

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

The mass increase

Nature conveniently provided early experimenters with high speed electrons emitted from radioactive isotopes. To try to find out what the "radiation" consisted of, experiments were devised to measure both the mass and electric charge of these particles. Results were inconsistent until it was realized that mass increased with velocity and that the mass seemed greater when resisting acceleration in the direction of motion. These two apparently different masses were called "longitudinal mass" m_l and "transverse mass" m_t. The original observations indicated that $m_l = \gamma^4 m_0$ and $m_t = \gamma^2 m_0$ but by 1915, it was established that $m_l = \gamma^3 m_0$ and $m_t = \gamma\, m_0$.

The value for transverse mass being greater because the kinetic energy depends on γ which is itself increasing. When this was fully appreciated, the terms were dropped and replaced with "relativistic mass" $m_r = \gamma\, m_0$.

Just as we found with the contraction in length, there are two different things that we are dealing with. One is the real mass increase caused the velocity of an object through the background, the other is the apparent increases in mass due to the relative velocity between us and an object when we attempt to accelerate it. We have no way of knowing how fast the earth is travelling through the background but it is not likely to be more than a few percent of the speed of light. When we accelerate an electron to near light speed and measure its increase in mass, for all practical purposes, we can consider the laboratory to be stationary relative to the background, so we are in effect directly observing the real increase in mass.

The mass increase is the first indication that mass might not be what it was assumed to be. There had been earlier attempts to explain mass in terms of the emerging theory that matter consisted of nothing but electric charges. With the Lorentz contraction established and the new experimental results, both Abraham and

Lorentz set about devising theories of electromagnetic mass. Abraham deduced that $m_l = \gamma^4 m_0$ and $m_t = \gamma^2 m_0$, while Lorentz found that $m_l = \gamma^3 m_0$ and $m_t = \gamma\, m_0$. Both theories were flawed because neither understand the effect of the Lorentz contraction on the electron's electric field and the energy stored in it. We have shown that it does not change and that the whole of the increase in mass is due to the contraction of the electric field resulting in an increase in the energy content of the magnetic field.

If we had a god-given device for measuring the magnetic field, we would discover that the flux density B was greater by a factor γ than our ordinary measurement. Now the energy density depends on B^2, so the kinetic energy must be greater by a factor γ^2. We follow Lorentz's method of working in the contracted units we measure with our contracted ruler. Everything appears normal and spherically symmetric making the integrals much simpler than those of Abraham's method. Like Lorentz, we conclude that in the moving system it would appear that $m_l = \gamma^4 m_0$ and $m_t = \gamma^2 m_0$. Lorentz then argues that since the moving system was contracted, all the volumes were smaller by a factor γ than they appeared to be from within the moving system. He therefore divided his answers by γ and concluded that from the stationary system, the mass appeared to be $m_l = \gamma^3 m_0$ and $m_t = \gamma\, m_0$.

Mass is responsible for slowing the universe down. Without it, all the electric forces between electrons and protons would cause everything to rush together with infinite acceleration and the universe would end in a big bang as soon as it was created. This means that every single process in nature is in effect measuring mass by its speed. Watches used to use the oscillation of a "balance wheel" geared to the hands. Now they use the oscillations of a crystal counted electronically. Any change in mass will affect their time keeping.

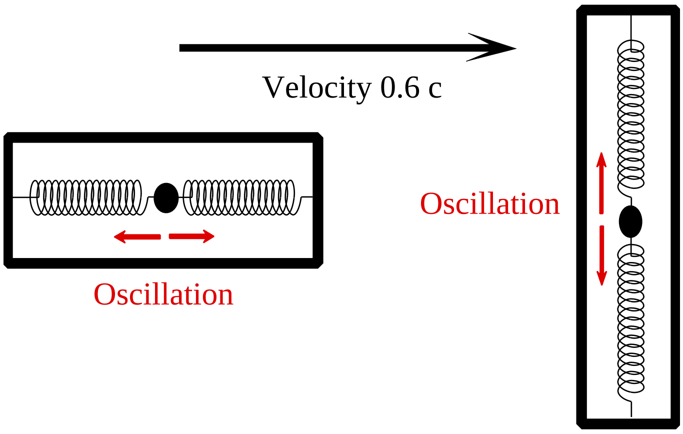
Slowing of clocks

Clocks have always been very important in navigation, so great effort has been put into developing clocks of greater and greater accuracy. This led to the development of atomic clocks culminating in the GPS system in which satellites carry atomic clocks continuously transmitting their position and time back to earth. The biggest effect of putting an atomic clock into orbit is that it speeds up due to the smaller effect of gravitational potential. When that is corrected for, the clocks are then found to run slow because of their velocity around the earth, allowing us to measure the slowing of clocks with great accuracy.

We really can imagine ourselves on the space station receiving the radio time signal from earth and measuring the slowing of our clocks. How can we explain this in terms of the contraction and the mass increase. The problem is that clocks are three dimensional objects while we know that the contraction acts only in the direction of motion and that the mass increase depends on direction.

The answer lies in Lorentz's derivation of the increase in mass. He used the same co-ordinate system that we would naturally measure with our rulers on board the space station. It would appear to us that mass had increased by $m_l = \gamma^4 m_0$ and $m_t = \gamma^2 m_0$.

Consider a simple oscillating system moving at $\frac{3}{5}$ of the speed of light, such that $\gamma = \frac{5}{4}$. When the oscillation is in the direction of motion, the contraction in length has two effect. It reduces the distance over which the mass oscillates and it increases the strength of the springs. Each of these acts to increase the acceleration by a factor of γ. But the longitudinal mass has increased by a factor of γ^4 decreasing the acceleration. The net result is that the acceleration is reduced by a factor of γ^2.



Now the period of oscillation is inversely proportional to the square root of the acceleration. So the effect is to increase the period by a factor γ.

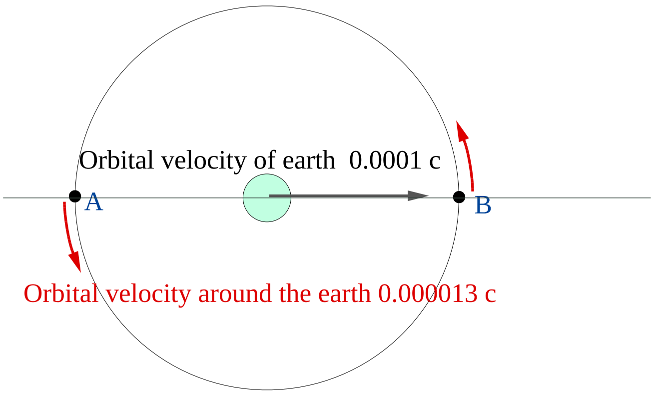
When the oscillation is perpendicular to the direction of motion, the forces and distances are unaffected and the acceleration is determined by the transverse mass with the affect that the period is also increased by a factor γ.

Both of these situations result in a slowing of clocks based on simple oscillators by a factor of γ.

Synchronisation problems

There are two ways of synchronising a clock with a master clock. One way is to place it beside the master clock and set it to the same time ad the other. The other way is to send a signal from one to another by any means from using a telescope to directly observe a distant clock to using radio signals. The first widespread system of synchronisation ever to be used involved taking a clock from town to town by train to set all the station clocks to railway time. A modern household will probably be using three different time systems. Radio controlled clocks tuned to receive time signals; internet time delivered to the computers over the internet and most accurate of all GPS time calculated by the satnav in the car. The differences between these clocks will of course be too small to measure in seconds, but the effects on GPS satellites can be measured in milliseconds.

We have no way of knowing the velocity of the earth through the background, but we do know its orbital velocity and this allows us to calculate the effects on GPS satellites relative to a clock at the centre of the earth. Real GPS satellites have orbits canted at 55° to the earth's equatorial plane making the calculations somewhat harder and the results will also depend on the time of year. For simplicity we will assume an orbit in the same plane as the earth's orbit.



As the satellite goes from A to B, it travels faster than the earth and its clock looses 19.534 μs (micro seconds). On the return from B to A it is moving more slowly than the earth and its clock gains 15.932 μs. The difference of 3.602 μs which is the time we would expect the the satellite's clock to loose over a clock at the centre of the earth due to the orbital speed of the satellite around the earth. So the synchronization error is 17.733 μs.

In this example, the speed of the satellite is about $\frac{1}{8}$ of the speed of the earth and the formula $t = \dfrac{v\,x}{c^2}$ gives a good approximation. By way of comparison, the synchronization error for clocks on the earth's surface is less than 200 nanoseconds.

One might expect these synchronisation errors to affect the GPS system, but in fact they exactly cancel out the effect due to the radio signals from the satellite travelling at the speed of light relative to the sun.