The slowing of clocks

HOME: The Physics of Bruce Harvey

We do not say that time is affected. Clocks and measurements of time are affected. This is part of the philosophical difference between Lorentz-Poincaré relativity and Einstein's theory. We assume that there is an ultimate reality which we try to measure. Einstein assumes that it is the observation that is real. An assumption which is no more than thinly disguised existentialism.

We might be tempted to give Einstein the credit for his light clock derivation of the effect on clocks in which they appear to slow by a factor of γ, but as Whittaker refers to the principle being used earlier by Voigt, Fitzgerald, Larmor and Lorentz[1iv] this is to give credit where it is not due. If we introduce the light clock into Lorentz-Poincaré relativity, then the light clock in the moving system really does run slow. When the light pulse travels back and forth perpendicular to the x axis as seen in the moving system, it really moves in a zigzag through the stationary system and the legs of its journey are longer by a factor γ as can be calculated using Pythagoras Theorem. Einstein used the ownership of light trick to derive the same expression. If an observer travelling through my system has a light clock and uses light emitted from a source at rest in my system, then his light clock will run slow. On the other hand in Einstein's theory all observers have equal status and there is no stationary system. The other observer should be able to use light emitted from a source in his own system with the result that his light clock does not run slow.

Clocks are a problem because they are three dimensional machines which suffer a Lorentz contraction in only one dimension!!! So we need three theories as to why a pendulum clock should slow depending whether its pendulum swings perpendicular to the line of motion, parallel to it or if the line of motion is vertical. The historical accident of the incorrect experimental data luckily gave the correct effect on mass for calculating the effect on clocks. An agile mind can work these all out using the contraction in length and the concepts of longitudinal and transverse masses provided they use Abraham's $m_t = \gamma^2 m_0$ and $m_l = \gamma^4 m_0$. Fortunately, pendulum clocks do not work well on ships of either the sea or space going varieties and most clocks use a mechanism involving some form of oscillation executing simple harmonic motion which does not primarily depend on gravity. The formula for SHM requires that the the mass increase by a factor of γ^2 in order to increase the period by a factor γ.

It is interesting to see how SHM varies with direction. When it is parallel to the direction of motion compared to transverse oscillation, the longitudinal mass applies introducing a factor of γ^2. This is countered by two effects of the contraction. The amplitude is reduced by a factor of γ and the gradient of the potential which produces the force is increased by a factor γ.

One of the more fundamental forms of clock is a planet. It orbits and spins with fixed periods and our measurement of time is fundamentally a mapping of events onto the simultaneous orbital and rotational state of the earth. We might imagine a flywheel mounted on frictionless bearing in a vacuum and use its rotations as a clock on our space ship. If we assume it has constant rotational kinetic energy, it too slows as predicted due to the increase of its moment of inertia.

$$\mathcal{E}_{rot} = \tfrac{1}{2} m k^2 \omega^2 \;\rightarrow\; T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{m k^2}{2\,\mathcal{E}_{rot}}}$$

where k the radius of gyration and $\mathcal{E}_{rot}$ the rotational kinetic energy are constant. The period T varies as the square root of the mass, so to cause T to increases by a factor of γ, the mass must increase by a factor of γ^2.

Abraham's result fits nicely with our understanding of the relationship between period of oscillation and mass in vibrating systems. We are forced to conclude that within the moving system, mass is apparently increased by a factor of γ^2, but that for one reason or another, when we try to observe this from the stationary system, it seems that $m_t = \gamma m_0$ and $m_l = \gamma^3 m_0$.

This remained an inconsistency in the theory until the author developed his classical theory of the quantised energy levels of the hydrogen atom. Bohr's quantum theory is based on the quantisation of angular momentum without any explanation as to why or how nature might work like this. In our unified theory, it is electric and magnetic flux which are quantised. Orbiting electrons are not only subject to Newton's laws of motion and Maxwell's electromagnetism, but also to orbital mechanics. When these factors are combined with Lorentz's theory of electromagnetic mass, the quantised energy levels emerge.

The GPS system placed atomic clocks in orbit and requires measurements of time which are accurate enough to be affected by the slowing of clocks. They reveal that the slowing of clocks is real confirming the Lorentz Poincaré theory of relativity. Now an atomic clock actually measures the energy levels within the atom through the relationship $E = h\nu$. So the slowing of an atomic clock corresponds to a reduction in the energy levels within the cesium atoms emitting the light used to produce the beat frequency which the clock counts. However, the earth is a moving system and the speed through the background of a laboratory varies as the earth spins and orbits the sun. We detect no change in the $E = h\nu$ relationship and so must conclude that our unit of energy is affected by motion through the background.

If we now apply this to the relationship $E = mc^2$ and the relativistic mass increase, it appears to us within the laboratory moving through the background that mass is indeed increased by factors of $m_t = \gamma^2 m_0$ and $m_l = \gamma^4 m_0$ because inertial mass is the property of matter resisting acceleration. Acceleration produces a change in kinetic energy which we measure with units which are reduced in magnitude by a factor γ. So it appears to us accelerating a mass (such as the balance wheel of a clock) within our moving system that it has increased in mass by a further factor of γ giving $m_t = \gamma^2 m_0$ and $m_l = \gamma^4 m_0$ (producing the observed slowing of the clock) instead of the $m_t = \gamma m_0$ and $m_l = \gamma^3 m_0$ observed when accelerating a mass to near light speed (in which case our laboratory approximates to the stationary system).