A quantum approach to relativity

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Abstract

Special Relativity depends on the speed of light being constant in space. This was originally founded in a wave model for electromagnetic radiation. If fundamental physics are viewed from the point of view of quanta in differing frames of reference, a new concept emerges. It is difficult to reconcile energy change when viewed from different frames of reference. The difficulty has been considered by using a tape recorder analogy. The nature of mass is considered with reference to the concept of a de Broglie vector. The concept of mass equivalence has been introduced.

1. Introduction

The concept of special relativity was grounded in the then current view of "waves through the Ether" (a medium that was hypothesised to carry light and other electromagnetic waves). It was assumed that the speed of light must be absolute and constant with respect to the ether. This implies that, in a non-relativistic universe, different values for the speed of light should be measured when the Earth travels at differing speeds in differing directions (because the measured speed should be the addition of the two speeds). Michelson and Morley carried out an experiment [1] to detect the Earth's motion through the "Ether". However, they were unable to detect any difference in the speed of light when measured in different directions. Kennedy and Thorndyke [2] later verified that there was no observed change in the measured speed of light when the surface of the Earth travels in different directions. Thus Einstein, in his 1905 paper, proposed that the speed of light was constant for all observers, leading to special relativity.

However, the conclusions drawn from the experiment have omitted a fundamental element. The only valid conclusion that can be drawn from the results of the Michelson and Morley experiment is that the speed of light is **observed** to be constant within a **single** frame of reference. This does, of course, not mean that relativity is "wrong", any more than Newtonian mechanics or Galilean relativity are "wrong". We have revisited special relativity in a subsequent paper. However, it is useful here to explore frames of reference from the point of view of non-relativistic quanta.

2. Energy and the observer

This analysis does not refer to elastic collisions, where all observers agree that energy is conserved. Nor does it refer to inelastic collisions or separations involving two or more bodies where momentum is conserved because all observers will agree on the energy absorbed or emitted. Rather, it concerns an isolated particle where the energy transport is entirely in the form of photon transport. A real example of this might be the annihilation that occurs with an electron-positron interaction. The following is an example where $v<<c$.

Consider four frames of reference, denoted by F_0, F_1, F_2 and F_3 with the relative velocities of the frames be ${}^0V_1 = v$ ms^{-1}, ${}^0V_2 = 2v$ ms^{-1}, ${}^0V_3 = 3v$ ms^{-1}, with ${}^1V_2 = v$ ms^{-1}, ${}^1V_3 = 2v$ ms^{-1} and ${}^2V_3 = v$ ms^{-1}. The superscript denotes the frame of reference of the observer and the subscript the frame of reference of an observed particle (We will consider the term particle to include any co-acting group of particles). A particle, **P**, mass m kg, moving in F_2 is observed in frame F_0 to have kinetic energy ${}^0E_2 = 2.0mv^2$ J. If that particle accelerates to F_3, its kinetic energy is observed to increase to ${}^0E_3 = 4.5mv^2$ J, representing an increase of $2.5\ mv^2$ J. However, as observed from F_1, its kinetic energy increases from ${}^1E_2 = 0.5mv^2$ J, to ${}^1E_3 = 2.0mv^2$ J, representing an increase of $1.5mv^2$ J. Thus the change in kinetic energy is different for the two observers. So the frame of reference of the observer determines not only the observed kinetic energy, but also the change in energy for the same observed phenomenon. In order to develop the analysis, we have introduced the concept of the **de Boglie vector**.

3. The de Broglie Vector

We know that where v<<c, the (kinetic) energy of a particle is given by $e = ½\ mv^2$. We also know that when mass becomes converted to energy (i.e. light speed quantum particles) we have $e = mc^2$. This leads us to conjecture a universal formula:

$$e = \frac{mv^2}{2}\left(1 + \frac{v^2}{c^2}\right) \tag{1}$$

The first part of the RHS of Equation 1 is the linear kinetic energy, while the second part, $½\ mv^4/c^2$ can be regarded as the **de Broglie energy** resulting from the rotation of the de Broglie vector in **de Broglie space**. This would be associated with a **de Broglie velocity**, $v_{db} = v^2/c$, corresponding to the rotation of the de Broglie vector in de Broglie space. If we consider $v_{db} = \omega r_{db}$, where ω is the rotational velocity in radians per second and r_{db} is the amplitude of the de Broglie vector, we can calculate the amplitude of the de Broglie vector. We can do this using $\omega = 2\pi f_{db}$, where f_{db} is the **de Broglie frequency** calculated from the de Broglie wavelength, λ_{db} by $v = \lambda_{db} f_{db}$ with v the linear velocity of the quantum particle. The de Broglie wavelength is defined as $\lambda_{db} = h/mv$, so the de Broglie frequency, f_{db}, is given by

$$f_{db} = \frac{mv^2}{h} \tag{2}$$

Therefore, the amplitude of the de Broglie vector, r_{db}, is given by:

$$r_{db} = \frac{v^2 h}{2\pi m v^2 c} \qquad 3$$

which reduces to:

$$r_{db} = \frac{\hbar}{mc} \qquad 4$$

Note that r_{db} is independent of the frame of reference of the observer and can therefore be regarded as the de Broglie signature of the particle.

4. Frequency and the frame of reference

Consider the **de Broglie frequency**, f_{db}, of particle $\mathbf{P}$. If particle $\mathbf{P}$ in F_3 leaves an observer in F_0, it will be observed to have $f_{db} = 9mv^2/h$ Hz. It will be observed to arrive at an observer in F_2 with $f_{db} = mv^2/h$ Hz, a red shift of 89%. However, it will be observed to arrive at an observer in F_1 with $f_{db} = 4mv^2/h$ Hz, a red shift of 56%. Notice that the phenomenon of red shift is described here using neither wave theory nor special relativity.

5. The tape recorder analogy

In order to understand this phenomenon, the simple, 1-dimensional, analogy of a tape recorder may be used. Consider each frame of reference as a magnetic tape. All frames of reference move at constant speeds that differ from every other frame of reference. It is useful here to consider the concept of the **de Broglie vector**. Every particle will have a de Broglie vector, which on rotation in de Broglie space produces the de Broglie frequency associated with the particle. Every particle will be observed from within its own frame of reference to have a de Broglie frequency of zero. However, in this analogy, the phase of the de Broglie vector will be different at every position in this frame of reference. From Equation 2, the phase shift ϕ of the de Broglie vector l m along the tape is governed by the equation:

$$\phi = \frac{2\pi m v^2 t}{h} \qquad 5$$

which reduces to:

$$\phi = \frac{lmv}{\hbar} \qquad 6$$

Hence, moving along the tape will result in the observation of a rotation of the vector and the generation of a de Broglie frequency. But, because the tape represents a single frame of reference, it is impossible to move along it, because that involves changing to another frame of reference. So, to move along the tape, the particle would have to move to another frame of reference (in this analogy, another tape) by accelerating, which means there would be an energy gain. If after time *t*, it transfers back to the original frame of reference we have ϕ defined by Equation 6. Note that the phase shift ϕ is the convolution of the distance along the tape and the velocity at which it moved in the frame of reference during its relocation. So, if two identical particles moved from the same starting place to the same resting place, but in different frames of reference (i.e. at different velocities), each would have a phase shift different to the other.

The analogy may give us an insight into the apparent differences in energy changes, as measured from different frames of reference. The idea that energy change depends on the observing mechanism in the frame of reference of the observer is a direct result of such an analogy.

6. The nature of mass

Mass has always been considered as the amount of "substance" in a particle, related to a universal, attractive force, gravity (in general relativity, the curvature of space). However, if the tape recorder analogy is accepted, mass becomes identified with the de Broglie signature hypothesised in Section 4 above. It is normally assumed that photons have no mass. This in part stems from relativity, which proposes that no mass can achieve the speed of light. However, photons have a frequency which can be regarded as the de Broglie frequency and the energy is related by the standard equation:

$$e = hf \text{ J} \qquad (7)$$

Substituting this into Equation 1, an ultra violet photon, with $f = 10^{15}$ Hz would have a **mass equivalence** of 1.5×10^{-35} kg, which is more than 5 orders of magnitude less than that of an electron. This implies that high-energy gammas would have a mass equivalence similar to that of an electron. Notice the use of the term mass equivalence, rather than mass, because the hypothesis is that mass equivalence is the manifestation of the de Broglie signature, rather that the normally accepted reverse assumption. If this is the case, it may have an impact on our assumptions about General Relativity as well as Special Relativity.

7. Conclusions

A mechanism has been proposed to describe the motion and energy of a quantum particle, as observed from any frame of reference, by a single quantum property, the de Broglie vector. The vector and its rotation completely describe the mass and energy of the particle, as observed from that frame of reference. The rotation of the vector in a given frame of reference accounts for differing values of measured energy change, as observed from different reference frames.

References

[1] R S Shanckland: *American Journal of Physics* **32** p16
[2] R J Kennedy and E M Thorndyke *Physical Review* **42** p400 (1932)