Absolute and Relative Speeds of Light

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It is shown that in particular case of photons, the Lorentz transform formulae for distance and time are simpler and take the same form as that of - corrected for relativity - Doppler formulae for the length and period of the wave. It means that considering light as particles and using Lorentz transform we obtained an unexpected result indicating that light is an electromagnetic wave which obeys the Doppler formulae. According to Doppler the length and period of the wave are relative and transform in such a way that their ratio does not change. The Doppler formulae show that the phase speed of the wave defined as the ratio of the length of the wave to its period is absolute. Should light be considered as a wave then the second Einstein postulate would automatically be given by Doppler formulae whether corrected for relativity or not. Light considered as a wave would have at least two speeds: the absolute phase speed and the relative speed of the wave front. Particles (photons) do not have two different speeds but the waves do. Instead of considering the light as photons and introducing the second Einstein postulate, we propose to accept the idea of particle-wave duality of light. In the case of waves it would automatically assure the existence of the absolute phase speed and would provide the relative speed of the light wave front. It is argued that introducing corrections for relativity into the Doppler formulae for electromagnetic waves we should also correct Doppler formulae for elastic waves. Otherwise the first Einstein postulate is violated.

1 Introduction

The discussion whether the speed of light is absolute or relative started a long time ago. To date it has continued under the silent assumption that light has only one speed. Validity of such an assumption is questioned in this paper.

Particle-wave duality of light is generally accepted. In some experiments light behaves like waves, in others like particles (3). The difference between waves and particles is significant. Waves have two speeds which are defined differently. One of them is the speed of the wavefront (here called b), which is defined as the ratio of the distance (path traveled by light) to the corresponding time. The other, the phase speed (called c) is defined as the ratio of wavelength to the period of the wave. Considering light as particles only – as is the case in Special Relativity Theory (SRT) - we cannot have two speeds of light.

In classical physics the phase speed of any wave depends solely on the parameters of the medium. The velocity of the observer affects the wavelength and the period of the wave but their ratio remains constant.

Apart from the phase speed c there is also the speed of the wavefront, which depends on observer velocity u. It is obvious that when the detector approaches the wavefront the relative speed of the wavefront is greater and when it runs away is smaller.

The term 'speed of the front of the wave' is often used when analyzing shock waves (2). On the basis of the Special Relativity Theory we cannot use the idea of the speed of the wavefront. Postulated by Einstein the absolute value of light velocity results from the Lorentz transform formulae for moving objects. The formulae in two equivalent versions are presented in section 2. Their form in the particular case of objects moving at the speed of light (photons) is also shown in that section.

On the basis of classical waves theory the speed of the wavefront is relative and depends on the velocity of the observer. According to Doppler formulae (1) wavelengths and periods of waves are also relative, however, their ratio defining the phase speed is not. The phase speed is absolute. Original Doppler formulae for electromagnetic waves and that corrected for relativity are presented in section 3. The analogy between Lorentz formulae in the particular case of photons and the corrected for relativity Doppler formulae is also pointed out in that section. It shows the possible way of obtaining Lorentz transform formulae from the relativistic Doppler formulae for electromagnetic waves.

The relativistic version of the Doppler formulae for elastic waves does not exist, however, by replacing the speed of light by the speed of elastic waves we can obtain them from the formulae for electromagnetic waves. Using them we can construct formulae analogous to that of Lorentz but with a different velocity. These pseudo-Lorentz formulae are presented in section 4. Conclusions are presented in section 5.

2 Lorentz formulae for moving photons.

Original Lorentz transform formulae are given below:

$$x' = \frac{x - ut}{\sqrt{1 - u^2/c^2}} \qquad t' = \frac{t - ux/c^2}{\sqrt{1 - u^2/c^2}} \qquad (1), (2)$$

$$v' = x'/t' = \frac{v - u}{1 - uv/c^2} \qquad v = x/t \qquad (3), (4)$$

where
x – distance, t - time,
v – object velocity,
u – observer velocity,
c - speed of light.

The two first equations present the direct transform formulae. The third equation shows the relation between the direct transform formulae for the distance, time and velocity. The fourth equation presents a similar relation between corresponding inverse transform formulae.

Please note that the equation (3) has been obtained from equations (1) and (2) using equation (4). Therefore the use of this equation here should not be questioned. Using equation (4) we can write equations (1) and (2) as follows:

$$x' = x\frac{1-u/v}{\sqrt{1-u^2/c^2}} \qquad t' = t\frac{1-uv/c^2}{\sqrt{1-u^2/c^2}} \qquad (5), (6)$$

By replacing every velocity v of moving object by velocity *c* in these equations, we obtain the Lorentz transform formulae for photons. They are presented below in three different versions:

$$x' = x\frac{1-u/c}{\sqrt{1-u^2/c^2}} = x\sqrt{\frac{1-u/c}{1+u/c}} = x\frac{\sqrt{1-u^2/c^2}}{1+u/c} \qquad (7)$$

$$t' = t\frac{1-u/c}{\sqrt{1-u^2/c^2}} = t\sqrt{\frac{1-u/c}{1+u/c}} = t\frac{\sqrt{1-u^2/c^2}}{1+u/c} \qquad (8)$$

$$c' = x'/t' = x/t = c \qquad (9)$$

Le us compare formulae (7, 8, 9) with that of Doppler for electromagnetic waves corrected for relativity.

3 Corrected for relativity the Doppler formulae for moving observer

The Doppler formulae corrected for special relativity for motionless source of waves and moving observer can also be presented in three different versions:

$$\lambda' = \lambda\frac{1-u/c}{\sqrt{1-u^2/c^2}} = \lambda\sqrt{\frac{1-u/c}{1+u/c}} = \lambda\frac{\sqrt{1-u^2/c^2}}{1+u/c} \qquad (10)$$

$$T' = T\frac{1-u/c}{\sqrt{1-u^2/c^2}} = T\sqrt{\frac{1-u/c}{1+u/c}} = T\frac{\sqrt{1-u^2/c^2}}{1+u/c} \qquad (11)$$

$$c' = \lambda'/T' = \lambda/T = c \qquad (12)$$

where λ - length of wave, T – period of wave, u – in general case means the difference between velocity of observer and velocity of source of waves; here we assume velocity of source equals null so u means velocity of observer.

In the third version, making the nominator equal to one, we obtain classical Doppler formulae for moving observer. If the observer does not move but the source of waves does, we have only to replace the observer velocity u by the source velocity v.

It is not the case with uncorrected Doppler formulae. In the first version making the denominator equal to one and replacing velocity of observer by velocity of the wave source, we obtain the classical Doppler formulae for moving source of waves.

The comparison shows that in equations (10, 11) replacing period and length of wave by time and distance respectively and considering λ/T as velocity of an object, we obtain Lorentz transform formulae for photons.

Please note that in Doppler formulae changes of period and length of waves registered by moving observer are identical, which results in constancy of the wavelength to period ratio. Constancy of the ratio means constancy of the phase speed of light in any inertial system of coordinates.

It is quite different when we consider light as particles. In such a case in order to achieve constancy of the light speed we need the Lorentz transform formulae. Such a formulae can be obtained from that of Doppler replacing wavelength & period of waves by distance & time respectively and introducing coefficients presented in brackets. After such a modification we obtain formulae as follows:

$$x' = x\frac{1-\frac{u}{c}\cdot\left\langle\frac{c}{v}\right\rangle}{\sqrt{1-u^2/c^2}} \qquad t' = t\frac{1-\frac{u}{c}\cdot\left\langle\frac{v}{c}\right\rangle}{\sqrt{1-u^2/c^2}} \qquad (13),\ (14)$$

$$v' = x'/t' = \frac{x}{t}\cdot\frac{1-\frac{u}{v}}{1-\frac{uv}{c^2}} = v\frac{1-\frac{u}{v}}{1-\frac{uv}{c^2}} = \frac{v-u}{1-\frac{uv}{c^2}} \qquad (15)$$

So when $v < c$ there are Lorentz transform formulae for photons and when $v/c = 1$ we have (after replacing x, t by λ, T) the relativistic Doppler formulae for electromagnetic waves.

4 Relativistic Doppler Formulae for elastic P and S waves

Classical Doppler formulae for elastic waves are fully analogous to that for electromagnetic waves. When introducing corrections for relativity to one of them we cannot leave the other uncorrected. There should be no exceptions from relativity. So for elastic S (shear, torsional, transverse) waves the Doppler formulae corrected for relativity should read:

$$\lambda' = \lambda \frac{1 - u/\beta}{\sqrt{1 - u^2/\beta^2}} \qquad T' = T \frac{1 - u/\beta}{\sqrt{1 - u^2/\beta^2}} \qquad (16), (17)$$

$$\beta' = \lambda'/T' = \lambda/T = \beta \qquad (18)$$

where β - speed of the S (shear) elastic waves.

Having obtained the above formulae and remembering the relation between Doppler and Lorentz formulae shown in Section 2 we can arrive at the pseudo-Lorentz formulae for elastic S waves as presented below:

$$x' = \frac{x - ut}{\sqrt{1 - u^2/\beta^2}} \qquad t' = \frac{t - ux/\beta^2}{\sqrt{1 - u^2/\beta^2}} \qquad (19), (20)$$

$$v' = x'/t' = \frac{v - u}{1 - uv/\beta^2} \qquad v = x/t \qquad (21), (22)$$

Similar pseudo-Lorentz formulae for elastic P waves (irrotational, longitudinal) can be obtained by replacing speed β with speed α.

In SRT we do not consider elastic waves at all. On the one hand we cannot have three different versions of expressions for time, distance and object velocity, versions in which the only difference refers to velocity of waves. On the other hand it is not good to tolerate exceptions from Special Relativity Theory.

6 Conclusions

By analyzing Doppler and Lorentz formulae and referring to facts known from the theory of waves the following conclusions can be formulated:

1 Both versions (classical and relativistic) of Doppler formulae for length and period of wave in the case of moving observer and motionless source of waves, show that their ratio defining the phase speed of waves is constant for observers in inertial frames of reference. Considering light as waves the second Einstein postulate is not needed. It follows from the Doppler formulae for waves.

2 Electromagnetic waves as well as the elastic ones have two speeds. The phase speed constant for any observer in an inertial frame of reference and the speed of the wavefront which depends on the observer velocity.

3 Light considered as photons (particles) cannot have two different speeds. Considering light as photons we have only one speed of light. Using the second Einstein postulate and Lorentz transform we make it constant but we ignore the speed of the wavefront, which depends on the velocity of the observer.

4 The problem whether the speed of light is absolute or relative can be solved when light is considered as electromagnetic waves. In such a case light has two speeds: the phase speed which is absolute and the speed of the wavefront, which should be relative (should depend on the velocity of the observer).

5 It is shown that in the case of particles moving with velocity c the Lorentz transform formulae - after replacing x, t by λ, T - are no more than the relativistic version of Doppler formulae for wavelength and period of electromagnetic waves.

6 It cannot be that Doppler formulae for electromagnetic waves are corrected for relativity and Doppler formulae for elastic waves are not. Such a situation contradicts the very idea of relativity.

7 By independently measuring the relative speed of the wavefront $b = c - u$ and the phase speed $c = \lambda/T$ we could calculate the absolute observer velocity. Experimental verification that the speed of the light wavefront is relative would be of great importance.

References

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