The Conflict between the Relativity of Rotation and the Fact that the Speed of Light is the Maximum Speed

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Abstract

When analysing the issue of relative motion between two bodies, one of which is rotating around itself, it becomes clear that the common perception that fixing the reference system on the rotating body means the movement of the other body around it at a speed equal to the angular velocity multiplied by the distance between the two bodies is a false perception based on mixing the concept of relative motion with another different concept. Therefore, the rotational motion is relative motion and does not conflict with the fact that the speed of light is the maximum speed.

The Apparent Conflict between General Relativity and Special Relativity

The issue of relativity of motion is the basis on which the general theory of relativity was built, and it was the primary and continuous motivation that prompted its discoverer to search for and discover the theory. There is complete agreement among all physicists about the relativity of linear motion, but it seems that rotational motion still raises many problems for many, the most important of which is the conflict between the fact that the speed of light is the maximum speed and the general principle of relativity.

Suppose that we have two bodies E and S with a distance R between them, and that E is rotating around itself with an angular speed ω as we see it in the reference system in which S is at rest. Now if we fix the reference system in the body E, we will see from it that the body S is rotating around E with an angular speed ω in a circle of radius R, and the problem in this case is that if the distance R increases by a sufficient amount, the linear speed of body S will exceed the speed of light.

Thus, it appears as if there is a conflict between the most important result of special relativity and the general principle of relativity. This problem appeared very early[i] after the discovery of the theory of relativity, and opinions were divided on how to get rid of it.

Attempts to Resolve the Contradiction

Some physicists[ii] resorted to sacrificing the generality of the principle of relativity and claimed that rotational motion is absolute motion. This is a logically correct solution, but it is a mathematically and physically rejected solution because mathematics and physics do not admit exceptions due to formal differences such as the difference between motion in a circular path and motion in a straight line, especially if the matter relates to a basic, comprehensive and complete theory such as general relativity. Either the theory applies to all cases, or we reject it and look for another theory.

What has been said about sacrificing the generality of the general principle of relativity can also be said about the other trend[iii] that wants to get rid of the problem by sacrificing the generality of the fact that the speed of light is the maximum speed at which bodies can move relative to each other. There is another manifestation of the weakness of these two trends, which is their coexistence. If we choose one of them as a solution to the problem, an unanswerable question will arise: Why do we not choose the other solution?

There are other approaches[iv] to solving the problem by keeping the general principle of relativity and the principle of finiteness of speeds, then boldly and arbitrarily theorizing about the relationship between linear speed and angular speed, and ending up modifying the simple relationship to become a relationship with some complexity and elegant mathematical expressions that include the speed of light, such as those that appear in the Lorentz transformations, to ultimately achieve the purpose for which it was designed, which is to get rid of the ghost of the continuous increase in linear speed with the increase in radius.

I have no plan here to criticize these solutions in detail, but I want to show now, conclusively and with mathematical and geometric evidence, that the basis on which this conflict is built is wrong. It will become clear that the claim that the relative motion observed by the observer in the reference system fixed on body E (the body that rotates around itself when viewed from S) is the rotation of body S around it is an incorrect claim and is based on a specific concept of the relativity of motion related to the motion of extensions of specific bodies and not on the concept of the relativity of motion on which the theory of relativity is based, which is an abstract concept that only examines the geometric relationship between two points: when we say the observer in the contexts of general relativity, what is meant is a person located at a specific point in a body who wants to observe the motion of another point in another body regardless of the motion of the extensions of the bodies in which the observer and the observed are located.

Analysis and Resolution

Suppose we want to study the relative velocity between the centre of a certain star and an observer located at the equator on the surface of a planet of radius r at a distance R from this star. In a system in which the star is stationary, the planet rotates about itself with an axis of rotation perpendicular to the distance between the planet and the star.

Let us examine the relative motion between the point where the observer is located and the centre of the star: for an observer located on the star, the observer located on the planet at a certain moment is moving with a linear velocity:

$$\mathbf{v=\omega r}$$

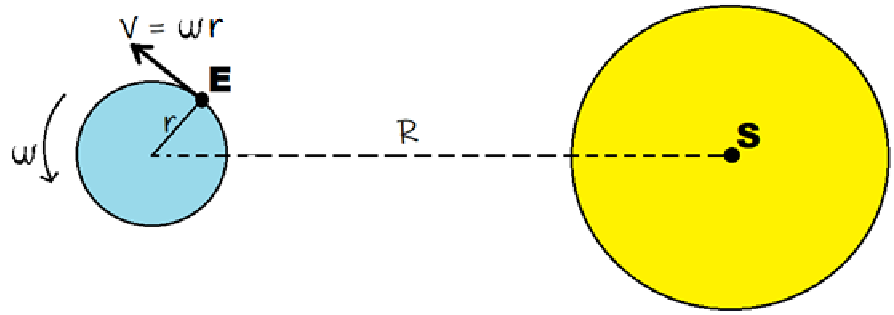

Fig (1): The relative motion of the between the spinning planet and the star as observed from the star.

Now we want to know what this relative motion between the observer and the centre of the star would look like if we observe it from a system in which the observer in the planet is stationary. We will now ignore the rest of the planet and focus our analysis on the point where this observer is located. The matter will become clearer if we restrict our research to a specific moment and not the history and future of his entire motion. According to the previous reference system, the observer at that moment is moving at a specific linear velocity that can be calculated by multiplying the rotational velocity by the radius of the planet, and its direction can be determined from the location of the body on the planet at that moment. The important thing here is to clarify that when we want to know what the motion between the two points would look like when we look from a reference system in which the observer on the planet is stationary, this same velocity will be transferred, but in the opposite direction, to the point that was stationary in the previous reference system. This procedure will not differ between this speed being the result of a rotational motion or a purely linear motion. This is the important fact on which this analysis is based. The concept of relative motion in general relativity is concerned with what happens at a specific moment and is not affected by the history and future of the motion. This is the natural concept of motion not only in relativity but in all branches of physics and mathematics. For example, in problems of body collision, we are concerned with the speed and direction of motion at the moment of collision, and we do not care whether the body was originally moving in a straight, circular or elliptical path. In mathematics, the slope is the slope at a specific point, and it does not matter whether looking at the rest of the parts of the shape shows that the point is part of a straight line, a circle, or anything else.

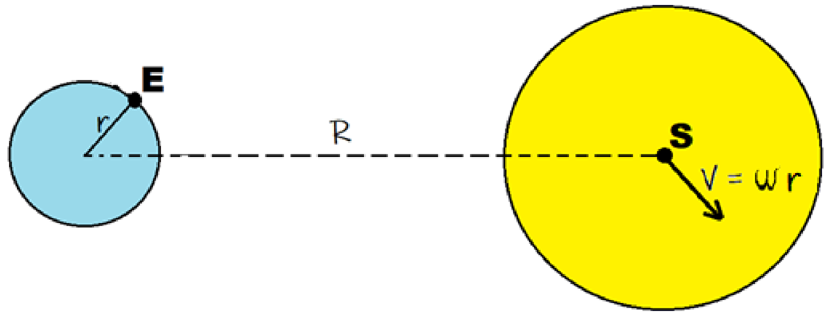

Fig (2): The correct relative motion as observed from the planet.

It is clear from this that fixing the reference system at a point on the body that is rotating on its axis does not result in observing a speed equal to the product of the radius and the angular velocity of the bodies that represent the reference system from which we observe the rotation. Rather, in this case we will simply observe for these bodies an instantaneous motion equal to and opposite to the instantaneous linear velocity with which the point on the body that we see rotating moves from the reference system in which we observe the rotation.

Here an important question arises: If the matter is that simple, then where did the very common conception come from that considers the relative motion corresponding to the rotation of a body around itself while it is among stationary bodies outside to be the rotation of these bodies around it with the same angular velocity in the opposite direction?

The answer to this question is that this error resulted from mixing the concept of relative motion and transferring the reference system between two points with another concept related to the motion of extended bodies, and let us now call it the extended concept of relativity of motion. According to the concept of general relativity, the relativity of motion means the possibility of transferring the reference system freely from one point to another in order to arrive at a description of motion without justification for preferring one point over another. As for the extended concept of relativity of motion, it is the possibility of transferring the reference system between two observers such that this transfer does not lead to a change in the positional relationships between parts of different bodies whose parts move relative to each other.

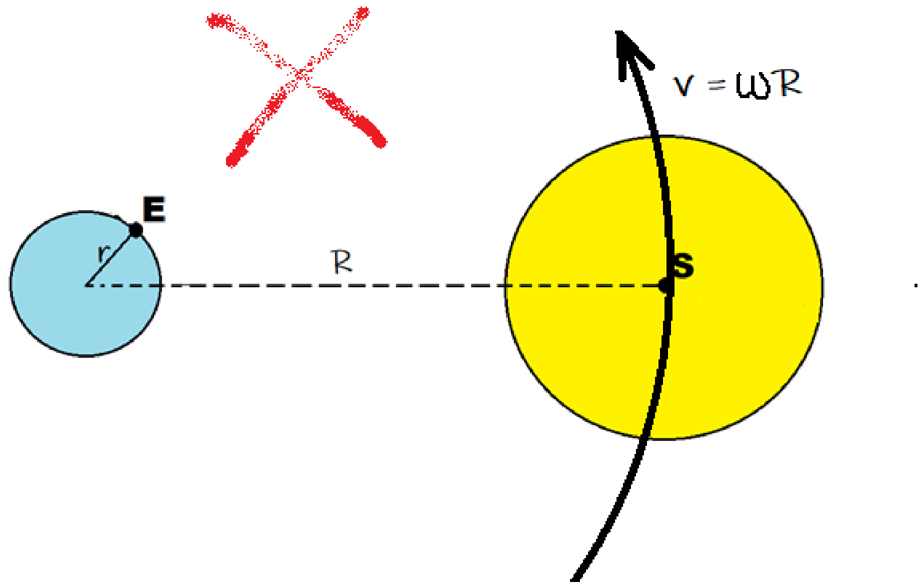

Fig (3): This is not the correct way to find the velocity of the star as seen from the planet.

The attempt to find a relative motion observed from two different reference systems for the motion of a body rotating around itself in a way that preserves all the positional relations between the observation point and the points located on the extensions of the body is not among the topics of the theory of relativity, and it may be needed by someone who wants to study something like some practical aspects of theories of vision or other things.

Conclusion

In the case of two bodies, one of which is stationary and the other rotating around itself, any point in the body that is rotating around itself moves instantaneously linearly. Therefore, fixing the reference system on this point and considering it stationary leads to monitoring an instantaneous linear speed in the other body, (which was stationary in the previous reference system). This speed is equal and opposite in direction to the speed of the point in the rotating body (as we see in the previous reference system), and thus it is clear that the relativity of speed does not have any problem when we apply it between any two points individually. Monitoring and analysing relative speed in this way leads to a mismatch between the visions of the two observers regarding the positional relationships of the rest of the points on the extensions of the two bodies, and this does not represent a problem for the principle of relativity of motion. The problem of speeds greater than the speed of light arises when we want to achieve the relativity of motion between a point and an extended body so that the relations of the point and the extended body as a whole remain the same when moving from one reference system to another, and these cases are not among the issues of the theory of relativity.

References

[i] See for example W De Sitter. "On the relativity of rotation in Einstein's theory"1917.
[ii] arXiv: On the Absoluteness of Rotation. Peter Hrasko 2023.
[iii] Salter Horners Advanced Physics A2 Student Book. Heinemann.
[iv] Relativistic Rotation. J. Güémez et al 2018 J. Phys.: Conf. Ser. 1141 012131