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A Glimpse of Special Theory of Relativity

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ABSTRACT

This article provides a brief outline of Special Theory of Relativity. The physics before the relativity, the special relativity in itself, and the consequences of special relativity are discussed here.

Introduction

The special theory of relativity was formulated by Albert Einstein in his 1905 paper "On the electrodynamics of moving bodies". It was drawn out from the Maxwell-Lorentz theory of electromagnetic phenomenon, hence all the facts that are in support of Maxwell-Lorentz theory also supports the special theory of relativity. Before the advent of relativity, it was long considered from the time of Galileo-Newton that the motion of any object could be described with a absolute frame of reference, i.e, either at absolute rest or at the state of absolute motion. The theory of relativity replaced the term 'absolute' with the term 'relative'. Thus, according to relativity, motion of objects can only be measured relative to a certain point or a frame of reference.

Before the Relativity

Prelude to the special theory of relativity, Euclidean geometry had dominated every area of physics which basically would deal with the objects in the form of straight lines; the intangible property of two points, which would provide the exact measurement between them. This geometry would then resolve itself into a number of axioms which would allow us to determine the relative position of two practicable bodies. Thus the system of co-ordinates was introduced for the precise numerical measurement of the path between any two objects/points lying on a surface. This method was indubitably dependent upon the location and position of the points from the surface relative to the given point. So the scene of any event that happens could be described by the use of three space co-ordinates(x, y, and z) where the length of perpendiculars dropped from the event to three perpendicular axes would give us the physical location of event, precisely, with the help of foundations set by the Euclidean geometry.
Before the relativity, the laws of Newtonian dynamics were powerful in physics in describing the state of motion of any body, which argued that a body in a state of rest or in the state of uniform motion would continue as it is unless it is acted upon by an external force. So, it eventually predicts that a reference frame can be sought which could be able to describe the description of bodies. But these frames, now known as Galilean frames were soon found out that they were

incapable to describe the motion of heavenly bodies considering Earth as an absolute frame of reference.

Since every description of events happening in the space involves the use of a rigid frame of reference, it was clearly understood that there was no such independent reference frame existing to which all events could be judged relative. Hence the concept of absolute frame of reference was not adequate enough to describe the laws of nature. For the complete description of a body in motion, not only the position of the body in space is needed but even the time with which the body alters its motion should also be taken into consideration.

Under the Galilean frames of reference, the physical description of a body of mass *m* moving uniformly with respect to frame S will also be moving uniformly relative to the next frame S' if S' is moving with relative translation motion with respect to S.

Thence came the relativity principle which justified that the Galilean frames will be sufficient for the description of natural phenomena if they move uniformly relative to each other as the physical non-equivalence of events in different directions have never been realized.

The Special Theory of Relativity

Einstein formulated his theory on the basis of two postulates.

1. The principle of relativity -which stated that the laws of nature are not affected by the changes under which a certain physical system may undergo.
2. The principle of invariant of speed of light -which stated that light, always propagates in vacuum with a definite velocity *c* and is independent of the state of motion of the source emitting it.

Relativity demands that the measurement of distance should be made in accordance with their relative frames as the actual measurement of distances for certain events may not be equal when observed from two different frames. Previous of relativity, Newtonian dynamics had assumed that time had an absolute significance and is independent of the state of anybody in its state of motion. But relativity showed that the time and space are inseparable from each other. By the theorem on the addition of velocities it was clear that the time and space interval between any two events at any two points is independent of the condition of motion for a given body of a certain frame of reference.

This problem was solved by the Lorentz transformation law which provided a concrete basis for determining the space-time magnitude of an event, even when the frames of references are changed from one to another.

Consequences

Relativity brought a drastic change in the field of mechanics. The laws of Newtonian dynamics were soon replaced by the relativity. The long thought length contraction and time dilation were no more an illusion, but were a part of reality, which an observer would notice for the bodies with velocity comparable to the velocity of light.

Any rod of length l at a frame S' at time t moving with the velocity v relative to any other frame of reference s would lose its length by $l_0\sqrt{1-\frac{v^2}{c^2}}$ to a observer at s-frame. So higher the velocity of the rod in its motion, would result in more shortening of length and for ultimately at the speed of light (v=c), we would have $\sqrt{1-\frac{v^2}{c^2}}$ = 0 and even for higher velocities than the speed of light, our result would be imaginary.

Similarly from Lorentz transformation, we have,

$$t' = \frac{t_0}{\sqrt{1-\frac{v^2}{c^2}}}$$

So to an observer at s'-frame, he will find that clock goes more slowly than that of an observer at s-frame and higher is his velocity, his clocks ticks more slowly.

Furthermore, the relativity expresses that the kinetic energy of a body is not given by the classically used expression $\frac{mv^2}{2}$ but by $\frac{mc^2}{\sqrt{1-\frac{v^2}{c^2}}}$.

Even in this above expression when the velocity of the object approaches the velocity of light 'c', the expression itself approaches infinity. It too provides a clear idea that the velocity of an object in any case must be less than the velocity of light at vacuum.

Before the relativity, mass and energy were two separate quantities in physics and were described by two independent conservation laws,i.e., conservation of mass and and conservation of energy. But relativity united them to a single law given by Einstein's most famous equation $E=mc^2$. Thus the conservation of energy must hold true in every frame of references provided that the physical system neither absorbs nor emits the energy. For the transition from one frame to another frame of reference, Lorentz transformation is the ultimate deciding factor.

Further when a body of mass m moving with velocity v without any change in its velocity during the event, consumes E amount of energy, then the K.E. of the body is given as $\frac{\left(m+\frac{E_0}{c^2}\right)c^2}{\sqrt{1-\frac{v^2}{c^2}}}$

where, E_0 is the initial energy and even this expression yields that the inertial mass of increases by the amount$\frac{E_0}{c^2}$. This shows that the inertial mass of the body varies accordingly with the change in the energy of the body.

Conclusion

The special theory of relativity has hence modified the Newtonian dynamics to describe the laws of nature. The unification of the two basic postulates of relativity as proposed by Einstein has led us to determine all the events by the help of Lorentz transformation law involving the use of co-ordinates x, y, z, and time t. Mass and Energy came as equivalent and a measure of each other's

pointing out the fact that they are inseparable. The velocity of constancy of light plays the most important part and it is the limiting velocity for all of the cases.
From relativity, it was clear that every reference frame has its own particular time. Time appeared to be independent of the state of motion unlikely as in the Newtonian dynamics where time had absolute significance. The time value is associated with all the events happening in the nature so it is mandatory, to describe the properties of any events happening with greater precision, so the concept of space time co-ordinates as set by Minkowski has prevailed. Thus space and time are no more independent but are linked together as space-time. Hence the theory of relativity has even robbed time of its independence.

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