ENTRI

SPECIAL THEORY OF RELATIVITY

Theory of relativity was proposed by Albert Einstein in 1905 which states that there is no absolute state like absolute space, time and mass exist in the universe, all states are relative.

POSTULATES:

1. The laws of Physics are the same in all inertial frames of reference.

2. The velocity of the light in free space is constant, it is independent of the relative motion of the source and the observer

The 1st postulate says all physical laws are same in the frame of reference moving with the uniform velocity with respect to one another.

If the laws of physics are different for different observers in the relative motion, the observer could determine from this difference that which of them were stationary in space and which of them were moving. But such distinction does not exist, so this postulate implies that there is no way to detect absolute uniform motion.

The laws of physics seem to be simplest in inertial frames. For example, when you are in a plane flying at a constant altitude and speed, physics seems to work exactly the same as if you were standing on the surface of the Earth. However, in a plane that is taking off, matters are somewhat more complicated. In these cases, the net force on an object, F, is not equal to the product of mass and acceleration, ma. Instead, F is equal to ma plus a fictitious force. This situation is not as simple as in an inertial frame. Not only are laws of physics simplest in inertial frames, but they should be the same in all inertial frames, since there is no preferred frame and no absolute motion. Einstein incorporated these ideas into his first postulate of special relativity.

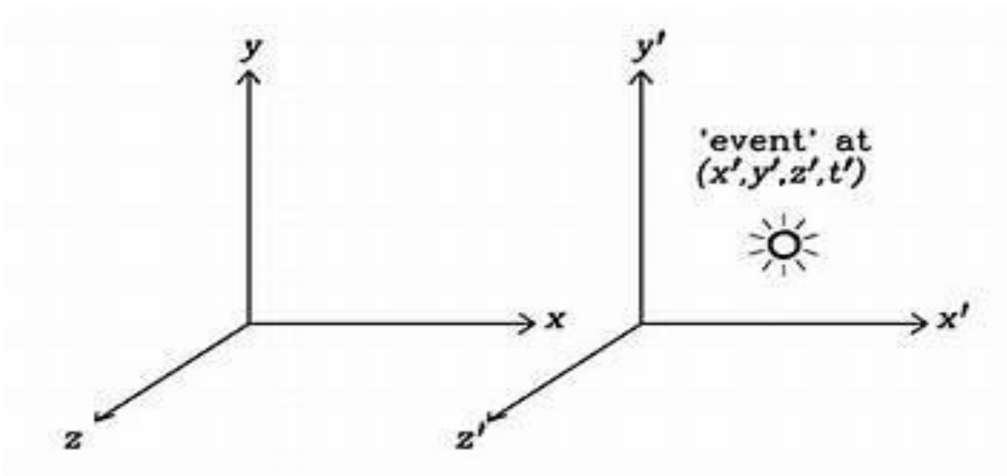
The second postulate: The laws of electricity and magnetism and Newton's laws were explained the concept of light in 19th century. In particular, the laws of electricity and magnetism predict that light travels at $c = 3 \times 10^8$ m/s in a vacuum, but they do not specify the frame of reference in which light has this speed.

Vector addition of light in different frames is not allowed by Maxwell's equations. So either Maxwell's equations are wrong, or an object with mass cannot travel at speed c. Einstein concluded that the latter is true. The light in a vacuum must always travel at speed c relative to any observer. Maxwell's equations are correct, and Newton's addition of velocities is not correct for light.

Furthermore, the Michelson-Morley null results were successfully explained by second postulates.

LORENTZ TRANSFORMATION EQUATIONS

We can derive a set of transformation equations based on postulates of special theory of relativity i,e invariance of light velocity in free space.



Consider two observer o and o' in two frame of reference S and S' respectively. The frames be in relative motion with respect to each other I,e S' is moving with a constant velocity v relative to frame S along positive x axis. Suppose we make measurements of time from the instant when origins of S & S' just coincides at t=0.

When O & O' coincides, let a flash of light be emitted which gives rise to a spherical wavefront. After a time t, the observer O observes that light has reached a point P as shown in figure.

For observer O, the distance of point P is r = ct

$$r^2 = x^2 + y^2 + z^2$$

$$c^2 t^2 = x^2 + y^2 + z^2$$

Similarly for observer O' will note that light has reached the same point P in a time t' with same velocity

$$r' = ct' \quad r'^2 = x'^2 + y'^2 + z'^2$$

$$c^2 t'^2 = x'^2 + y'^2 + z'^2$$

The above both equations are equal since both observer are at the centre of the expanding wavefront.

$$x^2 + y^2 + z^2 = x'^2 + y'^2 + z'^2$$

since there is no motion in Y & Z

Y = Y'   Z = Z' as they are perpendicular to v.

The equation becomes $x^2 - c^2t^2 = x'^2 - c^2t'^2$ --------------   (1)

Any transformation equation that we obtain must satisfy the above equation.

For the observer O in S frame or O' in S' frame, the equation is given by

$$X' = k\,(x - vt)$$

Similarly the origin O of S is

$$X = k\,(x' + vt')$$

The same constant k is taken because two frames distinguishes only by their sign in relative motion.

$$X = k\,(x' + vt')$$

$$= k\,(k(x - vt) + vt')$$

$$t' = x\,(1 - k^2) + kt$$

substituting for x' and t' in equation (1)

$$x^2 - c^2t^2 = (k\,(x - vt))^2 - c^2\,\{x\,(1 - k^2)/kv + kt\}^2$$

After simplifying we get,   k = $\frac{}{\sqrt{\ }}$

/ Substituting

in transformation equations , we get

Lorentz transformation equations.

$$x' = \frac{x - vt}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$y' = y$$

$$z' = z \qquad \Longleftrightarrow$$

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

Inverse Lorentz Transformation equations are

$$\Longleftrightarrow \quad \begin{aligned} x &= \frac{x' + vt'}{\sqrt{1-\frac{v^2}{c^2}}} \\ y &= y' \\ z &= z' \\ t &= \frac{t' + \left(v/c^2\right) x'}{\sqrt{1-\frac{v^2}{c^2}}} \end{aligned}$$

Significant aspects:

1. The measurement of time as well as position depend upon the frame of reference of the observer so that the two events which occur simultaneously in one frame of reference need not be simultaneous when viewed from another.
2. If the relative velocity v of the frame S' relative to S is very small as compared to velocity of the light c, k becomes nearly 1 so that Lorentz equations reduce to Galilean equations
3. t can be used for transforming one reference frame to another.
4. Lorentz transformation uses the speed of light for referring frames as it is constant.

Conclusion :

- The measurements of space and time are not absolute but are dependent upon the relative motion between observer and phenomenon observed.

Effects which are result of relativity and Lorentz transformation equations are

1. Length Contraction
2. Time dilation