Modern Physics

(Lec-1)

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Date: 27.09.2023

OUTLINES

- Theory of relativity
- Frame of Reference
- Postulates of special relativity
- Galilean Transformation

Modern Physics

Relativity:

According to classical mechanics space, time and mass are constant, these are not relative. Einstein said that space, time and mass are not constant or absolute, these are relative. This theory of Einstein is called theory of relativity.

There are two parts:

I. **Special or restricted theory of relativity:** The special theory of relativity, developed in 1905, treats problems involving inertial frames of reference, which are frames of reference moving at constant velocity with respect to one another.

II. **General theory of relativity:** The general theory of relativity, proposed by Einstein in 1915, treats problems involving inertial frames of reference accelerated with respect to one another.

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❖ Relative Motion

The first step is to clarify what we mean by motion. Using Cartesian co-ordinate system in three dimensions, we can characterize any location by three co-ordinates of that space point. When we say that something is moving, what we mean is that its position relative to something else is changing. That is all motion is relative. In each case a frame of reference is part of the description of the motion.

❖ Frame of Reference

A coordinate system relative to which the measurements are taken is known as frame of reference.

❖ Inertial Frame of Reference

A coordinate system in which Newton's first law (i.e., law of inertia) is valid is known as inertial frame of reference. A reference frame which is at rest or moving with constant velocity is inertial reference frame, while the accelerated frame is known as non-inertial frame of reference.

Postulates of the Special Theory of Relativity

- First Postulate**:** This postulate is called the principal of relativity. Stated as,

  "The laws of the physics are same in all inertial frames of reference."

  Explanation: This postulate expresses the absence of an absolute or fixed frame of reference. If the laws of physics were different for different observers in relative motion, it could be determined from these differences which of them were "stationary" in space and which were moving." But because there is no fixed frame of reference, this distinction between state of rest and of uniform motion is not possible.

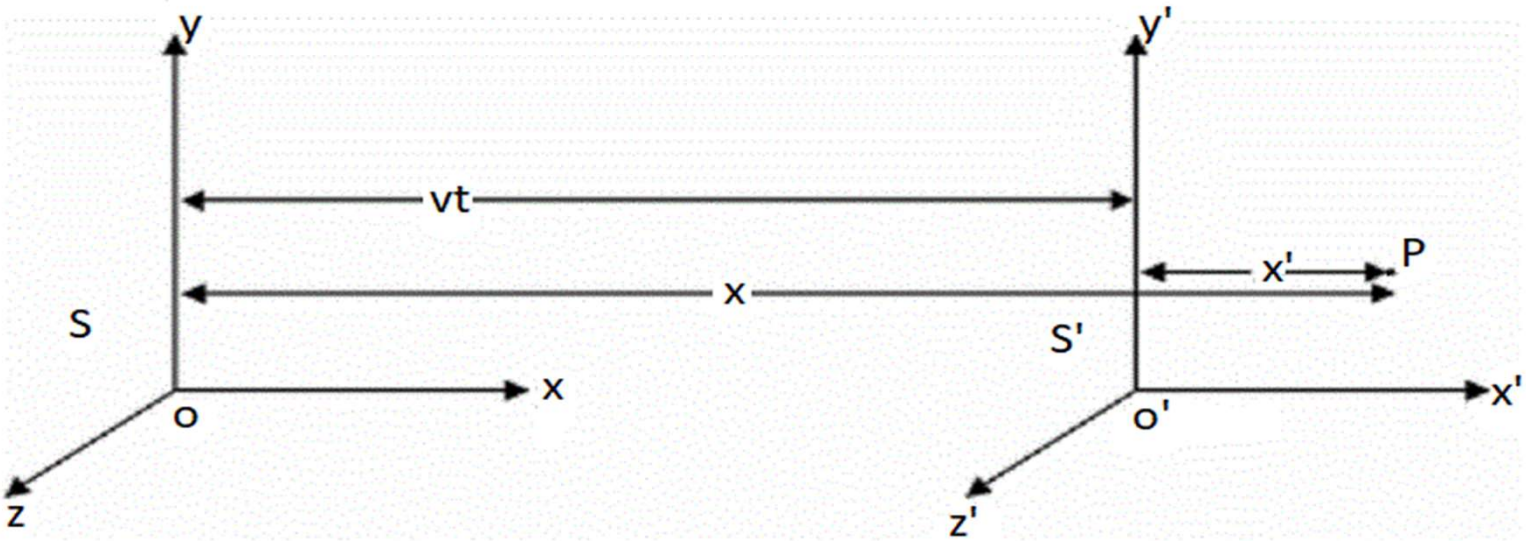
- Second Postulate: This postulate is called the principal of constant velocity of light. Stated as,

"The speed of the light in free space has the same value in all inertial frames of reference"

Explanation: This postulate tells that the speed of light in vacuum is always the same $3x10^8$ ms^{-1} no matter what the speed of the observer or the source. This a person moving toward or away from a source of light will measure the same speed for that light as someone at rest with respect to the source.

GALILEAN TRANSFORMATION

- The equation of classical physics, which establishes or expresses the relation between time & co-ordinates moving with constant speed with respect to one another are called Galilean Transformation.
- Consider two observers in two different inertial frames S and S'. Frame S is at rest and S' is moving with uniform velocity v along x-axis with respect to frame S. Suppose at t=0, the origins of two frames coincide.



Both the observers observe the same event. The position and time of event observed by S is denoted by (x,y,z,t) and position and time of the event observed by S' is denoted by (x',y',z',t'). Then the measurements in x direction made in S will exceed those made in S' by an amount vt, which represents the distance that S' has moved in the x direction.

Thus from the figure, we can easily establish the Galilean transformation between the coordinates as,

G.T.	Inverse G.T.
$x' = x - vt$	$\Rightarrow x = x' + vt$

And since there is no relative motion in y and z directions,

$$y' = y$$
$$z' = z$$
$$t' = t$$

Failure of Galilean transformation: The second postulate calls for the same value of the speed of light c when determined in S or S'. This contradicts with Galilean transformation. If we measure the speed of light in the x-direction in the S system to be c, however, in the S' system it will be c'= c-u Clearly a different transformation is required if the postulates of special relativity are to be satisfied.

Consequences of Einstein's postulates:

There are four important consequences of Einstein's postulates:

Relativity of Time (Time dilation): Moving clocks tick slower than an observer's "stationary" clock.

Relativity of Length (Length contraction): Objects are observed to be shortened in the direction that they are moving with respect to the observer.

Mass-energy equivalence: According to the relationship $E = mc^2$, energy and mass are equivalent and transmutable.

