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Paper- DSC1AT

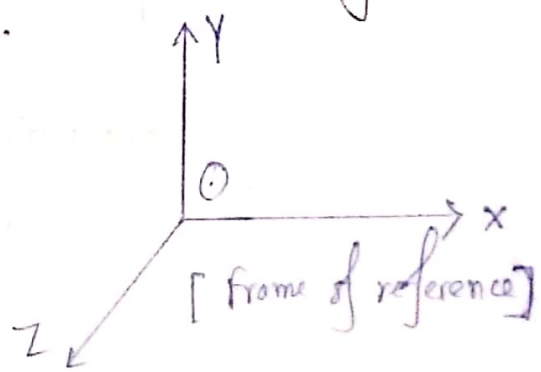
Topic- Special Theory of Relativity

Special Theory of Relativity (STR)

☑ In 1905 Albert Einstein published a paper with a title "on the electrodynamics of moving bodies." This work of Einstein gave a totally different notion of physical world. It changed the foundation of physics and also our understanding of nature. This theory has originated from the analysis of electromagnetic theory. In most of the books discussion of special theory of relativity starts with Michelsion Morley experiment. Therefore, it appears as if this theory came into existence in search of explanation for negative result of Michelson Morley experiment. But that it is not true. Einstein was not even aware of Michelson Morley experiment.

In the following we briefly discuss the fundamental concepts of this theory.

☑ **Frame of reference** :- A place from where observations are made is called frame of reference. In physics a frame of reference is represented by a co-ordinate system with respect to which spatial co-ordinate of any point in space is determined and we also associated a clock with the coordinate system to measure time of any event in space.

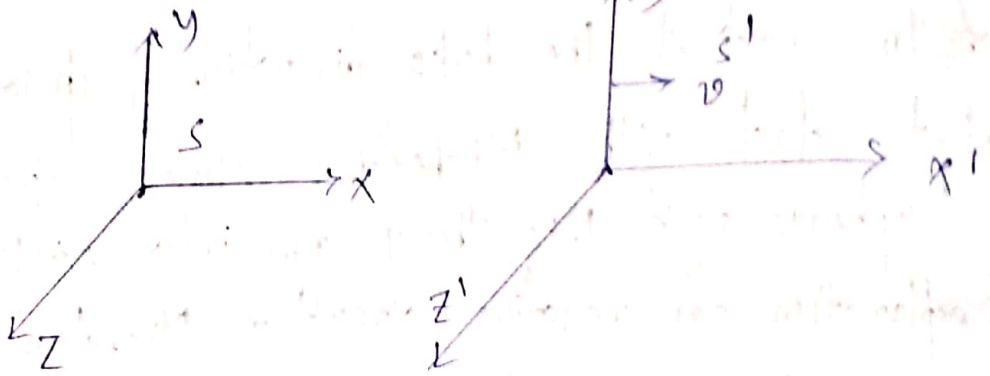


[frame of reference]

☑ Frame of reference are of two types:

1. **Inertial frame of reference** :⇒

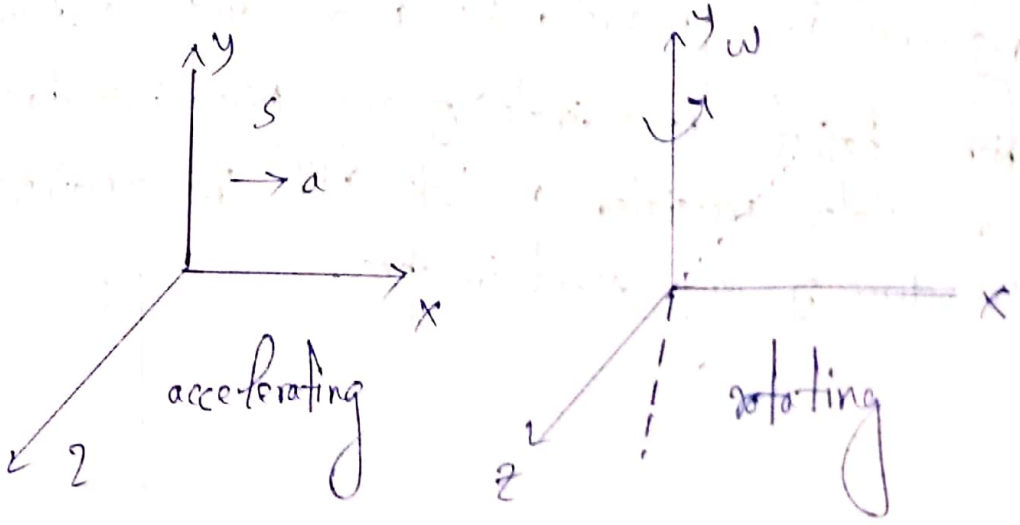
Two frames are said to be inertial if they are at rest or moving with constant velocity w.r.t each other.



In figure shown s' is moving with constant speed v. w.r.t s therefore, s and s' are inertial frames.

2. **Non- inertial frame of reference** :-

A frame of reference is said to be non-inertial if it is either acce-lerating or rotating



☑ Postulates of STR :⇒

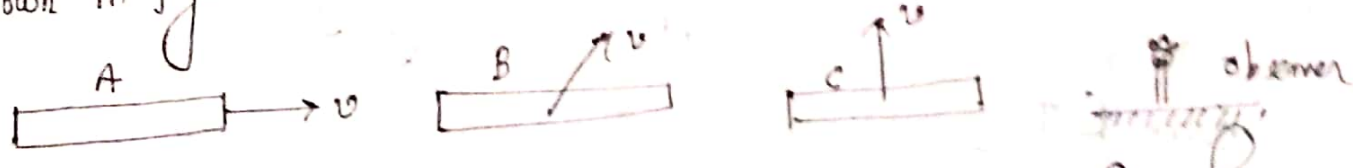
STR deals with inertial frames of reference. And it is based on following two postulates.

First Postulate: All inertial frames are "equivalent". Therefore, laws of physics must be invariant in all inertial frames.

Second Postulate: speed (magnitude) of light in vaccuum has value in all inertial frame. And speed of light is the ultimate speed in vaccuum.

☑ Length Contraction:

This is an important relativistic effect. It has been confirmed by several experiments. This effect tells that if a moving rod has velocity component parallel to its length then the rod gets contracted. Consider three situation shown in figure.



Rods A, B and C are moving with respect to an observer on ground. If the observer does measurement he/she will find that rod A and B are contracted whereas rod C

is not contracted.

Let us consider a rod of rest (proper) length L_0 kept in s' frame.

Let x_1' and x_2' be coordinates of the ends of rod.

$\therefore x_2' - x_1' = L_0$

Rod is at rest in s' frame so x_1' and x_2' need not be measured simultaneously.

To measure length of rod in S frame coordinates of ends must be measured simultaneously because rod is moving w.r.to S frame.

Let x_1 and x_2 be end coordinates of rod in S frame at time t.

$\therefore x_2 - x_1 = L$ (apparent length of rod)

from L-T

$x_1' = (x_1 - vt)\gamma$

$\therefore x_2' = (x_2 - vt)\gamma$

$$x_2' - x_1' = (x_2 - x_1)\gamma$$

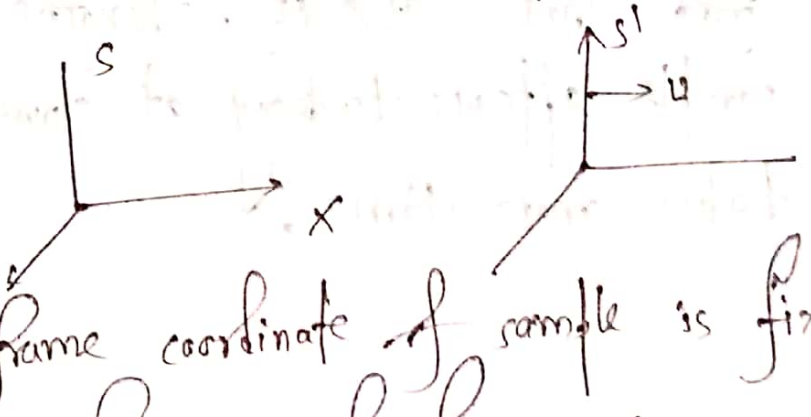
or $L = L\gamma$

or $L = \frac{L_0}{\gamma} = L_0\sqrt{1 - v^2/c^2}$

$\therefore \sqrt{1 - v^2/c^2} < 1 \quad \therefore L < L_0$

Time dilation :-

By time dilation we mean slowing down of a process while in motion w.r.t an observer due to which completion of process takes more time than is stationary case.



In s' frame coordinate of sample is fixed whereas in s it is changing. Therefore $\Delta x' = 0$ and $\Delta x \neq 0$ from differential from of inverse L-T.

$$\Delta t = \left(\Delta t' + \frac{\Delta x' v}{c^2}\right)\gamma$$

$\because \Delta x' = 0$, therefore $\Delta t = \gamma \Delta t'$

or,

$$\boxed{\Delta t = \frac{\Delta t'}{\sqrt{1 - v^2/c^2}}}$$

We did not want to involve coordinate so we used inverse LT; if we had used direct L-T, Δx would have also come in the expression. $\Delta t'$ is measured in s' frame where $\Delta x' = 0$. Therefore its proper time. It is also called time in rest frame. We find that $\Delta t > \Delta t'$, therefore while in motion radioactive sample appears to decay at slower rate & its completion takes more time.