# TIME DILATION & SIMULTANEITY:

## B.Sc. Part-1, Hons. & Sub.

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## TIME DILATION

Consider two successive events occurring at the same point $x'$ in the inertial frame $S'$. Let $t_1'$ and $t_2'$ be the times recorded by the observer in frame $S'$. Then the time interval measured by him is $t_2' - t_1'$. For the observer in $S'$, the rest frame is $S'$ itself. The time interval between events in the rest frame, that is, time interval as measured by a clock in $S'$, is called the **proper time** . Hence,

$$\Delta\tau = t_2' - t_1' \qquad (1)$$

an observer in frame $S$ measures these instants as

$$t_1 = \gamma[t_1' + (vx'/c^2)] \qquad t_2 = \gamma[t_2' + (vx'/c^2)]$$

The time interval according to the observer in frame $S$ is then $\Delta t = t_2 - t_1$, which is given by

$$\Delta t = \gamma(t_2' - t_1') \qquad \text{or} \qquad \Delta t = \gamma \Delta\tau$$

$$\Delta t = \frac{\Delta\tau}{\sqrt{1 - v^2/c^2}} = \frac{\Delta\tau}{\sqrt{1-\beta^2}} \qquad (2)$$

Since $g > 1$, it follows from Eq. (1) that the proper time interval is a minimum. The effect is known as **time dilation** and is equivalent to the slowing down of moving clocks. Hence, growth, aging, pulse rate, heartbeats, etc. are slowed down in a fast-moving frame. If the velocity of the moving frame $v = c, \Delta t \rightarrow \infty$ and the process of aging will stop altogether.

The time dilation effect has been verified experimentally by observation on elementary particles and by atomic clocks accurate to nanoseconds carried aboard jet planes.

# SIMULTANEITY

Another important consequence of Lorentz transformation is that simultaneity is relative. Consider two events occurring at two different points $x_1$ and $x_2$ at times $t_1$ and $t_2$ in the inertial system $S$. Let $t_1'$ and $t_2'$ be the times at which the two events are observed to occur with respect to $S'$. Then from Lorentz transformation

$$t_1' = \gamma\left(t_1 - \frac{vx_1}{c^2}\right) \qquad t_2' = \gamma\left(t_2 - \frac{vx_2}{c^2}\right)$$

$$t_2' - t_1' = \gamma(t_2 - t_1) + \frac{\gamma v}{c^2}(x_1 - x_2) \qquad (3$$

If the two events are occurring at the same instant in $S$, $t_2 - t_1 = 0$ and

$$t_2' - t_1' = \frac{\gamma v}{c^2}(x_1 - x_2) \neq 0 \qquad (4)$$

That is, two events that are simultaneous in one reference frame are not simultaneous in another frame of reference moving relative to the first, unless the two events occur at the same point in space. It implies that clocks that appear to be synchronized in one frame of reference will not necessarily be synchronized in another frame of reference in relative motion.