U3A

10-Feb-2026 Term 1 / Week 3

Time Dilation

- We derived the equation for Time dilation, as per Einstein's special theory of Relativity (published in 1905).

- The equation is:
(with reference to GPS system)

$$\Delta t_e = \Delta t_s \cdot \frac{1}{\sqrt{1 - v^2/c^2}}$$

where, Δt_e – time elapsed on Earth or Stationery clock
Δt_s – time elapsed on satellite or moving clock.

- There were conceptual difficulty during derivation, especially the concepts of stationery observer, speed of light, etc.
- However, the main concept of Time Dilation is that:
"The clock on a fast moving object slows down compared to stationary or slow moving object."
(as per special theory of Relativity)
- The above concept can also be illustrated using acoustic clocks in a simpler way. (Refer to the video link on the "seshveda" web site notes!)

- (Explain the concept briefly in the class!)

- Surprisingly, the above concept also applies to life span of biological systems and atomic particles.

- Time dilation is mind boggling however, it has been proven through experiments, even by carrying clocks on a plane!

Ex. 1 In the particle accelarator at Large Hadron Collider (LHC) at Geneva, the particles can travel around the ring in about 90 μs for a 27 km lap.

Calculate the speed achieved by the particles.

$$v = D/t \cong \frac{27\,\text{km}}{90\,\mu s}$$

$$\cong 300{,}000\ \text{km/s}$$

In fact, the particles can achieve a speed of approx. $0.999999991 \times c$ where c – speed of light!

- LHC has enabled conducting experiments to verify the life time of moving particles, and compare it with the Time Dilation Equation.

Ex. 2 A Muon (electron with mass) has a life span of about 2.2 μs. If a Muon travels at a speed of 0.98 times speed of light, calculate the new life span of the Muon.

We have velocity of Muon

$v = 0.98c$ or $v/c = 0.98$

& $\Delta t_s = 2.2\ \mu s$

(for the moving object)

However, for the stationary observer, life span is as per Time Dilation Equation.

$$\Delta t_e = \frac{\Delta t_s}{\sqrt{1-(v/c)^2}}$$

$$= \frac{2.2\ \mu s}{\sqrt{1-(0.98)^2}}$$

$$= \underline{\underline{11.055\ \mu s}}$$

The above value has been verified by experimental results.

Ex. 3

Home work Problem

(Refer to Page 11 of last week's Notes

- As per above Example, the satellite clock slows down by about 7.3 μs/day.

- However, satellite has significant mass and hence the satellite clock is also affected by the Gravity as per "General Theory of Relativity equation for Time Dilation", published by Einstein in 1915!

$$\Delta t_r = \Delta t_o \sqrt{1 - \frac{GM}{rc^2}}$$

where;

Δt_r - time elapsed at distance of 'r' from Gravitational Centre.

Δt_o - Timespan unaffected by gravity

G - Universal Gravitational Constant ($G = 6.67408 \times 10^{-11}$)

M - Mass of the Gravitational Object (For Earth, $M = 5.972 \times 10^{24}$ kg)

c - Speed of light ($c = 2.998 \times 10^8$ m/s)

r - Distance from Gravitational Centre.

($r_{earth\ surface} = 6,371$ km

$r_{satellite} = 26,371$ km)

(from centre of earth)

Homework

Assuming $\Delta t_0 = 24$ hrs (86,400 sec)

Calculate Δt_r for earth's surface (GPS device)

and Δt_r for the satellite.