

# Modern Physics

## Tutorial 1

### Special Relativity

LUMS School of Science and Engineering

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## 1 Decay of Muon

The muon is an unstable particle that spontaneously decays into an electron and two neutrinos. If the number of muons at  $t=0$  is  $N_0$ , the number at time  $t$  is given by  $N = N_0 e^{-\frac{t}{\tau}}$ , where  $\tau$  is the mean life time, equal to  $2.2\mu s$ . Suppose the muons move at a speed of  $0.95c$  and there are  $5.0 \times 10^4$  muons at  $t=0$ .

- What is the observed lifetime of the muons?
- How many muons remain after traveling a distance of 3 km?

## 2 Time Dilation

In 1962, when Scott Carpenter orbited Earth 22 times, the press stated that for each orbit he aged 2 millionths of a second less than if he had remained on Earth.

- Assuming that he was 160km above Earth in an eastbound circular orbit, determine the time difference between someone on Earth and the orbiting astronaut for the 22 orbits.
- Did the press report accurate information?

## 3 Relativity of Simultaneity

Suppose our Sun is about to explode. In an effort to escape, we depart in a spaceship at  $v = 0.80c$  and head toward the star Tau Ceti, 12 lightyears away. When we reach the midpoint of our journey from the Earth, we see our Sun explode and, unfortunately, at the same instant we see Tau Ceti explode as well.

- In the spaceship's frame of reference, should we conclude that the two explosions occurred simultaneously? If not, which occurred first?
- In a frame of reference in which the Sun and TauCeti are at rest, did they explode simultaneously? If not, which exploded first?

## 4 Twin Paradox

A space explorer  $A$  sets off at a steady  $0.95c$  to a distant star. After exploring the star for a short time, he returns at the same speed and gets home after a total absence of 80 years (as measured by earth-bound observers). How long do  $A$ 's clocks say that he was gone, and by how much has he aged as compared to his twin  $B$  who stayed behind on earth?