2.8: Measuring Particle Speed

reference frame clocks and rods put to use

The recording clocks reveal particle motion through the lattice: Each clock that the particle passes records the time of passage as well as the space location of this event. How can the path of the particle be described in terms of numbers? By recording locations of these events along the path. Distances between locations of successive events and time lapse between them reveal the particle speed-speed being space separation divided by time taken to traverse this separation.

Speed in meters per meter

The conventional unit of speed is meters per second. However, when time is measured in meters of light-travel time, speed is expressed in meters of distance covered per meter of time. A flash of light moves one meter of distance in one meter of light-travel time: its speed has the value unity in units of meters per meter.[1] In contrast, a particle loping along at half light speed moves one half meter of distance per meter of time; its speed equals one half in units of meter per meter. More generally, particle speed in meters per meter is the ratio of its speed to light speed:

$$\begin{aligned}(\text{particle speed}) &= \frac{(\text{meters of distance covered by particle})}{(\text{meters of time required to cover that distance})} \\ &= \frac{(\text{particle speed in meters/second})}{(\text{speed of light in meters/second})}\end{aligned}$$

In this book we use the letter v to symbolize the speed of a particle in meters of distance per meter of time, or simply meters per meter. Some authors use the lowercase Greek letter beta: β. Let v_{conv} stand for velocity in conventional units (such as meters per second) and c stand for light speed in the same conventional units. Then

$$v = \frac{v_{\text{conv}}}{c}$$

Test for free-float frame

From the motion of test particles through a latticework of clocks - or rather from records of coincidences of these particles with clocks - we determine whether the latticework constitutes a free-float frame.[2] If records show:

a. that - within some specified accuracy - a test particle moves consecutively past clocks that lie in a straight line,
b. that test-particle speed calculated from the same records is constant - again, within some specified accuracy - and,
c. that the same results are true for as many test-particle paths as the most industrious observer cares to trace throughout the given region of space and time,

then the lattice constitutes a free-float (inertial) frame throughout that region of spacetime.

Question and Answer

Particle speed as a fraction of light speed is certainly an unconventional unit of measure. What advantages does it have that justify the work needed to become familiar with it?

Answer

The big advantage is that it is a measure of speed independent of units of space and time. Suppose that a particle moves with respect to Earth at half light speed. Then it travels—with respect to Earth—one half meter of distance in one meter of light travel time. It travels one half light-year of distance in a period of one year. It travels one half light-second of distance in a time of one second, one half light-minute in one minute. Units do not matter as long as we use the same units to measure distance and time; the result always equals the same number: 1/2. Another way to say this is that speed is a fraction; same units on top and bottom of the fraction cancel one another. Fundamentally, v is unit-free. Of course, if we wish we can speak of “meters per meter."

1 Speed in meters per meter

2 Test for free-float frame