2.6: Locating Events With a Latticework of Clocks

only the nearest clock records an event

The fundamental concept in physics is **event**. An event is specified not only by a place but also by a time of happening. Some examples of events are emission of a particle or a flash of light (from, say, an explosion), reflection or absorption of a particle or light flash, a collision.

Latticework of rods and clocks

How can we determine the place and time at which an event occurs in a given free-float frame? Think of constructing a frame by assembling meter sticks into a cubical latticework similar to the jungle gym seen on playgrounds (Figure 2.6.1). At every intersection of this latticework fix a clock. These clocks are identical. They can be constructed in any manner, but their readings are in meters of light-travel time (Section 1.4).[1]

How are the clocks to be set? We want them all to read the "same time" as one another for observers in this frame. When one clock reads midnight (00.00 hours $= 0$ meters), all clocks in the same frame should read midnight (zero). That is, we want the clocks to be **synchronized** in this frame.[2]

Synchronizing clocks in lattice

How are the several clocks in the lattice to be synchronized? As follows: Pick one clock in the lattice as the standard and call it the **reference clock**. Start this reference clock with its pointer set initially at zero time. At this instant let it send out a flash of light that spreads out as a spherical wave in all directions.

Reference event defined

Call the flash emission the **reference event** and the spreading spherical wave the **reference flash**.[3]

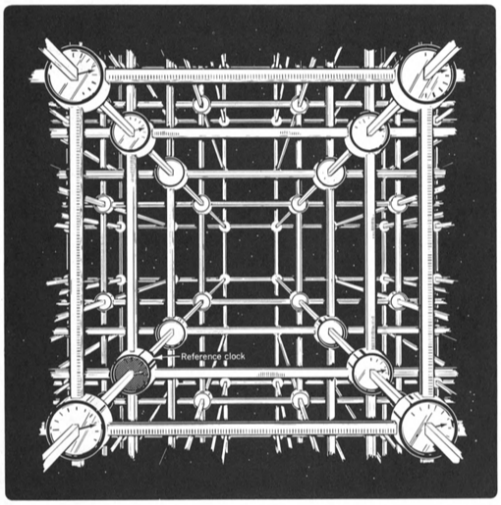

Figure 2.6.1: Latticework of meter sticks and clocks.

When the reference flash gets to a slave clock 5 meters away, we want that clock to read 5 meters of light-travel time. Why? Because it takes light 5 meters of light-travel time to travel the 5 meters of distance from reference clock to slave clock. So an assistant sets the slave clock to 5 meters of time long before the experiment begins, holds it at 5 meters, and releases it only when the reference flash arrives. (The assistant has zero reaction time or the slave clock is set ahead an additional time equal to the reaction time.) When assistants at all slave clocks in the lattice follow this prearranged procedure (each setting his slave clock to a time in meters equal to his own distance from the reference clock and starting it when the reference light flash arrives), the lattice clocks are said to be **synchronized**.

Question and Answer

This is an awkward way to synchronize lattice clocks with one another. Is there some simpler and more conventional way to carry out this synchronization?

Answer

There are other possible ways to synchronize clocks. For example, an extra portable clock could be set to the reference clock at the origin and carried around the lattice in order to set the rest of the clocks. However, this procedure involves a moving clock. We saw in Chapter 1 that the time between two events is not necessarily the same as recorded by clocks in relative motion. The portable clock will not even agree with the reference clock when it is brought back next to it! (This idea is explored more fully in Section 4.6.) However, when we use a moving clock traveling at a speed that is a very small fraction of light speed, its reading is only slightly different from that of clocks fixed in the lattice. In this case the second method of synchronization gives a result nearly equal to the first - and standard - method. Moreover, the error can be made as small as desired by carrying the portable clock around sufficiently slowly.

Use the latticework of synchronized clocks to determine location and time at which any given event occurs.[4] The space position of the event is taken to be the location of the clock nearest the event. The location of this clock is measured along three lattice directions from the reference clock: northward, eastward, and upward. The time of the event is taken to be the time recorded on the same lattice clock nearest the event. The spacetime location of an event then consists of four numbers, three numbers that specify the space position of the clock nearest the event and one number that specifies the time the event occurs as recorded by that clock.

The clocks, when installed by a foresighted experimenter, will be *recording* clocks. Each clock is able to detect the occurrence of an event (collision, passage of light-flash or particle). Each reads into its memory the nature of the event, the time of the event, and the location of the clock. The memory of all clocks can then be read and analyzed, perhaps by automatic equipment.

Question and Answer

Why a latticework built of rods that are 1 meter long? What is special about 1 meter? Why not a lattice separation of 100 meters between recording clocks? Or 1 millimeter?

Answer

When a clock in the 1-meter lattice records an event, we will not know whether the event so recorded is 0.4 meters to the left of the clock, for instance, or 0.2 meters to the right. The location of the event will be uncertain to some substantial fraction of a meter. The time of the event will also be uncertain with some appreciable fraction of a meter of light-travel time, because it may take that long for a light signal from the event to reach the nearest clock. However, this accuracy of a meter or less is quite adequate for observing the passage of a rocket. It is extravagantly good for measurements on planetary orbits - for a planet it would even be reasonable to increase the lattice spacing from 1 meter to hundreds of meters.

Neither 100 meters nor 1 meter is a lattice spacing suitable for studying the tracks of particles in a high-energy accelerator. There a centimeter or a millimeter would be more appropriate. The location and time of an event can be determined to whatever accuracy is desired by constructing a latticework with sufficiently small spacing.

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1 Latticework of rods and clocks

2 Synchronizing clocks in lattice

3 Reference event defined

4 Locate event with latticework
