2.9: Rocket Frame

does in move? or is it the one at rest?

Rocket frame defined

Let two reference frames be two different latticeworks of meter sticks and clocks, one moving uniformly relative to the other, and in such a way that one row of clocks in each frame coincides along the direction of relative motion of the two frames (Figure 2.9.1). Call one of these frames **laboratory frame** and the other - moving to the right relative to the laboratory frame-**rocket frame**.[1] The rocket is *unpowered* and coasts along with constant velocity relative to the laboratory. Let rocket and laboratory latticeworks be overlapping in the sense that a region of spacetime exists common to both frames. Test particles move through this common region of spacetime. From motion of these test particles as recorded by his own clocks, the laboratory observer verifies that his frame is free-float (inertial). From motion of the same test particles as recorded by her own clocks, the rocket observer verifies that her frame is also free-float (inertial).

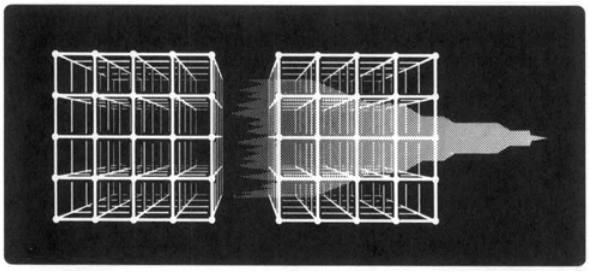

Figure 2.9.1: **Laboratory and rocket frames**. A second ago the two latticeworks were intermeshed.

Different frames lead to different descriptions

Now we can describe the motion of any particle with respect to the laboratory frame. The same particles and - if they collide-the same collisions may be measured and described with respect to the free-float rocket frame as well. These particles, their paths through spacetime, and events of their collisions have an existence independent of any free-float frames in which they are observed, recorded, and described. However, descriptions of these common paths and events are typically different for different free-float frames.[2] For example, laboratory and rocket observers may not agree on the direction of motion of a given test particle (Figure 2.9.2). Every track that is straight as plotted with respect to one reference frame is straight also with respect to the other frame, because both are free-float frames. This straightness in both frames is possible only because *one free-float frame has uniform velocity relative to any other overlapping free-float frame*. However, the direction of this path differs from laboratory to rocket frame, except in the special case in which the particle moves along the line of relative motion of two frames.

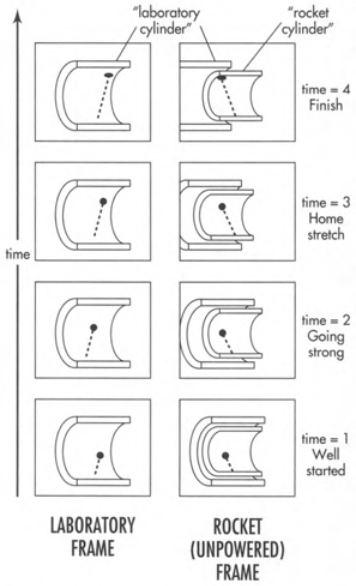

Figure 2.9.2: A series of "snapshots" of **a typical test particle as measured from laboratory and rocket free-float frames, represented by cutaway cylinders**. Start at the bottom and read upward (time progresses from bottom to top).

Many possible free-float frames

How many different free-float rocket frames can there be in a given region of spacetime? An unlimited number![3] Any unpowered rocket moving through that region in any direction is an acceptable free-float frame from which to make observations. More: There is nothing unique about any of these frames as long as each of them is free-float. All "rocket" frames are unpowered, all are equivalent for carrying out experiments. Even the so-called "laboratory frame" is not unique; you can rename it "Rocket Frame Six" and no one will ever know the difference![4] All free-float (inertial) frames are equivalent arenas in which to carry out physics experiment. That is the logical basis for special relativity, as described more fully in Chapter 3.

✔ Question and Answer

A rocket carries a firecracker. The firecracker explodes. Does this event-the explosion - take place in the rocket frame or in the laboratory frame? Which is the "home" frame for the event? A second firecracker, originally at rest in the laboratory frame, explodes. Does this second event occur in the laboratory frame or in the rocket frame?

Answer

Events are primary, the essential stuff of Nature. Reference frames are secondary, devised by humans for locating and comparing events. A given event occurs in both frames - and in all possible frames moving in all possible directions and with all possible constant relative speeds through the region of spacetime in which the event occurs. The apparatus that "causes" the event may be at rest in one free-float frame; another apparatus that "causes" a second event may be at rest in a second free-float frame in motion relative to the first. No matter. Each event has its own unique existence. Neither is "owned" by any frame at all.

A spark jumps 1 millimeter from the antenna of Mary's passing spaceship to a pen in the pocket of John who lounges in the laboratory doorway (Section 1.2). The "apparatus" that makes the spark has parts riding in different reference frames - pen in laboratory frame, antenna in rocket frame. The spark jump - in which frame does this event occur? It is not the property of Mary, not the property of John - not the property of any other observer in the vicinity, no matter what his or her state of motion. The spark-jump event provides data for every observer.

Drive a steel surveying stake into the ground to mark the corner of a plot of land. Is this a "Daytime stake" or a "Nighttime stake"? Neither! It is just a *stake*, marking a location in *space*, the arena of surveying. Similarly an event is neither a "laboratory event" nor a "rocket event." It is just an *event*, marking a location in spacetime, the arena of science.

Laboratory frame or rocket frame: Which one is the "primary" free-float frame, the one "really" at rest? There is no way to tell! We apply the names "laboratory" and "rocket" to two free-float enclosures in interstellar space. Someone switches the nameplates

while we sleep. When we wake up, there is no way to decide which is which. This realization leads to Einstein's Principle of Relativity and proof of the invariance of the interval, as described in Chapter 3.

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1 Rocket frame defined

2 Different frames lead to different descriptions

3 Many possible free-float frames

4 No unique free-float frame
