

5.9: Touring Spacetime Without a Reference Frame

all you need is worldlines and events

Events and worldlines exist independent of any reference frame

An explosion is an explosion. Your birth was your birth. An event is an event. Every event has a concreteness, an existence, a reality independent of any reference frame. So, too, does a worldline that connects the trail of event points left by a high-speed sparkplug that flashes as it streaks along. Events mark worldlines, independent of any reference frame.¹

Worldlines also locate events. The intersection of two worldlines locates an event as clearly and sharply as the intersection of two straws specifies the place of a dust speck in a great barn full of hay (Figure 5.9.1). To say that an event marks a collision between two particles is identification enough. The worldlines of those two particles are rooted in the past and stretch out into the future. They have a rich texture of connections with nearby worldlines. The nearby worldlines in turn are linked in a hundred ways with worldlines more remote. How then does one tell the location of an event? Tell first what worldlines thread the event. Next follow each of these worldlines. Name additional events that they encounter. These events pick out further worldlines. Eventually the whole barn of hay is cataloged. Each event is named. One can find one's way as surely to a given intersection as the London dweller can pick her path to the meeting of St. James's Street and Piccadilly. No numbers giving space and time location of an event in a given reference frame. No reference frame at all!

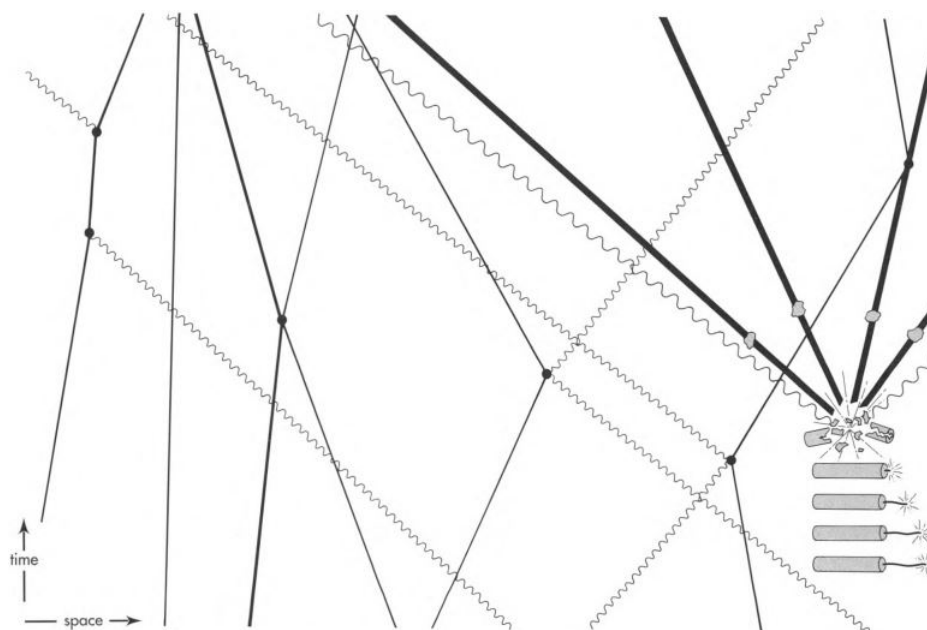


Figure 5.9.1: The crossing of straws in a bam full of bay is a symbol for the worldlines that fill up spacetime. By their crossings and jogs, these worldlines mark events with a uniqueness beyond all need of reference frames. Straight worldlines track particles with mass; wiggly worldlines trace photons. Typical events symbolized in the map (black dots) from left to right: absorption of a photon; reemission of a photon; collision between a particle and a particle; collision between a photon and another particle; another collision between a photon and a particle; explosion of a firecracker; collision of a particle from outside with one of the fragments of that firecracker.

Locate house at intersection of streets

Most streets in Japan have no names and most houses no numbers. Yet mail is delivered just the same. Each house is named after its senior occupant, and everyone knows how the streets interconnect these named houses.² Now print the map of Japanese streets on a rubber sheet and stretch the sheet this way and that. The postal carrier is not fooled. Each house has its unique name and the same interconnections with neighbor houses as on the unstretched map. So dispense with all maps! Replace them with a catalog or directory that lists each house by name, notes streets passing the house, and tabulates the distance to each neighboring house along the streets.

Locate event at intersection of worldlines

Similarly, the visual pattern of event dots on a spacetime map (spacetime diagram) and the apparent lengths of worldlines that connect them depend on the reference frame from which they are observed (for example, compare alternative spacetime maps of

the same worldline shown in the figure in Sample Problem 5.8.1).³ However, each named event is the same for every observer; the event of your birth is unique to you and to everyone connected with you. Moreover, the segment of a worldline that connects one event with the next has a unique magnitude—the interval or proper time — also the same for every observer.

Events and worldlines alone can describe Nature

Therefore dispense with reference frames altogether! Replace them with a catalog or directory that lists each event by name, notes each worldline that threads the event, and tabulates the interval that connects the event with the next event along each worldline. With this directory in hand we can say precisely how all events are interconnected with each other and which events caused which other events. That is the essence of science; in principle we need no reference frames.⁴

But reference frames are convenient. We are accustomed to them. Most of us prefer to live on named streets with numbered houses. Similarly, most of us speak easily of space separations between events and time separations between the same events as if space and time separations were unconnected. In this way we enjoy the concreteness of using our latticework of rods and clocks while suffering the provinciality of a single reference frame. So be it! Nevertheless, with worldlines Nature gives us power to relate events — to do science— without reference frames at all.

1 Events and worldlines exist independent of any reference frame

2 Locate house at intersection of streets

3 Locate event at intersection of worldlines

4 Events and worldlines alone can describe Nature

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