Chapter Four

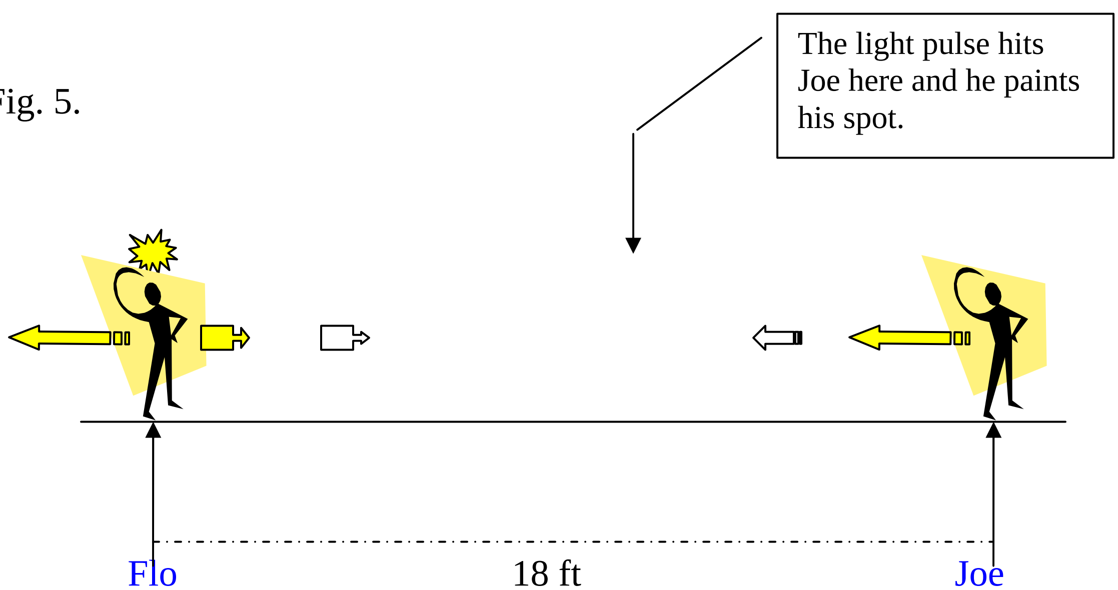
Questions that can't be answered?

We were discussing light cones. How do you decide if something is inside it, on it, or outside it? First of all, that's a bad question. You always need to compare two events, and ask if they are inside, outside, or on the light cone relative to each other.

Secondly, is this two-event light cone determination the same for all observers? Have we finally found something in Einstein's Relativity that is absolute? The answer, you will be happy to know, is yes.

In order to demonstrate this we need once more to call on Flo and Joe. You may think they are getting tired of all this experimenting, but they're not. They are on the cutting edge of experimental science. Such people do not tire. (At least that's what they tell their funding agency when they need, for example, more paint.) We are going to take a closer at Flo and Joe's last experiment in which Flo, when she painted, sent out a beam of light, causing Joe to paint his spot. A zoomed-in picture of Flo and Joe, as seen by the rocket ship folks, is shown below.

Fig. 5.



In Fig. 5 Flo has just painted and sends a pulse of light toward Joe, who, is going to the left. The pulse hits him where the arrow indicates.

Remember, we are now in the rocket ship considering ourselves at rest.[•]

Flo just painted her spot. How far does Joe move before he paints his? The amount of time he travels is $T_{Joe} - T_{Flo} = 50/c - 40/c = 10/c$. His speed is 0.8c, so, his distance is simply:

Joe's distance = 0.8c X 10/c = 8 ft (before the light pulse hits him).

Now, since Joe went 8 ft before the light pulse hit him, that's where he painted his spot on our rocket ship. Looking at Fig. 5 we see the two spots ended up 10 ft apart. We can now calculate the speed of light as measured in the rocket ship: it's just the distance the pulse went (10 ft) divided by the time it traveled (10/c). Guess what:

Speed of light measured in rocket system = 10/(10/c) = c !

What we have just demonstrated is, definitely, strange. Flo sent out a light pulse toward Joe. Some people in a rocket ship, going in the same direction as the light pulse, and at 80% of its speed, measured the same speed as Flo and Joe did for the light pulse. Think about it: there's a convoy of trucks going down the road at 80 mph. A car passes them going 100 mph. The people in the convoy measure the time it takes for the car to pass them and divide the length of their convoy by that time. This gives them the speed of the car relative to them. It should be 20 mph, and it is (except for a tiny Einsteinian correction). Everyday examples like this have built up our intuition about relative speeds. The trouble is, we don't have any experience with light beams and high speeds so our intuition fails us when we think about the above example. Two different observers, moving relative to each other, measure the speed of a passing pulse of light and they both get the same speed? It seems strange.

It seems strange, but it's true. And it's true, not only for the particular Flo-Joe experiment that we discussed, but for any observers moving with any (constant) velocities in any direction. If any one observer measures that two separated events are "on the light cone", that is, the distance between the events divided by the time between them is equal to c, then all other observers will find the same ratio: their distance divided by their time will be

[•] Remember also, or look back at Ch. 3, that T_{Joe}= 50/c and T_{Flo}=40/c.

equal to c. Similarly, when two events are either inside or outside the light cone all observers will agree on that fact.

Experimentally speaking, if two events (on, or inside, the light cone) can be causally connected by one observer they can be for all observers. Likewise, if two events are outside the light cone they can never be causally connected; one of them could not possibly have caused the other.

These conclusions about causality are comforting, and must have been so for Einstein. If his new theory could be shown to violate causality he definitely would have had to junk it.

So we see that, although most things are "relative" in Relativity, some things are absolute, namely, the speed of light, and the causality properties of events.

Hearkening back to our discussion at the end of Chapter Three, we now find that different astronomers on different planets can disagree on which of two stars blew up first, but only if the events were outside the light cone. In that case the question of which one blew up first is meaningless. It cannot be answered. Normally we don't like questions that cannot be answered, but in this case, at least, we understand why.

Now we can muse again about the Keepers of Intra-galactic Records. Before they knew about Special Relativity (or whatever the galactic name for it is), they used to get a lot of flak about the entries in their books on the subject of "Order in which Stars Blew Up". But now they know that the time sequence of any two stars which blew up outside the light cone cannot be determined. The Keepers just put asterisks besides those cases. ("Asterisks", how appropriate.)

Actually, I still find it a little difficult to give up the idea of absolute simultaneity, and maybe you do too. Let's think about your mother, who lives in far-away Florida. Since you are a fixed distance apart you can keep synchronized clocks, and talk about doing things at the same time. You can even write letters that say things like, "I put the baby to bed at 9:01 last night. What were you doing?" She writes back, "That's when I turned off my TV."

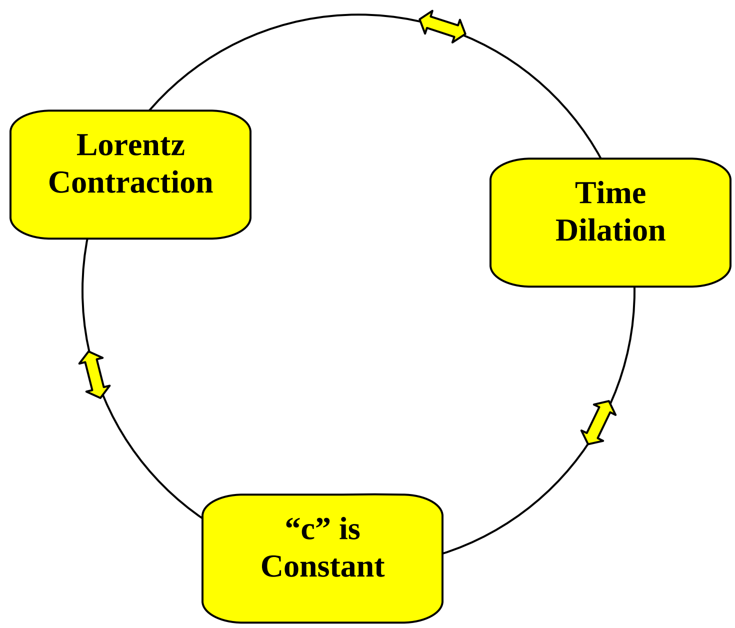
But if you think about the fact that you and your mother, and Florida, are all whizzing around the center of our galaxy at 150 miles per second• your perspective changes. Some alien rocket ships going by the Earth could disagree with you on who was doing what when.

I guess it doesn't matter as long as the aliens can't read your mail. (Or can they? Are you using email?)

At this point in our little book I hope that you, (the reader), are getting confident that Einstein's crazy ideas are not so crazy after all. In Chapter One we started with the assumption that moving eggs cook slowly (time dilation) and showed this led to Lorentz contraction. In the present chapter we demonstrated the constancy of the speed of light (c) for all observers.

Einstein, on the other hand, started by assuming the constancy of c and went from there. We can picture this in the following figure.

Fig. 6. Cornerstones of Special Relativity



These three postulates of Special Relativity are all intimately related. If any one of them is true it can be proved that the others must be also.

• That's a pretty good clip, nearly .001 times the speed of light, but it still takes 200 million years to make one full revolution around the center of our galaxy.

We started with Time Dilation and went around the circle counterclockwise. Einstein, in his 1905 paper, started with the constancy of “c” and went around the other way, using some fancy mathematics.

On our trip around the circle we also found some interesting corollaries: simultaneity is not absolute, nothing can move faster than c, and causality is absolute. One hundred years after Einstein these “crazy” ideas have become part of the fabric of modern science.

We’ve covered a lot of ground, but there is still some interesting territory ahead.