# Simultaneity in the Priya-Ryan-firecrackers question

Here are the Team Up questions and their answers. Note that the questions as written were not very precise, so I've cleaned up the wording of the question. When I did this, I realized I made a mistake in the answers to 3 and 4 in that both answers are correct for certain unstated assumptions, but they are correct for DIFFERENT unstated assumptions. So I've made the assumptions explicit and changed the answers to reflect this change.

Why are there different possible answers? Because our assumptions are wrong. If you assume the speed of light is constant for both Priya and Ryan, as we will see, you cannot assume they agree on lengths and times.

The firecrackers will make burn marks on the ground at the positions where they explode.
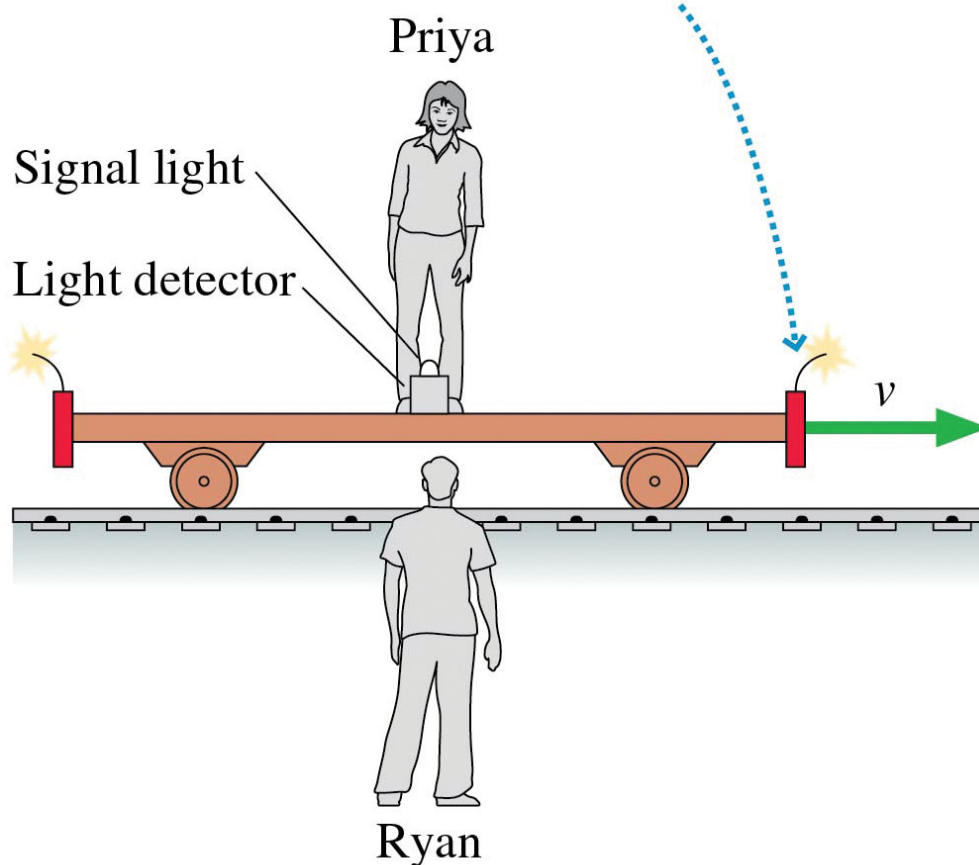
A 12-m-long train moves at half the speed of light relative to the ground as shown above. Priya is in the middle of the train. Ryan is right beside her, though at rest relative to the ground, at the instant that the two firecrackers explode. The scorch marks are equidistant from Ryan, and Ryan sees both explosions at the same time. When Ryan sees the two explosions, he measures that Priya is at x=+3 m relative to himself, though he only "sees" her as being at x=+2 m, though the virtual "clock" beside her would say that her image is about 6.7 ns "old". Both Priya and Ryan are clever enough to ignore the optical illusions associated with finite speed-of-light travel times, so we will talk about what they measure as opposed to what they observe.

We will answer a few questions using the following assumptions, some of which are wrong: Ryan and Priya agree on the relative distance between each other, as well as other

questions involving relative distances, for example Ryan and Priya agree that the train is 12 m in length; Ryan and Priya agree on their relative speed (though they disagree on the direction); Ryan and Priya agree that light travels at the speed of light.

1. According to Ryan, where is Priya when Priya receives light from the front firecracker?

   Ryan sees Priya move at half the speed of light toward the firecracker, and light move towards Priya at the speed of light. When Priya has moved 2 m to the right, light will have moved 4 m to the left. So Ryan measures that Priya is at x=+2m when Ryan sees Priya receive the light from the front firecracker.

2. According to Ryan, where is Priya when Priya receives light from the rear firecracker?

   Now the light is chasing Priya. When the light reaches Ryan, Priya will be at +3 m. When the light reaches +6 m, Priya will also be at +6 m. So Ryan measures that Priya is at +6 m when Ryan sees Priya receive the light from the rear firecracker.

3. If Priya measures Ryan to be at x=-2 m when Priya receives the light from the front firecracker, where does Priya measure Ryan was when she measures that the front firecracker exploded?

   Priya measures that the light travelled 6 m to get to her. During that time, she measures Ryan travelled 3 m. So Ryan must have been at x=+1 m when the front firecracker exploded. This is different from what Ryan measures.

4. If Priya measures Ryan to be at x=-6 m when Priya receives the light from the rear firecracker, where does Priya measure Ryan was when she measures that the rear firecracker exploded?

   Again, Priya measures that the light travelled 6 m to get to her. During that time, she measures Ryan travelled 3 m. So Ryan must have been at x=-3 m when Priya measures that the rear firecracker exploded.

Conclusions: Priya and Ryan disagree on their relative positions at 'the same time' as when the firecrackers exploded, so they measure different times. Ryan measures that they were simultaneous. Priya measures that the front firecracker happened first.

Priya needs to believe that the front firecracker exploded first because Priya needs to believe that the light from both firecrackers reach Ryan at the same time, but this will happen when Ryan is at x=-3m according to Priya.

Note the discrepancy! Priya and Ryan should believe that Ryan is at x=-3m when he receives the light from both explosions, AND Ryan should be at x=-3m when Priya believes that the rear firecracker exploded. These two beliefs contradict each other.

So not only is simultaneity a thing which they disagree about, but there must be other problems too! As we will discover, our assumption about lengths being a thing they can agree upon is not correct. So all these calculations are invalid since our assumptions are false.

And yet we have learned that simultaneity is a difficult concept in the theory of relativity, and specifically that different observers will not, in general, agree on the simultaneity of two events that happen in different locations. So this was time well invested.