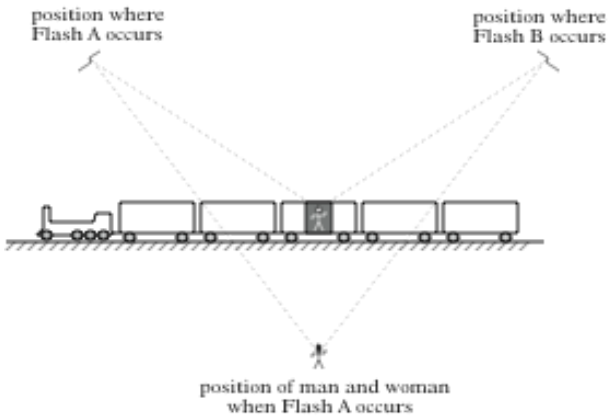
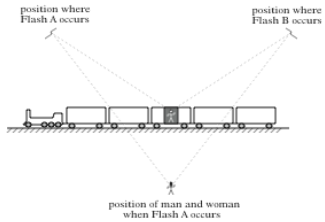
Relativistic Time Dilation, *The Train,* and *Simultaneity*

From Martin Gardner's
Relativity for the Millions

•Did the flashes occur simultaneously?



•Two individuals observe two lightening flashes that occur some distance apart. One of the individuals, a man, stands in a field. The other individual, a woman, is in a train. There is relative motion between the two.



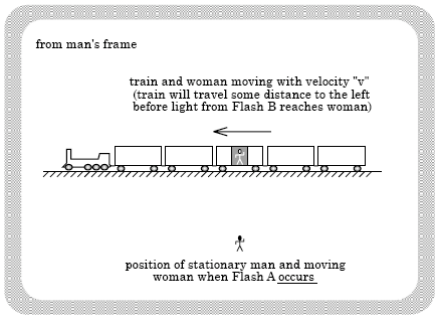
•It is known that when lightening flash A occurs, the man is opposite the woman and the physical location of the flashes are equidistant from both (that is, the distance between flash A and the man, and flash B and the man, are the same; likewise for the woman).

•Furthermore, the man sees the flashes at the same time (i.e., the light from both reaches him at the same instant) and the woman sees the flashes at different times (flash B arrives later than flash A).

•Again, it is known that when lightening flash A occurs, the man is opposite the woman and the physical location of the flashes are equidistant from both (that is, the distance between flash A and the man, and flash B and the man, are the same; likewise for the woman).

•Also, the man sees the flashes at the same time (i.e., the light from both reaches him at the same instant) and the woman sees the flashes at different times (flash B arrives later than flash A).

•From the man's frame of reference: As far as the man is concerned, his frame of reference is stationary.

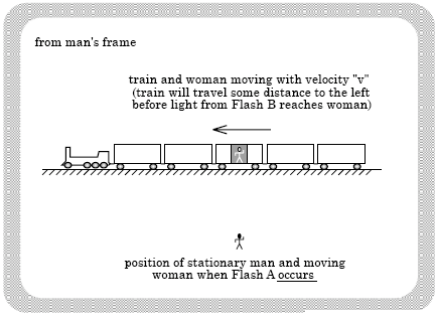


- •The distance between him and both flashes is the same.
- •As he sees both flashes arrive at the same time, he concludes that the flashes must have occurred simultaneously.
- •If the woman takes the *man's frame of reference* as stationary, her analysis agrees with his. That is:

•She knows she is equidistant from the flash origins when she is opposite the man.

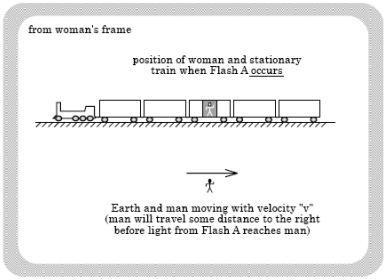
•She knows that flash A occurs when she is across from the man.

•She knows the speed of the train. She can calculate how far the train travels by the time the light from flash A reaches her. With that information, she can calculate how long thereafter the light from flash B should arrive if, in fact, flashes A and B occurred at the same time.



•She makes her calculations and finds that the calculated and observed time differences are the same. Her conclusion is that the flashes must have occurred simultaneously.

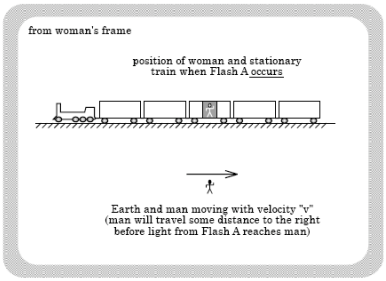
•From the woman's (and train's) frame of reference: As far as the woman is concerned, her frame of reference is stationary.



- •She knows the distance between herself and both flashes *is the same when both flashes occur* whether they occurred simultaneously or not.
- •The only way the flashes can travel equidistant paths and arrive at different times is if they flash at different times. In short, the two flash events must not have occurred simultaneously.

•If the man takes the *woman's frame of reference* as stationary (i.e., if he accepts the notion that the earth is moving underneath the stationary train and, hence, that *he is moving to the right*), his analysis will agree with hers. Specifically:

•He knows he is equidistant from the *flash origins* when he is opposite her.



- •He also knows that flash A occurs when he is opposite the woman.
- •He knows that by the time the light from flash A reaches him, he will have moved to the right of the stationary woman. That means the light from flash A moves further to reach him than does the light from Flash B.

•But the light from the two flashes arrive at the same time, so flash A must have occurred before flash B and the two events must not be simultaneous.

•Bottom line: Simultaneity depends upon the frame of reference you choose. If you find it evident in one frame, it will not be evident in another even though any two frames may be perfectly legitimate.