Length Contraction

Moving Objects Look Shorter

Besides that time run more slowly in a reference frame that moves with a high speed, the special theory of relativity also confirms that moving objects look shorter than they are at rest. Another thought experiment can help us comprehend why this is true.

Figure 3-1a shows the view of a spaceship heading from Earth to Neptune at a very high speed of 0.8c as observed on Earth. The distance between Earth and Neptune is about 5 * 10^9 km, and it will take the spaceship about 6 hours to get there. That is the measurement by an observer on Earth. However, because of time dilation, people on the spaceship will only spend 3.5 hours of their lives to get there. Figure 3-2b shows what the astronauts see on their spaceship; Earth is moving away from them at 0.8c and Neptune is moving towards them at 0.8c. Since the astronauts measure the same speed but less time for their trip, they must also measure a shorter distance between Earth and Neptune than the observer on Earth does. By using the equation d = v*t. The space travelers calculate the distance of the trip as only about 3 * 10^9 km.

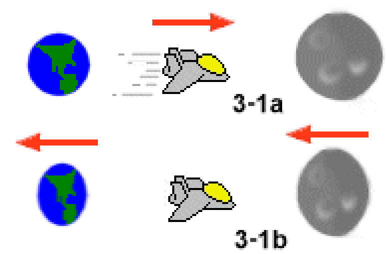

Figure 3-1: (a) This is the view of spaceship travelling at high speed from Earth to Neptune as seen by people on Earth. (b) This is the view of the same situation as viewed by the astronauts. Earth and Neptune are moving "backward" at ver high velocity.

The shortening of distance is a result of theory of relativity known as length contraction. It applies to not only the distance between two places but also the length of an moving object such as a spaceship. That is, the length of an object is measured to be shorter than when at rest. Length contraction occurs only in the dimension of an object that is in the direction of motion. The other dimensions remain unchanged. Like time dilation, the effect of length contraction can be computed by an equation. If the length of an object at rest is L_0, then when it is moving at a velocity v, its length will be measured to be

$$L = L_0\sqrt{1 - v^2 / c^2}$$

Yet, the amount of contraction is noticeable only when the object is moving at an extremely high velocity that human beings are not able to achieve with current technology.

Space-Time: The Fourth Dimension

So far we have talked about time dilation and length contraction. The special theory of relativity further dioceses the relationship between time and length (or space). Notice that according to the time dilation and length contraction formulae, the observer in the inertial (rest) reference frame sees that the object moving at a high velocity appear shorter and that the event in that object takes a longer time interval to complete. In a sense these two effects balance each other. That is, space is exchanged for time! This result led to the idea of four-dimensional "space-time." in which space takes up three dimensions and time is the fourth dimension. You may think this idea does not make sense. It is more convincing from another point of view. An object exists for a certain amount of time at a particular place, so the four dimensions refers to the fact that an object or event is described by four quantities, three of which identify the location in space and one of which specifies the time. Moreover, time and space can be exchanged for a little amount when the reference frame is changed.

Indeed, it is hard to understand the idea of four dimensional space-time. We have found in the thought experiments that space and time are not completely separate quantities. Our difficulty in accepting the idea of space-time is equivalent to the situation in the seventeenth century at Galileo and Newton's era. Before Galileo, the vertical dimension was considered totally different from the two horizontal dimensions. Yet Galileo showed that the only difference between the vertical and horizontal dimensions is that the vertical dimension is the direction in which gravity acts. That is a fact we accept today. Perhaps now we need to put more effort to believe that time and space are interchangeable. This is not to say that there is no distinction between space and time. The theory of special relativity just proves that space and time are not independent of each other.

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