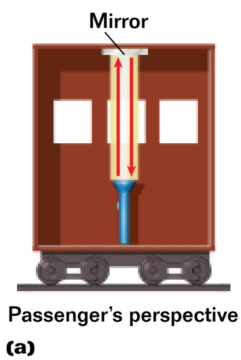
Special Relativity and Time Dilation

In the kinematics chapters, you worked with equations that describe motion in terms of a time interval (Δt). Before Einstein developed the special theory of relativity, everyone assumed that Δt must be the same for any observer, whether that observer is at rest or in motion with respect to the event being measured. This idea is often expressed by the statement that time is *absolute.*

The relativity of time

In 1905, Einstein challenged the assumption that time is absolute in a paper titled "The Electrodynamics of Moving Bodies," which contained his special theory of relativity. The special theory of relativity applies to observers and events that are moving with constant velocity (in uniform motion) with respect to one another. One of the consequences of this theory is that Δt *does* depend on the observer's motion. Consider a passenger in a train that is moving uniformly with respect to an observer standing beside the track, as shown in **Figure 1.** The passenger on the train shines a pulse of light toward a mirror directly above him and measures the amount of time it takes for the pulse to return. Because the passenger is moving along with the train, he sees the pulse of light travel directly up and then directly back down, as in **Figure 1(a).** The observer beside the track, however, sees the pulse hit the mirror at an angle, as in **Figure 1(b),** because the train is moving with respect to the track. Thus, the distance the light travels according to the observer is *greater* than the distance the light travels from the perspective of the passenger.

One of the postulates of Einstein's theory of relativity, which follows from James Clerk Maxwell's equations about light waves, is that the speed of light is the same for *any* observer, even when there is motion between the source of light and the observer. Light is different from all other phenomena in this respect. Although this postulate seems counterintuitive, it was strongly supported by an experiment performed in 1851 by Armand Fizeau. But if the speed of light is the same for both the passenger on the train and the observer beside the track while the distances traveled are different, the time intervals observed by each person must also be different. Thus, the observer beside the track measures a longer time interval than the passenger does. This effect is known as *time dilation.*



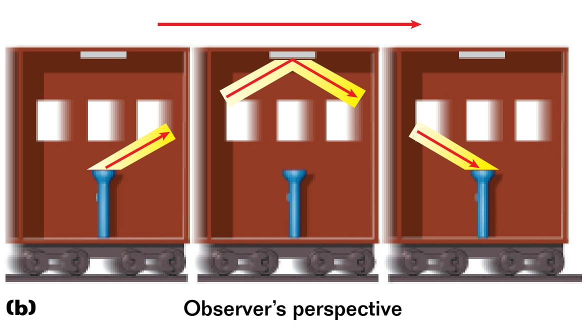


Figure 1
(a) A passenger on a train sends a pulse of light toward a mirror directly above. **(b)** Relative to a stationary observer beside the track, the distance the light travels is greater than that measured by the passenger.