## Calculating time dilation

Time dilation is given by the following equation, where $\Delta t'$ represents the time interval measured by the person beside the track, and $\Delta t$ represents the time interval measured by the person on the train:

$$\Delta t' = \frac{\Delta t}{\sqrt{1 - \frac{v^2}{c^2}}}$$

In this equation, $v$ represents the speed of the train relative to the person beside the track, and $c$ is the speed of light in a vacuum, $3.00 \times 10^8$ m/s. At speeds with which we are familiar, where $v$ is much smaller than $c$, the term $\frac{v^2}{c^2}$ is such a small fraction that $\Delta t'$ is essentially equal to $\Delta t$. For this reason, we do not observe the effects of time dilation in our typical experiences. But when speeds are closer to the speed of light, time dilation becomes more noticeable. As seen by this equation, time dilation becomes infinite as $v$ approaches the speed of light.

According to Einstein, the motion between the train and the track is *relative;* that is, either system can be considered to be in motion with respect to the other. For the passenger, the train is stationary and the observer beside the track is in motion. If the light experiment is repeated by the observer beside the track, then the passenger would see the light travel a greater distance than the observer would. So, according to the passenger, it is the observer beside the track whose clock runs more slowly. Observers see their clocks running as if they were not moving. Any clocks in motion relative to the observers will seem to the observers to run slowly. Similarly, by comparing the differences between the time intervals of their own clocks and clocks moving relative to theirs, observers can determine how fast the other clocks are moving with respect to their own.

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## Experimental verification

The effects we have been considering hold true for all physical processes, including chemical and biological reactions. Scientists have demonstrated time dilation by comparing the lifetime of muons (a type of unstable elementary particle) traveling at $0.9994c$ with the lifetime of stationary muons. In another experiment, atomic clocks on jet planes flying around the world were compared with identical clocks at the U.S. Naval Observatory. In both cases, time dilations were observed that matched the predictions of Einstein's theory of special relativity within the limits of experimental error.