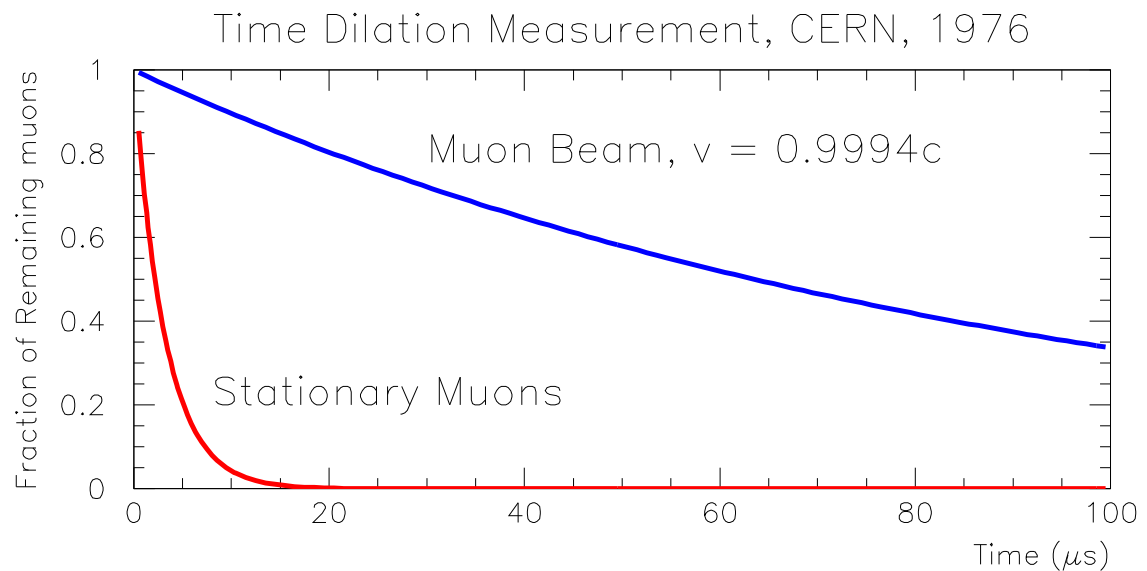


The Twins Paradox

Consider two twins. One sets out at the age of 25 on a spaceship from Earth at a speed of $0.99c$ where c is the speed of light. The Earthbound twin goes on about her business accumulating the normal accoutrements of advancing age (gray hair, drooping body parts, *etc.*). After twenty years have passed for the Earthbound twin, the spacefaring one returns. When they finally meet the voyager is NOT twenty years older! She looks only a few years older than when she left and shows few signs of age. How much has she aged during her journey?



Time Dilation

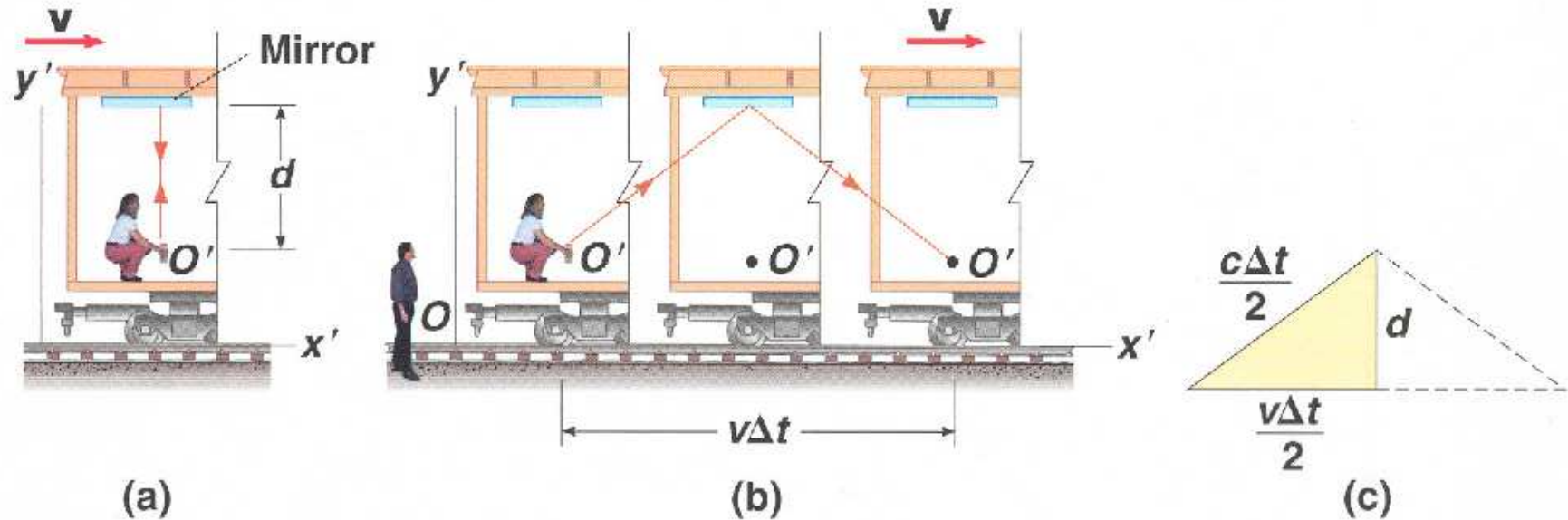


The Postulates

1. Physics is the same in all inertial reference frames (hopefully).
2. The speed of light is the same in all inertial reference frames.

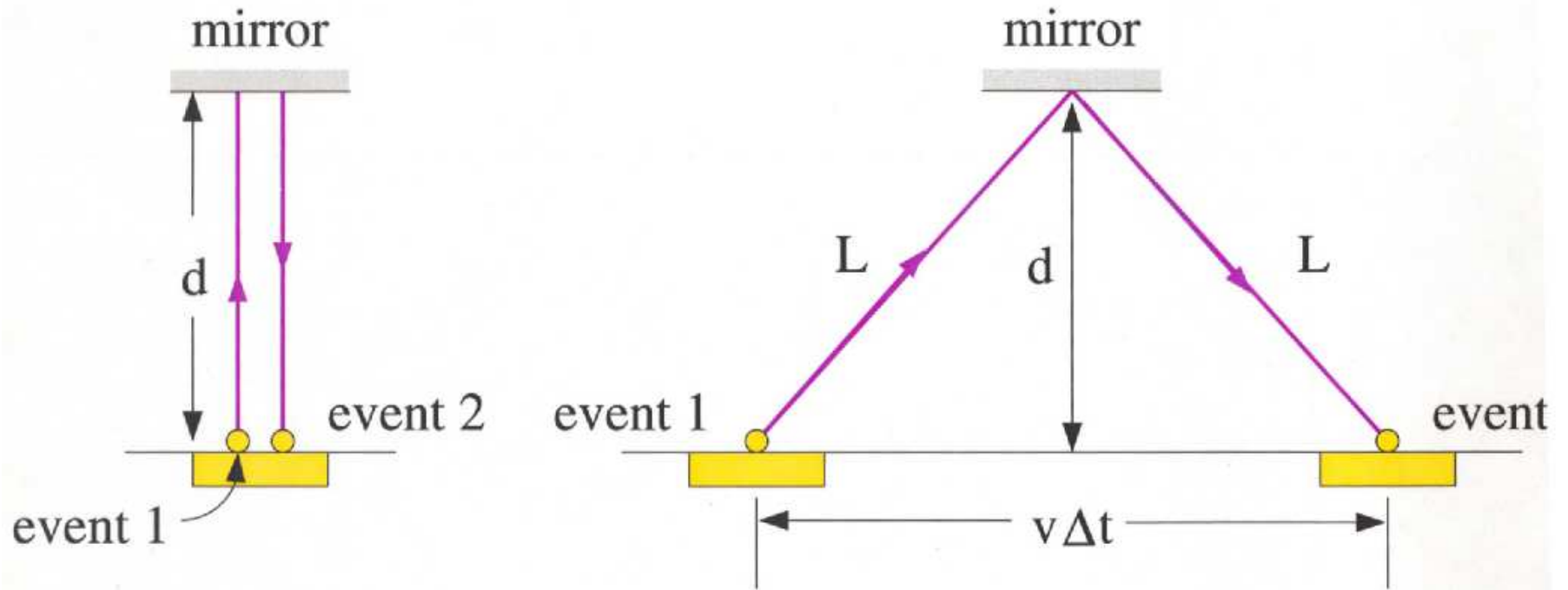


Time Dilation



*Serway and Jewett, Physics for Scientists and Engineers, 6/e
Figure 39.6*

Time Dilation



Einstein's Big Year (1905)

- March Sends paper to *Annalen der Physik* building on the work of Max Planck on the quantization of light. He uses this radical new idea to explain the photoelectric effect simply and effectively. This is the only work specifically mentioned in Einstein's citation for the Nobel Prize in 1922.
- May Sends another paper to *Annalen der Physik* on how to measure the Boltzmann constant using the motion of small particles in a gas or liquid (Brownian motion). This helps establish the modern atomic theory and spawns a variety of experiments that lead to several Nobel Prizes.
- June Another paper goes to *Annalen der Physik* reconciling the deep contradictions between electromagnetism and motion. He invents Special Relativity to fix this contradiction leading to time dilation and other strange effects.
- September Einstein reports a discovery deep in the heart of Special Relativity and electromagnetism. He says, "I cannot possibly know whether the good Lord does not laugh at it and has led me up the garden path." The result is $E = mc^2$.

Another Twins Paradox

Consider two twins again. One sets out at the age of 25 on a spaceship from Earth at a speed of $0.99c$ where c is the speed of light. After twenty years have passed for the Earthbound twin, the spacefaring one returns. What is the mileage on the spacefaring twin's spaceship? In other words, what distance did she measure in traveling outward from the Earth at $0.99c$, turning around at the midpoint of her trip, and returning directly to Earth?

