M.8.2.4 Time Dilation

Videos: Time dilation – Moving Clocks tick Slower

Why is time slower in rockets?

Einstein proposed that, Time seems to travel more slowly in a moving frame of reference when viewed from a stationary frame.

This does not mean that the person in the moving frame of reference sees their own clock run more slowly. From their perspective, the clock would be perfectly normal. It is the perception from **another** frame of reference that is different.

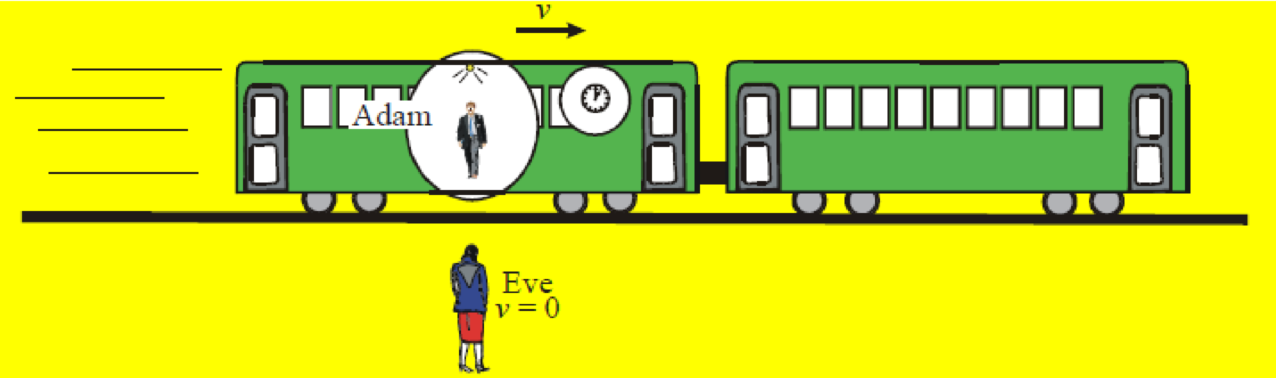

Figure 7.10 Eve would see the clock on the moving train seem to run slower than normal. Adam would not observe any change in the clock's behaviour.

In Einstein's equation for time dilation, the symbol t is used to represent the time that a stationary observer (Eve) measures using a stationary clock, for an event that the observer sees occurring in a moving frame of reference. The symbol t_0 is then the time that passes on the moving clock, which is also known as the **proper time**.

The factor that the proper time is multiplied by is given the symbol gamma, γ, so that:

$$t = \gamma t_0$$

γ = Lorentz factor

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

v is the speed of the moving frame of reference
c is the speed of light in a vacuum (3×10^8 m s^{-1})
t is the time observed in the stationary frame
t_0 is the time observed in the moving frame (proper time)

v (m s^{-1})	$\frac{v}{c}$	γ
3.00×10^2	0.000001	1.000000000
3.00×10^5	0.00100	1.0000005
3.00×10^7	0.100	1.005
1.50×10^8	0.500	1.155
2.60×10^8	0.866	2.00
2.70×10^8	0.900	2.29
2.97×10^8	0.990	7.09
2.997×10^8	0.999	22.4

TABLE 6.2.1 The value of the Lorentz factor at various speeds

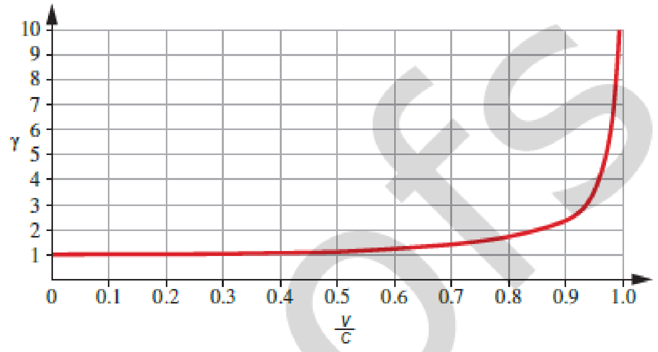

FIGURE 6.2.4 The graph of the Lorentz factor versus $\frac{v}{c}$

Example

Assume *Gedanken* conditions exist in this example. A stationary observer on Earth sees a very fast car passing by, travelling at 2.50×10^8 m s^{-1}. In the car is a clock on which 3.00s passes. Calculate how many seconds pass by on the stationary observer's clock during this observation. Use $c = 3.00 \times 10^8$ m s^{-1}.

$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} = 1.809$ $\quad\quad t = 1.809 \times 3.00 = 5.43\ sec$

The Global Positioning System (GPS) is commonly used to locate positions on Earth. A highly accurate clock on board each orbiting satellite continually broadcasts the time to GPS receivers on Earth. Each GPS receiver has a clock that is assumed to be **identical** to that on the satellite. Over a period of exactly 24 hours the total time difference between the clock in the orbiting satellite and the clock in the GPS receiver is not zero, but 0.000038 s.

GPS satellite in orbit

Example 25 (2007 Q7, 2 marks)

Assuming this time difference is due to special relativity, which **one or more** of the following statements is correct?

A. The GPS receiver measures the satellite clock running at the same rate as itself.

B. The GPS receiver measures the satellite clock running more slowly than itself.

C. The GPS receiver measures the satellite clock running faster than itself.

D. The orbit radius of the satellite is shortened due to relativity.

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