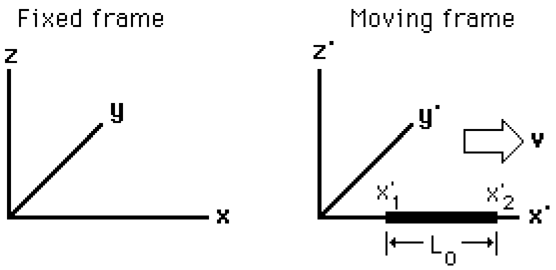
Length Contraction



The length of any object in a moving frame will appear foreshortened in the direction of motion, or contracted. The amount of contraction can be calculated from the Lorentz transformation. The length is maximum in the frame in which the object is at rest.

If the length $L_0 = x'_2 - x'_1$ is measured in the moving reference frame, then $L = x_2 - x_1$ can be calculated using the Lorentz transformation.

$$L_0 = x'_2 - x'_1 = \frac{x_2 - vt_2 - x_1 + vt_1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

But since the two measurements made in the fixed frame are made simultaneously in that frame, $t_2 = t_1$, and

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

Length contraction

For v = [ ] c, L = [ ] L_0

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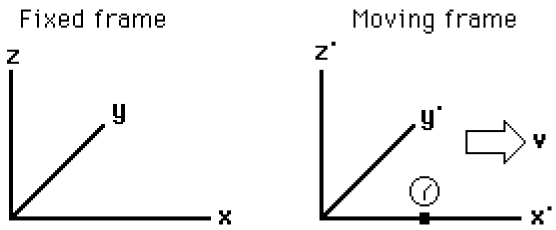
Time Dilation



A clock in a moving frame will be seen to be running slow, or "dilated" according to the Lorentz transformation. The time will always be shortest as measured in its rest frame. The time measured in the frame in which the clock is at rest is called the "proper time".

If the time interval $T_0 = t'_2 - t'_1$ is measured in the moving reference frame, then $T = t_2 - t_1$ can be calculated using the Lorentz transformation.

$$T = t_2 - t_1 = \frac{t'_2 + \frac{vx'_2}{c^2} - t'_1 + \frac{vx'_1}{c^2}}{\sqrt{1 - \frac{v^2}{c^2}}}$$

The time measurements made in the moving frame are made at the same location, so the expression reduces to:

$$T = \frac{T_0}{\sqrt{1 - \frac{v^2}{c^2}}} = T_0 \gamma$$

For v = [ ] c, T = [ ] T_0

For small velocities at which the relativity factor is very close to 1, then the time dilation can be expanded in a binomial expansion to get the approximate expression:

$$T \approx T_0 \left[1 + \frac{v^2}{2c^2} \right]$$

See also Gravitational time dilation

Time dilation experiments

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Relativity concepts

Relativistic Mass

The increase in effective mass with speed is given by the expression

$$m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}} = \gamma m_0 \qquad m_0 = \text{"rest mass"}$$

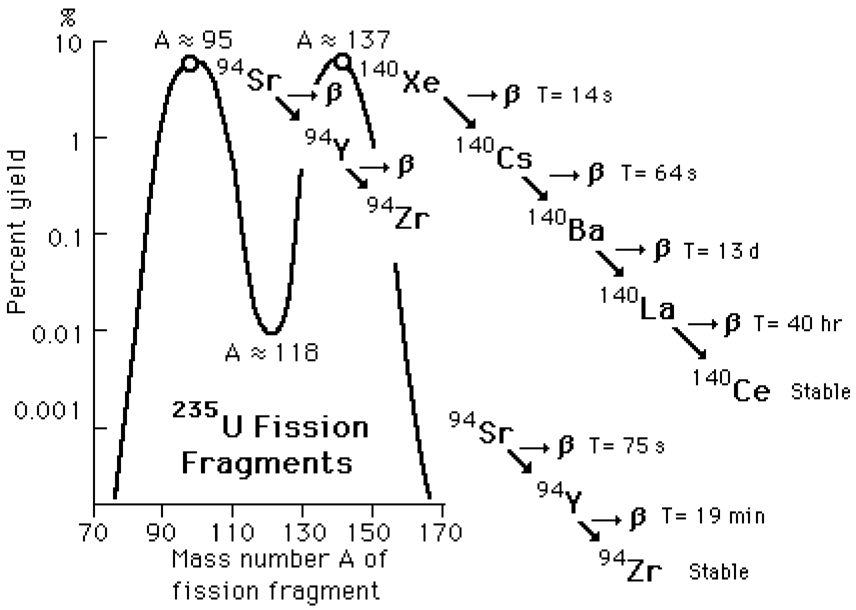
It follows from the Lorentz transformation when collisions are described from a fixed and moving reference frame, where it arises as a result of conservation of momentum.

For v = ______ c, m = ______ m_0

The increase in relativistic effective mass makes the speed of light c the speed limit of the universe. This increased effective mass is evident in cyclotrons and other accelerators where the speed approaches c. Exploring the calculation above will show that you have to reach 14% of the speed of light, or about 42 million m/s before you change the mass by 1%.

Fission Fragment Decay

This particular set of fragments from uranium-235 fission undergoes a series of beta decays to form stable end products.



Constant Acceleration Motion

Constant acceleration motion can be characterized by formuli and by motion graphs.