The relativity of simultaneity
If two events in different places are judged by one observer to be simultaneous then they will not generally be judged to be simultaneous by another observer in a different reference frame in relative motion. In other words, whether or not two events are seen by you to be simultaneous depends upon where you are standing.
Try this thought experiment offered by Einstein:
A train is fitted with light operated doors. The light fitting is in the centre of the roof, and is operated by a train traveller standing in the middle of the floor. When the train is travelling at half the speed of light, the train traveller turns on the light. The light travels forwards and backwards with equal speed and reaches both doors at the same time. The doors then open, and the train traveller sees them opening simultaneously. An observer standing outside the train watches this happen, but sees the back door opening before the front. This is because the back door is advancing on the light waves coming from the light, while the front door is moving away from the light waves.

The equivalence between mass and energy
The rest mass of an object is equivalent to a certain quantity of energy. Mass can be converted into energy under extraordinary circumstances and, conversely, energy can be converted into mass. For example, part of the mass is converted into energy in nuclear fission reactions. When a particle and its anti-particle collide, the entire mass is converted into energy.
Einstein's famous equation expresses the equivalence between energy, ***E*** and mass, ***m***: $E=mc^2$. The amount of energy given off in a nuclear transmutation is related by this equation to the amount of mass "lost".
In Special Relativity, the Law of Conservation of Energy and the Law of Conservation of Mass have been replaced by the *Law of Conservation of Mass-Energy*.

Length contraction
The length of an object measured within its rest frame is called its proper length (L_o).
Observers in different reference frames in relative motion will always measure the length (L_v) to be shorter.
The equation that expresses this is

$$l_v = l_0 \sqrt{1 - \frac{v^2}{c^2}}$$

For example: A train that is measured to be 100 metres long when at rest, travels at 80% of the speed of light (0.8 ***c***). A person inside the train will measure the length of the train to be 100 m. A person standing by the side of the track will observe the train to be just 60 metres long.

Time dilation
The time taken for an event to occur within its rest frame is called the proper time (t_o).
Observers in different reference frames in relative motion will always judge the time taken (t_v) to be longer.
The equation that expresses this is

$$t_v = \frac{t_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

For example: A traveller on a train with a speed of 0.8 ***c***, picks up and opens a newspaper. The event takes 1.0 second as measured by the train traveller. As observed by a person standing by the side of the track the event takes 1.7 seconds.

Mass dilation

Another consequence of the theory of Special Relativity is that the mass of a moving object increases as its velocity increases. This is the phenomenon of *mass dilation*. It is another expression of the mass-energy equivalence and is represented mathematically as:

$$m_v = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

where
m = relativistic mass of particle,
m_0 = rest mass of particle,
v is the velocity of the particle relative to a stationary observer and
c = speed of light.

This effect is noticeable only at relativistic speeds. As an object is accelerated close to the speed of light its mass increases. The more massive it becomes, the more energy that has to be used to give it the same acceleration, making further accelerations more and more difficult. The energy that is put into attempted acceleration is instead converted into mass. The total energy of an object is then its kinetic energy plus the energy embodied in its mass.

To accelerate even the smallest body to the speed of light would require an infinite amount of energy, all the energy of the universe, plus a whole lot “more”. Thus material objects are limited to speeds less than the speed of light.