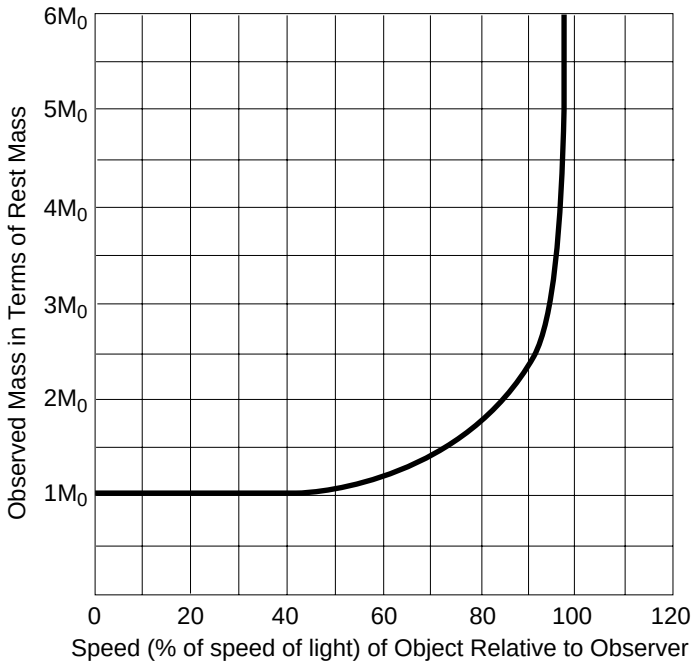
Mass, Energy, the Speed of Light—It's Not Intuitive!

How are the mass and the kinetic energy of an object related to the object's speed? Two theories of physics provide two distinct sets of answers!

Newtonian Physics (pre-Einstein) gives good results if the object is moving pretty slowly—less than about 10% of the speed of light (the speed of light is 300,000,000 meters/sec or 186,000 mi/sec).	**Special Relativity** (one of Einstein's 1905 theories) deals with faster-moving objects. The faster an object moves, the more necessary it is to use this theory in order to be accurate.
• The mass of an object does not change with speed; it changes only if we cut off or add a piece to the object.	• As an object moves faster, its mass increases. (Note: this is true if "faster" is measured relative to an observer who is also the one measuring the mass. If the person measuring the mass is moving right along with the object, s/he will not observe any change in mass.) As an object approaches the speed of light, its mass approaches infinity (see diagram).
• Force = mass × acceleration (Newton's Second Law); this is, to accelerate something, you need only apply a net force to it. The larger the mass you want to accelerate by a given amount, the larger force you will need, but by applying sufficient force, you can make an object go as fast as you like.	• Because masses approach infinity with increasing speed, it is impossible to accelerate a material object to (or past) the speed of light. To do so would require an infinite force.
• Kinetic energy = 0.5 × mass × velocity squared. Since mass doesn't change, when the kinetic energy of an object changes, its speed must be changing.	• Since masses change with speed, a change in kinetic energy must involve both a change in speed and a change in mass. At speeds close to the speed of light, most of this change is in mass.

At low velocities, the increase in mass is small. A particle moving at one-fifth the speed of light (60,000 km/sec or 37,000 mi/sec) has a mass only 2% greater than its rest mass. When a particle's speed approaches the speed of light, however, the mass increase (called the relativistic mass increase) is significant.



Inside the Advanced Light Source, electrons are boosted up to a very high kinetic energy of 1.5 billion electron volts (1.5 GeV). During the very early part of this energy boost, the electrons are in the speed range covered by Newtonian physics, and most of their gain in kinetic energy comes from speeding up. As the electrons approach the speed of light, they move into the relativistic regime, and successive energy boosts produce more change in the electrons' masses than in their speeds.