

Physics implications of “c”

Abstract

In Physics we commonly discuss things in terms of the speed at which light travels. It is commonly understood that nothing can travel faster than the speed of light. Here I wish to explore some of the very interesting implications of this “speed limit” and how it affects the world as we know it. I will also discuss the theory behind Tachyons, or superluminal particles and an interesting theory called VSL or Variable Speed of Light.

Upon waking Albert Einstein recalls a dream he had that night. In the dream he was walking over a hill on a foggy morning and noticed some cows eating grass through the fence in the valley below him. He remembered how ambivalent the cows seemed toward the electric fence and decided that it must not be working. He then noticed a man carrying a battery walking toward the opposite end of the fence. The man connected the terminals of the battery to the fence. Just as the man touched the wire to the second terminal on the battery all of the cows jumped back from the fence. He continued his walk down the hill and talked to the man. He commented on how his cows had very good reflexes, since they all jumped back at the same time when he had connected the battery. The man laughed and said that Einstein was mistaken. The cows jumped back one at a time, in order down the fence. He argued with the man for a while and then awoke.

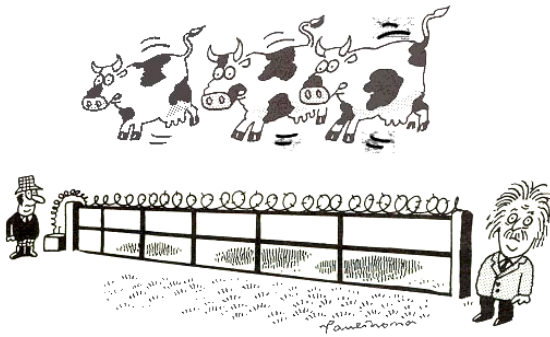


fig. 1

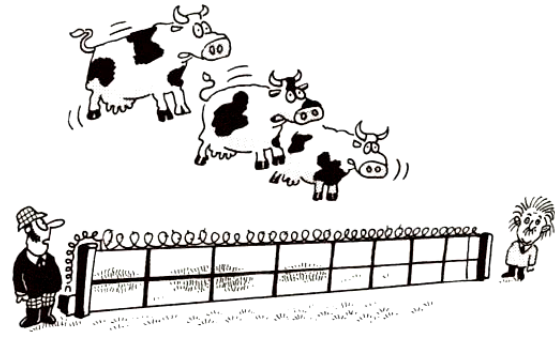


fig. 2

Einstein thought about the dream for a while and concluded that this showed how events are relative to the point of view of the observer. Since the electricity traveled down the wire at the same speed as the images of the man connecting the battery and the cows jumping back from the fence, all of the images reached him at the same time. The man however connected the battery, and then after some time saw the first cow jump, and then the second and so on. Due to the two different frames of reference the two observers

saw two very different things. This of course could not actually be observed, due to the very high speed at which light travels.¹ This dream illustrates how important a good imagination is. Einstein would not have interpreted his dream in such a manner if he were not currently working on the problem of relativity. One could even say that he would not have had the dream to begin with. The point of this illustration is to show that what some might quickly dismiss as ludicrous, could be a very important finding. While you cannot entertain every possibility, it is important to think about problems in different ways.

Ever since the sound barrier was broken, people have been asking: "Why can't we break the light speed barrier too, what's the big difference?" It is too soon to tell if the light barrier can be broken, but one thing is certain -- it's a wholly different problem than breaking the sound barrier. The sound barrier was broken by an object that was made of matter, not sound. The atoms and molecules that make up matter are connected by electromagnetic fields; the same stuff that light is made of. In the case of the light speed barrier, the thing that's trying to break the barrier is made up of the same stuff as the barrier itself.² How can an object travel faster than that which links its atoms?

Some of the interesting things that happen as you approach the speed of light are length contraction and time dilation. With length contraction things appear to become shorter and shorter, in the direction of travel, as they approach the speed of light. This means that an object would become infinitely flat right before c . There are many theories about black holes and this phenomenon of length contraction. Time dilation is also very interesting. As figure 3 illustrates, a person traveling at 99.9% of the speed of light would appear to age some 200 times slower to a person in a non inertial reference frame. This is observed on a daily basis in accelerator facilities around the world. Many particles of interest are very short lived. If it were not for time dilation, the particles would not make it to their interaction points.

What would happen if you could relax this speed limit for conversation purposes and accelerate some small bit of matter, say a proton, to the speed of light. In the equation in figure 3 it is obvious that this particle would live infinitely long as far as we could tell. Now what if you could travel faster than the speed of light? It is easy to imagine that you could effectively travel back in time. Since no information can travel faster than c , you could travel faster than information. You could travel to Mars and be back before you left, or could you? Only if you could travel faster than twice the speed of light, could you travel and return to the same place before you left. Time is not an object but a measure. Can you imagine a situation in which time halts to a standstill and then restarts? The flick would come from something that actually couldn't act, for it is would be also still. You realize how easy it is to come to the conclusion that 'time' could never have 'started'? Ergo, there was never a beginning and there will never be an end for the Cosmos. Time is measured by change, which in turn is a result of energy effects. Time is a dimension of Energy. So what about the proton you accelerated to the speed of light? How much energy would it take to accelerate the single proton to the speed of light? It would take an infinite amount of energy to accelerate even the smallest amount of matter to the speed of light according to Relativity.

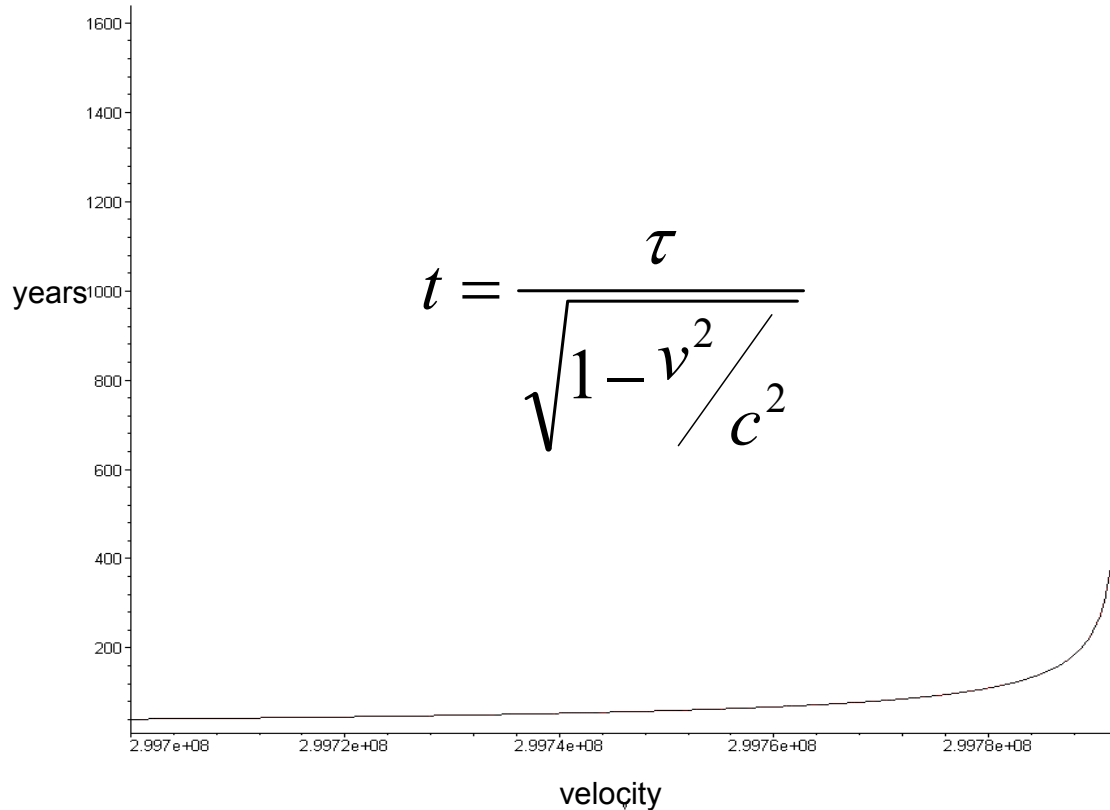


fig. 3

It is more interesting for the proton to just imagine approaching the speed of light. As you get closer and closer to c , the mass gets bigger and bigger. So what if you could increase the mass of a proton by say 34 orders of magnitude? The proton would still not be traveling faster than c but some very interesting things could happen. If you could overcome the strong force in the proton with gravitational force you would produce a miniature black hole. The mass would collapse in upon itself. Of course the extent of the black hole would only be the diameter of a proton and it would be very short lived but who cares, it would be fun. The proton black hole could even fit in the astrophysical classification of black holes. They are classified by mass, spin and charge. With energies of 10-20 TeV (10^{12} eV), the LHC at CERN may very well provide the first experimental black holes on Earth.³ This information could even provide some insight into Dark Matter.

It is evident from figure 4 that accelerating matter to the speed of light is not possible using current ways of thinking. If it is impossible to accelerate even a proton to the speed of light, how is it possible to have particles which travel faster than c ? Tachyons are particles whose velocity exceeds the velocity of light. While many believe that the existence of particles with hyperluminal (superluminal) velocities (FTL, or Faster-Than-Light velocities) is precluded by relativity, this is not the case if the particle

is created with a velocity already exceeding the velocity of light. What relativity precludes, within the boundaries of our present technologies, is the acceleration of a subluminal particle to hyperluminal velocities. What is also not precluded is the possibility that technology might someday be developed that will permit the relativistic limitations to be overcome, and hyperluminal velocities to be achieved by subluminal objects.⁴ It is believed that tachyons exist but no experimental evidence has been found. Interestingly enough, if they do exist, most people believe that we could never detect them. In order to detect them you would have to slow them down enough to see them. If you apply the same equations to tachyons as you apply to matter, it is impossible to slow a tachyon down below the speed of light. You see their lower speed limit would be matter's upper speed limit.

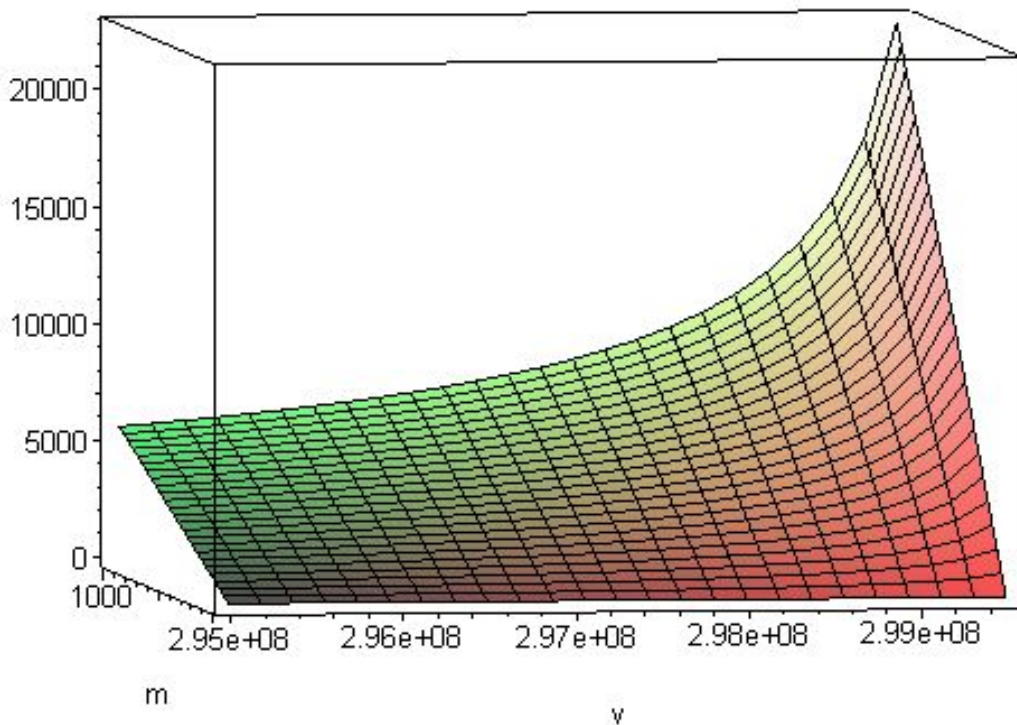


fig. 4

The only hope of seeing tachyons experimentally would be if they carried a charge. Charged particles which travel faster than the speed of light emit Cherenkov radiation.⁵ Cherenkov radiation is commonly used in particle detectors today in a variety of different ways. When a particle travels close to the speed of light in a vacuum and it enters a medium with an index of refraction greater than 1, it sends a shock wave through the material. This shock wave excites the vibrational modes in the molecules of the medium and this causes the emission of light. Some people believe that if you could detect Cherenkov radiation in a vacuum, this would be proof of superluminal particles. It is not understood how this light should be emitted in an absolute vacuum, devoid of all matter. There must be something present for the charged particle to excite, to generate

the light. While we may not have proof that they exist, we don't have proof that they do not exist either.

If tachyons do exist, where did they come from? The most popular theory is that they were born during the first Epoch of the Big Bang, when matter was in a different state than we think of it today. If all of the tachyons traveled faster than light and all traveled outward with the Big Bang, wouldn't they all have passed us by now? It is possible that the tachyons interact with each other like matter does and thus would have collisions and some analog to a gravitational force. These forces along with charge could change their directions. Or maybe tachyons are still being generated today. Some believe that supernovae and black holes could be tachyon factories. Of course supernovae, black holes, and dark matter can be used to explain all sorts of unexplained things in physics, like tachyons, cosmic rays, and even the expansion of the universe. It's kind of like answering a question with a question though.

One of Albert Einstein's fundamental insights was that the speed of light, known as c , is a constant for all things, no matter how fast they move. But what if Einstein missed something? Some theorists and astronomers suspect that c varies and that they may be able to detect subtle shifts in its value.¹ Since we are relaxing so many laws of Physics already, what if we say that c is not really a constant but a constantly varying constant? What if light traveled at a much higher rate a long time ago? There are some very interesting papers, and a book, by Joao Magueijo about this very subject. He formulates a theory called VSL or Variable speed of Light. He says that light could have traveled at speeds much, much higher than the constant c we think of today. He came up with the idea while at college at Cambridge after a night of drinking. What started as a whimsical idea has developed into a very plausible theory. He first tried to use the idea as a solution to the horizon problem of our known universe and soon found that it could be used to explain many other unsolved problems in Physics.

If c was much larger in the past of our universe, how would one prove it? It is after all the responsibility of the person making the claim to prove it, not for someone else to disprove it. Many attempts have been made to use the VSL theory to explain things such as very high energy cosmic rays, and the discrepancy of the fine structure constant. The most energetic known particles in the universe are enigmatic cosmic rays that pelt Earth with a punch exceeding 10^{20} electron volts. But according to Einstein's theory of special relativity, such cosmic rays should not be able to travel far through space before they smack into other radiation and lose some energy. So far, nobody has been able to explain such energetic cosmic rays. One possible answer is that the speed of light increases as particles near an absolute energy limit. A vast experiment going on in the Pampas of Argentina may help solve the mystery. Spread out over an area the size of Rhode Island, a network of detectors is designed to catch enough of the rare high-energy rays to help scientists determine where they formed and how. If they come from cosmic distances, then Einstein's theory of light may need some correction. The cosmic rays may, however, hail from our stellar neighborhood, a genesis that would require no changes to the speed of light.

A team of astronomers led by John K. Webb at Australia's University of New South Wales has studied light emitted by distant quasars 10 billion years ago. On its journey toward Earth, the light passed through clouds of atoms of various elements. Each of those elements absorbs certain frequencies of light, which are determined by a constant of nature called α , or the fine-structure constant. The light that is not absorbed continues on its way. Measurements of that light suggest that α has actually grown by 0.001 percent over many billions of years. Since α depends on the speed of light, a slight change in light's velocity may explain that growth. However, many astrophysicists regard the findings with considerable skepticism.

Some theories that postulate a variable speed of light suggest that the value of c depends on the frequency of the radiation. A satellite mission planned for 2006 will test that hypothesis. Named the Gamma-Ray Large Area Space Telescope, it will collect light coming from so-called gamma-ray bursts, the most extreme explosions known in the cosmos. Astrophysicists will be able to measure how long it takes different frequencies of light from those explosions to reach Earth. If higher frequencies of light move slightly faster than lower frequencies, and they race across space for billions of years, then the mismatch should become noticeable by the time they hit the satellite telescope.

Joao Magueijo had a great deal of trouble in getting anyone to publish his work. People are too afraid of being embarrassed if they publish something in contradiction with the current way of thinking. People are certainly not anxious to publish something which may contradict Einstein. Magueijo tried all of the wrong methods of getting published. When he met opposition, he did all the wrong things. He lashed out at the administration which was responsible for silencing him. When he finally got published, many of his books were recalled because of the slanderous accusations printed within. With the information age upon us, he was able to get his work out to many interested scientists. He has now been cited in over 150 subsequent papers. His work is gaining popularity.

If you look back at the history of Physics, you quickly see that it is filled with this same scenario over and over again. I am not suggesting that this is the new revolution in Physics, I am only saying that the Science community must be more tolerant and open minded. Imagination leads to innovation. If students in science only use what they have learned to reproduce the same results, we will never make new discoveries.

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