NEWTON, FORGIVE ME.

THE SCIENCE THAT ENDED CLASSICAL PHYSICS

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PHYSICS COURSEWORK 2006.

Classical Physics is the physics before the 20th Century, and the main man behind all of this was sir Isaac Newton. When he was at university he developed calculus, the method we now use to measure motion and factors affected by the motion of an object. It lasted about 300 years before it was questioned, but then however, during the 19th century two physicists, Michelson and Morley, came across a problem. You see, Newton had also developed a method of mathematics which enabled us to calculate the addition of speeds or momentums, relatively. In other words if you are stationary, and you throw a ball to a stationary observer at 10 m/s, the observer sees the ball move at 10 m/s. But if you are moving at 5 m/s and throw the ball to the stationary observer at 10 m/s then the stationary observer will see the ball move at 15m/s, although you still see it move at 10m/s. This is relative. (I.e. the speed of the ball is relative to a, the thrower and b, the stationery observer). In addition to this Newton believed that motion changed with time. This is a fundamental idea of classical physics. Motion was summed up by Newton in three laws:

[1]1. Every object in a state of uniform motion tends to remain in that state of motion unless an external force is applied to it.
2. The relationship between an object's mass *m*, its acceleration a, and the applied force *F* is $F = ma$. Acceleration and force are vectors (as indicated by their symbols being displayed in slant bold font); in this law the direction of the force vector is the same as the direction of the acceleration vector.
3. For every action there is an equal and opposite reaction.

In this article I am going to try to illustrate that speed does not change with time, but time changes with speed. Since Newton's life we have learnt that the speed of light is constant. And this was realized by Albert Einstein.

[2]To return to Michelson and Morley and their problem as mentioned above, they tried an experiment with light. Due to relatively recent work having been carried out on waves, people knew that with a sound wave, for instance, if fired into a wind, travelling at 10m/s, and we know that sound travels through the air at 330m/s, then the sound wave would appear to travel at 320m/s. This caused the assumption that there must also therefore be a medium for light to travel through. Having discovered that sound could not travel through a vacuum, it was also thought that light would not be able to travel without *its* medium. This was called the 'ether'.

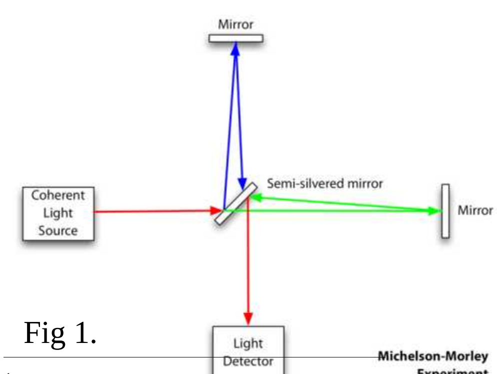


Fig 1.

Michelson and Morley set up their apparatus in a dark basement as they thought any slight wind movement would destroy the chance of achieving proper results.
They wanted to see whether *if there was an ether, then due to the earth flying round the sun at hundreds of thousands of m/s an ether wind would occur. At one point of the year they would*

[1] Online Journey through astronomy - website
[2] wikipedia - website

be travelling into it, and like sound, light would be slowed, and at another time of the year, they would be moving away from it. So the speed of light should speed up
[3]In their basement they got a huge tray of mercury, floated a large piece of flat marble in the centre of it, then set up their apparatus on top of that. This would reduce almost all potential vibration and also could be turned 360 degrees. On top of the marble they set up a light source firing towards a semi-silvered mirror in the centre. (See fig 1). Because of the semi-silvered mirror the light would split so that half the light would travel through the mirror, and the other half would be reflected at 90 degrees. Each of these beams would then bounce off 2 other mirrors (see fig 1 again), back to the middle, join up and reflect down into a light detector which they had also set up at the bottom. If there was any difference in the speed of the lights, at some point they would be out of phase and very little light would be detected. The light beam pointing into the ether wind would slow and cause destructive interference with the other when they met back up. They would then do the same thing when they were moving away from the ether and see if it sped up. (See fig 2.)

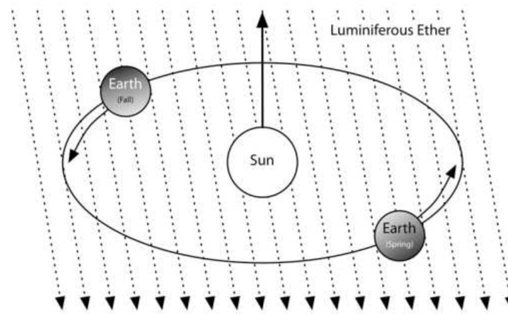


Fig 2

This experiment is considered to be the most famous 'failed' experiment. They had picked up so little change in the speeds of the light beams that, once they had accounted for error, *no change, **was** an option*. After this they went their separate ways.

The next person to attempt an explanation for the Michelson – Morley experiment was Hendrik Lorentz. He proposed an idea of length contraction. Using this he planned on explaining the failure of the Michelson-Morley experiment. His version of it still assumed the existence of'ether' *and with no explanation, he stated that it was **impossible** to exceed the speed of light*

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

The equation on the left, is what Lorentz came up with. It is a ratio of the contraction i.e. if you put the values of the speed of a moving object in, this will give you a ratio to 1, 1 being normal length. As Einstein said it is an "Ad hoc" equation because there was very little thought going into it about the practical world. It was also calculated mathematically so there was a lot of assumption about the ether and the speed of light. But it was a beginning of an explanation to why the Michelson-Morley experiment failed and also was a basis of Einstein's works.

Length contraction states that as an object gets closer and closer to the speed of light its length contracts relative to a stationary object. But at this time this was all speculation to explain what was not happening.

Another scientist on the topic, Minkowksi, said that if we look at time as a dimension in length then we can put time on a graph as we put speed, or distance.

[3] Wikipedia - website

If you take an ordinary Cartesian graph with speed against distance then you can tell how a body moves through a distance. But if you change the speed axis, or along side it you have a time axis, as a length, i.e. a fourth dimension, then we now have what is called a space time diagram. What Lorentz did was design the Lorentz transformation. It was a method of understanding certain things that happen due to traveling at high speeds. But first I need to go into more detail about the things that change the faster you travel.

This document is going to try and explain where the work of Isaac Newton breaks down.

Newton believed that Motion changes with time, which is fine for everyday situations. In everyday situations you don't really encounter speeds close to that of light so classical physics holds up and predicts correctly, but as you get closer to the speed of light, this is no longer the case. I have already talked a little about the speculation of length contraction, and I am now going to go on and continue to explain what really happens, but with practical examples to prove it actually happens as well as the theory. I will first explain time dilation. It is one that puzzles people the most and is the most talked about, because it is a form of time travel, which has interested people for thousands of years to the extent that television has been influenced by it.

Time Dilation.

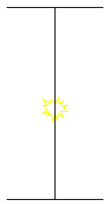
The basis of the explanation of this is from Pythagoras. The right angle triangle rule.
$S^2 = x^2 + y^2$

We need to use our imagination. Light travels at 3×10^8 ms^{-1}. Imagine two mirrors, one on top of the other 1.5×10^8 m apart. If you set a beam of light going between them, it would take one second for the light to get back to where it started. So this technically is a clock.

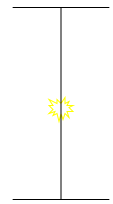
Now if a train driver takes this clock onto his train before setting off he checks his clock to make sure he isn't leaving late and goes. He travels at 30000ms^{-1}. To him, the clock continues to tell him he is making good time and he will be at his destination when he is supposed to be. Although the train is moving, if he couldn't see outside, the clock to him is stationary. This is called his inertial reference frame. But if he looks outside and sees a man on a platform shoot by, the man to him, because he feels stationary is moving. This is called his frame of reference.

Now this man on the platform manages to get a glimpse into the cabin of the train and sees the clock. He checks his watch to see if the train is on time and his clock, which happens to be the same model, and it seems to be out of sync with the one on the train. Actually it seems to be running faster than the one on the train. And then he realizes why. The one on the train has further to travel…..

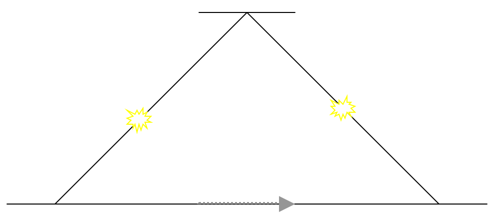
I shall now explain what I am getting at.



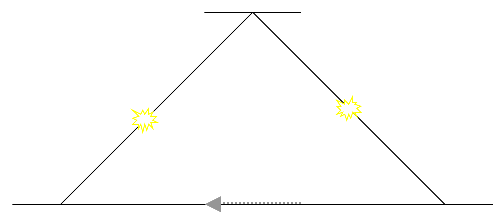
The light clock of the man on platform – as he sees it



The light clock of the train driver, in the train – as he sees it.



The light clock of the train driver's as the man on the railway sees it. As he sees the light beam reflect off the top the whole clock has moved on.

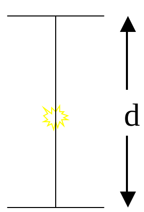


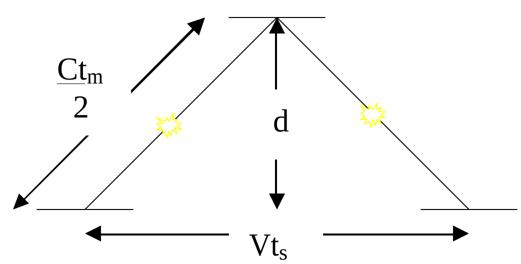
The light clock of the man on the platform as the train driver sees it. As he sees the light beam reflect off the top the whole clock seems to have moved back.

So he sees one tick on his clock as 1 second but on the train a tick as more than one second, what is this saying? Time on the train is slower than that when stationary? Yes. As an object travels faster, its frame of reference slows down, or, from the viewpoint of the frame of reference, the objects actions slow down…..

So now I have told you all this, lets use the basic maths I mentioned earlier to see if any of this makes sense.

I have below a copy of the light clocks from above. But here I have given every distance a letter.
This explanation covers both views- from that of the man in the station and the man in the train. But I shall talk about it from the perspective of the man on the platform.





d = the distance apart of the two mirrors in the light clock of the man on the platform. I made it this distance so that it takes light 1 second to travel from one mirror to the other and back again.
$V = 30000ms^{-1}$

Because we have two clocks, we have two sets of times so I shall call the stationary time t_1 and the moving time t_m.
$t = s/v$
Therefore $t_s = 2d/C$ and $d = t_sC/2$
But in the case of tm, we don't know $Ct_m/2$ so therefore $Ct_m/2 = (t_sC/2)^2 + (Vt_s/2)^2$
(Pythagoras)
We don't know the length of time for the moving clock so we can rearrange for it.
$t_m = t_s/ (1 - v^2/C^2)$

We know what d equals, and what v equals, therefore,
$t_m = 1/ \ (1-30000^2/300000000^2)$
So the ratio of one unit of time on the train: one unit of time on the man on the platforms clock = 1.00000005:1

The times are different.

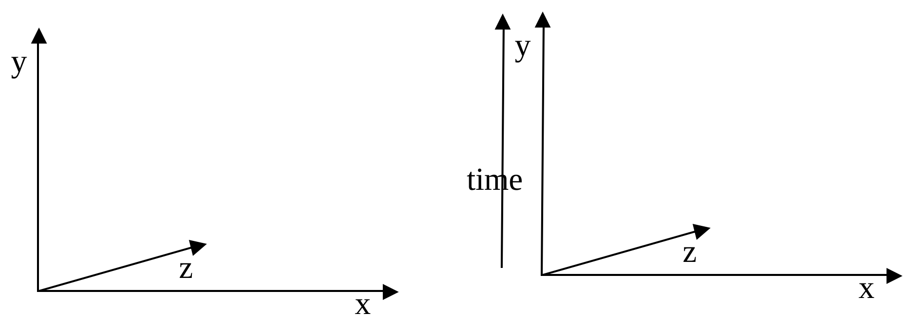
This may seem very little, but the ratio gets bigger very quickly as you reach the speed of light because if v = c then t_m = 1/0 which equals infinity! Yes, a tick takes infinity time to happen………

So I have justified that time does actually dilate as an object speeds up. I have explained this in theory but there are real life examples where time dilation affects every day situations.

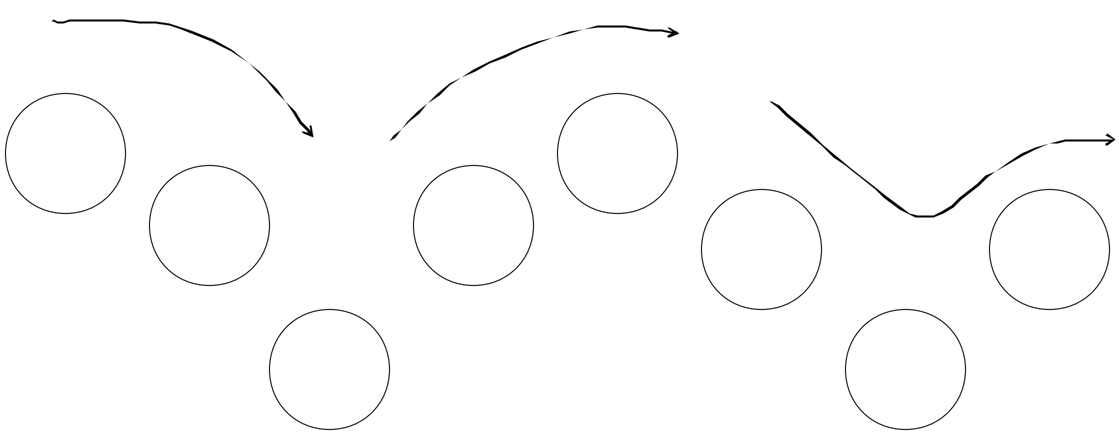
The recent technology, in car GPS navigation, is a prime example of this. Because the satellites in orbit are geostationary they have to travel a further distance in a shorter time, i.e. travel quicker than the earth. When the signal from your car is sent to the satellite and computers calculate where you are and where your going, due to time dilation on the satellite the signal getting back to you will not be what you are after. This has to be accounted for in the design of the system.

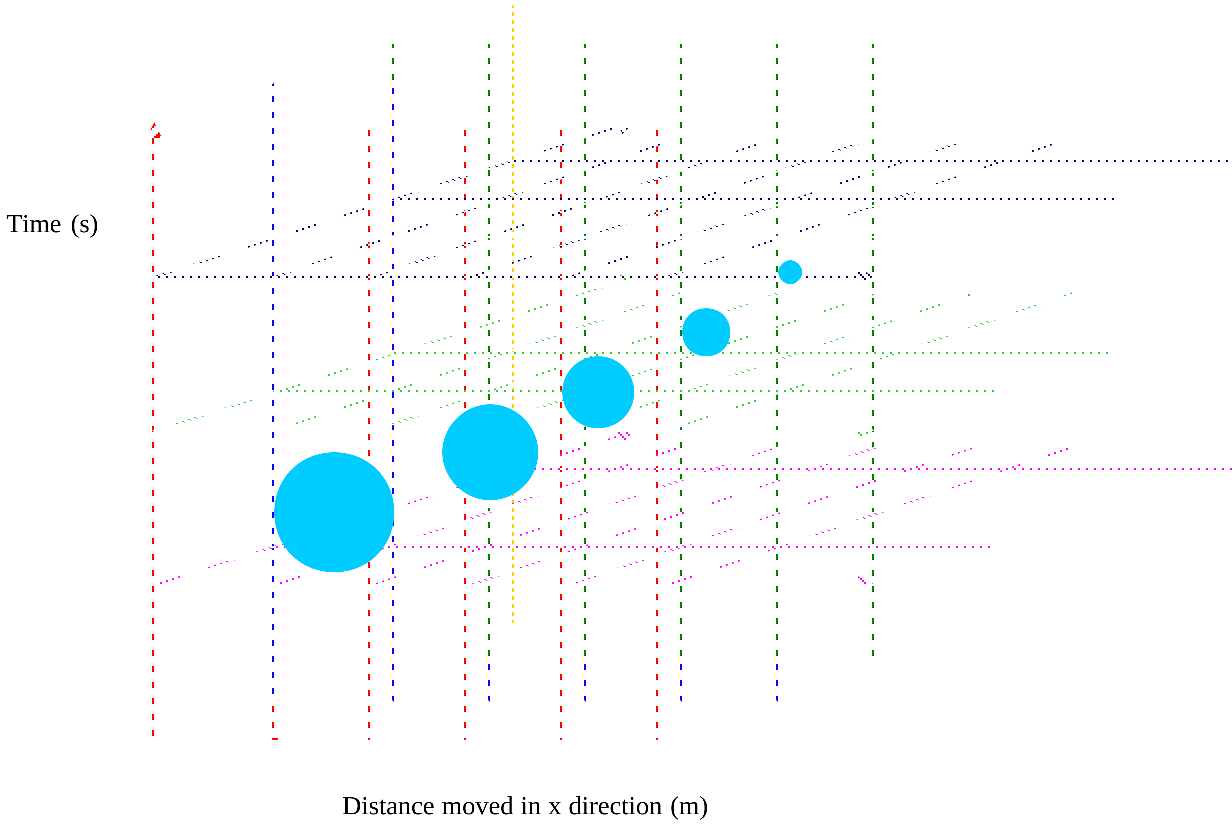
I will now explain the Lorentz transformation that I mentioned earlier because I have an example to use with it.

As I mentioned before, a scientist named Minkowski said that if time was converted to a dimension, then we would have a four dimensional universe. We can put time as an axis along side the vertical distance on a graph, i.e.



This means that we can now see how things move through space with time. Take the path of a bouncing ball…..

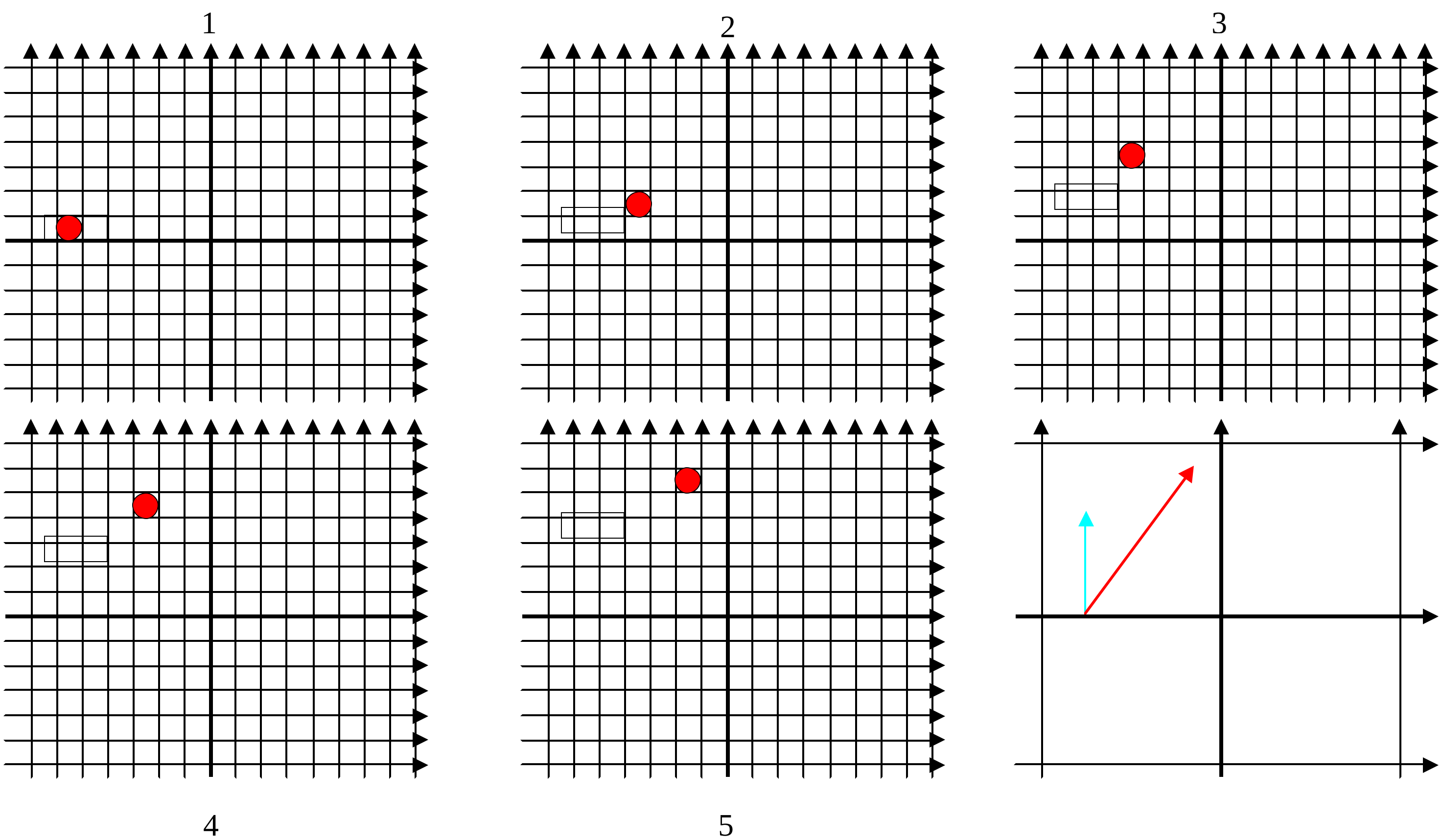



Time (s)
Distance moved in x direction (m)

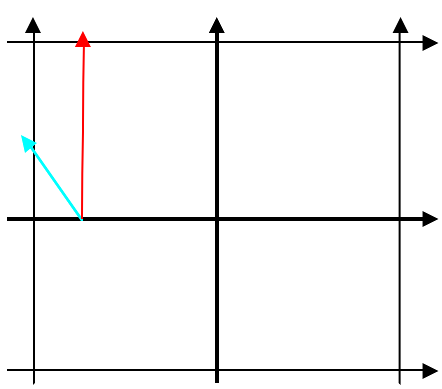
This diagram probably looks exceedingly wrong. But if you think about it, this is the path it would take. Time can’t go backwards, so each step is one higher than the next, and they get further apart as the ball falls further towards the ground. I have left out vertical movement for the simplicity of the picture.

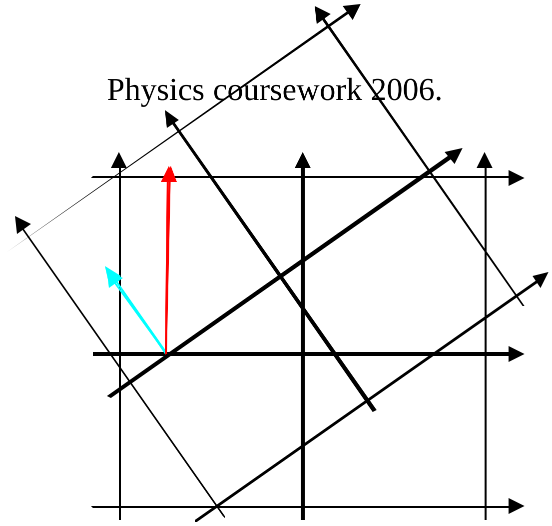
If I remove the z axis for ease of drawing and explanation I will explain the lorentz transformation and how we can use it to expalin time dilation.

A stationary box, watches a ball roll by, through time….

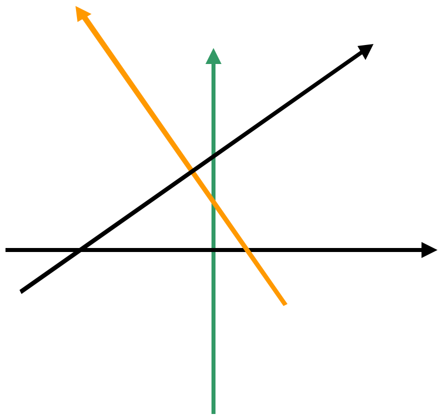


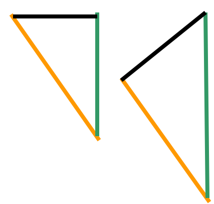
The diagram on the right shows the paths that each object takes through time relative to the square.
But to the ball…..





In the diagram, on the right →, I have put the two space time diagrams on top of each other and line them up so that the movement of the objects is the same. Now I can use this to prove time dilates.
I have coloured the two time axis green and orange, orange being the time axis of the ball. If you draw two right angled triangles between them, then from Pythagoras' theorem,the longest side is the time axes. I.e. in the first triangle below, the green time axis is stationary (this picture is from the perspective of the square) and the orange axis is longer, therefore it has dilated. And for the ball rolling the right hand triangle concludes that.





This also tells us something else very interesting. The black lines on the triangles represent distance moved. But if everything is relative to the square, (the green time axis) then when the ball is stationary, i.e. the right hand triangle the ball sees the length, the black line of the square at one length, but when the ball moves, the left hand triangle, and it looks at the square the length is shorter.

When the ball moves it thinks the square is actually moving and its length has contracted.

So when Lorentz tried to come up with a reason for the Michelson-Morley experiment failing with length contraction, he was right. He just didn't have anything backing for his work. The length contraction equation looks like this

$$L_1 = L_0\sqrt{1 - v^2/c^2}$$

L_0 being the length of the object when it is stationary and L1 being its new length after it has contracted

Again if an object were to travel the speed of light the v = c and L_1 would equal 0. Another odd thing when a body travels the speed of light.

The Twin Paradox

[4]Consider a space ship going from Earth to the nearest star system a distance *d* = 4.45 light years away, at speed *v* = 0.866*c* (at 86.6% of the speed of light). The round trip will

[4] Wikipedia - website

take $t = 2d / v = 10.28$ years in Earth time (*i.e.* everybody on earth will be 10.28 years older when the ship returns). Ignoring the effects of the earth's rotation on its axis and around the sun (at speeds negligible compared to the speed of light), those on Earth predict the aging of the travellers during their trip as reduced by the factor $\epsilon = \sqrt{1 - v^2/c^2}$, the inverse of the Lorentz factor. In this case $\varepsilon = 0.5$ and they expect the travellers to be $0.5\times10.28 = 5.14$ years older when they return.

The ship's crew calculate how long the trip will take them. They realize that the distant star system and the earth are moving relative to the ship at speed v relative to the ship during the trip. Therefore, the distance between the earth and the star system will be shortened (by the length contraction) to $\varepsilon d = 0.5d = 2.23$ light years, for both the outward and return journeys. Each half of the journey takes $2.23 / v = 2.57$ years, and the round trip takes $2\times2.57 = 5.14$ years. The crew arrives home having aged 5.14 years, just as those on Earth expected.

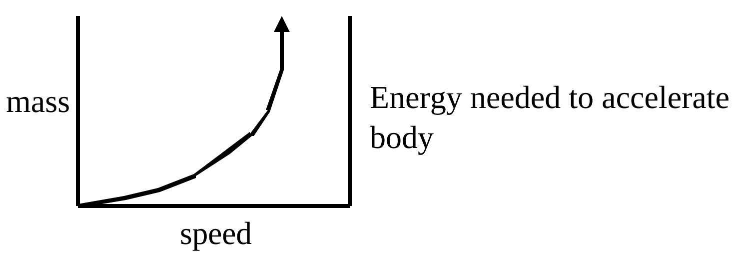
If a pair of twins were born on the day the ship left, and one went on the journey while the other stayed on earth, the twins will meet again when the traveller is 5.14 years old and the stay-at-home twin is 10.28 years old. This outcome is predicted by Einstein's special theory of relativity. It is a consequence of the experimentally verified phenomenon of time dilation, in which a moving clock is found to experience a reduced amount of proper time as determined by clocks synchronized with a stationary clock.

To some this up a poem was written to explain it:

[5]*There once was a girl named Miss Bright,*
Who could travel much faster than light.
She left one day,
In a relative way.
And returned the previous night.

Anon

So I have covered time dilation and length contraction and what happens when a body travels the speed of light – time stops and they are infinitely small. But this can't happen. If a body traveled the speed of light, time would stop. – not a possibility. So what stops the body traveling the speed of light? Well, what actually happens is, as a body gets closer and closer to the speed of light its mass increases. So that more and more energy is needed to accelerate it more and you cannot reach the speed of light.



[5] Science@NASA - website

This is very hard to justify though, through experiment, or illustration of experiment, so I shall explain it through simplistic maths.

The effort to move an object or in physics terms the work done to move an object is equal to the force needed to move it multiplied by the distance moved.

W= F x D.

But also the energy needed, ½ mv^2, to bring the object up to a certain speed is equal to the work done. In other words ½ mv^2 = FD. But in terms of momentum,

F = the rate of change of momentum of the object, where momentum = mass x velocity. But when an object is traveling very close to the speed of light, c, then v = c because the change in speed is negligible, yet there is still a change in momentum, because momentum has a rate of change. Therefore the force is still working to accelerate the object, which concludes that the mass must be the thing changing. It is increasing as the object is accelerated more and more.

There is very little more I can do to explain this, except draw the diagram above to give an illustration. It's a strange idea but it happens.

Here is the equation to calculate the increase in mass of a particle, where m = new mass, and m_0 = mass at rest

[6]

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

In Cern, Geneva, scientists are accelerating particles very close to the speed of light to find out more about sub atomic structure. Here they are feeling the effects of this because the particles are gaining mass, which they have to account for to get accurate results.

So now I have explained what the theory of special relativity concluded, in fact Einstein made two postulates:

[7]1. First postulate (principle of relativity)

The laws of electrodynamics and optics will be valid for all frames of reference in which the laws of mechanics hold good (non-accelerating frames).

In other words: Every physical theory should look the same mathematically to every inertial observer; the laws of physics are independent of the state of inertial motion.

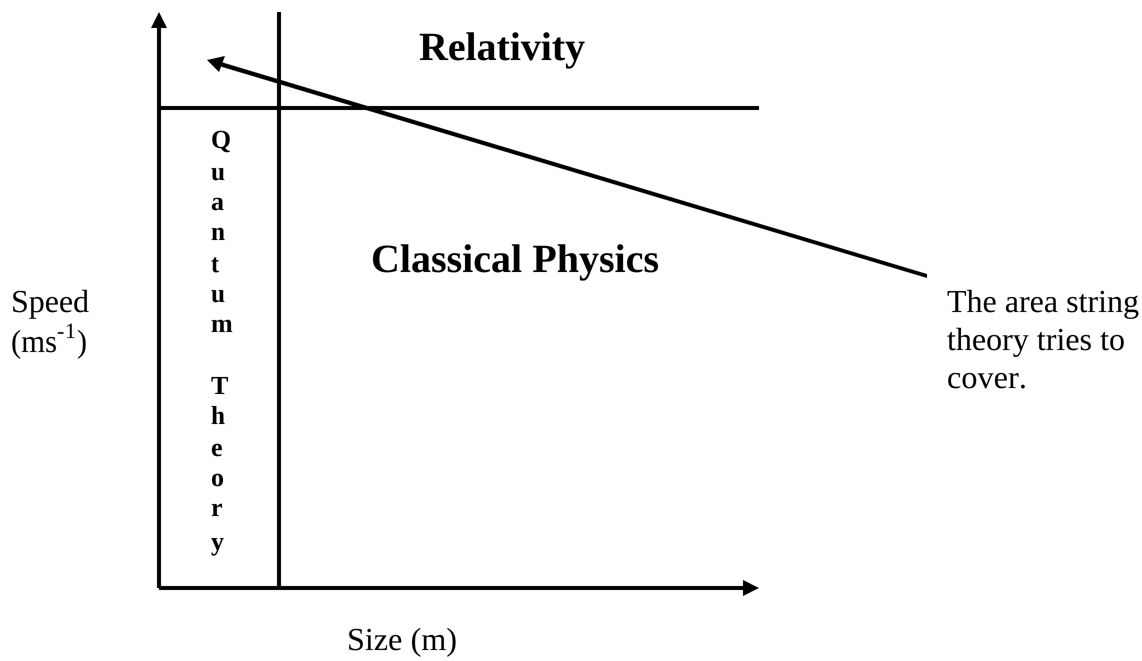
[6] Physlink - website
[7] Wikipedia - website

2. Second postulate (invariance of *c*)

> Light is always propagated in empty space with a definite velocity c that is independent of the state of motion of the emitting body; here the velocity of light c is defined as the two-way velocity, determined with a single clock.

And now the reason I began writing this.

Classical physics – the work of Isaac Newton which lasted about 400 years un-contested, doesn't quite cover everything we may need.



Look at this diagram above. What I have talked about for the last ten pages is only relevant in the green box at the top where the size can be anything that is not very small, it seems to break down here. Where it is affected is by speed. The speed must be great otherwise the affects of relativity are negligible.

The red is an area my article does not cover and is only relevant when the size of what we are talking about is very small – the area where relativity breaks down. The blue tries to cover the part where the red and green over lap and don't quite agree. This is called string theory and I haven't covered this either.

But what I have decided to talk about is the orange and the green areas. Until relativity the orange went all the way to the top. And to the left, But this is not the case.

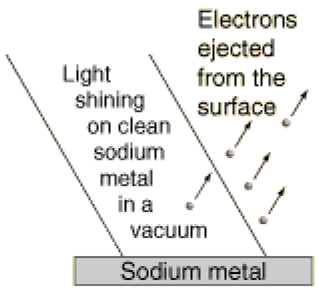
One website I looked at explained modern physics as
[8] "Phenomena that cannot be explained by classical physics, thus motivating the need for a new theory."

[8] Greenhill School, modern physics syllabus - website

There were a number of experiments that were done that were in complete contradiction to classical physics, such as the photo electric effect. This was a very simple experiment that concluded that when light was shone on a metal plate the plate gave out electrons.

Newton thought of light as particles and because electricity hadn't been invented there was very little he could do to test this, he thought nothing more of it and continued his experiments. But now we know this is not the case. In some instances light is a particle, but in others it acts as a wave. The use of classical physics cannot explain this idea and we have to resort to modern physics.

The problems with the photoelectric effect:



[9]1. The electrons were emitted immediately - no time lag!

2. Increasing the intensity of the light increased the number of photoelectrons, but not their maximum kinetic energy!

3. Red light will not cause the ejection of electrons, no matter what the intensity!

4. A weak violet light will eject only a few electrons, but their maximum kinetic energies are greater than those for intense light of longer wavelengths!

We need modern physics.

Another problem with classical mechanics is the acceleration of particles to collisions, when they reach close to the speed of light they seem to gain mass? They are smaller? Classical physics has no answer. Again, we need modern physics.

And of course there are the examples I have already mentioned like CERN, The twin paradox, and the light clock. By the way all though such a clock sounds ridiculous these type of clocks are called atomic clocks, and to test relativity they have put them in jets and flown them round the world at high speeds.

When they have landed, all though speed is constant, (which I hope I have made clear in this report), and the clocks therefore should be seriously accurate, after their flight they came back out of sync. Even if we didn't know Modern physics, classical physics just can't answer these questions.

There is a lot of math's and physics to explain these holes in classical physics, some of which I have covered, a lot which I haven't because thats not what I am wanting to write about, But this is gives you an idea of where it breaks down, and the rest of the article gives you an idea of where it is picked up again.

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[9] Hyper physics - website

This all began to get realized when people stated and had the technology to do work with light and waves. Questions just kept popping up and values weren't coming out right – like poor Michelson and Morley, they had no idea what was going wrong, and went down in history for the greatest *failed* experiment ever. Yet they began modern physics.

There is no way Newton could have even thought about any of these problems, as he had not the technology to see the particle, nor accelerate it to high speeds. If he had, he would have had to design classical physics, modern physics, the electron microscope and a lot more. His work has been superceded but because what he did was so accurate, we still use what he worked out to work out any everyday situation problem and many engineering problems, unless they involve small or fast.

Isaac Newton

[10]*"Newton, forgive me," wrote Einstein; "you found the only way which in your age was just barely possible for a man with the highest powers of thought and creativity. The concepts which you created are guiding our thinking in physics even today..." Albert Einstein.*

[11]*"If I have seen further than others, it is by standing upon the shoulders of giants." Isaac Newton.*

[10] American institute of physics - website
[11] World changing - website

Bibliography → 668 words.
Foot notes.

	Name	**Media type**
1	http://csep10.phys.utk.edu/astr161/lect/history/newton3laws.html	Website
2	http://en.wikipedia.org/wiki/Michelson-Morley_experiment	Website
3	http://en.wikipedia.org/wiki/Michelson-Morley_experiment	Website
4	Twin Paradox: www.wikipedi.org search: twin paradox	Website
5	http://science.nasa.gov/headlines/y2000/ast24may_1m.htm	Website
6	http://www.physlink.com/Education/AskExperts/ae161.cfm	Website
7	http://en.wikipedia.org/wiki/Special_relativity#Postulates	Website
8	http://modernphysics.homestead.com/class.html	Website
9	http://hyperphysics.phy-astr.gsu.edu/hbase/mod1.html	Website
10	http://www.aip.org/history/einstein/ae17.htm	Website
11	http://www.worldchanging.com/archives/001293.html	Website

Evaluation of Footnotes

1. After checking more than just this site for Newton's three laws of motion, although they all seemed to agree one what the principles were stating, this site seemed to explain it in the plainest English. It is a straight copy from the site, and would have been whichever site I got them from, I thought it necessary to make sure the English was simple enough to understand.
2. This is reference to the pictures I took directly from the site. Again with an explanation in words they do the job of giving a pictorial explanation along side. They are simple and useful diagrams that help to break up the text a bit.
3. Same as 2. – Same source.
4. I didn't want to get this example wrong so I took a straight copy and paste for this too. There was no contradiction with this and other explanations of the twin paradox but this was gave some figures to help explain it, which I thought was important and a good idea to have when explaining something that is quite difficult to grasp.
5. There isn't really much to say on this except that the poem was the most useful thing I found on the site. I went looking for general reference, but all in all not a good site, I didn't think, to learn from.
6. When looking for information about why mass increases as a body reaches the speed of light, this was the first site I came across that explained it in a way I could understand. It was very brief but gave me a good enough basis to look else where.
7. Just Einstein's postulates. I had used Wikipedia for other research so I thought I would be able to find a simplistic explanation of them. It agreed with most other sites I found but some had them the other way around and said that it was important to understand them in that order.
8. Not a very useful site, but had this useful one sentence, that was relevant at this one moment.
9. Hyperphysics. A brilliant website covering almost all physics, and very reliable with easy explanations.

10. Just a quote but also had the photograph to go with it. I didn't get anything else off this site, but was useful for this.

11. Again didn't use it for research but seemed to get the quote right, as other sites said the same thing.

Evaluation of Research Sites.

www.superstringtheory.com
A very handy site, with lots of useful information. Unfortunately I only used it to find out the relationship between quantum theory, relativity and string theory. But well worth a look.
http://www.btinternet.com/~j.doyle/SR/sr1.htm
Where all my research started. Lots of beginners info on the topic brilliant for first reading.
www.einsteinyear.org
A lot of information on Einstein, some helpful points here and there. Didn't use it much but it clarified some things.
http://casa.colorado.edu/~ajsh/sr/time.html
Some brilliant diagrams to explain what the site is trying to get across. Good explanations, but didn't cover everything related to the topic
http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html
Already talked about Hyper physics. A good site for checking up on some points but I wouldn't start here as a complete beginner on a topic.
http://www.geocities.com/ResearchTriangle/System/8956/Bondi/a1.htm
Poor explanation of Minkowski space-time. Started talking about three dimensions that space-time can move in, then suddenly lost two somewhere…
http://www-groups.dcs.st-and.ac.uk/~history/HistTopics/Special_relativity.html
Good history, not a lot of science
http://abyss.uoregon.edu/~js/glossary/special_relativity.html
A serious amount of text, don't seem to fool around with pictures. A lot of writing to get your head round.
New Scientist magazine No 15
A very good simplistic explanation of what special relativity is all about.
http://en.wikipedia.org/wiki/Special_relativity#Postulates
A brief but quite good explanation of everything. Still a lot to cover but had some useful points.