Challenging Modern Physics

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Questioning Einstein's
Relativity Theories

Al Kelly

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Challenging Modern Physics: Questioning Einstein's Relativity Theories

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Dublin 2005

There was a young lady named Bright,
Whose speed was far faster than light.
She went out one day,
In a relative way
And returned on the previous night.

Reginald Buller (1913)

Contents

When in doubt, make a fool of yourself. There is a microscopically thin line between being brilliantly creative and acting like the most gigantic idiot. So what the hell, leap.

Cynthia Heimel

Preface

No theory can ever be proven; it can only be falsified. The well-known *'all swans are white*' proverb was falsified when the first flock of black swans was discovered in Australia. Each theory stands as the best available until someone devises a theory that better fits experimental evidence.

Newton's Laws held for 300 years until Einstein came along with his 'special theory of relativity'. Experiments carried out since the launch of Einstein's theory in 1905 show anomalies. This book sets out a different explanation of the behaviour of light, which dispels those particular anomalies.

The book starts with a standard explanation of the special theory of relativity to acquaint the reader with the claims of that theory. Some problems with the theory are next described; these are euphemistically named 'paradoxes'. It is shown that Einstein was not the first to derive the famous equation $E = mc^2$, which has become synonymous with his name. Next, experimental evidence that cannot be explained by Special Relativity is given. In the light of this evidence, the two basic postulates of the special theory on the behaviour of light are shown to be untenable. A new theory is then developed, which conforms to the experimental evidence. This theory is simple; it requires no exotic concepts such as the slowing of time with speed, which are required by the special theory.

Novel experiments on the relative motion of magnets and conductors are described. These were undertaken because the movement of a conductor near the stationary pole of a magnet and the movement of that pole near a stationary conductor did not always give the same result. This result was claimed to be in contradiction to relativity theory, which requires that it is solely the relative motion of the magnet and conductor that matters. However, in the event, it is another basic law of physics that is shown to be in need of revision (Faraday's Law) – the experimental results are shown not to contradict relativity theory.

The Big Bang theory of the beginning of the universe is questioned and an alternative proposed. The source of much of the mysterious missing 'dark matter', which has been sought for decades by astronomers, is located. An explanation of the peculiar shapes of some galaxies is proffered.

It will be seen that everyday phenomena such as light and gravity are not yet properly understood. Perhaps this book will spur the reader to solve some of the unexplained mysteries of nature.

The general reader can skip the occasional mathematics without losing the trend of the debate. The conclusions drawn are also, in each instance, stated in words. In relation to the important aspects of the theory proposed in this book, there will be some repetition to ensure that the reader has grasped the kernel of the proposed theory.

There is not a single concept of which I am convinced that it will survive, and I am unsure whether I am on the right way at all.

Albert Einstein (1949)

Chapter 1

Special Theory of Relativity

Before Relativity

Before Einstein propounded the theory of Special Relativity, there were unexplained problems created by the assumption that light was behaving in the same way as sound. Sound travels through different media, such as the air. However, because it travels through (or piggybacks on) the air, the speed of sound, as measured by an observer, will vary depending on (a) the velocity of the air and the direction in which the air is travelling, and (b) any motion of the observer in relation to the source of the sound.

It was naturally assumed that light also travelled through a medium called 'ether'. Otherwise, the light coming from the stars would be travelling through 'nothing', which seemed an unacceptable proposition. It was also assumed that the measured velocity of light relative to an observer should vary in a similar manner to sound.

But then one famous experiment upset that notion.

The Michelson and Morley Experiment

Let us reflect on the famous 1887 Michelson and Morley[1] experiment. If there were an ether, the time measured for light emitted upon earth to travel at right angles to the direction of the motion of the earth on its orbit around the sun should prove different from the time for light to travel in the same direction as the motion of the earth upon its orbit. A test of this would confirm the motion of the earth and the existence of the ether.

Michelson later explained the experiment to his children as recorded by his daughter Dorothy Michelson (1973) as follows[2]:

> *Suppose we have a river of width w (say 100 feet) and two swimmers who swim at the same speed v (say, 5 feet per second). The river is flowing at a steady rate, say 3 feet per second. The swimmers race in the following way: they both start at the same point on the bank. One swims directly across the river to the closest point on the opposite bank, then turns around and swims back. The other stays on one side of the river, swimming upstream a distance (measured along the bank) exactly equal to the width of the river, and then swims back to the start. Who wins?*
>
> *Consider the swimmer going upstream and back. Going 100 feet upstream, the speed relative to the bank is only 2 feet per second, so that takes 50 seconds. Coming back the speed is 8 feet per second, so it takes 12.5 seconds for a total of*

---

[1] References are listed alphabetically at the end of the book.

[2] SI units are used throughout but here we quote directly from the paper.

62.5 seconds.

Now consider the cross stream swimmer. It won't do to aim at the opposite bank – the flow will carry the swimmer downstream. To succeed in going directly across, the swimmer must aim upstream at the correct angle. The swimmer is going at 5 feet per second at an angle relative to the river and being carried downstream at 3 feet per second. In one second the swimmer will move 4 feet across (right angled triangle is 3, 4, and 5). So at a crossing rate of 4 feet per second the swimmer gets across in 25 seconds and back in the same time – total 50 seconds. The cross stream swimmer wins.

Michelson's idea was to construct a similar race for light pulses, with the ether playing the part of the river.

The prevailing theory was that the ether formed an absolute reference with respect to which the universe was stationary. An observer on earth would picture himself or herself as stationary. To this observer, the stationary ether would appear to be moving.

Taking the speed of the earth moving on its orbit as *v* km/s, to the observer in the laboratory, the ether flow would appear as *v* in the opposite direction. The speed of light is c km/s and the ether flow is *v* km/s through the laboratory.

Two light signals were sent out, one in the direction of the motion of the earth on its orbit around the sun and the other at right angles to that direction. These two signals are depicted in the two sketches in figure 1. If the apparatus were at rest in the supposed ether, the two light signals would come back at the same instant. If not, the effect of the ether would be that the two signals would not come back at the same time.

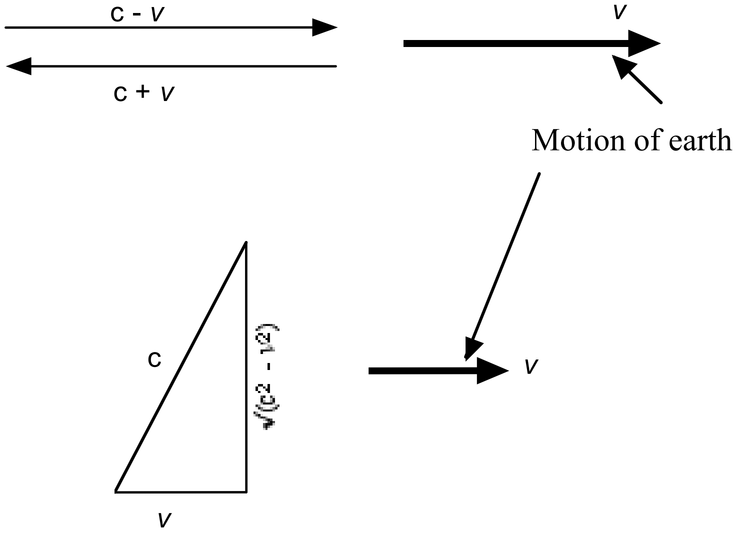

Figure 1: The Michelson and Morley Experiment

The earth's movement, which corresponds to the swimmer going with and against the flow in Michelson's explanation to his children, is in the direction of *v*. The ether flow in relation to the earth is therefore v to the left. In the top sketch, the speed of the light pulse going out and back in a straight line to the right for a distance L is $c - v$ on the outward journey and $c + v$ on the return journey, where v is the velocity of the earth relative to the supposed ether and c is the speed of light. Therefore, the time taken for the total journey would be:

$$[L/(c - v)] + [L/(c + v)] = [2Lc/(c^2 - v^2)]$$

The situation where the light signal is sent at right angles to the direction of the orbital motion of the earth is shown in the lower sketch of figure 1. This corresponds to the cross-stream swimmer. The result is different from the top sketch. Considering the right-angled triangle, the vertical component is $\sqrt{(c^2 - v^2)}$. The time for the double journey is:

$$2L/\sqrt{(c^2 - v^2)}$$

Because the times for the double journey in the two cases are different, it was foreseen that this difference could be used to determine the movement of the earth through the supposed ether. However, to Michelson and Morley's great surprise, no difference was detected.

While the experiment is always referred to as the Michelson and Morley experiment, Michelson alone had done an earlier test in 1881, where he proved the same result to an accuracy of one in two. The later more famous experiment was to an accuracy of one in forty, which was considered to be of sufficient accuracy to be generally accepted.

We need not go into the details of the apparatus, which had to detect one-millionth of a millionth of a second of time difference. Suffice it to say that it was based on measuring the difference in the interference fringes in continuous light sent in the two directions – the light should return at different times and thus set up these 'fringes' of light. The development of this method of measurement was a pioneering effort by Michelson, who had been a master in the U.S.A. navy. Many trials were made, but no difference in the time taken could be seen within the accuracy of the test equipment. He made the whole apparatus so that it could be rotated to find the maximum effect. The equipment was sufficiently accurate to detect one-tenth of the expected result. Thirteen tests culminating in an accuracy of 1:375 in 1930 are listed in Shankland (1955). Later, Jaseja et al. (1964) carried out a test to an accuracy of 1:1000. Any theory proposed must conform to this result. An even more accurate test that brings in another (startling) complication will be discussed later.

The Jaseja et al. test was 25 times more accurate than the Michelson and Morley test. We can therefore conclude that the speed of light is the same to very great accuracy in the direction of the orbital movement of the earth around the sun as the speed of light at right angles to that direction.

The Michelson and Morley experiment is renowned as the most famous test to have got a zero result. The result was so amazing that it was immediately known throughout the scientific world.

This puzzle led to some proposals that, in retrospect, seem bizarre. One suggestion was that the earth's movement through the ether was exactly balanced by some other movement of the solar system as a whole. Another was that the ether was dragged along by the earth when near the earth's surface. The Irish scientist Stokes had proposed in 1864 that a 'jelly-ether' existed, and this earlier idea persisted into the last century as a possible explanation (Wilson, 1987).

One explanation, proposed independently by the Irish scientist Fitzgerald in 1889 and the Dutch scientist Lorentz in 1892, required objects to contract in the direction of their motion (a fairly unlikely occurrence). This is known as the 'Lorentz-Fitzgerald contraction'. Fitzgerald wrote to Lorentz in November 1894 as follows:

> *A couple of years after Michelson's results were published, as well as I recollect, I wrote a letter to 'Science' the American paper that has recently become defunct, explaining my view, but I do not know if they ever published it, for I did not see the journal for some time afterwards. I am pretty sure that your publication is then prior to any of my printed publications for I have looked up several places where I thought I might have mentioned it but cannot find that I did.*

Fitzgerald also commented in that letter, *"I have been rather laughed at for my view over here."* The original letter to *Science* was dated May 2nd 1889 and actually appeared in *Science* in the issue dated May 24th. The letter went from Trinity College Dublin to Cork, 150 miles away, and then by tender to an ocean-going ship that sailed to New York, U.S.A. The letter was published 22 days later. The fact that the letter was actually published lay dormant until 1967, when it was discovered by Brush. What an efficient postal service, editorial review and publication organisation existed then!

The French scientist Poincaré had earlier concluded in 1899 that the movement of the earth with respect to an ether was *in principle* undetectable.

On occasions, such as in a letter written in 1952 (French, 1968), Einstein stated that he did not know of the Michelson and Morley experiment before 1905, when he published his famous paper launching his theory on relativity. The 1887 paper by Michelson and Morley referenced sources in German, Dutch and French, indicating that the findings would be known all over Europe. In 1922, Einstein had suggested that the test was the trigger to his relativity theory (see Highfield and Carter, 1993), and Einstein freely referred to Michelson and Morley in his 1916 book. There is other evidence that Einstein knew about the Michelson and Morley test as early as 1899.

Have Patience

Remember that in the 1930s there were reputed to be only three persons in the world who professed to understand and believe in Special Relativity; at least one of those (Einstein) is now dead. So do not be disheartened if you find the next few pages of this book abstruse or confusing. Unfortunately, we have to forge through the fog of Special Relativity to emerge into the sunlight of the later chapters; it is a purgatory that must be suffered before getting to the heaven of clarity and common sense. Remember this when you are tempted early on to throw the whole thing in the waste paper basket. Understanding clearly what is being claimed is quite different from believing that it is true. No apology is made to those who profess to believe in Special Relativity.

Special Theory of Relativity

Einstein set out two postulates in his special theory of relativity, which he launched in a paper in 1905. The theory is referred to as Special Relativity (SR for short) throughout this book.

The first postulate is that the *"laws of electrodynamics and optics will be valid for all frames of reference for which the equations of mechanics hold good"*. The second postulate states that *"light is always propagated in empty space with a definite velocity c which is independent of the state of motion of the emitting body"*. From these two postulates, Einstein concluded that:

1. *The laws by which the states of physical systems undergo changes are not affected, whether these changes of state be referred to the one or the other of two systems of co-ordinates in uniform translatory motion.*
2. *Any ray of light moves in the 'stationary' system of co-ordinates with the determined velocity c, whether the ray be emitted by a stationary or by a moving body.*

Based on the above postulates of SR, Einstein derived two requirements relating to the behaviour of light. The first states that *"light is always propagated in empty space with a definite velocity c which is independent of the state of motion of the emitting body"*. This first requirement says that light (just like sound in still air) is not affected by the speed of the emitting source. If a flash of light emanates from an aeroplane, the light flash goes out in relation to the spot at which the aeroplane was when the flash was let off; the speed of the light going out from that spot does not have the speed of the aeroplane added to its speed. There is really nothing unexpected about this.

The second requirement claims that *"light moves in the 'stationary' system of co-ordinates with the determined velocity c, whether the ray be emitted by a stationary or by a moving body"*. This requirement says that the speed of the light will be found to have the same value whether measured by a stationary observer at the spot where the light flash emanates or by an observer who is moving off at a uniform speed relative to that spot. The whole of SR is based upon this claim. If the reader fully accepts the claim, the rest of the theory follows logically. If, on the other hand, the reader is sceptical of such a claim, then read on!

This second requirement is a rather startling claim. In this respect, light should not behave like sound in still air. The measured speed of sound is directly affected by the speed of the observer in relation to the point of emission of the sound pulse. This is a well-known phenomenon. Additionally, the movement of the air through which the sound pulse moves has to be added to the speed of the sound in relation to the observer.

It is immediately obvious that this second proposal by Einstein fits the Michelson and Morley result, where the speed of the light was measured as the same whether going with the orbital motion of the earth around the sun or at right angles to that direction. Einstein’s proposal meant that, in such a test, you could never get any answer except the constant speed of light.

The speed of light in a vacuum is about 300,000 km/s (= c). In air, it is slightly less (0.9997c). The speed c is usually used for the speed of light in a vacuum or air because the difference is insignificant.

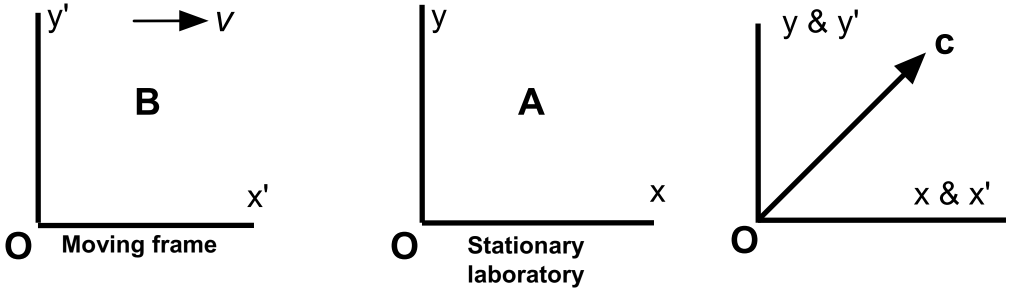

Figure 2a *Figure 2b*

Figure 2: Frames of Reference

In figure 2a, two frames of reference are shown. The one on the left, where an observer B is situated, is the moving frame, which is moving with a uniform velocity *v* with respect to the laboratory in the +*x* direction. The frame of reference on the right of figure 2a is the stationary laboratory, in which the stationary observer A is situated. At the exact place and time when the two frames have the same origin O and the same x and y axes, let a pulse of light be emitted at this origin. This is the situation depicted in figure 2b. Here, both frames of reference coincide.

SR propounded that a pulse of light emitted at the coincident origin of the two frames spreads out as a sphere as measured in both frames (one stationary and the other moving) and will spread at the speed of light in either frame. While the light spreads out in every direction as a sphere, the line with the thick arrowhead in figure 2b shows it in one direction only.

SR says that the light spreads out as a sphere whose radius is expanding at the speed c, as measured in all frames of reference that are inertial, i.e. that have a uniform velocity relative to each other. In the case of figure 2, because one frame is stationary and the other travels at a constant speed of *v* in the +*x* direction, the two frames can be described as inertial, and therefore SR will apply. The observer at A in the laboratory stationary frame of reference will observe that a sphere of light emanates from the origin and travels outwards at a speed c. Also, the observer at B in the moving frame will observe that a sphere (the one emanating from the same flash of light) spreads outwards at a speed of c as measured in the moving frame (from the same instant and from the same origin that was coincident for the moving frame and the laboratory at that instant). This is as stated in Møller (1952) and Katz (1964). It was also described by Einstein in his 1916 book *Relativity (The Special and the General Theory)*. In his paper launching his general theory in 1916, Einstein stated:

> *Thus the special theory does not depart from classical mechanics through the postulate of relativity, but through the postulate of the constancy of the velocity of light in vacuo.*

Einstein made it clear here that it was solely his claim that the speed of light is always measured as a constant by observers in uniform motion with respect to each other that was the revolutionary aspect of his proposals.

The above is a brief description of the usual interpretation of SR. Later in the book, the basic assumptions of that theory will be the subject of closer scrutiny.

To translate the observations of the stationary observer in the laboratory to the observations of the observer in the moving frame of reference, both of whom must get the same value for the speed of light as measured with respect to themselves, SR has to be used. The allowances that have to be made because of the relative motions of the observers give rise to the equations of SR, which will be derived below.

Note: A ‘frame of reference’ defines the place with reference to which measurements are being taken. For example, imagine yourself on an aeroplane that is flying at a steady speed and altitude. In this case, you could consider yourself to be in a ‘stationary’ frame of reference and would observe other things as moving relative to that frame. In this book, the qualification ‘inertial’ is implied whenever reference is made to a frame of reference under SR.

The Einstein Train

Let us now discuss the Einstein ‘train’ (figure 3), which Einstein used in his 1916 book to give an example of SR in practice. This is what he wrote:

> *People in this train will with advantage use the train as a rigid reference-body (co-ordinate system); they regard all events in reference to the train. Then every event which takes place along the line also takes place at a particular point of the train.*
>
> *Are two events (e.g. the two strokes of lightning A and B) which are simultaneous with reference to the railway embankment also simultaneous relatively to the train? We shall show directly that the answer must be in the negative.*
>
> *When we say that the lightning strokes A and B are simultaneous with respect to the embankment, we mean: the rays of light emitted at the places A and B, where the lightning occurs, meet each other at the mid-point M of the length A—B of the embankment. But the events A and B also correspond to positions A and B on the train. Let M' be the mid point of the distance A—B on the travelling train.*

> *Just when the flashes (as judged from the embankment) of lightning occur, this point M' naturally coincides with the point M, but it moves towards the right in the diagram with the velocity v of the train. If an observer sitting in the position M' in the train did not possess this velocity, then he would remain permanently at M and the light rays emitted by the flashes of lightning A and B would reach him simultaneously, i.e. they would reach him just where he is situated. Now in reality (considered with reference to the railway embankment) he is hastening towards the beam of light coming from B, whilst he is riding on ahead of the beam of light coming from A. Hence the observer will see the beam of light emitted from B earlier than he will see that emitted from A. Observers who take the railway train as their reference-body must therefore come to the conclusion that the lightning flash B took place earlier than the lightning flash A. We thus arrive at the important result:*
>
> *Events which are simultaneous with reference to the embankment are not simultaneous with respect to the train, and vice versa (relativity of simultaneity). Every reference-body (co-ordinate system) has its own particular time; unless we are told the reference-body to which the statement of time refers, there is no meaning in the statement of time of an event.*

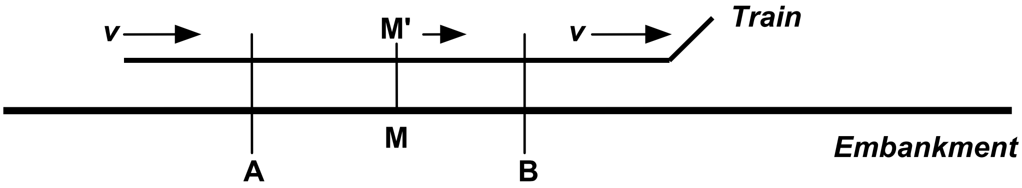

Figure 3: Einstein's Train

Remember that, according to SR, the speed of light *must* be the same to the two observers.

The reader may be surprised at Einstein's deductions. The person travelling on the train is assumed to be an expert in relativity theory! He is not allowed to conclude that the reason for the consecutive arrival of the two light signals is that the light has had a speed, in relation to himself, that is affected by the speed of the train. If he concluded that the light had speeds of c – v and c + v arriving from A and B respectively, this would have explained the matter equally well and in a far simpler manner. However, like Einstein, who wrote this explanation of the events, this person is a firm believer in SR.

The conclusions stipulated by Einstein are a necessary part of SR, which solved the problems thrown up by the Michelson and Morley experiment. No other solution seemed possible to Einstein. We shall revert to this matter later when the Michelson and Morley experiment is shown not to be the final word on this intriguing puzzle.

Having considered the moving train, we now move to the derivation of the main formulae of SR.

Time and Special Relativity

If one accepts the original assumptions on which SR is based, a number of curious consequences follow. One consequence of SR is that if two observers who are moving relative to each other measure an interval of time, they may not get the same result. Events that appear to be simultaneous to one observer may not appear to be so to a second observer who is in steady motion relative to the first observer. To show how this is so, consider figure 4, which depicts the usual SR derivation of the relationship between time as observed by two observers, one of whom is moving relative to the other.

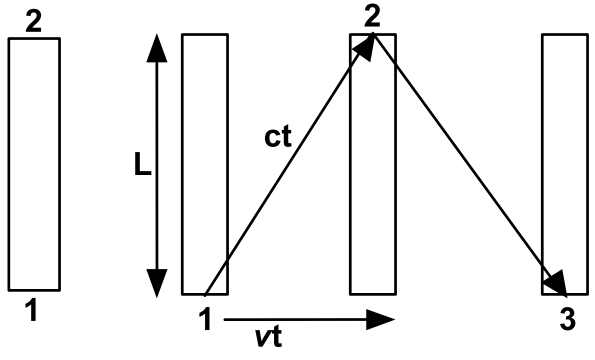

Figure 4a *Figure 4b*

Figure 4: Stationary and Moving Clocks

Figure 4a depicts a ‘rod clock’ – an imaginary rod, which is used to measure the time taken for a light signal to traverse the length of the rod. A light flash is emitted at point 1 and travels up a stationary rod to point 2, where there is a reflector that directs the light back down again to point 1. It is assumed that the detector is infinitely fast. An observer who is stationary in relation to that clock will record a total time of 2L/c for the light signal to travel up and down the length L of the rod.

Another rod clock is depicted in figure 4b. This clock is moving with uniform velocity v in the $+x$ direction. The clock is oriented at right angles to the direction of motion.

As mentioned before, the basic assumption of SR is that the speed of the light is the very same to the stationary and the moving observer. The automatic consequence of this is that the time measured by the moving observer must alter to match that basic assumption.

The speed of the light signal is assumed to be the same in relation to an observer who stays stationary in the laboratory (at point 1 in figure 4a) and to an observer who travels with a moving clock that is moving to the right at a speed of v (as in figure 4b). The observer who travels with the clock also records the light as travelling up the rod (which is moving to the right at speed v) and back again in a time of 2L/c.

Let us define t as the time taken for the light to travel up or down the rod clock as observed by the observer who is stationary in the laboratory. Let us define t' as the time taken for the light to travel up and down the rod clock as observed by the observer travelling with the clock. The distance that the clock travels to the right in time t at velocity v is vt. From the right-angled triangle, we see that:

$$v^2t^2 + L^2 = c^2t^2$$

$$t^2(c^2 - v^2) = L^2$$

and remember that L/c = t' (as defined by SR). Therefore, since

$$t^2 = (L^2)/(c^2 - v^2) = (L^2)/(c^2)[c^2/(c^2 - v^2)]$$

From this,

$$t^2 = t'^2[1/(1 - v^2/c^2)]$$

and

$$t = t'[1/(1 - v^2/c^2)]^{0.5}$$

Because it is used so often, it is convenient to shorten this relationship. The usual format is to take γ (gamma) as being equal to $[1/(1 - v^2/c^2)]^{0.5}$.

Therefore, t = γt'. If the velocity (v) is very high, i.e. very close to the speed of light, such as 0.999c, then there is a great difference between t and t' (t = 22t'). At such a speed, the laboratory observer observes the travelling clock to be running at a speed that is 1/22 of the clock in the laboratory. In other words, the travelling clock runs slow in relation to the stationary clock. This is the outcome of assuming that the speed of light is the very same to the stationary observer as to the moving observer.

Following from the above discussion, it is deduced that *"all moving clocks run slow, whether they be rod clocks, or atomic clocks, or biological clocks"* (Katz, 1964) because, for example, the intervals of a heart beat of the traveller will be observed by the stationary observer to be slower than his or her own heart beats. This follows from the fact that all clocks that are synchronised maintain that relationship. Such experiments are called 'thought experiments'; they are imagined occurrences. So, if we accept SR, we must believe that it is true that a moving clock runs slow with respect to a stationary observer.

Relative Motion

Figure 5 is a typical diagram used to aid the derivation of SR relationships. It shows times elapsed and distances travelled. It is often termed a 'space-time' diagram. The speeds are taken as uniform and in straight lines. The times are chosen to give round numbers in the results.

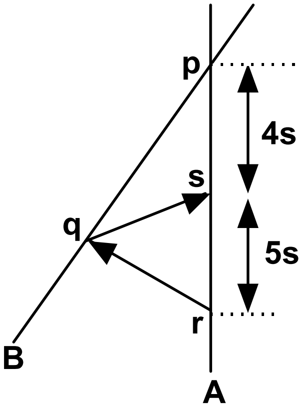

Figure 5: Relative Motion

B moves from B to p. A moves from A to p, where A and B meet. A is the observer in the stationary laboratory (oneself). At r, A sends out a signal to see where B is, and this signal is reflected from q back to meet A at s. A measures the time from when the light signal was emitted until it returned as 5 seconds. As stipulated by SR, A assumes that the signal took the same time to go to B as the return journey took from B back to A; therefore, A calculates that the time to reach B was 2.5 seconds. After s is passed, A measures a further 4 seconds before they both arrive at the same time at p.

The time taken by B to get from q to p (from the point of view of A) is the time taken from a point halfway between r and s to p; this time is 6.5 seconds. This is the time t referred to above.

However, the time taken by B is $t = 6.5 = \gamma t'$; thus $t' = 6.5/\gamma$ seconds. To calculate γ, we need the speed of B. The distance travelled by B is 2.5 light-seconds. (One light-second is the distance travelled by light in one second; this is 300,000 km.) A knows that B was that distance away when the signal hit B at q because A reckons that the signal took 2.5 seconds to get there. B travels this 2.5 light-seconds of distance in 6.5 seconds to arrive at p and meet A. The speed of B is distance divided by time, i.e. (2.5c)/(6.5) km/s.

As derived earlier, γ is $[1/(1 - v^2/c^2)]^{0.5}$. We have worked out that v is (2.5c)/(6.5). This gives the value of γ as 13/12. Therefore t' is $t/\gamma = (6.5)/(13/12) = 6$ seconds. This means that SR yields a time for B to go from q to p of 6 seconds. A sees that same interval as 6.5 seconds. B's time is running slower by 7.7% compared to A's time. This is the slowing of time as predicted by SR.

Because it is the relative motion of A and B that matters, the reader may be tempted to question whether the clock of A would similarly run slow according to observer B. We shall discuss this conundrum in the next chapter.

Distance

Before the launching of SR by Einstein in 1905, measurement of distance was considered to be straightforward. One metre of length was one metre of length, no matter who was doing the measurement. With the introduction of SR, it seemed that the measurement of length depended on the relative speed of the observer. Similar to the moving clock in figure 4, the length of a rod travelling parallel to the *x* axis is measured by an observer who travels with the rod and by a second observer who stays in the laboratory. One rod stays in the laboratory, and an exactly similar rod of equal length sets out at high speed. The same type of relationship emerges. Consider a rod travelling along the *x* axis with both ends on the *x* axis as it travels along (Katz, 1964).

Two ends of a rod are measured to determine the length of the rod. L' is the length as measured in the moving frame. L is the length as measured in the stationary laboratory.

$$L' = X'_2 - X'_1 = \gamma(X_2 - X_1) = \gamma L$$
$$L = L'/\gamma$$

As the value of γ is always greater than one, the length of the rod as measured in the laboratory frame (L) is less than the length measured in the travelling frame (L'). The length of the moving rod appears contracted to the stationary observer. This is called the 'Lorentz contraction'. At a speed of 0.999c, the travelling rod would be measured as 1/22 of the length of the original stationary laboratory rod.

Einstein made clear that such differences were not an illusion. He stated that *"space and time data have a physically real, and not a mere fictitious, significance"* (1922). He also made it clear in his first 1905 paper that the reverse situation applied: *"It is clear that the same results hold good of bodies at rest in the 'stationary' system, viewed from a system in uniform motion."* In other words, both rods are shorter as viewed from the other system; both of these systems are in uniform motion relative to the other. It is solely the relative motion that matters, and it is immaterial which system is considered to be at rest and which is considered to be in motion.

Momentum and Mass

In the same way, momentum is affected by SR. In Newtonian terms, momentum (p) is defined as $p = mv$, where m is the mass and v the velocity. Because of the relative motion, when a particle is travelling at velocity v, SR requires that $p = \gamma mv$. This relativistic equation can be interpreted in two ways: (i) the mass gets greater as the speed increases, or (ii) the momentum gets greater by a factor γ. Both (i) and (ii) amount to the same thing.

In SR, with respect to momentum and similar calculations, it is usually taken that the mass of a moving object increases with velocity. Therefore, to get the speed of an object up to the speed of light would need infinite momentum. As Einstein put it in *The Meaning of Relativity* (1922) (page 44), *"Momentum becomes infinite on approaching c."* Other texts say that mass becomes infinite when a speed of c is approached. Some texts just say that the momentum becomes infinite without specifically deducing that the mass becomes infinite. As Katz puts it (1964), *"the choice of interpretation is a matter of taste"*.

Energy

Einstein published a three-page second paper in 1905 as a quick follow-up to the paper that deduced SR. In this second paper (entitled *Does the inertia of a body depend upon its energy-content*), he stated that *"If a body gives off energy L in the form of radiation its mass diminishes by* L/c^2*."* He recorded here in words the relationship between energy and mass and the square of the speed of light. This later took the familiar form $E = mc^2$ (the energy in an object is equal to its mass multiplied by the square of the speed of light).

Under SR, the energy required to get a particle to attain the speed of light is infinite because, as we know from the previous section, mass (or momentum) increases with velocity and becomes infinite at the speed c.

$E = mc^2$: Who Got There First?

The equation $E = mc^2$ is synonymous with the name Einstein. However, it may come as a surprise to many to find out that Einstein was not in fact the first to derive the famous equation. In 1903, the Italian Olinto De Pretto, who was an engineer/industrialist with experience in materials and their properties, gave the precise formula $E = mc^2$. It was first published in June 1903. De Pretto delivered a second paper on November 29th 1903 in Venice, and this paper was published in the proceedings of the Venetian Royal Institute of Science, Literature and Art in February 1904. This is a translation of what De Pretto concluded in that paper:

> *Given then* $E = mc^2$*,* $m = 1$ *kg and* $c = 3 \times 10^6$ *km/s. anyone can see that the quantity of calories obtained is represented by 10794 followed by 9 zeros, that is more than ten thousand billions. To what terrible result has our reasoning brought us? Nobody will easily admit that an amount of energy equal to the quantity that can be derived from millions and millions of kilograms of coal is concealed and stored at a latent state in one kilogram of matter of any kind; this idea will be undoubtedly considered foolish. However, even if the result of our calculations be reduced somewhat, it should be nevertheless admitted that inside matter there must be stored so much energy as to strike anyone's imagination. What is in comparison to it, the energy that can be derived from the richest combustible or from the most powerful chemical reaction?*

De Pretto was amazed at his $E = mc^2$ equation.[3] What more proof do we need that this Italian preceded Einstein by two years?

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[3] In his paper, De Pretto used the symbol *v* for the speed of light.

De Pretto’s Reasoning

The reasoning used by De Pretto is very simple. Here is a synopsis of his derivation in a section headed *Energy of the Ether and Potential Energy in Matter*:

- Gravity attracts.
- A nearby mountain attracts a suspended lead wire.
- The force of attraction that unites all particles, molecules and atoms (even chemical cohesion) is the same force.
- To break a steel wire of 1 square millimetre cross section requires a 60 to 120 kg weight. This is small because it is concerned with molecules being separated.
- To break open atoms requires chemical reactions, which require much more energy.
- Not even mechanical force or chemical force is enough to separate the elementary particles that form atoms.
- There are therefore four degrees of attraction: the attraction between bodies, i.e. gravitational; molecular attraction; atomic attraction; and ultra-atomic attraction joining elementary particles.
- Two rough sheets, one of glass and the other of metal, can easily be separated. The rough contact plates have but a few points of contact. The smoother the plates, the greater the effort needed to separate the sheets. The attraction between the sheets varies inversely as the square of the distance between the sheets. Ideally, we could have such a smooth surface that the two sheets act as a single body (a very far-fetched idea).
- If molecules are separated by one ten-millionth of one mm, we take as the base case that of the steel wire of one square mm cross section that requires 120 kg to effect breakage. That is 120 kg/mm^2.
- Assume that the invisible roughness of the smooth faces of sheets in contact is one 10,000th of one mm. This is very different from our assumption regarding molecules – a thousand times different.
- If the distance between the two sheets is 1,000 times greater, then the attraction is 1,000 squared smaller than the force that holds molecules together. With this relationship (120 kg/mm^2), the attraction that holds two sheets of 10 cm sides together will be 120/1,000,000; we need 1,200 g to detach the sheets.
- These figures cannot be taken as a precise example but serve to give an idea of the attractive force between molecules.
- Atoms, being nearer to each other, must be much more solidly attracted.
- Particles of matter must be prevented from falling upon each other, and they are kept in continuous vibration around the point of equilibrium. As well as for particles of matter, this applies for ultra-atomic, atomic particles and molecules.
- All the energy in the universe resides in the ether. This is an infinite amount because space is infinite. All other forms (light, electricity, heat) are derivatives, which are by-

products caused by the movement of matter. Taking into account the immense speed of vibration of the ether, the formula mv^2 gives us an idea, if not a measure, of the immensity of the force it represents. Particles are prevented from falling one upon the other by the ether vibration, which maintains them in continuous vibration.

- Matter uses and stores energy as inertia, just like a steam engine that uses the energy in steam and stores energy in inertia as potential energy.
- All components of a body are animated by infinitesimal but very rapid movements equal perhaps to the vibration of the ether. It must be concluded that the matter in any body contains the sum of the energy represented by the entire mass of that body if it could move through space with the speed of a single particle.
- Such deductions lead us to an unexpected and incredible consequence. One kg of matter launched at the speed of light would represent an unimaginable and incredible amount of energy.
- The formula mv^2 gives us the potential energy[4] and the formula mv^2/8338 gives us such energy in calories.
- Given then $E = mc^2$, $m = 1$ kg and $c = 3 \times 10^6$ km/s, anyone can see that the quantity of calories obtained is represented by 10,794 followed by 9 zeros, which is more than ten thousand billion.
- To what terrible result has our reasoning brought us? Nobody will easily admit that an amount of energy equal to the quantity that can be derived from millions and millions of kilograms of coal is concealed and stored at a latent state in one kilogram of matter of any kind; undoubtedly, this idea will be considered foolish.
- However, even if the result of our calculations is reduced somewhat, it should nevertheless be admitted that there must be so much energy stored inside matter as to strike anyone’s imagination. What is the energy that can be derived from the richest combustible or from the most powerful chemical reaction in comparison to it?
- If it is accepted that all particles of matter are in motion, they may not necessarily vibrate with the same speed as the ether. Also, it is not perhaps rigorously correct to compare the latent energy to the energy represented by the same amount of matter that moves as one unit in space with the same speed. Whatever way you view it, we are forced to admit that there is such energy inside matter as beggars belief.
- De Pretto goes on the discuss uranium and thorium and their radioactive decay. He reasons that the emission of radiation from these substances was another case of energy transformation.
- De Pretto argues that the vibrations in matter must appear as heat. From this he deduces that within a huge mass (like the earth) where the losses are minimised, temperature must be great. He proposes this as a potential alternative explanation or contributor to heat at the centre of the earth.

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[4] Literally 'forza viva' as used by Liebnitz