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# Time is not a dimension

K.G.L. Löhlefink, (c) 2024

# Introduction

For those who expect an alternative theory, putting general and special relativity or quantum mechanics aside, this book will be disappointing. Then, also don't expect a "Grand Unified Theory" to be presented – the theory combining all four forces, especially reconciling Einstein's relativity and quantum mechanics. No, this book is only meant to give a different perspective on time and dimensions at the phenomenological level, which hopefully will lead to a new understanding. What I am trying to change is the narrative. The mathematics won't change and the theories won't change. It's just the way we talk about things, that prevents us from taking the next step. That's why I want to take the public in general on a journey, with as little mathematics (still some) as possible.

Probably you are familiar with the books, articles or videos presenting time as a dimension. Because we only perceive three dimensions, usually the axis "t" (for time) takes the place of the y- or z-axis and then the juggling with time horizons and light cones starts. Although a lot more information is available, this kind of representation is rather old. What I wanted to do since my youth is to detach time from the fourth dimension, because in my view those are two completely different concepts despite their relationship from some points of view. Even that's not a new approach, but it will probably help us to better understand some effects and perhaps allow other people to take the next steps, because they will no longer be captured in the old story, running in circles.

The idea for this book started decades ago, but after each attempt I had to give up, because I wasn't able to explain everything in a consistent way. When I was young, about fifty years ago, I felt time was just related to "change". Things are changing and holding information about the previous state, because the current state resulted from this previous state. When I tried and wrote about the subject, I got stuck in concepts like "speed", because that's displacement measured against time.

Later on I realised that a lot of riddles in physics are not really solved, but merely covered by a formula, providing great predictions. As said I won't even bring a new theory like MOND (MOdified Newtonian Dynamics), the brave attempt of Mordechai Milgrom raising an army of physicists to knock it down, despite good results.

Because it's mainly about the narrative, this book won't hold a lot of formulas, although some will be in after all. I just can't avoid them completely. The math will be kept as simple as possible. For some readers this will be too simple. If so, just skip the explanations and go on. For those who don't get it completely, I will try and explain the principles with the help of illustrations. If you still don't understand, consider it to be my fault.

Mathematics is very useful to describe things, but the other way round (drawing conclusions from mathematical formulas) is tricky. It can provide useful outcomes, but we might also end up with something disconnected from real life. A simple example is the surface of a square piece of land. We know that this can be calculated by squaring a side (e.g. sides 4 means the surface is 16). We also know that the square root of a number (16 in this example) can provide us with the side of a square with such a surface, but square roots are both positive and negative (4 and -4 in our example). Now nobody would sell pieces of land with sides -4 because the surface is still 16 (although it would be nice to create more space in densely populated countries!). There mathematics is disconnected from the real world, because to a certain extent negative numbers are in invention. Yet in finance the do a good job, but there most people won't buy squared currencies.

On the other hand, Paul Dirac thought he had created an artefact with his calculations, but then it turned out the predicted imaginary particle really exists. So things can go both ways.

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# TIME

## Measuring time (devices)

Have you ever wondered what time is? Well, at least it's something we measure with the help of devices. Before we had those devices we are able to tell the time using the cycles of day and night and the seasons. But the latter don't really tell us whether or not time is just a cycle, getting back again and again at the same point. For that notion we will refer to our lives, our bodies and minds. Somehow over "time" our bodies will wear and our memory will stack experiences until it falters. This indicates some start and end going in one direction. Yet a clock is also more or less cyclic, like the days and seasons are. The old ones had a spring, which could be winded and unwound numerous times, without showing a visual change. Of course eventually the cogwheels would break down and there always was a risk of getting rusty. The new ones have a longer cycle starting with the placement of a new battery and ending with the removal of an old one, until the device breaks down. In the end most of time at a more detailed level seems to be cyclical, but in the long run time is related to "decay".

## Order and disorder

Now let's have a closer look at decay, which actually is related to something we refer to as "entropy". Entropy is an interesting concept, because it came into existence from two different points of view, eventually merging to the same physical concept. (I'm simplifying here. For those who want to dig deeper in the history of entropy, please watch ...).
Here I will take the statistical route, being related to order and disorder, because it fits the purpose.

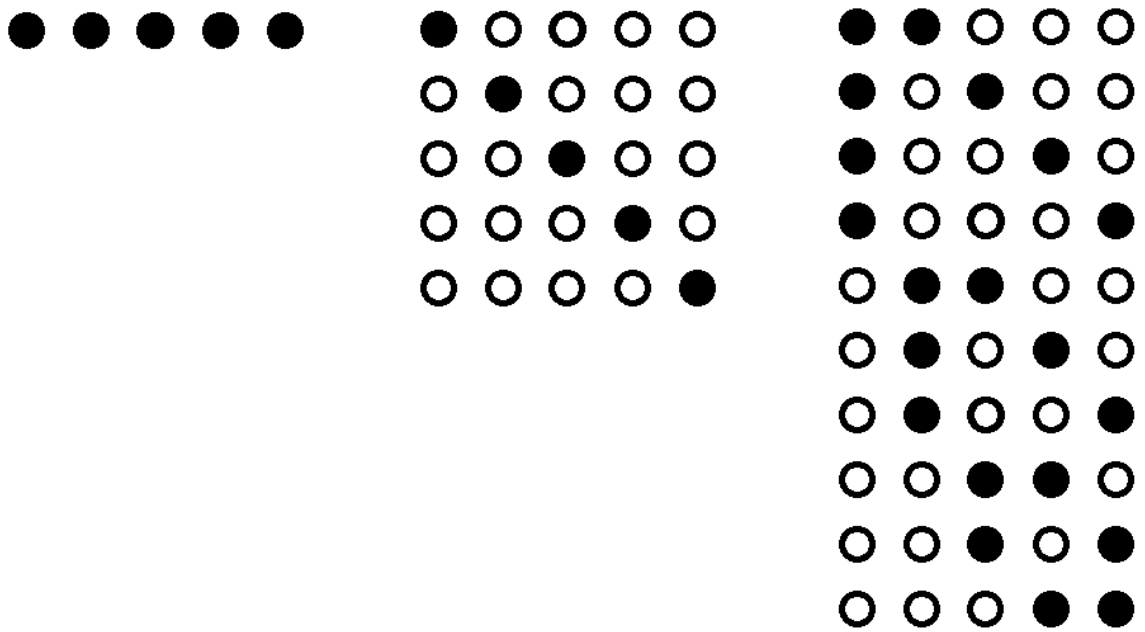
Imagine a set of marbles in a transparent box. Fifty are black and fifty are white. The black ones are in an array of 5x5, two layers above each other. The white are arranged in the same way, but stacked on top of the black ones: four layers of marbles in total. Now we have a very nice, orderly structure. If we start shaking (there is enough room left in the box to let the marbles move freely), the some black ones will start to move up and white ones will replace them. After the shaking there might be holes in the structure, but let's presume the four 5x5 layers are still there when we stop the shaking. Nobody will expect the white marbles to be still in the two layers at the top and the black ones at the two layers at the bottom. If you are the exception, expecting this structure will still be intact after the shaking, try for yourself. A cardboard box, the size of 5x5 marbles with a height of let's say eight marbles is not hard to make and marbles are not very expensive (and they don't even have to be new and any two colours will do).
Why is this happening? Why was the orderly structure we started with destroyed over time? Well, it's because this was not the most likely structure. To understand this, we will refer to some experiments with coins, even easier to understand.

Let's take five coins and put them on the table. All "heads up". Now we start tossing the coins the way we are used to (throwing in the air, shaking in the hollow of the hands), without manipulating the result and put them back in line.
Even for those who know the math the next experiment is a nice one.

We will start making a list of possible – overall – outcomes. With overall I mean that we won't look at the positions, but only at the number of heads and tails in the result. Actually we only have to count the heads, because we know that the number of tails is "five minus the number of heads" (if a coin is lost during the process, just replace it). The potential outcomes are 1, 2, 3, 4 or 5 heads.
Repeat the flipping of the five coins and write down the result after every round where all are flipped. After one hundred rounds the result will be something like this (results of my own experiment, using five 2 Euro coins):

| Tossing 5 coins, 100 times | | | |
|---|---|---|---|
| Heads | | = Tails | |
| 0 | 0 | 5 | 0 |
| 1 | 14 | 4 | 14 |
| 2 | 28 | 3 | 28 |
| 3 | 41 | 2 | 41 |
| 4 | 12 | 1 | 12 |
| 5 | 5 | 0 | 5 |

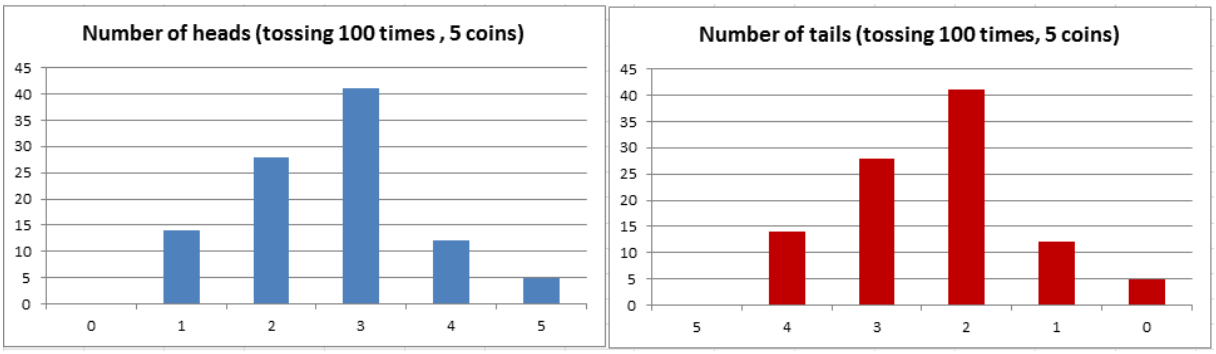
Because the coins have only two sides, 3 heads is equal to 2 tails, 0 heads is 5 tails and so on. It's not impossible to end with five times "heads up" again, but it is unlikely. Some readers will know why, but let me explain anyway.
There is only one way to come up with five heads: coins 1, 2, 3, 4 and 5 are all heads. However, for four heads, we have five combinations. It's easier to understand them from the position of the "tails" coin, which can be at position 1, 2, 3, 4 or 5. Five different options are available and therefore five times more chances to get this result. For two or three heads even more combinations are possible – all with the same chance, but taken together the chance is much higher to get this result.



In the examples above we can see there is only one way to get five times "heads". For one single "head" however, there are five combinations, shown as five lines. The first coin can be a "head" and

the other four “tails” the second one can be “head” and so on. With two heads, the number of possibilities is even larger. The ten lines to the right show the ten different combinations we all consider to be the same: “two heads” For us it’s all the same as we only look at the number of heads as a part of the total.

Of course three heads is two tails and therefore we don’t expect very different results for two heads and three. Of course it’s still not certain, but in the long run we expect patterns similar to the ones shown in the graphs below. The values shown are not the calculated theoretical values, because then the graphs would be symmetrical. I just performed the experiment myself and put the number of heads in the graph to the left and the corresponding number of tails (from the same experiment) to the right (be aware of the x-axis to the right being the mirror image of the one to the left). Basically it’s the visualisation of the table above.



The x-axis to the right is the mirror-image of the one to the left!

When we go back to the marbles, it’s even more complicated. The separate layers with black and white marbles are very unlikely and when we start shaking we get a more likely result.

Now I hope that you are able to translate this coin-experiment to the box with marbles. Although it’s not exactly the same, we could think about a black marble in a position as “heads” and a white one as “tails”. This way the experiment is similar to throwing a coin 100 times and getting only “tails” during the first fifty throws and then fifty times “heads” in a row. You will have some intuition about the chance of this happening.

What we learn from these examples is that what we consider as “chaotic” is much more common than what we consider as “neatly structured”, although it’s partly something created in our mind, because we don’t distinguish several patterns from each other.

## What is entropy?

After these experiments (the one with the marbles probably being a thought experiment only), we can get back to entropy. If we put it very simple, entropy is a measure of disorder. As a matter of fact it’s more like a measure of the likelihood of a certain situation. If we start out with a very orderly structure, like our box with the two layers of marbles, it won’t change if no energy is applied to the system (energy in the form of shaking, called “kinetic energy”). If we start shaking, a part of the energy will be invested in a new structure – almost certain a structure we will experience as more chaotic. For a simple structure, there is still a chance that the orderly situation will come up, but for

more complex systems the universe may not be around long enough to see it happen and that's a very long time!

It is possible to reverse the chaos of course, but this will also take some energy. Taking the marbles out of the box and putting them back in four layers with separate colours will create the original state again. Yet it won't happen as long as we humans (or some aliens) are not interfering.

Well, that's not completely true, because in some situations patches of structure will come into existence even in nature with its spontaneous processes. Think about crystals. Crystals are very orderly structures and we do know they exist. So somehow there are exceptions to the rule of the ever increasing chaos!

**Intermezzo**

A funny part of our "marble experiment" is the fact that the marbles will not take every possible position in the box when the shaking stops. Gravity is (usually) keeping them at four layers to the bottom. If we would do this experiment somewhere in space, without the influence of gravity (or at least where it's negligible), the marbles would float in the box and take every possible position. Actually then the entropy would even be higher. On earth we could do the experiment with gases, because gases are less affected by gravity. Their thermal energy is overriding it. So if we would take e.g. methane (CH4 – molecular weight about 16) and ammonia (NH3 – molecular weight about 17) the experiment could be performed on earth after all. Unfortunately these gas molecules don not have visible colours and are too small to be counted.

The alternative would be to take a video of what's happening in our box while shaking, but it's not that relevant to get all entropy states. The two layers at the bottom after shaking provide a good illustration of the principles of order and chaos and their relationship with "entropy".

## Our experience of time

If we humans are talking about time, we can refer to something cyclical, like day and night or a sequence of seasons. That's not a kind of time that's going anywhere. Things are just returning at the same point and everything is happening again. This notion of time works very well if we refer to "thing happening at the right time", like sowing and harvesting.

Apart from this, we also have some notion of a linear time, because we don't live forever. Not only our body withers, but also other beings, buildings and even mountains! This proceeding of time comes with decay, which is basically a process destroying order and bringing in chaos.

Let's consider a building. Think about it when it's fresh and new and then how it will be fifty years later. Of course it depends on the quality of the construction, but some damage will be visible, algae will probably cover the surface. Wooden pieces will be worn and probably be digested by fungi. During the lifetime of the building we will try and slow down this process by repairing, painting and cleaning, but the energy brought by sun and wind will bring more disorder and we have to do something to reverse this process.

It's very similar to our box with marbles. Think about a single brick in the building. How likely is it that all these lumps of molecules will stay in the same place? Why wouldn't small pieces go somewhere else? If a building is abandoned we suddenly see how the entropy is increasing. Over a couple of centuries, the structure is loses its order (with the help of nature of course) and eventually we will get a ruin.

Yet, on a more cosmic scale the same things are happening. Earth is changing. Other planets change too because they are bombarded with rock fragments travelling through space and don't have a dense atmosphere to protect them. Somehow time is always pointing towards chaos and we use this principle to measure time at a larger scale. Again this not completely true, because planet formation suggests the opposite: order is being created from chaos, but that's only happening when a lot of energy is available.

## Statistical approach with examples

Now let's go back from the cosmic scale to the very small atomic scale. Let's say that at a cosmic scale we were juggling with a box of millions of black and white marbles. How likely is, if we keep shaking, that one day two separate sets of layers will come up: the ones to the bottom being white and the ones to the top black? It would be as likely as flipping a coin millions of times and getting e.g. the first five million attempts only heads and the second five million attempts only tails. Nobody would believe such an event and it is extremely unlikely. Starting out with order, it's very likely that chaos will increase and for us this provides a nice way to measure time.

At the atomic scale we would have only one coin. It will be just heads or tails. Could we tell from the current situation if it's more or less chaotic than the previous one? Of course not! Actually we can think at this level about time going both directions. If we defined flipping from heads to tails as going forward in time, then going from tails to heads is going back in time. But are we really talking about "time" at this level?
We could also think about a box with two marbles in it – again a black and a white one. If we catch them in the corner, only two outcomes are possible: black to the top or white to the top. Again we could define going from white to the top to black to the top as going forward in time and the other way round as going back in time, but actually it's meaningless, because we are just flipping between two states and the chaos stays at the same level.

## Non-reversible

The big difference between the large and small number of marbles and the small number is that the latter is completely reversible, whilst the former only goes one way: towards chaos. In the end our perception of time is related to the macroscopic world, with its infinite number of possibilities, moving towards more chaos. At the atomic level, there is no direction. Time just doesn't exist!
Now you may ask how time behaves at an intermediate scale. There statistics applies and time is more applicable than at the atomic level (or even the level of elementary particles), but the outcome is not necessarily chaos, because events could also be in the direction of more order (from our human perspective).

Thinking like this, time is more like a continuum, existing more and more at a larger scale and less and less at a smaller scale. Therefore time travel seems to be possible at the microscopic level, but increasingly unlikely at a more macroscopic level like ours. Nevertheless we know that chaos can be turned back by investing energy. We are able to put marbles back in an orderly way (only not by shaking, but with the help of information). The question is whether we are really travelling back in time this way or simply building a reconstruction of the past. Just like we are able to restore a Roman temple or repair a damaged painting doesn't mean we actually travelled back in time. The world around us has changed towards more chaos and we are simply undoing the trend (very) locally, but it doesn't mean that the whole universe stepped back to an earlier stage. In other words, we always have a "time-context" telling us that we did not really travel back in time. And then we are still cheating at the local level, because we restored the past but we were not by tracing back every step it took to get to the present, just taking shortcuts, leading to something similar.

## A special hourglass

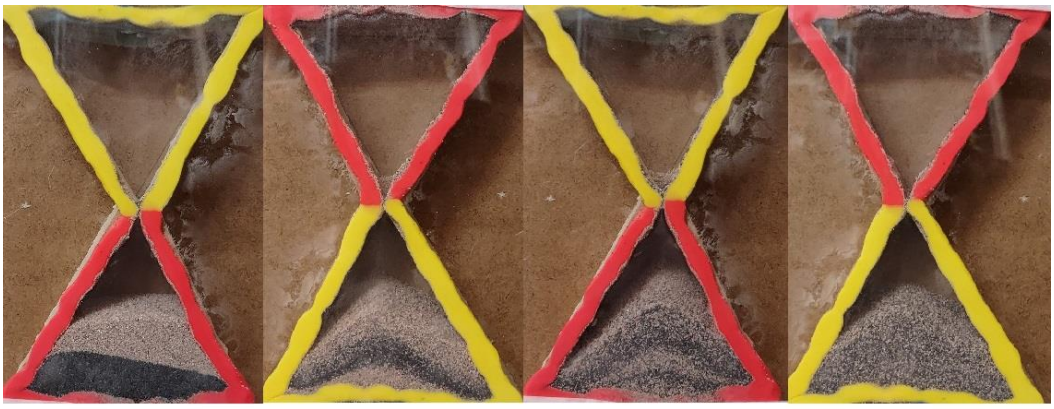
A normal hourglass seems to return to the start position, when the glass is turned when the sand was all at the lower half. And if nothing changed, the entropy is still the same. However, that's not true. If we use a very special hourglass, we can see that the chaos is increasing after all!
A simple hourglass is an instrument to measure time in a relative way. One has to remember the number of turns and that's OK. A small one (running only for minutes) will probably need nearly 300 turns during the day, but a large one could run for days. An extremely large one could probably keep track of a whole generation. We won't do that. Our experiment is simpler and similar to the box of marbles. We can think of the sand in the hourglass as a collection of millions of small marbles and the shaking is done by gravity (and us, turning the "glass" now and then).

Let's call it "the entropy hourglass". Here are some pictures of different eh... we shouldn't say "moments in time" because the time is what we are keeping track of with the help of the entropy in this device. "Different successive statuses" is a better expression. We know that the pattern goes from order to chaos, and by judging the degree of chaos we will be able to tell how much "time" has passed.

1 2 3 4 N

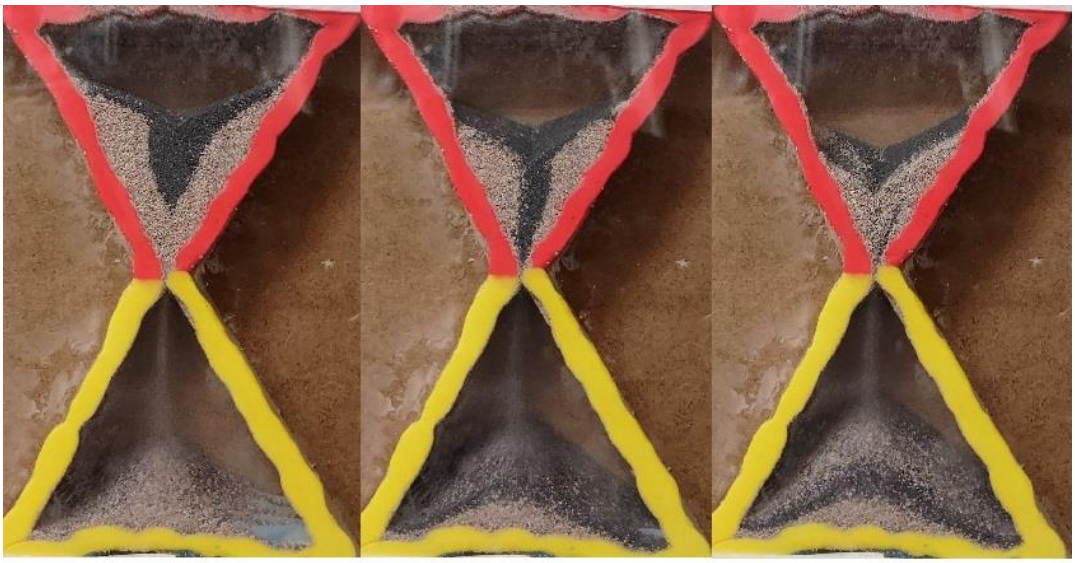
I created the object using board, wood, polycarbonate and yellow and red coloured modelling wax, to emphasise the position of the hourglass. Two layers of sand were brought in – first the light and then the dark grains (1). After the first turn (2) we can still see the layers, although less clear. After the second turn (3) the pattern is messier, but the remainders of the layers are still in place.

After the third turn (4) it looks already chaotic, but when we compare this picture with the one to the right (N), taken after a couple of additional turns, we can see it was not mixed completely yet!
The experiment was repeated with fresh layers. This time only four pictures are presented.



1 2 3 4

The in between states – pictures taken while the sand is still running – are also interesting.



A B C

These pictures are taken after the first turn, so between 1 and 2 of the second series. It shows very well how hard it is to predict the result. After every turn the colours are mixed a bit more, but the first turn is already destroying the original order.
We can restore the order of course, if we use a magnifier and separate the light from the dark grains again (a lot of patience needed), but it won't happen spontaneously!

## Our time is only one way

It the end we can say time is moving only one direction, even if we manage to undo changes at a local level. Our time is a human invention, measuring the state of the universe from what we consider as the start towards some end state we are not sure about yet. Our invention called "time" is going only one direction, because everything is connected and we simply cannot undo all the changes in the universe by tracking it back to an earlier state. Hence real time-travel is extremely

unlikely. Yet we could get close at a more local scale if we are willing to invest a lot of energy and have the right information.
At smaller scales time applies less and less and at the level of elementary particles, time simply doesn't exist in the way we know it. This is not confusing at all. If our macroscopic word is the sum of a nearly infinite number of states at the lower level and we refer to the changes thereof as "time", than time is something statistical, only applying to a complex system, not its elements.

## Stacking bricks

It's funny that we are dealing with time in a different way than when we are talking about something like a stack of bricks. If we are stacking bricks, we can point at one and ask what's underneath (similar to the past, because those bricks were put in place before the next layer came in). However, it makes no sense to ask what's above the one on top, because ***there is nothing*** above the top (yet). Of course we can put in another layer, but then the question is either the same: "what's above the one at the top of the stack" or changed to "what's above this specific brick (the one which was previously at the top of the stack). I'm not saying that the future can't be known, but only that it's not the way (most of) our brains experience time.

## A memory game

We know about the past only because our memory (brain), society's memory (books, paintings, statues, movies et cetera) and the memory of earth (e.g. rock layers with fossils) keep track of what happened in previous stages. I'm not using the word "before", because that could refer to time as well as an ordinal principle and I'm just referring to the latter. Like in the hourglass with two colours of sand, where we could see how order gradually changed in what we call "chaos", the previous state is somewhere hidden in the current one. I could refer to something very fashionable at the moment, the "blockchain", where previous states are part of the current one, but I prefer to come up with my own example, a rather simple game based on primes.

Before going on with this game, we have to think about a series of numbers: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 and so on and so forth. Such a series will contain prime numbers and those we will use for our game. Starting at 2, the 3, 5, 7, 11, 13, 17 and 19 are examples of primes, because they can only be divided by 1 and themselves to obtain an integer. All other attempts will get fractions. 11/1 = 11 and 11/11 = 1 but 11/2 will be 5.5 and that's not an integer (and the same goes for dividing by 3, 5 and 7). This means we can't decompose primes. When two primes are multiplied we get a number which can be divided by itself, by 1 and also by each of the two primes we used to create it. Let's try with 3 x 5 = 15. There is no other way to break down this number in its components than getting back to 5 and 3 again. Using three primes, we will still be able to derive the components, e.g. 3 x 7 x 11 will be 231 and there is no other way to decompose 231 in the smallest integers than 3, 7 and 11. Of course 21, 33, 77 are also components, but those can be broken down themselves into 3 and 7, 3 and 11 and 7 and 11. So eventually we will end up with 3, 7 and 11!

For non-primes the principle doesn't work, because they are compositions themselves. Take e.g. 6 and 8 to get 6 x 8 = 48. Breaking down 48, we get 2 (leaving 24), another 2 (leaving 12), another 2

(leaving 6) and another 2 (leaving 3 which is a prime). This is not a surprise, because 8 can be decomposed to 2 x 2 x 2 and 6 into 2 x 3.
In short, to get a number where we can only get back to the components we put in, we have to work with primes.

Let's think about our life being a walk along a line with primes. Now the rule is that one can walk along a line with increasing primes and multiply them, but after picking the first prime, the next one has to be a higher number. It is allowed to skip numbers. So 3, 5, 19 is fine and 5, 7, 17 too, but 11, 5, 19 is not, because we didn't move from smaller to larger. It's even allowed to walk along the line without selecting a number. This means no events are taking place and we are going through "life" without any relevant event, until the first one in the series (let's say 9941 which is a prime number). Now the next one can be 9949, 9967, 9973 or 10,007 or a higher one (all these numbers are primes).

Now let's take a simple example and walk the path 3, 7, 17, 23 which will provide us with a memory of 3 x 7 x 17 x 23 = 8211. This number holds the path we took from start to end. We can decompose this number and after getting the components, we will know that we went past 3, 7, 17 and 23 but skipped the numbers in between. If we would have had a stop at 11 as well, the memory would have been 90321. When we would have had a stop at 11 ***instead*** of 17 the memory would have been 5313 – a different total, represents different route!
Principles like this are used in cryptography, but here we are talking about our "memory" holding every previous state. No matter which path we walk along the line with primes, our "memory" will "know" what the previous steps have been. So the current state holds all the steps taken before, but not the steps to be taken.
We can't remember the future in this game, only the "past" (not in "time", but in the sense of previous steps). It is very similar to turning the hourglass, where the position of every grain of sand is determined by its previous position and the positions of the others. This means the current state holds the information of all previous states, just like in our game.

Unfortunately, just like our game, the situation gets more and more complex. Who would be able to see that the number 428206024543 represents the path 11, 17, 23, 9949 and 10007? It can be done with a computer, but when the numbers get really big it will take more and more time until the point where we won't live long enough to get the answer (that's why the principle is used in cryptography – at this moment we don't have the capacity to decompose very large products of prime numbers).

## The "speed" of time

It's a bit funny to talk about the "speed of time", because speed is defined as displacement per unit of time. So indirectly we are comparing time with time and that makes no sense. We don't have a way to determine time in an absolute way – it's all relative. So if somehow time at two different places would not be synchronised, strange effects would be the result. Let's say somebody knows for sure he or she has been aging ten years, but somewhere else several generations came and went. Because we believe time cannot be different in two places, we will come up with biological explanations first. Physical measurements will be done but if in the end we would discover that time was really going at a different "speed" in these two places, we would be confused.

Imagine this box of marbles again. Until now we have been looking at the whole pattern (although we were not able to look in the inner layers). After every shake we could observe the patterns from every side and if somewhere change was observed, the box would be in a “new state”. If we would consider every new state to be a next moment in time (let’s not use words like “second” or “minute” but just “step”), we could count the number of steps going from orderly to chaos, just like in our special hourglass. Of course with only 100 marbles it would not be very impressive, but with thousands of those, we would be able to observe a large number of “steps”.

## Radioactive decay

If we were looking at two different boxes, statistically a thousand steps for one would not be very different for a thousand steps of the other. If this sounds very unlikely, think about the decay of radioactive materials. There is something called “the weak force” doing the shaking for us. Most of us do not really understand what the weak force is, but we know it’s related to radioactive decay. Radioactive decay means that the atoms in the material break up and change into other ones. Doing so they emit particles or packets of radiation we can detect. A Geiger-Müller teller is probably the most well-known device when it comes to radioactivity.

Let’s say we start out with a billion of a billion atoms and about every second (yes, the way how we measure time in our world) on average, one of those billion of billions will decay. This means that on average we will hear or see a pulse, but we can’t predict exactly when. It could be two nearly at once, but also periods of three seconds without an event would be possible. If we would have a piece of this material ten times as large, we would observe ten times as many pulses, but if we only took a piece of 10% of this object, we would only get a pulse every ten seconds (the other 90% being moved to a distance were our detector won’t notice its decays of course).

Does this mean we could use such a lump of radioactive material as a clock? Well, yes. The only thing is that an atom that had a decay already can’t do it again (it depends on the material, but let’s presume only one step of decay is possible). Let’ start out with a lump of a different material with only one thousand atoms but still having one decay per thousand atoms during a second (on average). After a hundred seconds we would only have about 900 left and therefore the interval between two decays would have increased slightly, because fewer atoms are available. If after a couple of minutes only 500 atoms would be left, the time between two decays would be twice as long, because only half of the atoms are around. It’s just like the lottery: if all numbers are sold, all prizes will get out. If only half of the numbers were sold, only half of the prizes will get out.

Our radioactive clock with only 1000 atoms will come to halt when the last atom decays. We started with one atom decaying per second, because we had a thousand atoms, but actually there was a fair chance for every single atom to decay within a 1000 seconds. We only didn’t know which one. Actually we didn’t care, as long as one atom in the whole pack was decaying. However with only half of the atoms left the interval between the decays would have doubled, the interval will be ten times larger when only 100 atoms are left and with only one left, there would be a long time to wait, but eventually we would detect the last decay and then the Geiger-Müller teller would go silent.

The principle is very similar to preparing popcorn. After heating up the popping is quite frequent, but after a while we notice the pops are getting more apart, because less “unpopped” pieces of corn will

be around. Then they will get rare and we will turn off the heat, because there is no use in waiting for those last ten to pop. Those will be lost in the process and discarded.

So the radioactive decay is rather unpredictable at a detailed level (single atom), but with a larger number it's very predictable. The only think is that after its decay an atom won't be available anymore and with a small number of atoms the intervals will increase noticeable. With the billion times a billion atoms however, this effect will be negligible. Even when we wait for ten years the predictability will still be better than for our household clocks.

## Back to our cube with marbles

The cube is not going from one state to another with the help of the "weak force", but by shaking. This doesn't matter for our explanation. With every shake there is a change the pattern of the marbles will change, although it's not guaranteed.

Now let's consider the situation where we are observing the whole pattern from all sides and spotting every possible change at one of the sides. In contrast we could also be looking at the bottom only. Then we would see less change - probably only every two shakes would lead to a visible change at the bottom on average. If one party was looking at the bottom of the first cube and counting "steps" (new patterns coming up) and the other party was looking at all six sides of the other box, the number of steps counted would be very different. One team would observe more steps than the other. If they would use those devices as their clocks, they would not agree on the "speed" of time. Of course their physiology and geology would still be the same and this would only affect their communication. The group looking at all sides of the box would e.g. say that the average life span of a human would be over two Gigasteps (the prefix Giga means a thousand times a million, also referred to as a billion), but the other group, observing only the bottom, would think that it was more like one Gigastep (try and calculate yourself how many seconds a human will live!). Of course they could easily synchronise their devices and declare the step for the "Full Cube Group" (FCG-step) equal to something like e.g. half a step of the "Bottom Cube Group" (BCG) and go on. But what if the Bottom Cube Group did not really understand what the other group meant by "full cube", because they were not able to grasp the meaning of a third dimension?

That's a good moment to switch to the challenge of "dimensions".

# DIMENSIONS

## Flatland

Now it's time to introduce flatland. You may know about it. It was "invented" by a schoolmaster named Abbott https://en.wikipedia.org/wiki/Flatland Although it was primarily a social satire, Flatland was rediscovered as an instrument to think about higher dimensions, when it became relevant. It was Einstein's professor Minkowski who suggested him to work with a fourth dimension, although at the time an additional dimension was considered to be merely a mathematical trick, rather than something existing in real life.

## Our Flatland

The Flatland we are thinking about isn't primitive at all. Of course rules and behaviour are a bit different from ours, because they lack a third dimension. They cannot just walk past each other, but will jump instead. That's why they will always keep 1.5 metres distance, to allow jumpers to land. All those differences are details, as their society is really advanced. They live around a huger circle the call "Earth" and they know it circles around a distant, much bigger circle called "sun". In the past they had scientists like Newton and Keppler, who explained things around movement and gravity and scientists like Heisenberg, Schrödinger, Bohr, Pauli and Dirac, who built quantum mechanics. They also had an Einstein and they are – like us – struggling with the mismatch between quantum mechanics and relativity. Their mathematicians, like ours, are perfectly capable of calculating the "volume" of three, four or ten-dimensional circles. Normal people will only understand the circle and its circumference. In school they learn something is inside the circle, which can be calculated. It's called "volume" and it's formula is $(\text{circumference})^2/(4.\pi)$ – you can try for yourself, it works well. It's a bit confusing, because for us this is just the "surface" of a circle, but the surface is actually a kind of two-dimensional volume, isn't it?

All this information is not really important, it's just to show our flatland people are not stupid at all. During the last decades some scientists even suggested that they do not really live in a two-dimensional world, but that there are other dimensions, some so small that they cannot be perceived. Actually we know that they are three-dimensional indeed, but their third dimension is very, very small (far less than a micrometre)! That's how their biology is much alike ours, allowing them to think. They're only very, very flat.

## Measuring time in flatland

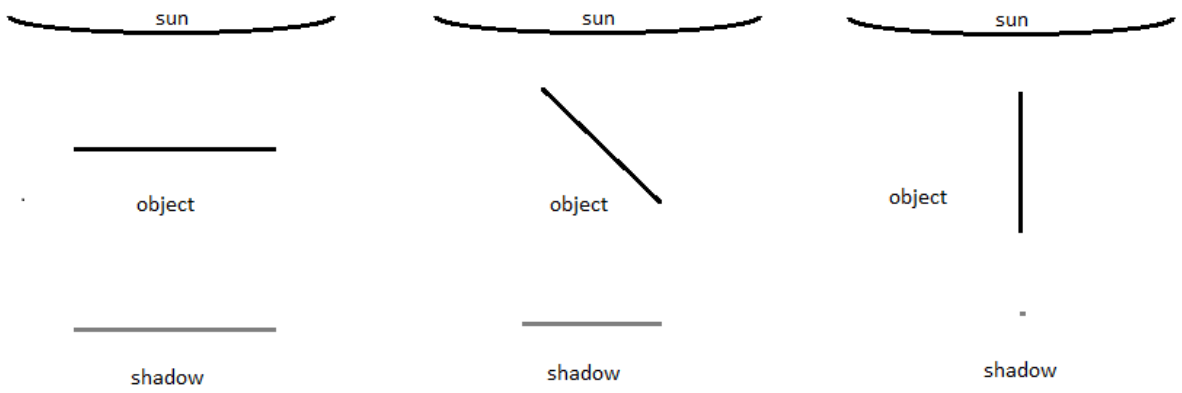
What really matters in our Flatland, is how they keep track of time. In ancient times they would use water dripping from pots, where "time" was related to the water-level in the pot. They would also use candles and determine time by measuring the remaining length of the candle. They invented hour-glasses, but in the end they came up with a device called "clock". Their clock is actually a straight line, with a marker on it moving from one side to another. They also have circular clocks, developed by artists, but the conventional clocks are linear. The marker will move from 0 to 24 hours, which is more or less equal to one round of their planet earth moving around the sun and covering the light and dark period together. They realise that time is actually more than those 24 hours, because things will change on a larger scale. They have seasons and they get older and die and

new people come into the world. They already know about entropy and they are aware that somehow disorder will increase, unless energy is put in to restore order. So in the end they have calendars and from geological investigations they know their earth is old – actually billions of years. However, in the end the accurate measurement of time is done with their clocks. The Flatland scientists are even able to measure picoseconds (a millionth of a millionth of a second)!

Now some scientists argued that time is actually the third dimension! They reasoned that moving in time is actually the same as moving in the third dimension. Some others said that this would mean it would be possible to get back in time. For us this seems a bit ridiculous, because we live in the third dimension and we know it's not time. Yet for us it would be something like a "fourth dimension". Somehow both the people in Flatland and we think about time being a dimension we can't perceive. There is a good reason for this belief. But first we have to move to something called trigonometry and projections. It will be presented as simple as possible, but it may be challenging for some readers.

## Lines and projections

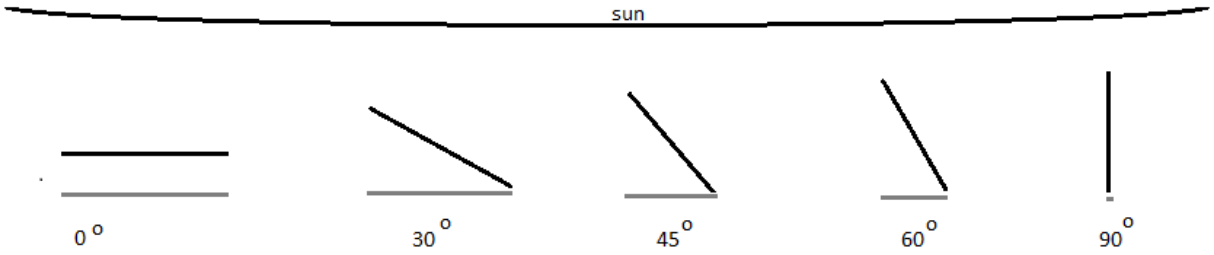
To understand some effects related to dimensions, we will start in a simple way. Think about a line. Not necessarily a "mathematical" line, but something very long and thin. Think about a match, a pencil or a needle. If you actually want to perform the experiment, don't take a very small object, but preferably something at least the size of a pencil or a knitting needle or a very large match.
Now we let the sun throw a shadow of the object at a plane parallel to it (e.g. a table, probably with a piece of white paper on it for better visibility). We will see that the shadow is more or less the same length as the object. However, if the object is tilted, the shadow will become shorter and if the object is perpendicular to the plane (pointing towards the sun or another light source), we will only see the thickness – no length.




In the picture the light source is the sun, because the sun is large and far away. A lamp will also do as long as it is a couple of metres apart. Otherwise the shadow will be much larger than the object.

For those who know the mathematics behind the principle, it's clear that the length of the shadow is related to the cosine of the angle between object and plane. For those who are not familiar with trigonometry or simply forgot, try and measure the length of the shadow when the angle between

object and plane is 0 (parallel), 30, 45, 60 and 90 (perpendicular) degrees. Divide it by the actual length of the object and look at the results. The picture below gives an example of the results.



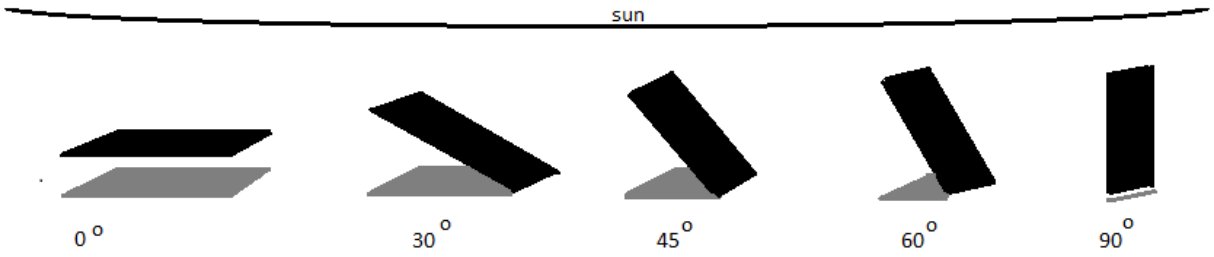

The results will be like this:

$0^o$ (parallel to the plane) – length of the shadow is equal to the length of the object
$30^o$ length of the shadow is nearly equal to 0.9 times the length of the object
$45^o$ length of the shadow is equal to about 0.7 times the length of the object
$60^o$ length of the shadow is equal to half the length of the object
$90^o$ length of the shadow is negligible.

The message is that how larger the angle with the plane is, the shorter the shadow will be (and of course some readers will know that we are talking about the cosine of the angle).

## Planes and projections

Now that we've performed the experiment with a "line", it's time for the next step.
Not lines, but a plane. There things will be pretty much the same, but we can tilt the plane in two directions. One of the options is shown below.




Of course the plane can also be tilted in the other direction and even in two directions at the same time.

## Relativity

No, not Einstein, not yet! There is so much information around about Einstein's relativity theories that we would forget about much earlier ideas about the subject, like Galileo's.
Let's start with two balloon's hovering close together above a huge field. The field is covered with grass and it looks the same everywhere. We turn around walk a bit and go back. Now we can see the balloons are five metres apart. Which one has moved? We can't tell, because the field underneath doesn't give us a clue and we don't remember how we moved ourselves. We know that we moved

ourselves, because we walked over the field. At least that's how we perceive the world. We could also think that we were hovering in the air without changing position, pushing the earth – together with the balloons back, but usually we don't do that.
However, for the balloons it's less simple to decide. They are apart, so we suppose that at least one has moved, probably both, but we just can't tell which one in which direction.
To be "sure" we need a frame of reference. Some spot we use as an anchor in space. Let's suppose before walking we planted a stick in the ground, underneath the balloons. Now we have this "frame of reference", because we presume a stick in the earth doesn't move – at least not really fast.
We walk, turn back and see either one balloon still hovering above the stick and the other one five metres away. Then our conclusion will be that the latter one has moved.
We could also see that both balloons are over two metres away from the stick and then we will think both have moved.
If we would have e.g. a red and a yellow balloon and we decide that the yellow one is the frame of reference, things would be different. Then we would always come to the conclusion that the red one had moved. Just because of our choices.

One could argue that the speed could be measured, or the amount of energy or the impulse, but that's not true. It all depends on the choice of our reference framework and movement is relative. So either the object moves or the frame of reference does, but the result is the same.
In daily life, earth is our frame of reference. We don't say that we drove to our work at a very high speed, because our office or workshop was also moving at high speed, but only a little bit slower (using e.g. the sun or the centre of our Milky Way as a point of reference). No, for us earth is the reference. We prefer to use something big as the frame of reference for something small. When we are talking about earth and sun, we use a different framework. We say that earth is moving around the sun, simply because then the math is much simpler than the other way round, but it's still a choice!
Now let's see how the choice of an unusual frame of reference can lead to paradoxical situations.
Somebody is leaving a house through the front door and is convinced that he is the centre of the universe and therefore he is rolling the earth beneath his feet, much like how an acrobat in a circus is walking on top of a huge ball. At the same time, somebody else is leaving the same house through the back door and she is also convinced that she is moving earth under her feet, whilst staying at the same place in space herself.
From the perspective of each of them, this makes sense, but both realities won't fit together. One person will think earth moves clockwise and the other is convinced that the movement is counter clockwise. Depending on who has the largest ego they might either decide that one of them is right, but we will most likely believe that both are moving relatively to the surface of the earth, taking the house as a frame of reference.
Newton's first law https://en.wikipedia.org/wiki/Newton's_laws_of_motion
states that: "A body remains at rest, ***or in motion at a constant speed in a straight line***, unless acted upon by a force.
Here we already see the relativity of motion: rest or constant speed is completely the same. It just depends on the reference we choose!

## Forces

The second part of the law “unless acted upon by a force” doesn’t change anything if we combine this with the third law: “If two bodies exert forces on each other, these forces have the same magnitude but opposite directions.”
If my feet are exerting a force on earth, earth is pushing back just as hard. So which one is moving, we or the earth? We can’t tell. The only thing we know is that it takes a lot more energy to move earth that to move a person, so we usually assume we are the ones moving. If we think about earth and our moon it’s less unequal. Indeed the moon is influencing earth – especially when it comes to the sea.

## Speed and acceleration

But what about speed? If something moves, we assume a force has been applied to it. Indeed, but how can we know whether it was our frame of reference or the object, which underwent a force? Now the only thing we could know for sure is “acceleration” (change of speed – including getting into motion). A force applied can be measured and we will be able to calculate the acceleration of the objects connected to the force. The acceleration will be proportional to the mass of the object. This is because Force (F) is equal to mass times acceleration). From the formula F = m.a, (Force equals mass times acceleration) we know that the ratio of the speeds will be proportional to the mass. Something like earth, weighing about 60 times 10^23 (10^23 is a 1 with 23 zeroes after it – that’s a hundred thousand times a billion times a billion).
So the force making a woman of 60 kg running 36 km per hour (36000 metre per 3600 seconds is 10 metres per second – very fast!) will give earth a speed of only 10 / 10^23 (= 0.00000000000000000001 metres per second. If we think about a human hair still being much more than a millionth of a metre (about 0.00001), much less than a billionth of a billionth is close to “nothing”!
Despite this intermezzo about speed and acceleration, we won’t use those words for a simple reason. Both have “time” in their formula and because time is a confusing term, currently pointing to two completely different phenomena, we should avoid it for now. For those who wonder where the time is: for (constant) speed it is the distance divided by time. Let’s say we walked 100 metres in 100 seconds, then the speed was 1 metre per second. Usually we will say 3600 metres per 3600 seconds or 3.6 km/h. But to get this speed, we have to get in motion first and this means we will get to this speed from 0 metres per second to 1 m/s in let’s day 2 seconds. That makes an acceleration of 1 m/s within 2 seconds or a change to 0.5 m/s in the first second, and then another 0.5 m/s in the second after (“second second” is a bit confusing, isn’t it?). The change in speed is 0.5 m/s per second or 0.5 m/(s .s). Both “seconds” are in the denominator and will be multiplied, so we can also write 0.5 $m/s^2$.
Nothing wrong with speed and acceleration, but when talking about time we should avoid it. Movement is less confusing than speed, because it only tells us that something was in one place at first and then was at another place. Force is also safe and if we leave out “speed” and “acceleration” for now. We can still say that applying a force leads to movement. That’s exactly what Newton told us!

## Projections (Lorentz/Fitzgerald contraction)

Now we are getting to something very strange. I won't explain the history of this discovery (it was more of a theory being confirmed afterwards), because a lot of information is available on Wikipedia and Youtube. Two physicists, Lorentz and FitzGerald came up (independently) with the idea that objects moving very, very fast will shrink. We are not talking about the speeds in the Formula 1 races and even not about the speed of our current space crafts, but about speeds close to the speed of light. In our daily life (even when talking about rockets launching satellites), the difference between moving and standing still is so small that nobody will notice. The speed of light is around 300,000,000 metres per second. If a light particle (a photon) would move around the world (40,000 kilometres or 40,000,000 metres at the equator) it would only take 40/300 = 0.13 seconds (130 milliseconds)! Even at 10% of the speed of light the shrinking effect would not be very impressive, but at half the speed of light we would certainly notice that a spaceship would be shorter. The principle is called the Lorentz or Lorentz/FitzGerald contraction.

The formula looks complex, but is actually quite easy to work with.

$$L_{obs} = L_{rest}\sqrt{1 - v^2/c^2}$$

The observed length ($L_{obs}$), is equal to the original length ($L_{rest}$), multiplied by a "shrinking factor" (the thing with the root-sign). This shrinking factor depends on the ratio of the square of the speed (v) and the square of the speed of light (always referred to as "c"). Let's presume there is no movement, so v = 0. Then $v^2/c^2$ will be 0 and even when divided by a large number ($c^2$) the result will still be 0. Zero, because one minus zero is 1 and the square root of 1 is still 1 (also -1 but we will ignore that option). Nothing will change and that's what we expect, because there is no movement at all.

On the other hand, if our space craft is moving with the speed of light (with v being equal to c), we could write c instead of v and then it's $c^2/c^2$ Of course that's one! 1 minus 1 is 0 and the square root of 0 is also 0, so the observed length would be 0 times the real length or just 0. No length left!

Now we know that all other values have to be in between. Let's try half the speed of light:

$(½* c)^2 / c^2$

is a bit trickier, but it's ¼ and 1 - ¼ will be 0.75. Now the length is not 75%, because we have to take the square root of 0.75 which is about 0.87. So the length we observe is only 87% of the length at rest. We will be able to notice such a difference!

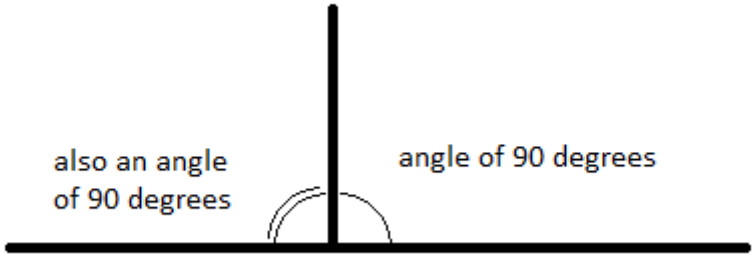
At 10% of the speed of light (0.1 x c) however, it will be $(0.1 * c)^2 / c^2$
which is 0.01 and $(1 - v^2/c^2)$ will be 0.99. After taking the square root this will be about 0.995. This means the observed length is only 0.5 per cent less and I don't think a lot of people would notice. With our advances instruments we would be able to detect it, but not with the naked eye.

The exact formula is not too relevant, but it is clear that the shrinkage goes from 0% to 100% (meaning nobody will be able to see the space ship anymore).

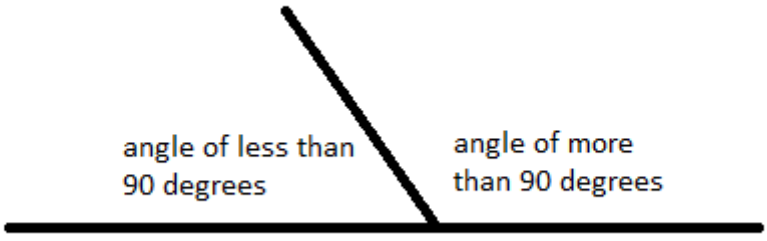
Instead of thinking about actually shrinking, we could also think of the object being at an angle. Just like our people in Flatland looked at a surface at an angle in the third dimension they didn't understand, we could look at an object at an angle in the fourth dimension. The object would seem shorter, but in reality it would just be tilted in the fourth dimension. The dimension we understand just as well as our Flatlanders understand the 3rd dimension!

This means we should not think about shrinkage, but about the object being rotated. A rotation of 90 degrees would mean the object being invisible, because it's perpendicular to the three dimensions we understand.
Yes, that's a strange one. Most of us can't imagine what it means to have something perpendicular to our three dimensions (although some people seem to be able to visualise it). With mathematics it's quite simple to do the calculations, but we won't go there. Instead we will use something between our flatland and us, using a trick.

We call the largest possible angle 90 degrees (perpendicular).



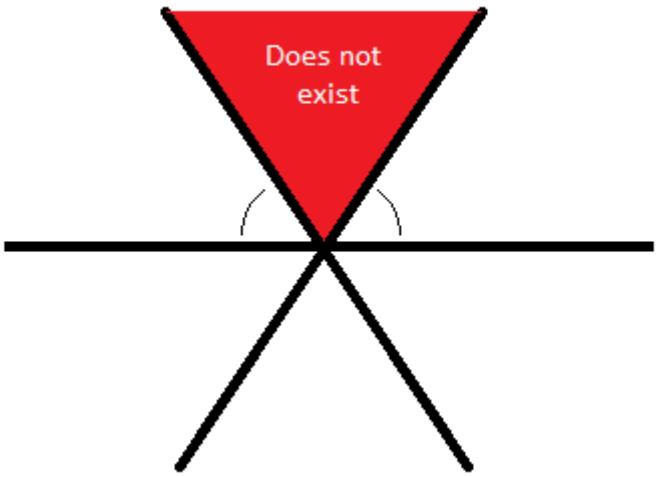

Of course we have larger angles, like 120 degrees, but then we are actually "stealing" from the other angle.



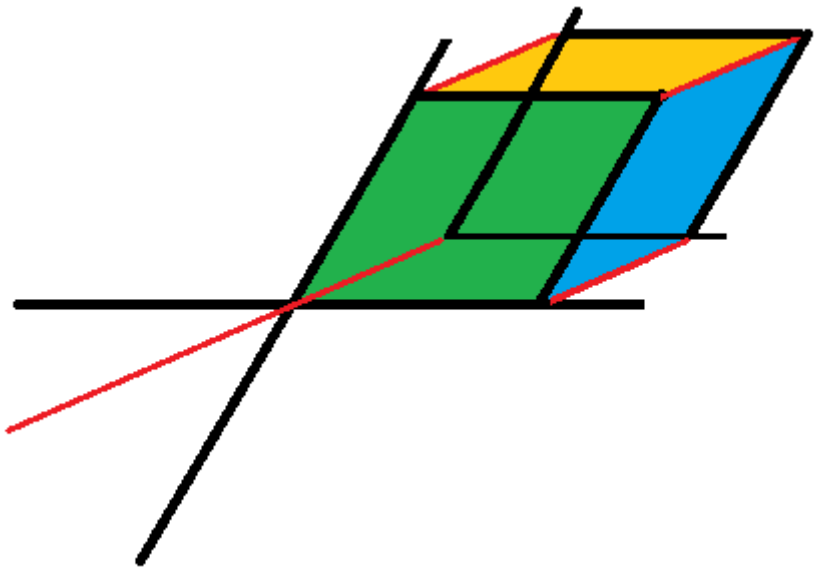

We defined the angle of a straight line as 180 degrees and we can only split it in two halves of 90. If one angle takes more, the other will get less, because angle 1 and angle 2 will always add up to 180 degrees.

Now Imagine a strange world (not our Flatland, but a world with three dimensions) where an angle can go up to 60 degrees at most they don't understand the part between 60 and 90 degrees, because

larger than 60 degrees means that the other angle will be less than 60 degrees. A straight line will be 120 degrees. The will have negative numbers and three dimensions and all, but a part of our reality will be non-existent to them.




When this is done in three dimensions, they will not live in a cubic world, like we do, but in “rhombic hexahedron” (a cube stretched by taking one corner and the opposite one and then distort the body)

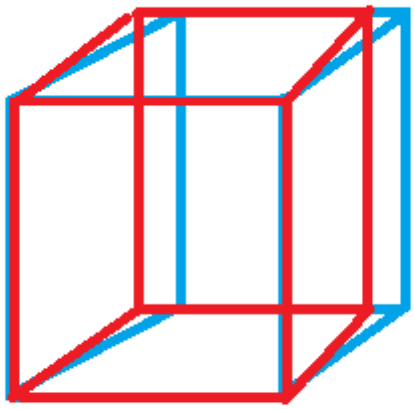


When this is done in every direction, they are just missing a part of the world as we know it. Many people object that they could make another angle with their axes, but that’s the point: they just don’t know what that means!

Now this may seem absurd, but we have no way of knowing that the same is not happening to us. A fourth dimension is an incomprehensible for us as is the angle beyond 60 degrees for the people in the rhombic world above. So don’t laugh at them unless you are able to understand what “perpendicular to hour three dimensions” actually means (without using mathematics)!

## Tilting cubes

It's probably still hard to imagine, but think about a situation where you can only walk along the edges of a cube. If another, slightly skewed cube is present, than you are able to see it, but you won't be able to follow those edges, because you just can't. You are bound to the edges of "your cube". The front faces share edges, so there you are able to walk the red cube, but as soon as you go to the back, only the blue lines will be accessible. No matter how hard you try, you will still end up at the blue ones.

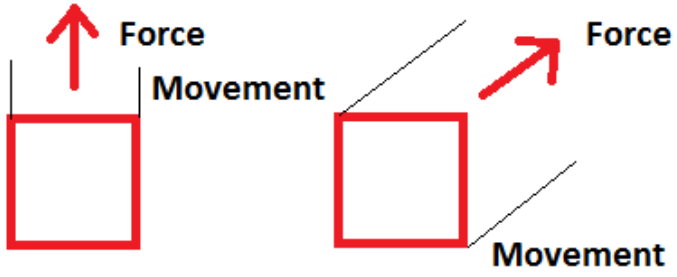


**Skewed cube**

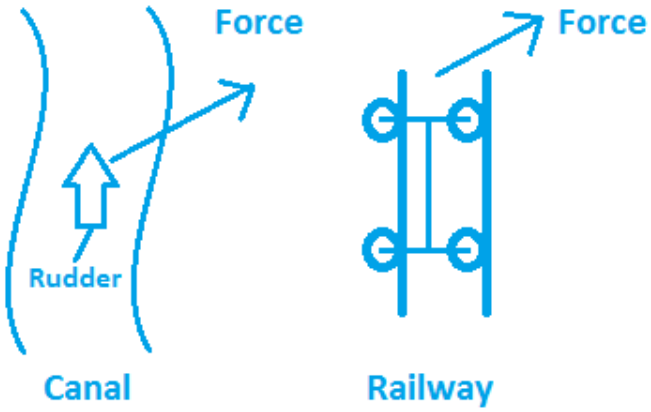
## Force at an angle

The shrinking of the length of objects is not the only strange effect observed at high speeds. The mass also seems to go up. The more an object is sped up, the more energy we have to apply to increase its speed even more. The formula is very similar to the shrinkage of length.

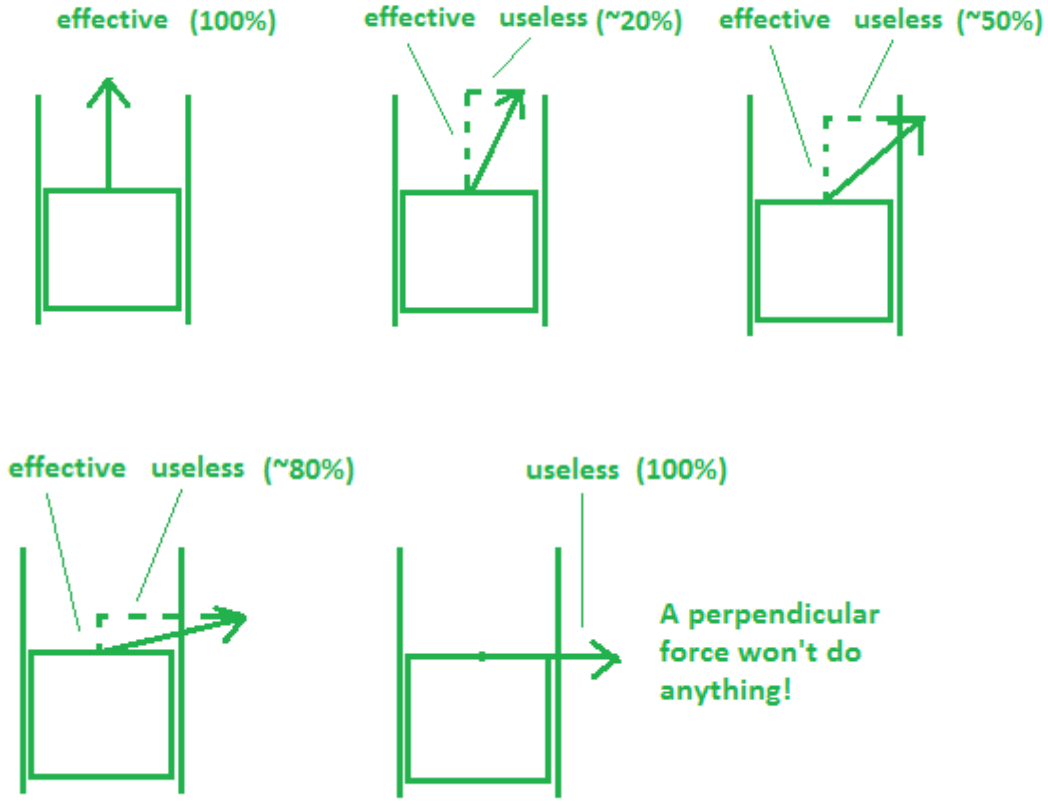
But let's take a step back. When we apply a force at something, it will move in the direction of the force.




But what if the object is not completely free to move? If it simply can't follow the direction of the force, but has to follow a path because the rudder of the boat tells it to do so, or because it's a carriage bound to the railway?




In such a situation only a part of the force will be effective. That's the part pointing in the right direction. Below we show a set of different angles and derive the part of the force that is effective (the other part will just cause friction and eventually create heat).




Imagine a strong person pulling a railway trolley. Walking in front of the trolley will be fully effective, but pulling from aside is completely useless. Nothing will happen. The angles in between are partly effective – nearly completely to only a very small part.

Now imagine that we have an object that is moving in a 4-dimensional space, at an angle with our 3-dimensional universe. And we, limited as we are, don't know how to apply this force at the right 4-dimensional angle, because we are stuck with our three dimensions. The more the object rotates into the fourth dimension, the larger the angle. However, we don't see this angle and are just surprised

that our force doesn't do what we expect! Our conclusion will be that the object is becoming heavier, so we are not able to move it. We increase the force but at a certain point the object will seem to have an infinite mass. In reality it is at 90 degrees with the force, still aligned with our 3d universe, but we can't see how.

Now it's time to have a look at the formula for the mass of an object at different accelerations.

$$m_{obs} = \frac{m_{rest}}{\sqrt{1 - v^2/c^2}}$$

The formula is very similar to the one for length, except there things seemed to get shorter, but here things are getting heavier – hence the different position of what we previously called the "shrinking factor". Now it's a kind of "growth factor" but still looks the same. Now the observed mass is equal to the rest mass (without any acceleration) ***divided*** by the same square root presented for length.

## Time dilatation

A third effect from applying a force (causing acceleration) is that time will slow down when an object is accelerated at high speed. Again a very familiar formula tells us how time will shrink. It's very much like the one for the Lorentz Fitzgerald contraction and the experienced mass.

$$\Delta t_{obs} = \frac{\Delta t_{rest}}{\sqrt{1 - v^2/c^2}}$$

Here we have to explain the symbol delta (the small triangle). It means that we are not talking about a moment in time, but a period (the difference between a later moment and an earlier moment in time). Apart from this the formula is very similar to the one for mass, but instead of seeming "heavier" the period seems "longer".

## A different perspective!

Shortening of objects, increase in mass and time dilatation seem to be different phenomena, but their formulas are too similar to think it's a coincidence. As a matter of fact all three can be explained by a rotation of our three-dimensional world in a four-dimensional space without us being able to understand what's going on!

## Our flatland

Remember ***our*** flatland. Although they didn't understand the third dimension, because it was too small to be observed and they just could not understand what "perpendicular to the plane of their world" would mean. Yet they perceived objects moving in the third dimension as a kind of projection. If a plane was at an angle, they would see it, but smaller than it the real plane. It would seem to be smaller and with the angle increasing eventually it would become so small that is would disappear.

If they would be able to apply a force to this plane, moving in another direction than their world, they would not be able to apply this force in the right direction and the conclusion would be that the object became heavier when the angle with the plane of their world became larger.
Even time – which they measured by observing in the plane of their world – would seem to go slower, because they missed the changes in the direction perpendicular to their world.

We would experience the same issues when dealing with a body tilting in the fourth dimension. It would seem to shrink, be heavier and time would be slower from our perspective.
Both in Flatland (dealing with an – impossible - third dimension) and in our world (dealing with an – impossible - fourth dimension) those strange effects would be caused by "acceleration". Before we think about that, let's consider time again.

Now be aware that it doesn't matter whether the 3D object was tilted or our Flatland was tilted as a whole. What matters is that the object and our Flatland were at an angle in the 3D space as a result of a force applied to one of them or even both.

## Time dilatation again (entropy at an angle)

Let's get back to our game with primes. This time we will only use the small ones.
Previously we talked about "missing" certain stops along the route, but what if we didn't miss them, but somehow can't recognise them, because they were in a "different dimension"?

We start with a simple situation: and object moves along a series of primes and its history is the product of all the primes it encountered. Here, in this example with six primes we see 30030.

| ----> our direction | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2 | 3 | 5 | 7 | 11 | 13 | **30.030** |

Now imagine that accelerating the object leads to a turning into an additional dimension. One we can't observe. Some of the primes are encountered, but not in our dimension, but an unknown one, perpendicular to ours. The missed primes are replaces by 1, because this won't change the product.

We think the object missed the 2 and when we calculate the product of all primes encountered, the number is lower. However, the 2 was encountered in this other dimension and in that direction not a lot has happened – only 2 was encountered. If we combine both products, we still see 30030.

| ----> our direction | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 3 | 5 | 7 | 11 | 13 | 15.015 | \| | |
| 2 | | | | | | | | \| | additional direction of accelerated object |
| 2 | | | | | | | **30030** | \/ | |

Now we accelerate the object even more and it turns even more into the direction of this dimension we can't observe. Now the product in our dimension is really slow. Hardly anything seems to be happening, but in the other dimension a lot is going on! If we combine the products again, we still get 30030!

| ----> our direction | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2 | 1 | 5 | 1 | 11 | 1 | 110 | \| | |
| 3 | | | | | | | | \| | additional direction of accelerated object |
| 7 | | | | | | | | V | |
| 13 | | | | | | | | | |
| 273 | | | | | | | **30030** | | |

Now finally the object is so much accelerated that it is moving with almost the speed of light. All the encounters with primes are in this other dimension. In our dimension the time of the object seems to be frozen!

| ----> our direction | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 1 | 1 | 1 | 1 | 1 | 1 | \| | |
| 2 | | | | | | | | \| | additional direction of accelerated object |
| 3 | | | | | | | | V | |
| 5 | | | | | | | | | |
| 7 | | | | | | | | | |
| 11 | | | | | | | | | |
| 13 | | | | | | | | | |
| 30.030 | | | | | | | **30030** | | |

The product of both dimensions is still 30030, but that's completely related to this other dimension.

Now imagine that the object in this story is a human being. Although this human only understands three dimensions, he or she is not aware of the rotation of the accelerated world in this fourth dimension, because this dimension can't be observed by human beings – even if we are in this four-dimensional space! The human experiences a completely normal journey from prime to prime, without missing a single one. On earth however, looking with a strong telescope, the scientists are convinced that only some primes are encountered or hardly any (at extremely high speed).

Now "encountering primes" is actually a kind of metaphor for "entropy" and entropy in comparison represents our time. So in the end an accelerated human can experience time completely different from an observer, watching from a fixed point.

The outcome is completely the same as in Einstein's equations, but time travel is impossible, because our time is related to the comparison of entropy and therefore will only go in one direction, building up history without being able to reverse it because of the law of statistics. For a very simple particle like an electron however, time doesn't exist. We just can't apply the principle of time to it, because there is no entropy, hence no objective clock.

Decaying particles are an exception, because just like in our radio-active material, the weak force lets them disintegrate and that's very similar to entropy. On a larger scale we can apply statistics and this makes it possible to say something about their lifespan.

## Conclusion (hypothesis)

**Time, size** and **movement** are not limited to three dimensions – or so it seems, because they share the same formula related to (high) speed. The angle we make in the fourth dimension determines our observations of length, mass and time. **So the fourth dimension is real, but it's certainly not time.**

To be honest I didn't change anything about physics in this whole story, except that I refuse to apply the word "time" to two completely different phenomena. In my career in business I learnt that it's not wise to use the same term for different concepts and I think we shouldn't do it in physics either. This means "time" is related to entropy and all the weird effects from Einstein's relativity are connected to a fourth dimension which we should not call "time" and not even refer to as "t".

## Proposal

My proposal is that we stop talking about a dimension time or t. Let's call the fourth dimension **w** – because we "**w**ave in and out of it" when a force is applied. **w** is perpendicular to x, to y and to z, just like z is perpendicular to both x and y.

So again: let's call out fourth dimension **w** and consider it a dimension like the three we know. As a matter of fact this was what Minkowski expected to happen in the future: the fourth dimension becoming a dimension like out other three.

## Speculation about the future

Living and moving in different directions in a 4-dimensional universe is weird and leads to strange situations. Personally I think that we just aren't used to those situations, but when the speed of travel will go up, it will become business as usual and even children in elementary school will realise that they are tilting in the fourth dimension.

# NEXT STEPS

Now we reconciled three different phenomena and connected them to a rotation of our three dimensions in a four-dimensional space, the question is how this rotation is initiated. Somehow it's related to movement, because the effects increase with speed.

## Acceleration (not speed)

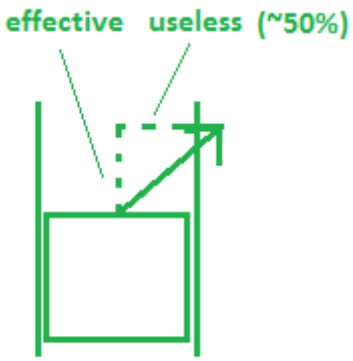
Speed is a tricky concept, because it is displacement in time, but time is just a series of events (shaking of a box of marbles, radioactive decay, picking prime numbers). Yet we can see that one object moves over a longer distance than another one during a number of "shakes", decays" or "primes selected". When we agree on our relative measure of "time", we can compare the distances and conclude that one object moved over a larger distance than another one and therefore has a higher "speed".

But didn't tell Newton that an object won't change its speed or direction without a force being applied? If something is moving, a force must have been applied at some moment. If the distance an object travels per unit of time (again: "shakes", "decays", selected primes or whatever relative measure we prefer to keep track of time) is not always the same when we check multiple times, we call that acceleration. Acceleration can be speeding up or slowing down, but let's take the former.
Let's say that somebody is counting ticks from radioactive decays. We know that's an irregular pattern, so we count a thousand ticks (much more reliable – let's call it a kilo-tick, like a kilogram is one thousand grams) and look at the position of the object.
At the first kilo-tick we put a dot and call this position zero. At the next tick we see that the object is one metre away. We would expect it to be two metres away when the next kilo-tick is heard, but it turns out to be three in total. Then it's seven and so on. The distance travelled between two kilo-ticks, is certainly increasing! If the pattern would go on like this, we would observe a displacement of about half a kilometre between two kiloticks.

| kiloticks | metres from start |
|---|---|
| 1 | 1 |
| 2 | 3 |
| 3 | 7 |
| 4 | 15 |
| 5 | 31 |
| 6 | 63 |
| 7 | 127 |
| 8 | 255 |
| 9 | 511 |
| 10 | 1023 |

Now let's say that light moves at a speed of threehundred million metres per kilo-tick. That's very fast, but if our object would go like this, it would reach 89% of the speed of light after only 29 seconds.
But wait! Our object can only travel larger distances between "those two kilo-ticks" when a force is applied. Without a force the displacement would be the same on average between every kilo-tick.

However, in an earlier chapter we supposed that higher “speed” leads to a rotation in four-dimensional space and if this happens, we can’t apply the force at the most effective angle. We only understand our own three dimensions and are pulling a little bit oblique, so the effective force decreases. Remember the picture:




Yet the speed increases still a bit and the objects is rotated more in the fourth-dimensional space, applying our force even more oblique, because we are bound to our own three dimensions.
The more the speed increases, the less effective the force will be, so after a number of kilo-ticks when the speed is around 90% of the speed of light, the angle will be (I leave out the math) 26 degrees, so a part of the force is useless. When this goes on, the force will be even more useless until the same speed is reached as light. Then the force will be perpendicular to the direction of movement (we don’t think so, because we don’t observe this fourth dimension) and won’t do anything at all.

Light has a constant speed and is not sensitive to this rotation. This can only mean that light is truly four-dimensional. It doesn’t matter in which direction we observe light, the speed is always the same – even if we move at high speed ourselves and rotate away from the other observers (or they do from us).

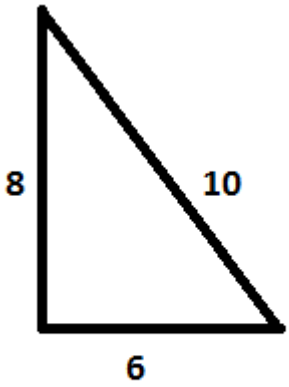
## Adding speeds

Adding the speed of two objects moving toward each other is simple. We do it all the time. If a lorry drives 50 km/h and another one drives the same speed but is going in the opposite direction, they will collide with a speed of 100 km/h, because the speeds can simply be summed. However, if the speed is much higher and therefore the lorries are already tilted in our new w dimension, they will hit each other at an angle (and angle we can’t observe). It’s pretty much the same as hitting each other at an angle in our well-known three dimensions. When they hit at an angle, the speeds can’t be simply summed. For that we need an intermezzo.

## Pythagorean Theorem

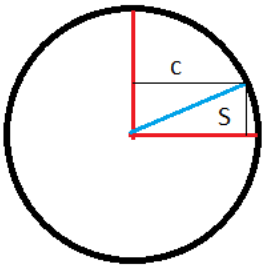
In the Pythagorean Theorem, we can calculate the size of a triangle (with a corner of 90 degrees) by summing the squared lengths of the sides to obtain the squared length of the oblique side (called hypotenuse).

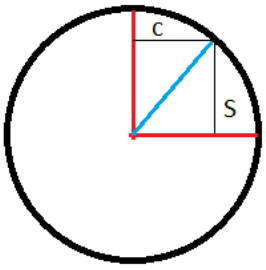
$3^2+4^2=5^2$

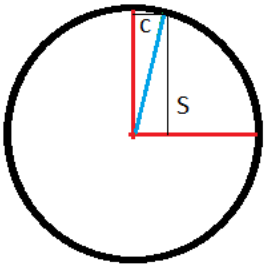



$6^2+8^2=10^2$

The numbers in the pictures are chosen nicely, but actually it works for all kinds of weird numbers. We can draw a circle and take both the horizontal and vertical "shadow" shadow of a radius at any angle to create a trangle.



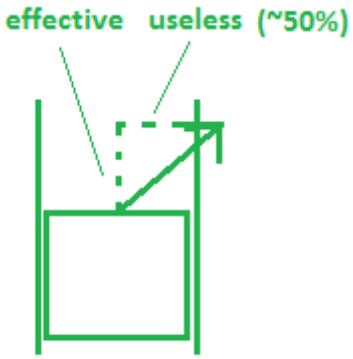




The blue line (hypotenuse) is always the radius of the circle (as are the red ones), but the black lines mark the horizontal and vertical "shadows" of the blue ones at the red ones (and are the same size as those shadows). We call then c and s. When those two "shadows" are squared, we get the squared length of the radius (the hypotenuse) again. So $c^2+s^2=\text{radius}^2$

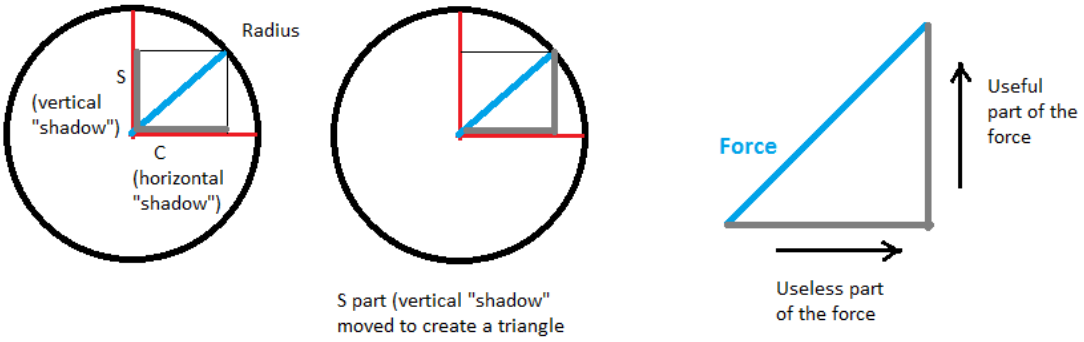
## Adding speeds at an angle

The circles show us how all kinds of different lengths of the "shadows" can be squared and summed to get the squared value of the radius. When adding speeds at an angle it's pretty much the same. Let's go back to the "force at an angle". In one of the examples we chose our angle in such a way that

half of the force was useful (in the direction the object was allowed to move) and have of the force was useless, because that part was perpendicular to the direction the object was allowed to move.




We could draw a triangle, where the force is the hypotenuse and the useful and useful parts of the force are the sides. As a matter of fact they are the horizontal and vertical “shadow” of the force. Below this is done as a part of the circle again first, with “shadows” and then more. Then one of the shadows is moved to create a triangle and finally we are more or less back with the original picture (but with the object left out).




Something similar is happening when adding speeds at an angle. If the speeds are not in the same direction, we can’t simply add them, but have to consider the part pointing in the same direction. The sum will be lower. For our new dimension w it’s the same. If the objects move at high speeds they will seem shorter and heavier and their time seems to slow down, but as a matter of fact they are approaching each other at an angle in our new dimension w. That’s why they see each other shorter and think the other’s clock is slowed down, but it’s the angle! We can only sum the “useful” parts of the speed and those are the parts moving in the same direction in dimensions x, y, z but also w.

Now let’s consider two objects moving towards each other at high speeds, from our neutral point of view as an observer. For us the objects are tilted into the fourth dimension, but because their speeds are in opposite directions, their angles will also be the opposite. For low speeds (remember, the speeds we observe at the Formula 1 or even for modern aeroplanes are “low speeds”), but when the

speed gets higher this matters. Let's take two objects moving towards each other at half the speed of light. We can't simply sum their speeds, because they seem to approach each other at a straight line, but looking in four dimensions they are tilted. Using the formula square root of $(1 - v^2/c^2)$ again, we get $\text{sqrt}(1-0.25c^2/c^2) = \text{sqrt}(0.75) = 0.866$ and this corresponds with an angle of $30^o$ but for the other one it's $-30^o$ because the speed is the opposite. They approach each other at an angle in the fourth dimension and this means their actual combined speed in our world are less (only 87% of the speed of light instead of the speed of light (obtained by simply summing the values: 0.5 c + 0.5 c).
The interesting effect is when the speeds get even higher. The angles in the fourth dimension will increase and the effective speed in our world (no angle in the fourth dimension) will actually decrease! At 80% of the speed of light the angles will be $53^o$ and $-53^o$ and the summed speeds in our world would only be 96% of the speed of light instead of 160% (80%+80%).
When both objects get very close to the speed of light, the both become (nearly) invisible for us and their effective speeds would be the opposite in the fourth dimension, but in our world nothing would be left of the effect, because of those angles. We would still see to objects, flying towards each other with (nearly) the speed of light each, but the effect would be negligible. The funny part is that when hitting each other, their speeds will slow down because of the collision and their effective speeds in our world will go up and down again – of course releasing an enormous amount of energy!

## Light as a multidimensional phenomenon

What about light. Why can't we just sum the speed of a light ray and a spaceship (or the speed of two spaceships for that matter)? Well, light seems to be a completely four-dimensional phenomenon. Its speed is always the same – even if we tilt into this fourth dimension **w**. This is only possible for something existing in four dimensions. It doesn't matter in which direction (even in the direction of w – perpendicular to x, y and z) we look. It also doesn't matter how fast we travel, because light will always travel at the speed of light at any four-dimensional angle.

## (Some) Literature on the subject

This booklet is meant for people who are interested in physics without necessarily having a solid mathematical background or physics education beyond secondary school. A lot of people learnt about trigonometry, but are not very familiar with the calculations and formulas (any more). This means that I also won't refer to heavy literature, but only to the more popular books, Wikipedia and YouTube.

**Books**

A Brief History of Time, Stephen Hawking https://www.amazon.com/Brief-History-Time-Stephen-Hawking/dp/0553380168 (and https://en.wikipedia.org/wiki/A_Brief_History_of_Time)

The order of time, Carlo Rovelli https://www.amazon.com/Order-Time-Carlo-Rovelli/dp/073521610X (and https://en.wikipedia.org/wiki/The_Order_of_Time_(book) )

**Wikipedia links**

https://en.wikipedia.org/wiki/Time_dilation
https://en.wikipedia.org/wiki/Length_contraction
https://en.wikipedia.org/wiki/Mass_in_special_relativity

**Videos**

https://youtu.be/uQSoaiubuA0?si=6zpk8TuHgkzj8-Eo (Brian Cox)
https://youtu.be/DSx96eRwuuA?si=nlD7yJSuf7eq_VAE (Alexander Unzicker)
https://youtu.be/Hu8z03b_5FQ?si=rATWHJKD83MpapdB (Alexander Unzicker)
https://youtu.be/TDjgQ_megMI?si=9Z2SaA1ewTH2yM2u (Alexander Unzicker)
https://www.wired.com/video/watch/theoretical-physicist-explains-time-in-5-levels-of-difficulty (Brian Greene)
*From these links you will get several suggestions for other videos on the subject.*