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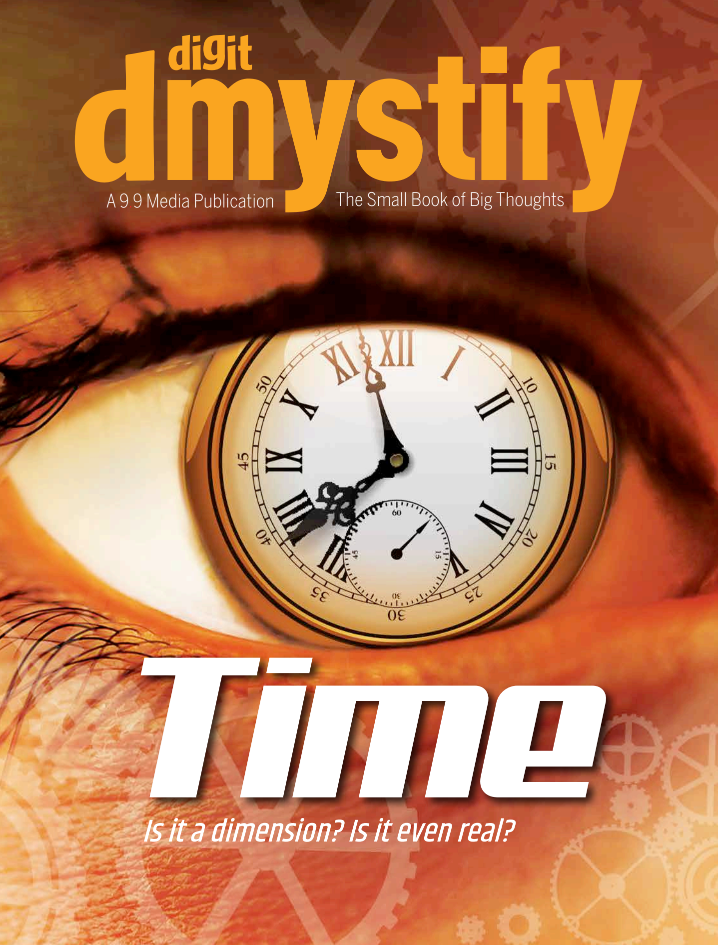

Time

Is it a dimension? Is it even real?

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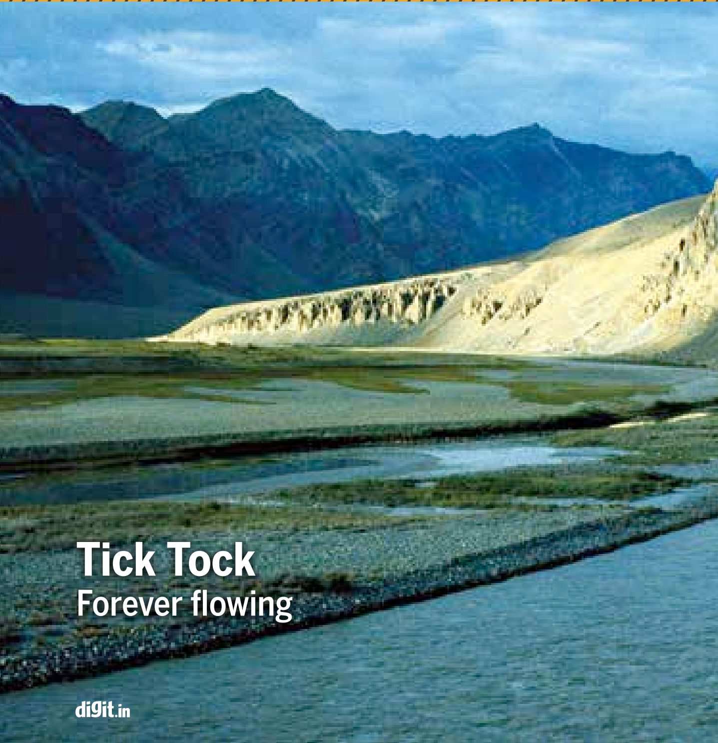
January 2017



Tick Tock

Forever flowing

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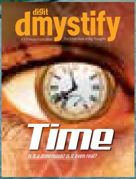

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Published by 9.9 Mediaworx

January 2017
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There's just never enough

Thus far, this book has been dedicated to explaining science that we're mostly sure about. Apart from String Theory and Dark Matter and Dark Energy, we've stuck to topics that are pretty much just scientific fact. Now with string theory and the dark stuff, we all know straight away that these are theories that are yet to be proven in anyway. We know that this is theoretical physics, at the cutting edge of human understanding, and we know it could quite possibly be all total hogwash, because the universe might actually work totally differently. These topics aren't obvious demonstrable facts like evolution, or gravity, for example.

Time, however, throws the proverbial spanner into the way the universe works. We all think we know what it is, we are all sure it exists, and that we just never seem to have enough of it – especially when deadlines loom, or when running late for anything, or indeed, when we're dying, we always wish we just had a little more... time. But what if it's all just something made up, something only we humans think about, and isn't another dimension at all, or isn't even something real? This book will look to dmystify Time, perhaps in a way you have not experienced it before, and get you to question your long accepted beliefs about reality, perhaps question your own sanity, and definitely question the sanity of this writer... ■

Is it real?

Let's see if we can really understand what time is

Read this sentence. Now read this one. Remember the first sentence you read? Then the second? What really is "first" and "second"? You are currently reading this sentence, right? Not anymore, now you are reading this one...

You read all of the above in the past. You might even read it again in the future, because it's a little confusing, perhaps. However, right now, you're reading this sentence. We live in the now, with the past that has gone before and the future that's yet to come. However, there is no "now", really, because the minute you measure a point called "now", it's already in the past...

This view of time has led some very smart people throughout the ages to believe that time is like a fast-flowing river. There is no here and now, because it's always moving, and you along with it. The classical view was that time was just a property of the universe, and there was no changing it, or slowing or speeding it up. Time, no matter where in the Universe you were, would run the same for every observer.

Einstein came along, however, and showed us that time was just a matter of perspective, and what might be simultaneous events in time for one observer, might be two distinct events separated by a significant amount of time to another observer.

When stars go boom!

Take for example something as simple as two stars going supernova (exploding) at exactly the same time – assume there is a grand clock somewhere that counts down time elapsed since the big bang, and these two events happened exactly at the same "time" by that clock after the big bang. One star is a billion light years away from us in one direction, and the other is in the exact opposite direction, exactly a billion light years away as well. A billion years from now, we will see both of them going nova at exactly the same time, right? Wrong!

We tend to forget that the Earth moves around the sun, the sun moves around the galactic centre of the Milky Way, and the Milky Way itself moves in space and time. Without knowing our movement relative to the two stars, we cannot know our direction of movement, and thus cannot accurately predict the difference between when we will see the two stars go nova. The only thing we know for sure is that the probability of seeing them explode at the same time is miniscule.

Let's simplify this however. Let's assume the Earth is totally stationary in space (for calculation purposes), and we reduce the distance to both stars to just 10 light years. Will we see the stars go nova at the same time? Yes, we will in such a special case. However, to an observer on a planet orbiting Proxima Centauri, the events will happen at different times because one star will be closer to that planet than the other.

What this boils down to is that time, and specifically events happening in the "now" are different for different observers. But if there is no absolute way of telling time, is it even real? Let's leave that question aside for now and look at how we've distinguished time over the centuries.

Solar years

Life forms have an inbuilt clock. Time, it seems, is an important aspect for life. This makes sense on a planet like ours where there are seasons, and there is changes with time. There are times of the year when it gets very hot, and times when it gets really cold. This factor alone meant that all life had to evolve a sense of timekeeping. Any organism that could live beyond a solar year, would have to deal with changing weather and seasons, and thus, any organism capable of preparing itself for change in seasons would survive longer and thus breed more. The perception of Time may very well be an evolutionary trait that was advantageous and thus is why all living things have the concept of time – consciously or subconsciously engrained into their very DNA. More on this later though.

Ageing and reproduction

We get older, that's how things work. You are born, you live, you grow old and eventually die (if there are no unnatural causes that

Try telling him time doesn't exist!

kill you sooner). It's no surprise that our obsession with time has increased as our life expectancy has grown. Ageing, however, is how most animals tell time, and in conjunction with reproductive cycles, we see how even simple animal forms can tell time. Within the DNA of most living creatures, based on evolution by natural selection, we have clocks ticking all the time. How does a bird know when it's ready to try and leave the nest to fly? How do its parents know? How does the body of an animal know what time of the year it is, in order to change hormones and put the animal into heat? How do animals know when to start migrating, or hibernating?

A part of us

Anyone who has a regular schedule, and wakes up at almost the same time every day will attest to experiencing those days when you suddenly wake up, for no apparent reason, and stare at your alarm clock about a minute or so before it is set to ring. Since the alarm didn't go off, what woke you up? It seems that we have a clock built into us, and it's able to tell us, "Almost 6 am, time to wake up!" Of course, that's not very scientific sounding.

The fact is, when it comes to humans, we have two clocks inbuilt into our brains. One is used for timing our circadian rhythm and to time the impulses sent to our muscles (for example), which is why we are able to jump at almost the exact moment we want to jump.

Some of us are better at such things than others, perhaps because some of us have a better internal clock for such things. Another clock that's inside our brain is there just to calculate the time elapsed. A lot of the brain is still quite a mystery to neuroscientists, so we're citing cutting edge research that is peer reviewed, but is not substantiated by many more varied studies.

Neuroscientists at the University of California, Irvine, USA, released a study in 2013 that found evidence of this second clock being situated in the hippocampus of our brains. For those who don't know what the hippocampus does, it's the part of the brain that is in charge of all of our memories – short- and long-term – and also our spatial memory. Another way to understand what it does is to know that people who suffer from Alzheimer's, suffer from degradation of the hippocampus.

The study was conducted on rats, and used the rats to discern time differences. It found that the rats who had their hippocampus disabled (chemically) were able to still differentiate between short and long intervals of, say, 4 and 12 minutes, but weren't able to do so when the difference was, say, 8 and 12 minutes.

Other similar studies have worked with rats by training them to release a treat by pressing on a lever at a very specific time. So, for example, a rat could be trained to press the lever every 10 seconds. If the rat presses the lever before 9 seconds, or after 11 seconds, it gets nothing, but if it presses it exactly 10 seconds after the last time it pressed the lever, it gets a treat. Amazingly, the rats are able to learn the rhythm and do so flawlessly. Then, the rats can be given chemical substances such as cocaine or marijuana and the effects noted. Interestingly, the rats given cocaine lose the rhythm and start pressing the lever too soon, and the rats given marijuana mellow out and press the lever too late. Once the effects of the drugs have worn off, the rats return to the precise timing and start getting their treats again.

Similarly in plants, there are genes that dictate the biological or circadian rhythm and turn on and off to tell the plant when it's night and when it's daytime. For example, a sunflower has to open up and face the sun at dawn, follow it till dusk and then close the petals and "sleep" at night, but it also has to wake up and be prepared for the next day on time, and sunflowers are always ready. This is because of the biological clock (in this case three genes) working to keep the plant on time. In plants, this is usually a function of three genes called CCA1, LHY and TOC1. CCA1+LHY work together in the early morning and are released in high levels, which break down the TOC1 genes still in the plant from the night time. The plant does all it usually does in the day, and towards dusk the CCA1+LHY levels fall and TOC1 is released in large quantities. This gets rid of any remaining CCA1+LHY, and again, as dawn approaches, TOC1 levels fall, and that's the signal to the plant's internal system to make loads of CCA1+LHY, and the cycle continues until death...

So is it real

If it's built into everything that's living, into the very DNA of life, doesn't that make time real? Perhaps. We're going to have to dive into philosophy to try and answer that one, and we're not the biggest fans of philosophy at Digit. We like our science to be evidence based. We will try and deal with that aspect in a later chapter though. For now, let's just say that what we know for sure is that time is something that living things can experience.

Entropy

The second law of thermodynamics states that entropy of a closed system only increases with the passage of time. This means that in a closed system, the amount of order of the system reduces as time passes. Thus, if you see a wine glass fall and shatter, you know you are moving with the arrow of time. However, if you were to see wine and shards of glass come together on the floor, form a glass, and then defy gravity to move upwards and onto a table, you'd know something was fishy. Since entropy (and thus randomness) only increases with time (in a closed system) we know that

The big freeze is coming! In about 10^{2500} years, so we're in no immediate danger...

the entropy of the entire universe (the ultimate closed system) is probably increasing with time, and thus, we have concepts such as the eventual heat death of our universe – where all galaxies speed away from one another and then break apart and everything goes back to cold nothingness. This is also called the Big Freeze, and is a valid theory about what happens at the end of our universe that began with a Big Bang.

When it comes to time, however, it is interesting to throw some wild ideas out there. What if time is nothing more than the measure of entropy of the universe, and isn't really a dimension, per se? Most believe it to be so, but there are some who believe that the "arrow of time" which is what entropy is also called, to be merely a case of us noticing entropy.

In fact, if time is merely a dimension, there has to be a way to go backwards, just as you can go backwards or forwards in the other three dimensions of space. Most physicists will tell you it's impossible to travel backwards in time, but perhaps that's not because of all the paradoxes it would cause, but more because time itself is just an illusion that arises from consciousness (or life)? In fact, when we look at the quantum world – where particles seem to defy the macro laws of physics, and there is evidence of "spooky action at a distance" – it's not unthinkable to imagine that we may be projecting an illusion of time on to everything...

More entropy

Entropy is not a "law" really, it's more a statistical conclusion. Take a simple deck of cards, for example, and shuffle them. There is no "law" that prevents the deck from being returned fully in order after being shuffled a number of times. A math geek will probably be able to sit down and calculate the probability of that happening – we've been told it's a probability of about 1 in 10^{68} (1 in 100 million trillion trillion trillion trillion trillion). To put that in perspective, there are an estimated 4 x 10^{68} atoms in our Milky Way galaxy!

Still, there's no reason why it couldn't happen, even if it is very, very, very unlikely. Thus, entropy increasing is just the most probable scenario, and that is why it almost always happens. Time itself may play no role in anything, because any change in state will always likely be towards more disorder (without external forces being applied). Perhaps entropy just always increases, and there is no arrow of time, because there is no way to reverse the arrow to see if entropy decreases when we do that...

It's a circle!

What is a watch or a clock? It keeps time, but what is the time it keeps? We made up the units of time, it's not like it was handed to us. Had we all been Martians or Venusians, the length of our years would be different and as a result, so would the length of our months, days, weeks, seconds, minutes... Thus, what is a second? What is the nanosecond that atomic clocks calculate? Keeping time is a very important business now, and accuracy of time is what runs the stock market, how we decide gold medals in photo finishes, how we decide winners in every race, how we decide world records and the like, how we communicate, how we navigate, etc. It's all circular referencing though, because there is no standard time. Just as there is no standard length, for that matter. However, we can at least calculate the distance to the sun and call it one astronomical unit. Regardless of speed (which is time based), if you set off towards the sun, you would get closer and get there eventually. You would see the Earth being left behind. You would see the sun getting larger, you would notice changes in distance. This is also how we measure time, and it's circular. You could, theoretically, be in a room with 300 people, and all 300 could decide to play a joke on you, and secretly give you a paralysing agent so that you couldn't move, and also take that same thing themselves, and everyone would just freeze in place. How would you know whether time was passing or not if this happened? Time is also dependent on reference points, and when you think about it, all of the clocks on Earth, no matter how accurate, are just keeping time with one another, and aren't really measuring "time" at all; they're just measuring the difference between one another...

Gottfried Wilhelm Leibniz

One of Newton's biggest rivals and considered to be the co-inventor of Calculus (both he and Newton invented calculus independently of one another), Leibniz was also a critic of Isaac Newton's laws of motion.

For one thing, Leibniz was critical of Newton's laws for being kind of circular in referencing things, as we also mentioned earlier. To understand Leibniz's position,we need to do a thought experiment. You can't think of something as complex as time without a good thought experiment or two thrown in, so here goes.

You're in the universe, inside the Milky Way, the solar system and somewhere on the surface of planet Earth. It's night time, you're looking up at the night sky, looking very hard to see things change (just in case). Now we're not too keen on the idea of God, but since it's a thought experiment, imagine God lifts up the entire universe and shifts it 10–inches to the right. Would you notice? Could you calculate the speed at which god moved the universe? How much time elapsed since God picked up the universe and put it down?

Don't worry, no one would be able to tell, because nothing changed, and if nothing changed in your field of reference, then you cannot measure anything, including time.

Another thought experiment is to imagine three points in space. Obviously any three points can form a triangle, so imagine you're

Not too many people argued with Newton, but Leibniz did...

moving this triangle through space. Say, you're in your room and moving the triangle about like a toy aeroplane. You could calculate the distance between the points, and how fast it was moving because of the stuff in the room that is a reference point. However, now imagine everything else in the universe disappears and there's only you and the triangle. With no frame of reference, can you even tell whether you are moving, or whether the triangle is? You can still calculate the distance between the three points, but can you calculate the speed at which you are moving through the void? Thus, it is still possible for the three space dimensions to exist and be measured in a void, but not time. So is it real?

Honestly, we don't know. Let's take a break from questioning the reality of time to look at how mankind has managed to measure time over the centuries... ■

Ancient times

How our ancestors started measuring time

Before it became important to know the exact time of the day, it was much more important to know the exact day of the year. We are, after all, creatures of habit, so we do want to know when winter will get here so as to keep the warm clothes ready, or when spring will come so we can prepare the land to sow crops, etc. However, the first indicator of a cycle in the night sky for the ancients was obviously the moon. We were able to notice that the moon waxes or wanes and completes a cycle every 28 days. Thus, we calculated lunar months before we could successfully calculate solar years.

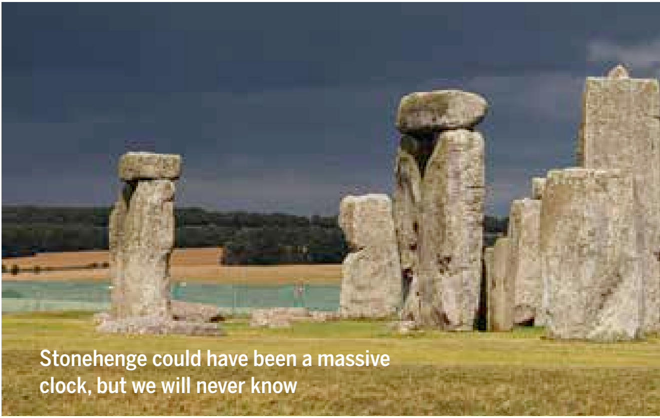
Not too many pre-historic structures made by mankind have survived to modern day, but a few, such as the Warren Field site in Scotland, where archaeologists discovered pits that had been dug between 8,000 and 10,000 years ago. Although discovered first in 2005, it was only a few years later that the scientists realised the configuration of the pits was in fact matching the lunar calendar. Not only that, but the central pit matched the mid-winter sunrise, which was a sort of correction done by these hunter-gatherers to correct for the difference between the solar year and the lunar year. This is an amazing find because it predates the oldest calendars found in history by at least 5,000 years, and possibly by as much as 7,000 years!

Image Credit: University of Birmingham

Artist's impression of the Warren Field site in 8000 BC with one of the pits being lit

Egyptian and Babylonian calendars

As usual, most of the ancient firsts in known history come from the middle east. The Sumerian (and later Babylonian) calendar was a lunar synodic calendar of 12 months with a thirteenth month inserted when needed. There were no fixed days in the calendar, as each new month started when there was a new moon. This meant that months were either 29 or 30 days long. Interestingly, the Babylonians considered every seventh day (after the first day of any month) to be an evil-day or a holy-day (which we now call



Stonehenge could have been a massive clock, but we will never know “holiday”), and thus officials were not allowed to perform a range of activities on these days. The twenty-eighth day of every month was known as a “rest-day”, and no one did anything except give offerings to the gods. The calendar, thus, consisted of three weeks each with seven days, and a final week with either eight or nine days, depending on when the new moon was spotted (a month of 29 or 30 days, since the synodic lunar month is actually 29.53 days).

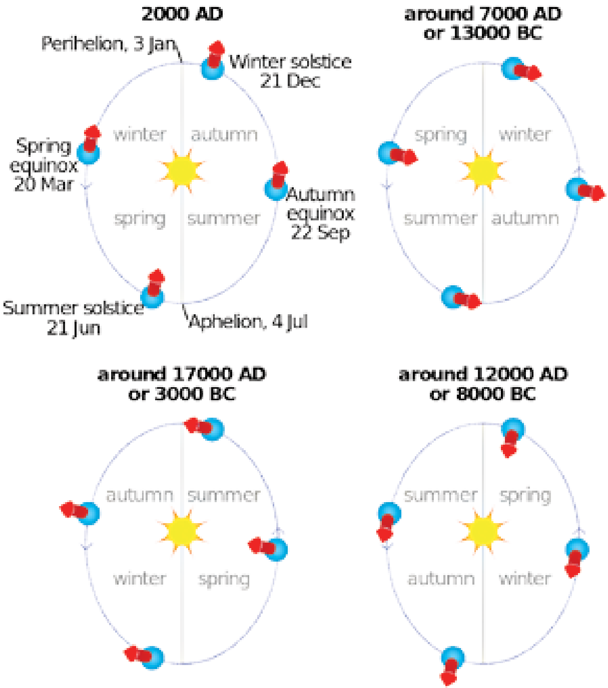
The Egyptians, of course, had a simpler (and more accurate) civil calendar that was 365 days long, much like the Gregorian calendar

we use today, except it was made up of 12 months with 30 days each and five extra days at the end of the year. Months were divided into three weeks of ten days each, and months were simply numbered from 1 to 12, and referred to as the sixth month, or eighth month, etc. This was the most efficient (and accurate) calendar of the ancient times by far, because it was merely a quarter of a day off the actual length of a year. Because of this one day loss every four years, the Egyptians noticed that the positions of the stars in the heavens were different, and called their year "the wandering year". Instead of correcting the calendar with a leap year as we do, the Egyptians calculated the difference, and didn't consider it an error, but instead considered it to be a cycle of 1,461 Egyptian years called the Sothic cycle. After 1461 years had passed, the star Sirius (Sopdet in Egyptian, and translated to Greek as Sothis) would just become visible at the horizon just before sunrise in Egypt.

Interestingly, the Egyptians also had religious calendars that were governed by the Lunar cycles, but these were only used for religious ceremonies, and were not the official or civil calendar we have mentioned above.

Indian calendars

The Hindu calendars were obviously varied across the length and breadth of India, and could roughly be broken into the Assamese,



Precession of the equinoxes explained

Bengali, Kannada, Malayalam, Nepali, Punjabi, Tamil, Tulu and the Vikrama Samvat calendars. All of them are based on a lunar cycle and calculate a sidereal year (365.256 days), as opposed to the Gregorian calendar we now use that calculates the tropical year (365.243 days). A sidereal year is longer because it calculates the time taken for the Earth to orbit the Sun using the fixed background of stars as a reference point. Because the Earth's axis also rotates (or wobbles), a tropical year is just a tad shorter than a sidereal year, and this was known in ancient India. Although there is some debate over exact interpretations, it is generally believed that very accurate measurements were needed for axial precession of the Earth. Some interpretations result in a calculation of 25,461 years, which is very close to the modern scientific accepted value of 25,771 years.

And more...

We could go on and on, but the fact is that ancient humans learnt pretty quickly that telling time (at least in days, months and years, was very important in order for civilisation to thrive. Of course, it was accompanied by a lot of superstition, and praying to the sun, or moon, or various celestial bodies, making sacrifices, even human ones, and more mumbo jumbo... however, there's no denying that ancient civilisations got pretty good at documenting our planet's seemingly never-ending rotation around the sun.

Time of day

It wasn't just the days, weeks, months and years that were important to ancient civilisations, ever since language was invented, and collaboration started amongst humans, there is no doubt that there was a need to tell the time of day. Imagine two cavemen with a rudimentary language, trying to decide to meet somewhere. First the problem of where: "*ugh* See this rock, walk in this direction *snort* and you will see another big rock, there we will meet." That's done, now the problem of when: "*growl* Wait for a night, then another night, *sniff* and one more night, then when the sun is hot and high in the sky, *ugh* meet me there. OK?"

And on the decided day, it gets cloudy and rains, and no one knows when it's afternoon because they can't see the sun, and you end up with two very confused cavemen wondering when to meet...

Long story short, we needed an accurate way of telling the time of the day. Many ingenious methods were used, including sundials, water clocks, and of course hourglasses.

The base 60 method of calculating the time – 60 seconds is a minute, 60 minutes an hour, etc – was in use at least 4,000 years ago (as early as 2,000 BCE) by the sumerians. The fact that we still use this method today is testament to the efficiency of the ancient system.

The water clock was the most used through the world, because water was the one thing that was always present wherever there was a human trying to tell the time. The Egyptians who lived near the equator were able to use the sun to tell time by using sundials, but the rest of the world wasn't blessed with as much sunlight as them.

The oldest clocks that archaeologists have found evidence of thus far are possibly Chinese water clocks that have been dated to about 4,000 BCE (over 6,000 years old).

Artifacts from Mohenjo-daro, as old as 2,800 BCE are thought to be clay water clocks, and it's quite possible that Indians were using water clocks for a lot longer than that as well. In fact, many believe that it was the ancient Indians who invented the water clock, but there is no clear evidence of this. One thing is for certain, it was either the Indians or the Chinese, because the evidence points to it originating in this region.

Most of the ancient water clocks found across civilisations are outflow types – fill water to a mark in a vessel and it empties slowly, marking off how much time has elapsed. These were obviously only useful if there was someone watching the clocks and making sure that as soon as they emptied either another clock was started or the same clock refilled immediately.

Another problem faced by a lot of civilisations was the fact that they considered 12 hours of light and 12 hours of darkness, and thus 24 hours in the day, but not only does this change as you move

Water clock from ancient Egypt

from the equator towards the poles, it also changes in seasons, and thus in summer the days are longer, while in winter the nights are longer. What this boiled down to was many such water clocks being re-calibrated often, and summer daylight hours just being a lot longer than winter daylight hours – since summer or winter, there were always a fixed 12 hours in the day.

Time's up!

Interestingly, a very popular usage of clocks was to time a client's visit to a lady working in a brothel. You couldn't have people using up the lady's time by spending all day there now could you?

Another popular usage was in courts, where people couldn't be given all day to plead their cases and waste the court's time. Thus, clocks were used to time the defendants, and make sure things kept moving along. This was used in Greek and Roman courts, and they were lenient enough to allow more time depending on the severity of punishment being faced by the defendant – someone facing a death penalty got a full jar of water, whilst petty criminals got only a fraction of the water clock filled.

Night clocks

Candle clocks were used at night, especially in China and Japan, as a way to tell time even at night. These were simple and not very accurate things that measured the rate of burning of a candle to tell time. The more a candle had burnt down, the later in the night it was...

Candle clocks weren't very accurate, but they were useful as a source of light as well

The incense clock, which burned a stick of incense instead of a candle, were probably invented in India. Although the oldest ones have been found in Japan, they have Devanagari script writing on them, which suggests that they were used by Buddhists and were perhaps of Indian origin. The incense clock was a little more accurate than the candle clock, because there was no flame that would flicker and change the rate of burn, and also were a lot safer for use indoors, as a fire caused by a burning incense stick is a lot rarer than one caused by a candle.

Hourglass

Eventually, after using water clocks for a long time, mankind realised that water could be replaced with fine sand, and this meant that the entire contraption could be made smaller and could also be sealed. Sand doesn't evaporate, or freeze, but it does need skilled glasswork to make the hourglass. Perhaps that's why it wasn't as popular, and was perhaps an expensive item. Some claim that the hourglass was invented in Alexandria in 150 BCE, and was pretty much exactly the same as the hourglasses we see today – just a case of really good design. However, in Europe, where historical evidence was preserved better than elsewhere in the world, hourglasses only start appearing in the fourteenth century ACE! That's over 1,400 years after it was supposedly invented in Alexandria. Perhaps the skilled glasswork needed to make one didn't become commonplace enough until then, but it is still surprising, because an hourglass is certainly much more convenient to use than a water clock!

The design of the hourglass has been the same for a very long time

Mechanical clocks

It was Christian monks who started off building mechanical clocks. Timing was very important for these holy men, because they wanted to pray at precise times, wake up, work and conduct life in a very ordered fashion. It was also the job of the monks to inform the rest of society about important times of the day, and they did so by ringing a bell to inform the townsfolk. This was a job they took seriously, and thus, some of them being skilled mechanically, took to building mechanical watches and clocks.

The first record of a mechanical clock was one built by Gerbert of Aurillac (who would later become Pope Sylvester II) in 996 ACE for the German town of Magdeburg. By the 11th century, mechanical clocks were popping up everywhere, and not as accomplishments listed in history, but as mere mentions in passing, which implies that they were already commonplace by then. There are several clocks that survive to this day that were made in the 14th and 15th centuries, but nothing older, sadly. There are clocks in England, France and Italy that all claim to be the oldest running clocks in the world, and there is no way to tell which claim is correct. The French clock, located in the Cathedral of Saint Peter of Beauvais is said to be from 1305 ACE and the English clock in the Salisbury cathedral is dated to about 1386, but both dates are disputed, leaving us with no option but to mention both, and hope that one of them is dated correctly.

It was Galileo Galilei who worked with pendulums and realised that they could be used in clocks in the 1580s. He never built one, though he did write about it. It was Christiaan Huygens, a Dutch scientist, who built the first pendulum clock in 1656. These were very accurate clocks, losing less than a minute per day (which was very accurate for the time).

What we know today as Grandfather Clocks were invented in England by English clockmaker William Clement in 1671. Because pendulums used to swing wildly – as much as 100 degrees – all clocks had been made with short pendulums, which meant that the swinging was rapid and thus also less efficient (and lost time more frequently). Clement made a design with an anchor escapement that allowed for much longer pendulums, with much less degree of swing (as little as 4 degrees). Lengthening the pendulum to 39 inches gave a swing time of a second, which means that the longer pendulum clocks kept better time. This is why grandfather clocks were so commonplace at the time.

Pocket watches

Christiaan Huygens built the first watch using a balance spring in 1675. There is some controversy with this claim because British physicist Robert Hooke claimed to have invented it in 1660, but he didn't use it in a watch, so it's usually just attributed to both men. Before the balance spring, pocket watches were terrible things that often lost a few hours of time accuracy a day, unless you kept winding them up constantly. With the balance spring, this time loss was reduced to under 10 minutes in one fell swoop, which is why it is such an important invention. Today, only the most expensive mechanical watches use them, and precision is something noted watchmakers pride themselves on.

Thomas Tompion, an English watchmaker was the first to use them widely, and even added on a minute hand to the watch, which, after much trial and error, eventually settled on the configuration we know even today.

Just another pocket watch

Wristwatches

These were actually available as early as 1571, when one was presented to the queen Elizabeth I as an "arm watch". Wristwatches were exclusively made for women, as men used pocket watches, and carried them in their coats. It wasn't until the late 1800s that military men started wearing wristwatches into battle. It became very important for regiments to co-ordinate attacks without visual signs used as communication, and this meant a planned attack at a fixed time. It was not feasible for army men to carry pocket watches, especially when they needed to quickly glance at the time, and could be either running on foot or riding horses. Thus, the humble wristwatch went from being a fashion accessory exclusively for women, to the big business it is today, and eventually killed off the pocket watch business.

Quartz

When Jacques and Pierre Curie discovered the piezoelectric properties of quartz in 1880, they had no idea they had just revolutionised the watch business! In 1927, the first quartz clock was built by Warren Marrison and J.W. Horton at Bell Telephone Laboratories in Canada, and these were used mainly in labs and in scientific research, because no one needed such accuracy at the time. In fact, countries such as the US kept official time on quartz clocks until

The inside of a standard quartz watch

they switched to atomic clocks in the 1960s. Seiko made the first quartz wristwatch in 1969, and quartz was officially available to the masses ever since. Even today quartz watches are more accurate and can be built a lot hardier than their mechanical counterparts, and dominate the market. The mechanical ones are now style statements and cost a lot more, despite not being as accurate! Quartz watches are generally synced to official atomic clocks by their manufacturers.

Which brings us to...

Atomic clocks, obviously. By measuring the rate of decay of radioactive elements (usually caesium), we arrive at more precise measurements of time. A modern atomic clock is by far the most accurate clock we have, and is actually accurate to 30 billionths of a second per year – that means it loses only about 30 billionths of a second of time per year, which means it would take about 33.333 million years for the clock to be one second off, which is pretty darn accurate. However, all of this doesn't change one immutable fact, which is that all of these clocks are used to measure our own little take on "time" based on where we live. No other race, born on any other planet but Earth will ever come up with a "second" that is the same as ours, because our "time" is something made up by us to explain our own years, days, hours, minutes and seconds... ■

In Physics

Let's quickly look at how time is defined in physics

Physics is known to be simplistic (well sometimes), and in physics, you could actually define time as "what a clock reads". In pre-Einstein physics, time was just another property of the universe, the same everywhere, much like length is the same everywhere – a metre ruler will still be a metre ruler on Mars, even if the Martians call it something else! Same for the second...

Basically, we took the average Earth day, divided it into 24 hours, each hour into 60 minutes, each minute into 60 seconds. Thus, the second was 1/86,400 of a mean solar day. Of course, the mean solar day (time between successive noons) changes because the rotation of the Earth is slowing because of tidal friction (very, very slowly). Thus, astronomers introduced the ephemeris second in 1952, which was exactly equal to 1 / 31,556,925.9747 of the tropical year of 1900.

Modern day SI unit definition of time is "the duration of 9,192,631,770 periods of radiation, corresponding to the transition between the two hyperfine levels of the ground state of the caesium 133 atom".

Basically, we just find a number in nature that matches the exact value we want, or rather, the value we expect a second to be, and then called that the standard second... circular logic once again!

After Einstein, well, we weren't as sure that time would be the same everywhere... so defining a second kind of became slightly lower priority.

Newton

Newton was convinced that time was absolute, and a property of our universe. To quote him: "Absolute, true, and mathematical time, of itself, and from its own nature flows equably without regard to anything external, and by another name is called duration: relative, apparent, and common time, is some sensible and external (whether accurate or unequable) measure of duration by the means of motion, which is commonly used instead of true time; such as an hour, a day, a month, a year."

Maxwell

In 1864, the Scottish physicist James Clerk Maxwell came up with his now famous equations, using which we were able to calculate the speed of light. This was found to be 299,792,458 metres per

James Clerk Maxwell

second. It's amazing we didn't slightly modify the value of a metre to round this off to 3 x 10^8 metres per second, given that we seem to love to change our measurements using circular logic... anyway, what this did was get the world thinking about light and other electromagnetism, which led a patent clerk sitting in a Swiss patent office blowing our minds forever...

Einstein

In 1905, Einstein released his paper on special relativity, which completely changed the notion we had of time, and made all time merely relative to an observer. We will paste a rather long quote from Einstein, for effect:

If at the point A of space there is a clock, an observer at A can determine the time values of events in the immediate proximity of A by finding the positions of the hands which are simultaneous with these events. If there is at the point B of space another clock in all respects resembling the one at A, it is possible for an observer at B to determine the time values of events in the immediate neighbourhood of B.

But it is not possible without further assumption to compare, in respect of time, an event at A with an event at B. We have so far defined only an "A time" and a "B time."

We have not defined a common "time" for A and B, for the latter cannot be defined at all unless we establish by definition that the *"time" required by light to travel from A to B equals the "time" it requires to travel from B to A. Let a ray of light start at the "A time" t_A from A towards B, let it at the "B time" t_B be reflected at B in the direction of A, and arrive again at A at the "A time" t'_A.*

In accordance with definition the two clocks synchronize if

$$t_B - t_A = t'_A - t_B$$

We assume that this definition of synchronism is free from contradictions, and possible for any number of points; and that the following relations are universally valid:—

If the clock at B synchronizes with the clock at A, the clock at A synchronizes with the clock at B.

If the clock at A synchronizes with the clock at B and also with the clock at C, the clocks at B and C also synchronize with each other.

—Albert Einstein, "On the Electrodynamics of Moving Bodies"

Einstein also showed that the speed of light was constant, and did not depend on whether an observer was moving. Thus, in a thought experiment, if you imagined yourself travelling in your car at, say, half the speed of light, and then turned on your headlights, the light from your headlights would not travel at 1.5 times the speed of light, but in fact travel at the speed of light, because light cannot travel faster than... err... light!

For this to be true, space and time would seem to not be the rigid and fixed entities they seem to be, and indeed that's the truth. He went on to explain time dilation because of travelling at relativistic speeds, and then also included gravity into the picture as something that also affects time, because it affects "spacetime". It was Einstein's relativity that added on the fourth dimension called time into our 4D spacetime world!

Quantum time

Let's be honest, we don't really understand quantum mechanics ourselves, so trying to explain it would be a tall order, and yet we have tried in the past as well. We hope we're not talking out of our hats, and suggest you take this section only as light reading material, and not any kind of authority on anything quantum. Our advance apologies to any budding quantum theorists reading this for the mistakes we are bound to make...

In order to even try and understand quantum time, we first have to understand how weird quantum particles are. It's all very well and good to be told about particle duality, and how light is both a wave and a particle... and all that jazz... but understanding the outcomes of an actual experiment ought to get the picture across nicely.

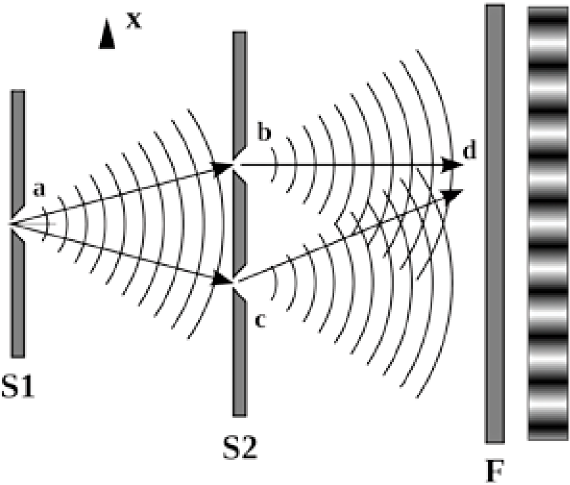
So we look at the double slit experiment that is now infamous as showcasing the oddities of the quantum world. If you were able to set up the experiment such that there is a light source capable of firing subatomic particles (photons, electrons, whatever), a screen on which to register the subatomic particles, and a barrier with two narrow slits in it capable of blocking out most of the particles, this is what you would observe:

If only one of the slits was opened and photons fired, you would see the photons make dots on the screen at a spot in line with the light source and the first slit. Close the first slit, open the second, fire photons, and you get dots in line with the light source and the second slit. Thus, you can see that light is made up of particles, and photons are travelling as if it they are a bullet fired from a gun. All well and good. Except for the fact that we obviously didn't aim the photons at either slit, they just kind of went through...

Now, you open out both slits and fire photons. What happens? If you had a machine gun and fired indiscriminately bullets would go through and leave marks on the screen directly in line with the slits and your gun. You should get two straight lines of bullet holes. With photons, you many lines! Why many? Well, because they suddenly act like a wave, and not only do they go through the slits, they also interfere with one another to create bands. If you do this experiment with water, you would see some waves from slit 1 exactly cancel some waves from slit 2. At the same time, some waves from both slits amplify one another, and some waves dampen each other (but do not cancel). Thus, for a wave you would get bands of light, and that's exactly what the researchers got.

In order to rule out interference of particles, they conducted this experiment with electrons, and shot only a single electron at a time through the double slits. Each electron made a mark on the screen, and as they kept firing one electron at a time, they noticed the wave pattern form again. So each electron was behaving as if it was part of a wave, and even though it hit the screen at only one spot, it played its part as if it were a wave. But how did the electrons know where to go, and that they were supposed to form a wave? How come each individual didn't just go through either the right or left slit, and what exactly were they interfering with? Did the electron interfere with itself to act like a wave interference pattern? How did individual electrons know there were two slits and follow the interference pattern that is associated with two slits? The same thing happens if you shoot atoms at the screen, so it's nothing to do with charges, or anything like that...

That's not the really spooky bit though, what's really weird is that physicists said ok, this is ridiculous, and set up a monitoring device to see which slit each individual atom (or electron) went through. Suddenly, the particles became shy, and refused to act like waves, and acted like particles, and all we got were two bands of lights – exactly as you would expect particles to behave. The very



Particles acting like waves

act of measuring which slit the particles went through ensured that they behaved like particles and changed the entire outcome. How did the particles know they were being watched?

Leave the detector there, but don't use it, and the atoms (or electrons or photons, or whatever) go back to acting like a wave!

There's a reason why we don't understand quantum mechanics... no one truly does. If you can explain why this happens using traditional physics, there's a Nobel prize with your name on it waiting for you...

Entanglement

That's not all, in the quantum world, pairs or groups of particles can be entangled, where we cannot know the state of one without knowing the state of the other. So, for example, if you generate and entangled pair whose overall spin is 0, and measure the spin of one particle, and find it to be clockwise on a particular axis, you can be sure that the spin of the other particle is counterclockwise on the same axis. Indeed, when it is measured, that is exactly what we find. What's interesting, however, is that they seem to remain entangled no matter how apart they are from one another. We can consider the act of measuring to be an interference with a particle's state, and using Schrodinger's cat as an example, a particle has all possible spins, for example, until we measure it – just as Schrodinger's cat is both dead and alive until it is checked on. Thus, we can consider that entangled particles are in no state, but when one is measured (or acted upon), the other knows, and assumes the opposite state (or whatever state is expected by us). This effect seems to work at huge distances, and thus, can be considered to be instantaneous communication across large distances, which is communication faster than the speed of light... which then opens up a whole new can of worms, because simpler concepts like time go for a toss in such situations.

So what's time in physics then?

Let's just say it's still a work in progress, and in order to marry the laws of the quantum world to the laws of the cosmological world, quite a few things we take for granted might become casualties in the process. Time could very well be one of those casualties, or not... until we have a unified theory of everything, we really cannot take anything for granted. It sure is exciting to imagine that answer might be arrived at in your own lifetime. What a time to be alive! ■

Philosophy

Since we still don't know for sure, let's (reluctantly) take a dive into the philosophy of time

When all else fails, we have no choice but to turn to philosophers. We're not going to be quoting any pseudoscience peddlers who don't even understand the words they use (like a certain person of Indian origin...) merely to sell more books. We will, however, mention a few ideas that even physicists like to toy with, and a few others that might be a little older...

Vedas

The Vedas are really interesting and the interpretations people make based on modern knowledge of science seem to suggest that they deal with some really large numbers of time. For example, Brahma's life is supposed to last 311 trillion and 40 billion years. That's 100 years in Brahma time, so a day in Brahma's life is about 8.64 billion years, though it is described as 4.32 billion years making the day, and another 4.32 billion years making up the night. A year in Brahma time is 3.1104 trillion human years... Brahma dies after 311.04 trillion years, and then there is nothing for another 311.04 trillion years, and then a new Brahma is born, and the cycle repeats.

Although modern science does not agree with the timelines, as the current accepted age of the universe by scientists is just under 14 billion years (13.82), Hinduism is one of the few ancient religions where the books at least get the numbers in the same orders of magnitude (billions, instead of thousands in most other religions).

In fact, of the ancients, it's the ancient Incas who were closest to the current scientific understanding of time, because they believed space and time to be a single idea, and they called it "pacha". This is very similar to Einstein's "spacetime".

Temporal finitism

It was obviously in the best interests of religion that time have a beginning, as indeed it was in their best interests that the universe have a beginning. When the Big Bang theory was accepted by scientists, the religious rejoiced, and a universe that exploded into being, must have had a creator, and finally they felt science and God could be reconciled.

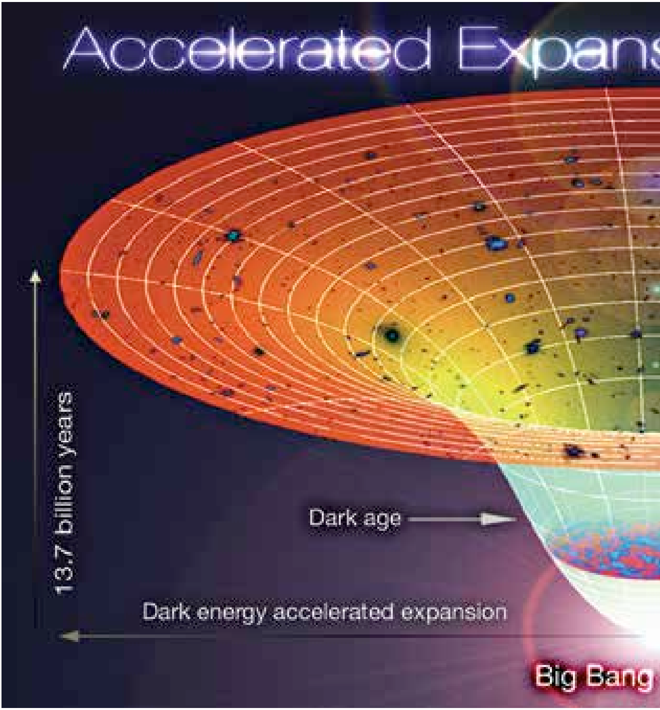
In fact, it was perhaps very unscientific of quite a few of the scientists who rejected the Big Bang theory, only because it went along with what religion seemed to be claiming, because in science it is much more important to follow the evidence and reasoning, no matter what the outcome, rather than to dislike a theory because you dislike the outcome. However, scientists are merely human too...

Before the Big Bang theory was accepted though, the argument of religious philosophers was against the infinite, because scientists believed it to be possible that the universe could have existed forever, and therefore the age of the universe could theoretically be infinite! The argument was put forth in this manner.

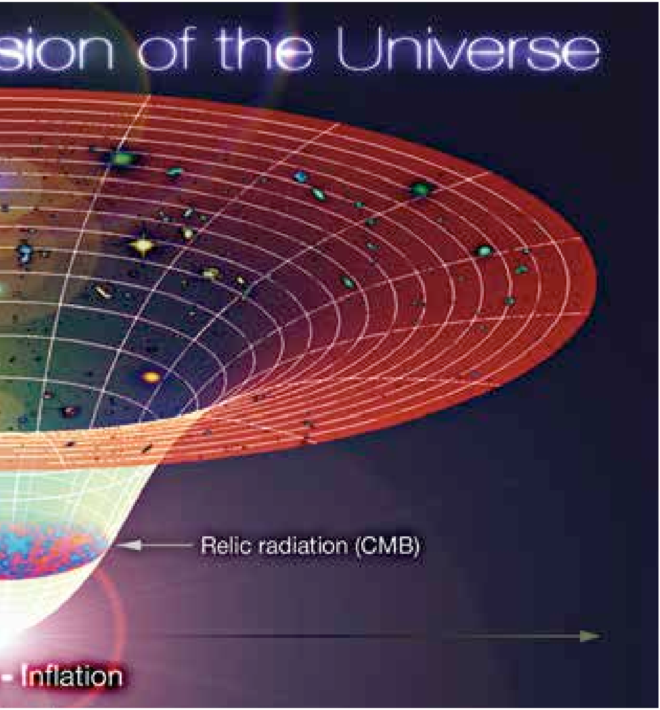
1. Actual infinities do not exist, they are merely a mathematical concept. For example, you can think of two points moving together at a constant speed to be halving the distance between two points in a certain time. Using mathematics, the would keep approaching each other and halving the distance forever, yet we know that objects approaching each other collide, and don't approach each other forever.
2. Claiming that the universe existed forever is an example of infinity
3. Therefore, since infinities cannot exist in reality, time had to have a beginning. And there is a temporal finitism to the universe...

Realists and idealists

Another two competing theories about the way things work were the realists who believed that time and space exist independent of



The universe had a beginning


sion of the Universe
Relic radiation (CMB)
Inflation

consciousness (or in other words, the observer). Thus, whether we are here to see it or not, the universe exists.

Idealists on the other hand believe that everything that we perceive to exist, only exists when we perceive it. Some idealists, also known as anti-realists, believe that although objects exist outside the mind (or our perception), space and time themselves do not exist unless the mind experiences it.

Relationists and Absolutists

We've already touched upon the contrasting positions taken by Newton and Leibniz. Leibniz believed in relationism, and argued against Newton's absolutism position. We've mentioned the thought experiments about God moving space 10–inches to the right earlier, so we won't repeat ourselves.

Another way Leibniz argued this was to ask people to consider two universes, identical in every way possible, except one was five feet more to the left of the other. How would you tell them apart?

The response from the other side was to imagine a bucket that contained water suspended from a rope. The water in the bucket has a flat surface. Now the bucket is spun by twisting the rope, and the water spins as well and develops a concave surface. The bucket is suddenly stopped, and we find that the water keeps spinning. Thus, the water is spinning with reference to something other than the bucket, because it can be either flat surfaced or concave surfaced when the bucket is still. That something other, was described by the people on Newton's side as space itself, and thus objects could move through space, even if there was no other object that was a frame of reference, because space itself was the reference.

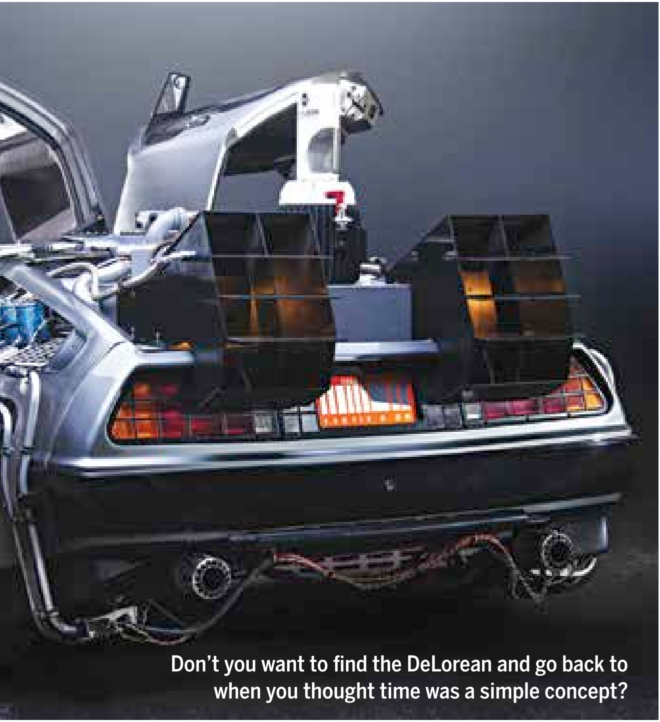
Eternalism and presentism

Another interesting philosophy of time is Eternalism. It is the belief that all events that have happened in all of time still exist – just as the universe exists in 3 dimensions, it also exists in all forms in the time dimension. Although Gandhi and Bhagat Singh don't exist today, in our "now" they exist in our past, in their "now". All things from the past, the present, and the future, all exist, and all are as real as we are now. We know that Gandhi and Bhagat Singh existed, and were real, we know that we exist and are real, however we know that Gandhi and Bhagat Singh would not have believed us to be real, no matter how much someone tried to convince them. And yet, here we are, as real as anyone else in the world is, in the past, the present or even in the future. You existed two minutes ago when you started reading this paragraph, you exist now, and you will still exist when you finish reading this book, and be just as real as past you, or present you.

However, presentism disagrees, and says all that is real is what exists in the now. Gandhi does not exist, because he does not exist now. He did exist in all of the "nows" that we may want to choose in his lifetime, but he does not exist now, and will not exist in the future. We exist in the now, and that makes us real. The future us may not exist tomorrow, so they are not real, not yet. They will only be real when tomorrow becomes "now", or basically, the present.

Problems with the direction of time

A popular problem with the direction of time is that fundamental physical laws were the same in the past as they are now. Thus, if you were to videotape an event, and then play it backwards, the laws of physics should still hold true for the entire



Don’t you want to find the DeLorean and go back to when you thought time was a simple concept?

duration of that event, whether played forwards or backwards. However, our experience does not support this because a wine glass that fell and shattered cannot reverse and form a glass again. You can remember the past, but you cannot remember the future. You feel like you can change the future, but you know you cannot change the past...

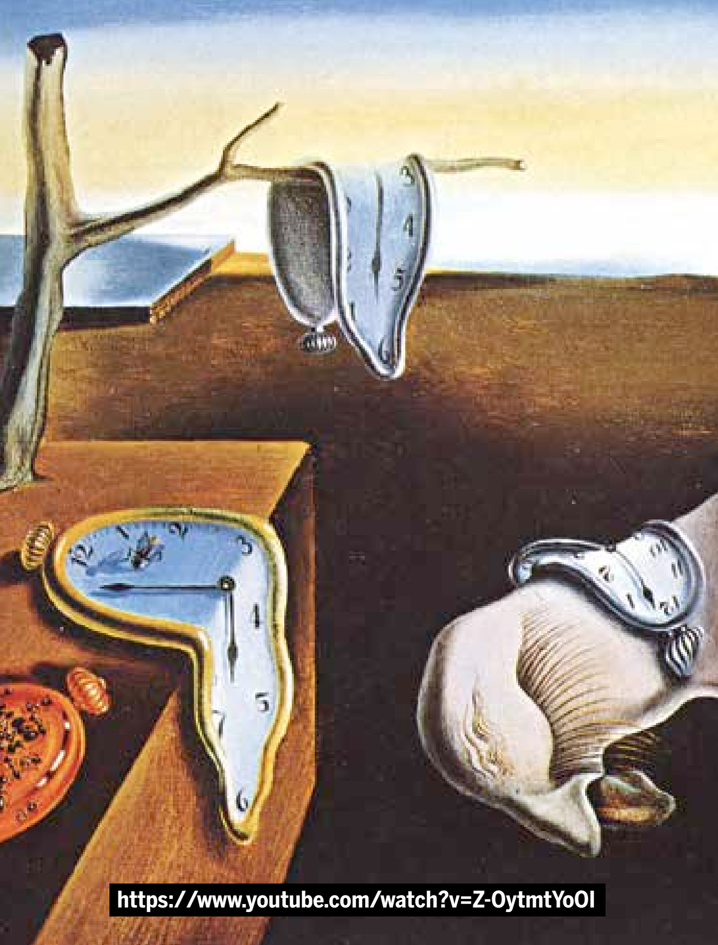
One idea that tried to tackle the problem was to look at everything as cause and effect. You need a cause to experience an effect and you cannot experience the effect before the cause has, well, caused it. Thus, our perception is based on causes, and that's why you can know the past but cannot change it, and you cannot know the future, but you feel you can change it (by "causing" something to happen in the present.)

People who believe that time is nothing more than our perception of ever increasing entropy in the universe find this a lot easier to deal with. Looking at the universe as a closed thermodynamic system, and applying the second law to it makes it easy to understand... well almost. The problem is, as you can do by expending energy, you can decrease the entropy of a system and create order. You can make bricks, and build a house, which is an ordered state, you can build a sand castle, which is a very ordered state of the sand, and thus, by using up energy, you can move from high entropy states to lower, so why can't you expend energy and go from the present to the past if all that time is, is the entropy of the universe increasing. Where are all the time travellers?

The end

It's about that time now when we finish with the book, and our apologies if this book made your head hurt. You're in good company though, because most of the smartest people who have ever lived on this planet in the past, present, and also those who will come for the foreseeable future will try to understand time and unlock the secrets it might hold. You or your future kids might actually witness some brilliant person come along and dmystify time a lot better than we have been able to. Who knows, you or your kids might be the ones to do so yourselves... only time will tell...

As always, remember to write in – *dmystify@digit.in* is where you should send feedback. Until next... time. ■



https://www.youtube.com/watch?v=Z-OytmtYoOI