Chapter 1: Introduction

"If you want to build a ship, don't drum up the men to gather wood, divide the work, and give orders. Instead, teach them to yearn for the vast and endless sea.

Antoine de Saint-Exupery

One balmy summer's night, when the sky is clear and smell of freshly cut grass hangs heavy in the warm still air, take time out, find a calm open space and gaze up at the stars. What do you see? As you take in the vista of shimmering dots that glisten in the blackness of space, surely you see beauty? Surely you see the majesty of the universe before you? If you do, then you are not alone. Ever since man could look up at the stars, others have marveled at such beauty and some have even dared to question why it should be so. From such curiosity came the very essence science itself.

The attention of physics is entirely focused on the universe and all it contains, as it tries to understand the very most fundamental workings of all we perceive as real. But physics is not an island. It is not self-sufficient when it comes to the tools needed to explain what it seeks to describe. In particular physics carries a high reliance on mathematics and uses it as the predominant language through which it chooses to speak. So tight is this relationship that we can consider mathematics to be the bedrock on which physics rests, the very foundation from which our very our deepest understandings of the universe are built. But there are still deeper foundations. Mathematics itself is based on the concept of individuality and the ability to group such individualities together into more useful concepts. From this the familiar concepts of numbers, arithmetic, geometry and algebra are created and today we put them to work with a high degree of success.

For most that care to consider such matters, that's it, dig down to the very base of mathematics and the roots go no further. Once it is understood where the basic building blocks come from, there is nothing below. But what if there were something below, something holding up numbers, all other mathematical concepts and all the various fields of science above that too? If that were the case then surely that something must be real stuff from which the universe is made? Surely that something must represent the very signature of everything itself?

In recent times the ideas behind information and computation have seen their profile rise and with the advent of technologies like the Internet and the World Wide Web it's not hard to see why. Yet most still see Information Technology and its near relation Computer Science as resting on top of physics and mathematics. We even have fundamental models of computation that clearly line up with fundamental physical models such as quantum mechanics. But what if we chose, for some rebellious reason, to turn the whole model on its head? What if we chose to suggest that physics and mathematics were founded on the notions of computation and information; numbers, arithmetic, algebra, quantum mechanics…everything!

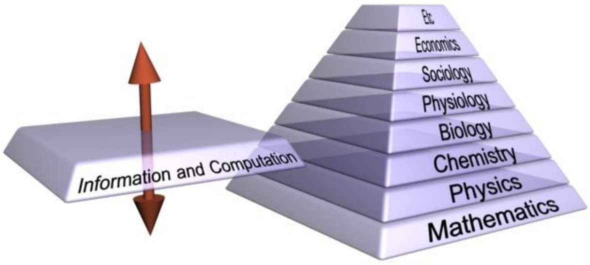


Figure 1: Where in science should information and computation sit?

Most contemporary scientists would wince at the proposition of mathematics not being fundamental, but there are a growing few who would not. Ask your everyday scientist where information and computing should sit in the stack of scientific disciplines and they will most likely respond with confusion. Perhaps above sociology and economics they might suggest, going on to suggest that entities like the Web are clearly propped up by such things. But there are those who think differently. To them the universe is just one gigantic computer system feeding on its own information and changing in ways we choose to consider as the reality around us.

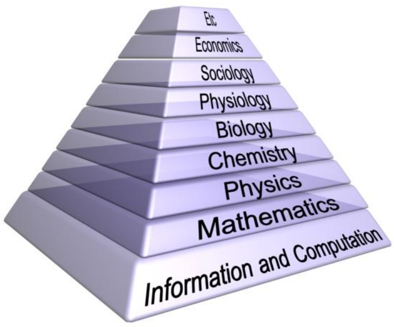


Figure 2: Information and computation as the bedrock of all other sciences.

The World Wide Web is a truly remarkable innovation. For large sections of this planet's population it now touches our lives through a veritable explosion of change. Some influences are obvious, like the personal knowledge gained from basic Web browsing, but many are not so apparent. For instance we now see extreme cases far removed from the interactions we might traditionally consider as normal within our global society's fabric. These predominantly relate to the vast collection of autonomous Web-software now chattering away in the background of our existence. Many refer to the components of this intertwined mesh as collaborating Web Services, but this is really a generalisation that has become quickly outmoded. What is profoundly relevant, however, is that the world around these components has changed in recent times and a tipping point has been reached beyond this which can be found an automated and intelligent environment hitherto beyond mankind's reach.

Why should this be so? The answer cannot so much be found with the software itself, or not at least if we are happy to consider such software one instance at a time. Rather it comes from the increasingly complex mesh of software-upon-software, computation-upon-computation and information-upon information into which each individual component is now being placed. From this diverse mixture of connectivity an emergent property may now be starting to rise. This is the swarm intelligence of the Web the common interpretation of its emergence is predominantly technical. But the Web is not wholly technical. The intention behind its inception may well have been so, but today it has evolved into a complex sociotechnical machine that is radically different. To characterise the modern Web as anything other than a global fusion of society, computation and information would be to do it an injustice. It is simply the largest human information construct in history. Furthermore the emphasis must be on "machine" here, as evidence exists in support of the Web as a computational device in its own right, independent of the skeletal support donated by its underlying Internet. This changes the game for Web-based software as it acts like molecules in an overall system of much richer, more natural, design.

This string of analogies in connection with the Web is used for deliberate reason, as current research points to the relevance of thinking taken from the physical sciences. In particular the areas of quantum mechanics and relativity stand out as holding particular promise. This implies a number of unfamiliar consequences for those who wish to understand the next generation of the Web-like systems. It also offers great promise for those who work in the classical sciences. Not only is the Web the largest synthetic system humankind has every created, but it also provides the largest sample set of data in existence, outside the informational mass of the very universe itself. If this could be, or more likely when it is, analysed across its full breadth and depth, the changes are high that new types of complex geometries, patterns and trends will be found. The search will then be on to investigate if fundamental laws at play in their formation and how these might relate to other fundamental laws already known.

It is already established fact, for instance, that the quantum model of computation has greatly strengthened our very understanding of what computation is. So it is plausible to suggest that thinking from physics' other great school of thought - that of the relativists - might also contribute in a similarly profound way. In fact, both physics and computing have already embraced the essence of relativity as a general underlying principle in many of their most fundamental models; the physicists commonly referring to it as "background-independence" [14] and computer scientists favouring the term "context-free" [15]. What Albert Einstein taught us was that at larger scales the differences between observable phenomena are not intrinsic to the phenomena but are due entirely to the necessity of describing the phenomena from the viewpoint of the observer [6]. Furthermore in the 1960's a different explanation of relativity was proposed, positing that the differences between unified phenomena were contingent, but not because of the viewpoint of a particular observer. Instead physicists made what seems to be an elementary observation: A given phenomenon can appear different because it may have a symmetry that is not respected by all the features of the context(s) to which it applies – an idea that gave rise to gauge theory in Quantum Physics. This only helps to suggest that if quantum mechanics presents a fundamental model of the universe [14] which should in turn, one day, be unified with other fundamental models of the universe, such as relativity, then perhaps the most fundamental models of computation are yet to come.

Those who subscribe to the quantum school of computation also freely align with the idea that the laws of quantum mechanics are responsible for the emergence of detail and structure in the universe [21]. They further openly consider the history of the universe to be one ongoing quantum computation [21] expressed via a language which consists of the laws of physics and their chemical and biological consequences. The laws of general relativity additionally state that at higher orders of scale, complexity and connectivity the physical fabric of the universe must be seen as curved and not straight, physical - space itself being considered as simply a warped[1] field through its most fundamental definition. Indeed the geometry of space is almost the same as a gravitational field [2]. All of this points to an alternative way of looking at reality, a way that relies on distinctly different geometries to the straight line variants with which we are generally familiar. In many ways too, mainstream theories of computation also need a refresh of perspective and history tells us not to be worried too much about such matters. Geometry suffered its own crisis long before computing. In 1817 one of the most eminent mathematicians of the day, Carl Friedrich Gauss, became convinced that the fifth of Euclid's[2] axioms[3] was independent of the other four and not self-evident, so he began to study the consequences of dropping it. However, even Gauss was too fearful of the reactions of the rest of the mathematical community to publish this result. Eight years later János Bolyai published his independent work on the study of geometry without Euclid's fifth axiom and generated a storm of controversy which lasted many years [16]. His work was considered to be in obvious breach of the real-world geometry that the mathematics sought to model and thus an unnecessary and fanciful exercise. Nonetheless, the new generalised geometry, of which Euclidean geometry is now understood to be a special case, gathered a following and led to many new ideas and results. In 1915, Einstein's General Theory of Relativity suggested that the geometry of our universe[4] is indeed non-Euclidean and was supported by much experimental evidence. The non-Euclidean geometry of our universe must now be taken into account in both the calculations of theoretical physics and those of a taxi's global positioning system [116][143][144][145]. This drives the point that what is naturally instinctive is not always right.

More on the Web and a Brief History

Might the Web provide a way to the change of perspective sought in computation? In order to start to answer this question we must first further clarify what the Web is not. It is not, for instance, the Internet, although it is dependent upon it. The two are sometimes perceived as synonymous, but they are not [7]. For this reason any use of the colloquialisms like "the Net" in reference to the Web can only serve to confuse and hence should be frowned upon. The Internet is a communications network, a global framework of wires, routing devices and computers on which the Web rests, and to think of the Web just in terms of electronics and silicon would be wrong. Other terms like "Information Super Highway" may also be easily misconstrued as characterising the Web but don't really quite get there. They do not convey the truly global, interconnected nature of its vast information bank, instead perhaps conjuring up unnecessarily images, heavily dependent on microprocessors and tin.

The Web is not as youthful as one might first think either. Computing pioneer Vannevar Bush outlined the Web's core idea, hyperlinked pages, back in 1945, making it a veritable old man of a concept on the timescale of modern computing. The word "hypertext" was also originally coined by Ted Nelson in 1963, and can be first found in print in a college newspaper article about a lecture he gave called "Computers, Creativity, and the Nature of the Written Word" in January, 1965. That year Nelson also tried to implement a version of Bush's original vision, but had little success connecting digital bits on a useful scale. His efforts were hence known only to an isolated group of disciples. Few of the hackers writing code for the emerging Web in the 1990s knew about Nelson or his hyperlinked dream machine [35], but it is nonetheless appropriate to give credit where credit is due. From such beginnings, the origins of the Web as we would begin recognise it today eventually materialised in 1980, when Tim Berners-Lee and Robert Cailliau built a system called ENQUIRE - referring to "Enquire Within

[1] This does not mean that there is some other fixed geometry that characterises space – that space is like a sphere or a saddle instead of a plane or straight line. The point is that the geometry of can be anything at all, because it evolves in time.
[2] Euclid, also known as Euclid of Alexandria, was a Greek mathematician, often referred to as the "Father of Geometry."
3 If a line segment intersects two straight lines forming two interior angles on the same side that sum to less than two right angles, then the two lines, if extended indefinitely, meet on that side on which the angles sum to less than two right angles.
4 Considerations of the shape of the universe can be split into two parts; the local geometry relates especially to the curvature of the observable universe, while the global geometry relates especially to the topology of the universe as a whole—which may or may not be within our ability to measure [145].

Upon Everything", a book Berners-Lee recalled from his youth. While it was rather different from the Web we see today, it contained many of the same core ideas.

It was not until March 1989, however, that Berners-Lee wrote "Information Management: A Proposal", while working at CERN , which referenced ENQUIRE and described a more elaborate information management system. He published a formal proposal for what would become the actual World Wide Web on November 12, 1990 and started implementation the very next day by writing the first Web page. During the Christmas holiday of that year, Berners-Lee built all the tools necessary for a working Web in the form of the first Web browser, which was a Web editor as well, and the first Web server. In August 1991, he posted a short summary of the World Wide Web project on the alt.hypertext newsgroup. This date also marked the debut of the Web as a publicly available service on the Internet. In April 1993, CERN finally announced that the World Wide Web would be free to anyone, with no fees due and the rest, as they say, is history. The Web quickly gained critical mass with the 1993 release of the graphical Mosaic web browser by the National Centre for Supercomputing Applications which was developed by Marc Andreessen and Eric Bina. This again was a seminal event as prior to the release of Mosaic, the Web was text based and its popularity was less than older protocols in use over the Internet . Mosaic's graphical user interface swept all that aside and allowed the Web to become by far and away the most popular protocol in use.

In more recent times it has become indisputable that the Web is having an increasingly profound impact on the way that we, as individuals and social groups, go about our everyday lives. But regardless we should not forget that it is only one integral part in humanity's ever growing ability to create and process information. Putting the Web into this wider context and an impressive picture is painted , as the much credited "didyouknow" presentation at www.shifthappens.com, helps to explain:

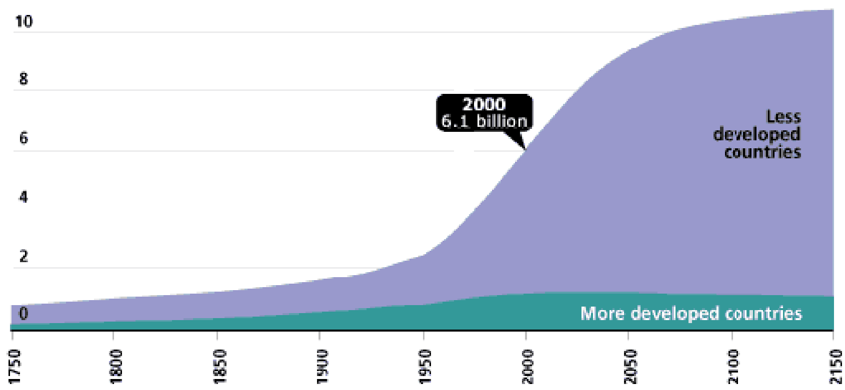
- There are over 2.7 billion searches performed on Google each month.
- The number of text messages sent and received every day exceeds the population of the planet.
- Today there are about 540,000 words in the English language. That's about 5 times as many as during Shakespeare's time.
- More than 3,000 new books are published every single day.
- It is estimated that 1.5 exabytes (1.5 x 10^{18}) of unique new information were generated in 2007. That's estimated to be more than in the previous 5,000 years.
- Predictions are that by 2013 a supercomputer will be built that exceeds the computation capability of the human brain.
- Predictions are that by 2049 a $1,000 computer will exceed the computational capabilities of the human race.

Such statistics are indeed impressive, but pointing out an exponential growth in information and our apatite to consume it is simply not enough. To appreciate the full picture, the great sea change under way in our population's demographic must also be understood. In the 400 years from 1500 to 1900, the human population of this planet increased at an average rate of just fewer than 3 million people per year. However, in the 100 years from 1900 to 2000, the average yearly increase increased to 44 million – nearly a 15-fold increase. So by such reckoning some calculations state that there are now more people alive today than all the humans who have ever lived since the dawn of civilisation. A profound conclusion if true, but it is only one of a number of related profound conclusions, if further conjectures are to be believed:

- 99% of all the scientists who have ever lived are alive today.

- 99% of all the geniuses who have ever lived are alive today. Likewise, 99% of all the idiots who ever lived...are alive today.
- More information is contained in one daily edition of the New York Times than was openly available in the entire 17th century.
- More new information is now publicly published every day than an army of 10,000 people could absorb. In fact, 10,000 people couldn't even catalogue it all.
- The acceleration of the acceleration in population growth is accelerating. Merely two decades from now there will be seven billion people living on this planet, a staggering figure in anyone's books.

Billions of People Alive



Year

Figure 3: Global Population Growth

In fact, to borrow a quote from the Web site providing most of the statistics above, "shift" truly is happening. Humankind is experiencing change as never seen before and the rate of that change is accelerating at a heart thumping pace. Couple this with the staggering rate at which the information we are producing is also accelerating and a clear conclusion must be reached. The Industrial Revolution of the 18th to the 19th century may well have seen major changes in agriculture, manufacturing, transport and so on, and a had a lasting effect on most aspects of our culture and society, but the changes we are experiencing today are of a magnitude far greater. This outlines the revolution of our time, and perhaps the greatest revolution that mankind will ever see. This is the Information Revolution and few yet understand its real significance.

New Ways in Which the Web Might Compute

In the late 1960's and early 1970's it seemed as though the Turing machine[5] model of computation was at least as powerful as any other model of computation, in the sense that a problem which could also be solved efficiently in the same model of computation could also be solved efficiently in a Turing machine model to simulate the other model of computation. This observation can be condensed into what is today known as the strong Church-Turing thesis [6]:

Any algorithmic process can be simulated efficiently using a Turing Machine.

[5] A Turing machine is a theoretical device that manipulates symbols contained on a strip of tape. Despite its simplicity, a Turing machine can be adapted to simulate the logic of any computer algorithm, and is particularly useful in explaining the functions of a CPU inside a computer. The "Turing" machine was described by Alan Turing in 1937. Turing machines are not intended as a practical computing technology, but rather as a thought experiment representing a computing machine. They help computer scientists understand the limits of mechanical computation.

The key strengthening in the strong Church-Turing thesis is the word efficiently. If the strong Church-Turing thesis is correct, then it implies that no matter what type of machine we use to perform our algorithms, that machine can be simulated efficiently using a standard Turing machine [6]. And since we can consider the Web to be a machine of sorts, the Church-Turing thesis similarly suggests that it should be open to simulation via a Turing machine.

The first major challenge to the strong Church-Turing thesis arose in the mid-1970's when Robert Solovay and Volker Strassen showed that it is possible to test whether an integer is prime or composite using a randomised algorithm. That is, the Solovay-Stressen test for primality[6] used randomness as an essential part of the algorithm. The algorithm did not determine whether a given integer was prime or composite with certainty. Instead the algorithm could determine that a number was probably prime or else composite with certainty. This was of especial significance at the time as no deterministic test for primality was then known. Thus it seemed as though computers with access to a random generator would be able to efficiently perform computational tasks with no efficient solution on a conventional determinist Turing machine. This discovery inspired a search for other randomised algorithms which has paid off handsomely [6].

Randomized algorithms pose a challenge to the strong Church-Turing thesis, suggesting there are efficiently solvable problems which cannot be efficiently solved on a deterministic Turing machine. This challenge appears to be easily resolved by a single modification to the thesis [6]:

Any Algorithmic process can be simulated efficiently using a probabilistic Turing Machine.

This is a supremely profound adjustment as it suggests that not all computation is discrete; that it is not "black and white". It further implies that Alan Turing's vision of computation is incomplete and begs the question as to if any further single model of computation is better or more "complete".

Motivated by this question the physicist David Deutsch asked whether the fundamental laws of physics could be used to devise a model of computation stronger that that embodied in the strong Church-Turing thesis. Because the laws of physics, and ultimately the universe, are quantum mechanical, Deutsch was naturally led to consider computational devices based upon the principles of quantum mechanics. These devises, quantum analogues of the machines defined forty nine years earlier by Turing, led ultimately to the modern conception of the quantum computer.

So a simple and immediate question is presented: If the Web can be considered as being an computational entity, what type of computer is it – classical, in a truly Church-Turing sense, quantum in a more contemporary sense, a mix of the two or something completely different? Trying to answer this question will be very important to us as our story unfolds.

Throughout most, if not all, of our recent digital history we have worked hard to engineer software to drive our computational devices towards a specific purpose or set of purposes. In doing so many useful programming languages have appeared and been applied with great success. Through such creativeness we have literally tried to climb inside the machine and convince it to do our bidding, pushing it in minute yet explicit increments towards a destiny of our own choosing. "Our code shall fit inside the box and the box shall do precisely as we ask", has been the IT industry's mantra to date. However, with the complexity and scale of the Web today we are presented with the opportunity to construct systems in a radically different way. It is now possible to "glue"

[6] The property associated with numbers only divisible by themselves and 1.

together “software”, creating it on the fly from a variety of locations and technologies. Indeed the Web is now allowing us to also question the very nature of software itself. For example, it is a common misconception that computer systems are built from two types of component; hardware and software. That is actually not true. There is one further type of component that is invariably left off the list – us. Without humans to create and run such systems they most certainly have no purpose. So, more correctly, computational systems - as we commonly understand them today - need three ingredients to survive. Hardware, software and the “wetware” that constitutes the thought processes inside our heads to create, run and maintain such systems.

The powers of wetware are consistently underplayed in IT circles, but let’s not forget that wetware is the only self-supporting element in the equation we have just described. Ever since intelligent beings have lived on our planet they have grouped together to create higher orders of computational capability. They have literally self-constructed their own computational systems. Take bees as a perfect example. There are over 20,000 known species of bee alive on Earth today, so they must be considered as a highly successful form of life. Yet each bee has little intelligence and thus little right to claim credit for such success. So where does this success come from? The answer comes from the swarm, the collective presence essential to every individual bee’s survival. The swarm takes the bee’s meager intellect and adds it to the capabilities of all its brothers and sisters. Its stitches together something far greater than the sum of its parts and allows a grander intelligence to emerge. And this capability is common across all forms of wetware not just bees. Some species exploit it more than others and we humans are not impervious immune to its attraction. We choose to live and congregate in cities, for instance, and such cities can be thought of as being computational and intelligent in many ways. Likewise a liking for swarm behavior is showing through on the Web, through sites like Facebook, Bebo and many other online communities. So, just as a swarm of bees can be considered to have emergent intelligence, the coming together of minds on the Web must also be considered as having the same, or similar, emergent potential. Add to that potential of the significant computational power of the software and hardware we bring with us to the Web and an emergent intelligence the likes of which we have never seen before is created.

Newton’s Bucket

In 1689 Sir Isaac Newton conducted an experiment with a bucket containing water. The experiment is quite simple and can be tried by most anyone. All you need to do is half fill a bucket with water and suspend it from a fixed point with a rope or some similarly flexible cord. Rotate the bucket, twisting the rope until it is reasonably tight. Next hold the bucket steady and let the water settle. At this point let the bucket go and watch what happens.

Immediately the bucket starts to rotate due to the tension in the twisted rope, but, at first the water inside does not follow this motion, remaining fairly stationary and flat on its surface. Slowly, however, the water begins to rotate with the bucket and as it does so its surface becomes concave, as indeed Newton's himself described [20]:-

> *“... the surface of the water will at first be flat, as before the bucket began to move; but after that, the bucket by gradually communicating its motion to the water, will make it begin to revolve, and recede little by little from the centre, and ascend up the sides of the bucket, forming itself into a concave figure (as I have experienced), and the swifter the motion becomes, the higher will the water rise, till at last, performing its revolutions in the same time with the vessel, it becomes relatively at rest in it.”*

Before too long the spin of the bucket slows as the rope loses its original tension and begins to twist in the opposite direction due to momentum[7]. The water is now spinning faster than the bucket and its surface remains concave.

This is an experiment that is easy to visualise and is one that we have all probably done at play at some time in our lives. As the bucket spins, the water rises up the sides of the bucket. Big deal, that's obvious right? Well….perhaps not. Newton was someone who never accepted the obvious and, on this occasion, he wanted to push further than accepting everyday observation. As always Newton wanted to understand the underlying principles involved and he used this experiment to ask a very fundamental question – what does spin itself mean?

It certainly doesn't mean spinning relative to the bucket, as might instinctively be thought. After the bucket is released and starts spinning, the water stays flat for a time, hence demonstrating that the two are not completely bound to one and other. Eventually, however, friction builds up between the water and the sides of the bucket and this causes the two to start to move together until they ultimately become comparable in their motion. As part of this process the water's surface becomes concave as centrifugal force compels the water to move out from the center of the rotation. After the bucket stops and the water goes on spinning relative to the bucket, its surface maintaining its concave shape until the energy in the system dies down and friction can no longer counteract the leveling influence of gravity. Thus the shape of the water's surface is not determined by the spin of the water relative to the bucket.

Newton then went on to push the experiment further, theorising that it might be undertaken in a completely empty space. This time he considered a different variant in which two rocks are tied together with a rope at a point in deep space, far from interference from any gravitational field. To run the experiment he imagined the rope being rotated about its centre, thereby becoming taut as the rocks pull outwards.

In this version of the experiment a particular problem is deliberately introduced, in that in such a vast empty space there is nothing obvious against which measure the rotation. This posed the basic question, in that if we can't measure rotation, how can it exist at all? From this Newton deduced that, regardless of the huge void, there had to be some means of comparison within reach, and that something had to be space itself. This was a major theoretical breakthrough and provided his strongest argument in support of the idea of absolute space – the container in which everything exists and against which all things can be compared.

Having made this jump Newton returned to his bucket experiment and proposed that spin can only ever be considered as a property with respect to an absolute space, the universal container which we implicitly consider as our everyday interpretation of the world around us. When the water is not rotating with respect to absolute space then its surface is flat but when it spins with respect to absolute space its surface is concave. Thus he somewhat reluctantly wrote in his Principia[8]:-

> *"I do not define time, space, place, and motion, as they are well known to all. Absolute space by its own nature, without reference to anything external, always remains similar and unmovable."*

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[7] In classical mechanics, momentum is the product of the mass and velocity of an object.

[8] Philosophiæ Naturalis Principia Mathematica, Latin for "Mathematical Principles of Natural Philosophy", often called the Principia, is a work in three books by Sir Isaac Newton, first published 5 July 1687.

For Newton, the boundaries of absolute space were necessary to make sense of the universe even at local levels, but he was uncomfortable with the fact that the human mind could never grasp the true meaning of these through any of our natural senses. We just had to accept the existence of absolute space without being able to touch, smell, touch or hear it. It was beyond our experience, yet was intrinsic to everything we experience, a paradox that has challenged science ever since the second it entered Newton's mind.

Other scientists, like Leibniz[9], did not believe in absolute space however. He argued that space only provided a means of encoding the relation of one object to another. It made no sense to claim that the universe was rotating or moving through space. He supported his argument with philosophical reasoning, but faced with Newton's bucket, he had no answer. He hence felt compelled to declare:-

> *"I grant there is a difference between absolute true motion of a body and a mere relative change of its situation with respect to another body. "*

For nearly two centuries Newton's case for absolute space did not see much contest, but after Einstein introduced the special theory of relativity in June 1905 the concept of absolute space was no longer seen as tenable. Through his deep insights into the structure of space and time, Einstein was able to cast aside Newton's ideas of a fixed space in which the universe plays out its life. But there was a tradeoff involved. Even though special relativity does not rely on the constant nature of absolute space, it still has its absolutes. Absolute spacetime is a feature of special relativity which, contrary to popular belief, does not claim that everything is relative. Although velocities, distances, and time intervals are relative, the theory still sits on a theorised platform of absolute spacetime. In special relativity observers moving at constant velocities relative to each other would not agree on the velocity of a bucket moving through space, nor would they agree about the time that has elapsed during any bucket experiment, but they would all agree on whether the bucket was accelerating or not [20].

Einstein further expanded on his ideas of relativity in 1915, with his more famous theory of general relativity. Through this he incorporated acceleration and gravity, but even before the theory's publication he claimed that Newton's interpretation of the bucket experiment was partially incorrect. He did so in a letter which he wrote to Ernst Mach[10] in 1913 in which he agreed with Mach's view that Newton's bucket could be seen as spinning relative to the planets around it. Einstein even included "Mach's principle" into general relativity. The theory is based on the equivalence of gravity and acceleration, something which has been checked experimentally today to a high degree of accuracy. Hence, the behaviour of Newton's spinning bucket is, as Mach claimed, determined by the gravitational forces of all the matter in the universe. But this this leaves a problem remaining, as Einstein conceded and in that general relativity cannot explain the behaviours expected in Newton's two rock version of the experiment. This is because the vast emptiness which Newton suggested surrounding his two rocks and rope can be seen as a universe in which no matter exists and hence little or no[11] gravity is present. This leads all observers to agree when the rock system is spinning through acceleration.

In 1918, however, Joseph Lense and Hans Thirring[12] obtained approximate solutions for the equations of general relativity for rotating bodies. Their results show that a massive rotating body drags space-time round with

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[9] Gottfried Wilhelm Leibniz was a German mathematician and philosopher.

[10] Ernst was an Austrian physicist and philosopher, remembered for his contributions to physics such as the Mach number and the study of shock waves. As a philosopher of science, he was a major influence on logical positivism and through his criticism of Newton, a forerunner of Einstein's relativity.

[11] . It is possible to argue that there will be gravity produced by the mass of the rock system, but this is negligible and will not produce the necessary *forces* to make the rope become taut.

[12] Josef Lense and Hans Thirring were Austrian physicists.

it. This is now called “frame dragging” or the “Lense-Thirring effect.” In 1966 Dieter Brill and Jeffrey Cohen showed that frame dragging should occur in a hollow sphere and in 1985 further progress by H Pfister and K Braun showed that sufficient centrifugal forces would be induced at the centre of the hollow massive sphere to cause water to form a concave surface in a bucket which is not rotating with respect to the distant stars.

Frame dragging has recently been verified experimentally. This involved using the rotating Earth as the massive body and putting a satellite into orbit with a gyroscope which kept it pointing in a fixed direction. Although the Earth has only a tiny frame dragging effect it was possible to detect the extremely small deviation of the gyroscope which it caused. A report of the experiment can be found on the NASA web-site [99].

Berners-Lee’s Box

So why this digression into physics again when we are supposed to be discussing information and computing? Some, like Isaac Newton, argue strongly that the universe must be finite and complete, whereas others, like Einstein, place less emphasis on such absolutes. Even so, all still rely on the need for some form of fixed context or background to make their ideas work. Newton reached out and proposed constraining raw space, while Einstein extending this proposition to incorporate the changing vista of spacetime. Furthermore, the broader scientific community appears not to be in dispute about what is using this background context. At its most basic level that thing is “information” and its use within any background context we have commonly come to known as “computation”. Hence the link and a reminder of the proposition the physics is simply computing and computing is simply physics.

All physical systems contain information by their very constitution. Atoms have a certain number of parts and occupy certain points in spacetime at a given point in the universe’s history. This is all information and as it changes over time to create the very fingerprint of reality itself. In addition, our most fundamental understandings of reality, the nuts and bolts at the base of quantum mechanics itself, suggest that all the matter can be seen as being entangled regardless of any notion of space. Everything is simply capable of informational connectedness regardless of its position in the universe and the ongoing dance of everything around it.

Now, take a step back for a moment and think of the World Wide Web instead. Here too can be found an informational space which some would see as finite. Others, on the other hand, would prefer to lean towards a definition more closely aligned with infinity. Also each blob of information contained within the Web possesses the innate capability to link to all others, as if entangled without regard for the differences or similarities between it and everything else. To some, in fact, the model of the Web is deeply analogous to physical models of the universe and, for them at least, many strong parallels exist. What is particularly useful about the Web, though, is that as a model it has undoubtedly gained great acceptance and credibility through direct interaction and use, indeed more so, one could argue, than all of science’s interactions with the natural world to date. This raises a huge potential in that if the Web can indeed be considered as being analogous to the universe, then might we not use it as a platform for experimentation to try and confirm or extend our understandings of reality itself? Could Tim Berners-Lee’s child be considered as the equivalent of Newton’s absolute space or Einstein’s absolute spacetime? Only time will tell, but herein can be found a beginner guide to try and find out.