THE WILSON'S INTRIGUE

STEM Issue 7: February 2022

BIO-CHEM
Mutant Catfish

ENGINEERING
Quantum Dots

MATHS
Group Theory

PHYSICS
Exoplanets

Introduction

Autumn is always a busy term for our writers and editors, but the Intrigue team has been broadening its understanding of new STEM concepts this term, ranging from whole brain emulations to reversing entropy.

This issue is particularly special as it welcomes a new generation of writers through the winners of the Intrigue Essay Competition (see page 5) while bidding farewell to the current set of editors.

The team of writers and editors is very proud to welcome you to the seventh issue of the Wilson's Intrigue STEM, written for students by students.

Our Mission

- Expand your knowledge
- Contribute to the Wilson's community
- Make complicated parts of science more accessible
- Popularise science and make it more interesting
- Inspire creativity through wider research

Acknowledgements

This issue would simply not be possible without the perseverance of the writers and editors, skilfully balancing their school and super-curricular explorations. Their intrigue for STEM and enthusiasm to share their research are the fundamental pillars of the magazine. A massive thank you to all students involved for their contributions!

A special thanks must go to Mr Benn, Mr Carew-Robinson, Dr Cooper, Mr Jackson, Mr Lissimore and Miss Roberts for once again proofreading and verifying the accuracy of our articles and the magazine as a whole.

If you would like to write in the eighth issue of the STEM magazine to indulge in researching and sharing a STEM curiosity, please email Ishan and Aadin at *MAKKARIS@wilsonsschool.sutton.sch.uk* and *PATELAAD@wilsonsschool.sutton.sch.uk* for more information.

Founded by Devanandh Murugesan and his team of editors in September 2019

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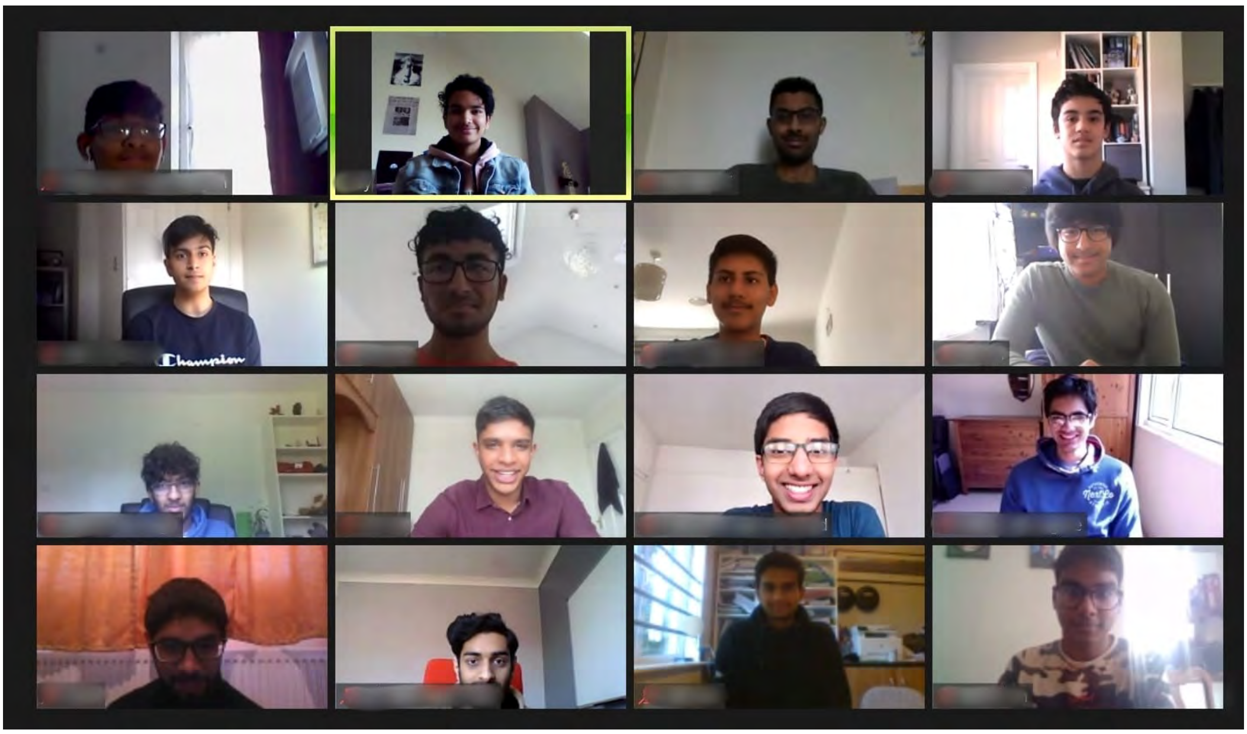

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Intrigue Essay Competition

During the summer term, pupils in year 7 - 9 had the opportunity to write as part of an exciting Intrigue Essay Competition With a word limit of 600 words, writers could explore anything and everything that fit the STEM description.

We were overwhelmed by the number of entries so a massive congratulations to all those who took part, and we hope you thoroughly enjoyed this experience of taking the time to explore a subject further, and will aspire to join the Intrigue team in the future!

With so many entries, it was particularly difficult to shortlist writers given the excellent calibre of journalistic flair on display in many of the articles but the judges would like to give particular congratulations to:

Honourable Mentions:

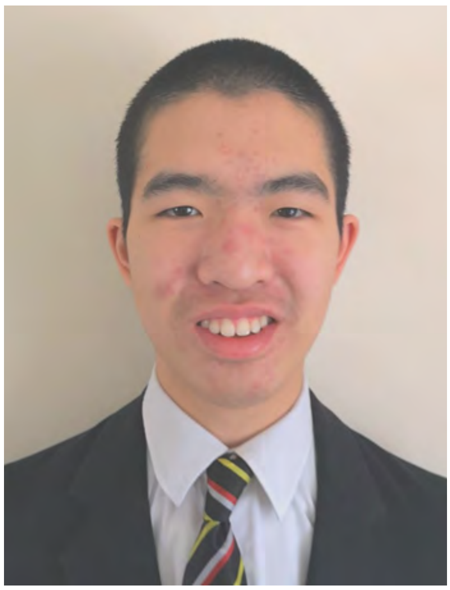
- Sajid (Year 8) writing about "Multiple Sclerosis"
- Farell (Year 8) writing about "Founder of DNA"
- Kharanshu (Year 8) writing about "5G"

YEAR 8 Best Article:
Shourya on Exoplanets (left)

Year 10 Best Article
Poorwa on Kardashev Scale (right)

Year 9 Best Article and OVERALL WINNER: Henry on Mutant Catfish

The judges found Henry's article very well written and focussed, taking consideration of a variety of factors. SPaG and grammar were also flawless within this article. They also found the voice within the article and the narrative that he follows unique and captivating.



The winners' articles can be found in the relevant section in this issue of the magazine.

DID YOU KNOW?

The transfer of pollen is key to the survival of angiosperms (flowering plants) but it only has a lifespan of two hours. The outer-coating, called the exine, however is so durable and long lasting that pollen trapped in sedimentary rocks can be studied, in a field called palynology.

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"Wherever the art of medicine is loved, there is also a love for humanity"

- **Hippocrates**

Can Induced Pluripotent Stem Cells Replace Embryonic Stem Cells in Research?

Are induced pluripotent stem cells the way forward in research?

By Ugas Jeyakanth (Y12)

Stem cells - a topic covered in Year 9 - can be different types: pluripotent embryonic stem cells can differentiate into most types of cell, and multipotent adult stem cells can only differentiate into the cell type that makes up the tissue around them. However, in 2006, Shinya Yamanaka and Kazutoshi Takahashi demonstrated that it is possible to reprogram the somatic cells of mice (cells that are not reproductive cells) to function like a pluripotent stem cell, by introducing different pluripotency-associated genes - known as reprogramming factors - to mouse embryonic fibroblasts [1]. In 2007, Yamanaka and James Thomson of the University of Wisconsin-Madison independently created the first human version of this type of cell, each using different sets of reprogramming factors [5]. These cells became known as induced pluripotent stem cells (iPS cells).

What are iPS cells and their uses?

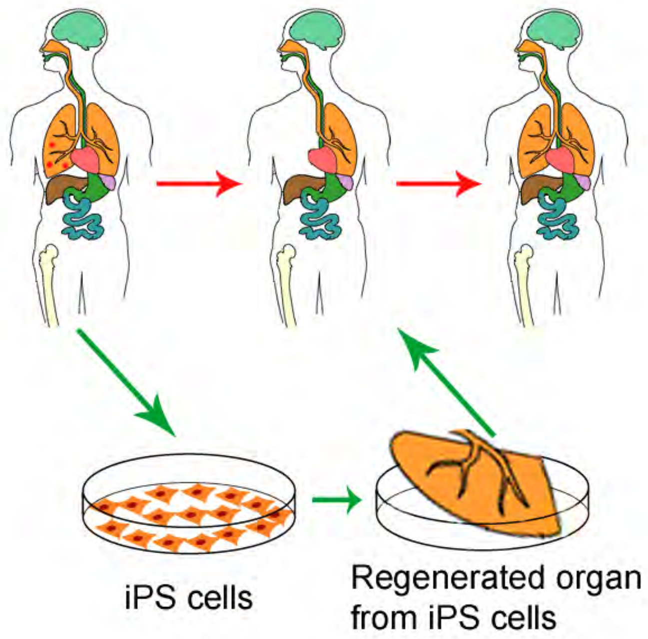
iPS cells are cells that are found in skin or blood tissue which are reprogrammed to a pluripotent state (behave in the same way that an embryonic stem cell would) which creates an unlimited source of any human cell type (for example, they can differentiate into blood cells to treat people with leukaemia) [2].

This creates a new type of regenerative medicine (replacing damaged tissue or organs with healthy ones), as, previously, tissue-specific cells could only produce like cells: new tissue formed with iPS cells can now replace most damaged tissue.

Disease modelling can also make use of iPS cells, as they can differentiate into any cell type of the body, and therefore can be used in preparing different disease models to study those pathological processes, particularly useful for neurodegenerative disorders such as Parkinson's disease as neurons are lost so it is difficult to study its underlying mechanisms [3]. This is also important because other cells derived from the body no longer grow after a certain period in laboratory culture. By using these iPS cell disease models, better treatments can be developed.

Another use of iPS cells is drug development - they can differentiate into specific somatic cells on which the drugs can be tested. This reduces the need for animal models, which are of limited effectiveness because drugs that affect animals may have no impact on humans and because chemicals may be more toxic in humans than in animals. The cost of pre-clinical trials is drastically reduced, as animal models can be replaced by iPS cells to estimate the bioavailability* of a new drug.

What are the benefits of iPS cells compared to embryonic stem cells?



A simple representation of how iPS cells can be used in organ regeneration [8]

Both iPS cells and embryonic stem cells are pluripotent, meaning they can differentiate into most cell types, so they are both effective in carrying out the processes above. However, iPS cells offer several advantages over embryonic stem cells. The most important one is that there are ethical concerns over the fact that obtaining embryonic stem cells kills the embryo [4], which is considered immoral by those who believe that human life starts at conception. On top of that, even though these stem cells are taken from "excess" embryos from IVF - it is also unethical to acquire these embryos when improper incentives are at play. iPS cells avoid this issue as they are obtained from the patient's skin or blood cells after informed consent.

The fact that iPS cells are autologous means that there is a reduced risk of immunorejection because the new healthy cells inserted into the patient have differentiated from the iPS cells, produced by the patient's somatic cells, avoiding histocompatibility* issues. Embryonic stem cells come from foreign embryos, so the transplanted stem cells have a high rejection rate (graft vs. host disease from an allogeneic* transplant).

What is stopping iPS cells from being used?

There are a few reasons why iPS cells are not used on a large scale. One important reason is that there is a low-efficiency rate of reprogramming the somatic cells into iPS cells, as low as 0.02% in certain non-dividing cell types [6]. Another concern is the retroviruses used in the production of iPS cells can insert their DNA in the genome and induce a cancer-causing gene expression, but non-retroviral methods of creating iPS cells have an even lower efficiency.

The gene set that is used to reprogram the somatic cells is also an issue as they can cause cancer; for example, the expression of Oct4, Sox2, Klf4, and c–Myc genes is associated with the development of multiple tumours [7].

While iPS cells have numerous benefits in patient healthcare and are bound to revolutionise medicine in the future, they are a long way away from cell line development. Until a gene set less prone to triggering carcinogenic gene expression can more efficiently induce pluripotency is found, this revolution has to be put on hold.

Glossary:

Bioavailability: The proportion of a drug or other substance which enters the circulation when introduced into the body and so is able to have an active effect

Allogeneic: Relating to tissues or cells which are genetically dissimilar and thus immunologically incompatible

Histocompatibility: When the body's immune system recognises cells as 'self' because of the nature of their cell surface proteins

Edited by Ishan Makkar

Intrigue Y9 Winner: Radioactive Fish in Chernobyl

By Henry (Y9)

The infamous 1986 Chernobyl disaster not only affected the media, but has also long affected the environment around it. Because of the proximity of the Chernobyl Power Plant to nearby bodies of water, a large number of aquatic species have been affected [1].

One of the most striking examples is the Wels Catfish, a large, muscular catfish that resides in most European waters. These fish can reach gigantic proportions – in the UK they are not native and are also not as large as those found on mainland Europe, where they have been confirmed to reach sizes of 144 kg and 2.78 m in length [2]. In the cooling ponds of Chernobyl, they are often claimed to be radioactive mutants who have grown to unusually large sizes. However, these claims about radiation being the cause have no concrete proof. The fish have, however, reached lengths of 1.65 m in Chernobyl [3]. "Very, very few mutations lead to extra-large size," explains radiation specialist, Dr Timothy Mousseau [4]. This eliminates the chance of radioactive mutation being the cause of their growth.

This now raises the following question: what is causing these fish to grow to such large sizes, in such a seemingly unforgiveable environment?

First, we must take into account that being large is very energy-consuming. This must mean that the fish have a plentiful supply of food, and little competition. Being one of the largest freshwater fish in Europe is good reason for the fish not having much competition, since they can quite easily scare off other species and consume smaller fish. They are also one of the most aggressive species of fish in Europe – there is BBC footage of these catfish eating pigeons, as well as numerous reports of these fish attacking humans [5, 6]. With this reputation, it becomes apparent why they have so little competition.

But surely this reputation will not aid it in catching prey if there is no prey?

Actually, contrary to what one would expect, the cooling ponds of Chernobyl are not entirely devoid of life. In fact, far from it. There is a plentiful supply of small (not that a fish has to be small to fit in its own mouth!) fish, that can often be seen in the footage of the 'mutant' catfish.

The final part of the guide to being big is to have a long life. On land, when the weight of a creature exceeds its volume, it would simply collapse. Ever noticed how elephants, the largest land animal today, are dwarfs in comparison to whales? That is because underwater, buoyancy and gravity essentially cancel each other out, and so aquatic wildlife keep growing for as long as they live. With a lifespan of 60 years, Wels Catfish have plenty of time to pack on the pounds [7].

So it was not radiation that made them grow so large; it was just a wide variety of environmental factors that are found exclusively in Chernobyl's cooling ponds. I still would not recommend eating them though!

Edited by Atharva Narkhede

A mutant catfish in Chernobyl

Antimicrobial Resistance

By Ishan Makkar (Y12)

The World Health Organisation (WHO) has declared that antimicrobial resistance (AMR) is "one of the top ten global public health threats facing humanity", with implications of it being a global health and development threat. But why? What is AMR and why should we be concerned about it? [1]

The Origin Story

Antimicrobial resistance is, by no means, a recent discovery. In fact, at his Nobel Prize Lecture in 1945, Alexander Fleming described the emergence of antimicrobial resistance, stating "It is not difficult to make microbes resistant to penicillin in the laboratory", following on with, "…and the same thing has occasionally happened in the body." Over seventy years later, this observation has spiralled into what could be a chaotic pandemic in the future, yet one that has often been underestimated .

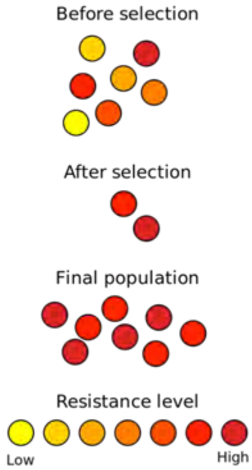
As defined by the WHO, AMR occurs when bacteria, viruses, fungi and parasites change over time and no longer respond to medicines - a process known as evolution by natural selection.

Natural selection is composed of six main stages, which help drive evolution:

- Mutation
- Variation
- Competition
- Selection pressure - *any environmental factor that favours the survival of one phenotype over another*
- Survival of the fittest
- Pass on

In the context of AMR, the steps below outline how the process would occur:

- A microbe gets a random **mutation**, which causes **variation** in a population. This mutation can be beneficial (advantageous) such as drug resistance.
- There is **competition** as these microbes compete for food/ water/ space, resources that allow them to grow and asexually reproduce.
- The **selection pressure** is the use of/ exposure to antibiotics.
- The **survival of the fittest** deems that the drug-resistant microbes will survive when the antibiotics are used.
- Resistant microbes will survive and rapidly divide (reproduce) in an environment with reduced competition following exposure to the selection pressure and **pass on** the genes that confer resistance to the drug .



A diagram illustrating the process of natural selection

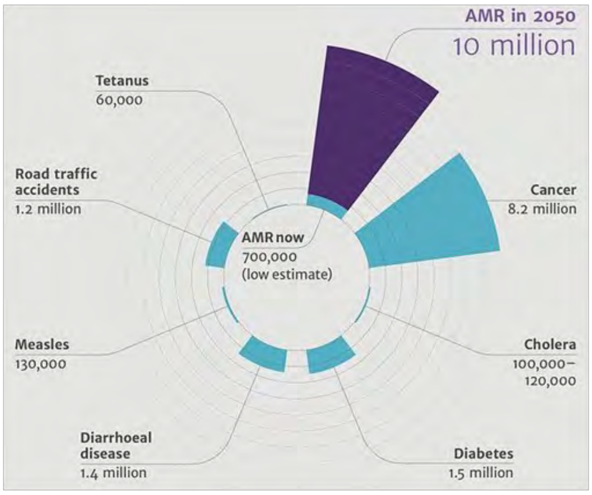
This process could repeat with multiple mutations conferring resistance to multiple antibiotics to make multi-drug resistant microbes. The percentage of microbes with microbial resistance in the population increases. Over many generations, this causes the evolution of the species.

AMR can also arise through the sharing of advantageous genes between microbes, caused by mobile genetic elements (MGEs). There are three key types[2]:

- Plasmids - Small circular strands of DNA found in the cytoplasm of a bacterial cell
- Transposons - Sequences of DNA that can be incorporated into chromosomal DNA and change the activity of the cell
- Phages - Viruses that can carry DNA between microbes

The Mechanisms of Resistance

When considering cellular biology, there are many complex structures and processes that can cause antibiotic resistance. One such mechanism is active efflux [3]. Efflux pumps are transport proteins, present on the cell membrane, involved in homeostasis - they expel toxic substances, e.g. antibiotics, within the bacterial cell into the external environment. This is an active process and as such, requires a source of chemical energy to function. One example are the *tet* determinants which provide resistance against tetracyclines . There could also be pumps present that can limit the uptake of a drug, preventing medicines from entering the cells entirely. Going one step further, drug-resistant bacteria can produce enzymes that cause the inactivation of antibiotics. For example, β-Lactamases make β-Lactam antibiotics, such as penicillins, inactive by degrading their chemical structure, which inhibits the cross-linking of peptidoglycan   (a polymer used in cell walls to maintain its structural integrity). Lastly, the drug target can be modified. An example of this can be seen with a specific type of antibiotic called quinolones. These target the gyrase genes that are associated with the coiling and supercoiling of DNA. The quinolones prevent this from occurring and so the bacterium is unable to divide and reproduce. However, if a mutation occurs, the activity of the quinolones is blocked and are rendered ineffective.



Dangers

With the COVID-19 pandemic having taken over our lives for the past 2 years, many concerns about antimicrobial resistance have been side-lined. Yet the dangers are still very much present. According to statistics published by the British Government in 2019[4], 700,000 people are estimated to die from drug-resistant infections - such as MRSA - each year, a significant number when compared to other diseases such as cholera or measles. In a report by Jim O'Neill in 2014, he predicted that by 2050 AMR would be responsible for ten million deaths globally.

The prevalence of antimicrobial resistance is mainly driven by the misuse and overuse of antimicrobials - many people mistakenly believe that they can be used for a broad range of conditions such as viral infections, when this is simply not the case. This may also be, in part, doctors being overly willing to prescribe antibiotics if a patient requests medication. Whatever the cause, the British Government predicts a three times rise in global antibiotic consumption by 2030. As explained above, when exposed to this selection pressure, microbes which have an advantageous mutation will successfully reproduce and increase their populations - if, for example, antibiotic courses are not completed. The world's healthcare systems desperately require new antimicrobials but that is easier said than done. Since the 1980s, there have been no new classes of antibiotics discovered and made available for use in treatments. Antimicrobial resistance hinders our ability to treat common infections and as antimicrobials become increasingly ineffective, the cost to healthcare systems increases significantly. In the same report, Jim O'Neill also predicted that AMR would result in a total GDP loss of $100.2 trillion by 2050[5].

To conclude, there have been growing concerns about the rise of AMR in the last 20 years yet little action has been taken. It is up to the work of individual governments and the WHO to ensure that diseases once thought to be under control do not haunt our future.

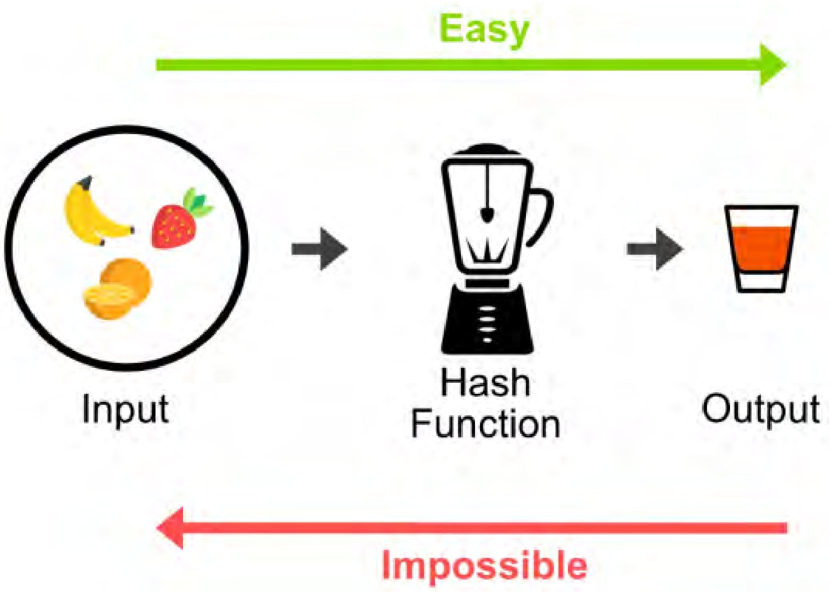
Edited by Aditya Jain

DID YOU KNOW?

A computer bug is a error, often in the coding, that causes a program to crash. The first computer bug was in fact an actual bug: in 1947, Grace Hopper was working as an admiral on a Mark II computer when she discovered a moth was stuck in the system causing the malfunction.

"Computing is not about computers any more. It is about living"

- **Nicholas Negroponte**



One Way Functions

By Jonathan Peter-Rajan (Y12)

Imagine this - you are a spy and you want to send a letter containing secret information back to your national intelligence in such a way that if it were intercepted by other governments, they would struggle to decode the message.

How would you go about doing this?

Most probably, the first thing that would've come to your mind is to apply some type of cipher (which is a fairly straightforward process) to your letter so it appears to be plain gibberish and this would make it very difficult for any third-parties to decode the message. However, this does not necessarily guarantee complete security since if anyone wants to decrypt the message, they can do it with ease if perhaps they spot a pattern and discover the cipher applied. So how do computer scientists go about securely encrypting digital information which is vital for ensuring that everything from personal data to entire digital financial infrastructures do not get jeopardized because the encryption was decoded?

One-way functions

In mathematics a function parallels a machine which follows a set of rules to provide a corresponding output for every input. This helps us understand what one-way functions are: a type of function where computing an output from an input is relatively easy but it is extremely difficult to revert the output back to the input (compute the inverse function). By contrast, two-way functions are easy to reverse. An example of two-way function would be demonstrated through the equation y = 3x; when we apply the input (x) of five, we get an output of 15 and in the same way, if we know that the output (y) is 15, we can easily solve to show that the input is five.

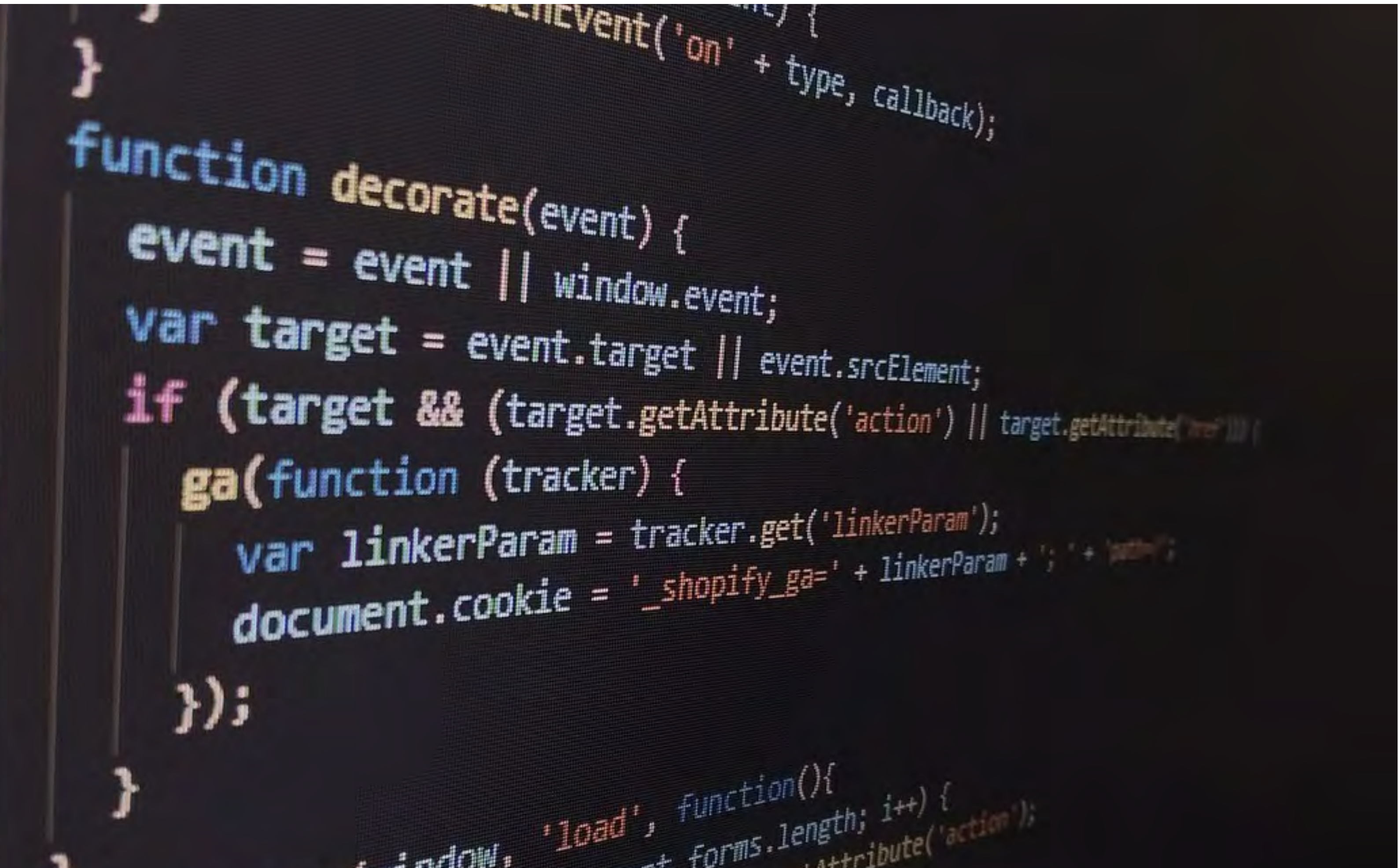
Examples of one-way functions in practice can be exhibited by factoring semiprimes and the modulus arithmetic. For example, let's take two primes (13 and 29) and multiply them to get a semiprime (377). It is difficult to find out the input (x and y) from the output (xy), which involves factorising xy in order to inverse the function. The reason why this is computationally complex (especially for cases where x and y are hundreds if not thousands of digits each) is because a computer has to systematically guess, searching through a massive list of numbers to only find two. It is so complex to do this with very long numbers that even the world's fastest computers would take years to brute force the solution. Since it is easy to multiply two primes but challenging and very resource/time consuming to factor the output, the factorisation of semiprimes is considered a one-way function. Factoring primes is also known to be a trapdoor one-way function since if one has additional secret information (e.g., one of the primes that factor the semiprime) one could very easily find the other prime(s) - this makes it useful in public-key encryptions. In the case of modulus arithmetic, let's take 27 mod 5 = 2 (where 27 is the input and 2 is the output). If we were to find the input knowing that x mod 5 = 2, it would also be computationally complex since there are an infinite number of possibilities for x and it is difficult to figure out which one of the possibilities is the input. Once again, this shows how one-way functions are easy to compute and are computationally complex to compute their inverse functions.

This feature of one-way functions makes them a fundamental aspect of modern-day cryptography. For example, they are applied in the RSA algorithm giving birth to the first public-key encryption, which heavily uses factorisation of semiprimes and modulus arithmetic. RSA encryption is widely used to securely transmit data across the internet such as e-mails and digital transactions. The way RSA works is that person a encrypts their message with person b's public key, which can only be decoded by person b's private key. In RSA, the public key is made by generating a very large semiprime and the private key is made involving the prime factors of the semiprime - it follows the principles of a trapdoor one-way function.

Although the idea behind one-way functions is simple, they aren't formally proven to exist - the examples shown above are merely candidates for one-way functions. This is because we cannot prove that finding the output by inverting the function is very hard because there is no guarantee that a polynomial time algorithm would be developed to do this easily in the future. A discovery of a proof that determines the existence of one-way functions would be revolutionary since it would lead on to answer a Millennium Prize Problem (where the discoverer of the solution would be rewarded $1 million) whether P = NP. To summarise, P refers to problems which can be solved by an algorithm and verified to check the solution is correct easily and NP (nondeterministic polynomial) refers to problems which are too computationally complex (like one-way functions) but the solution can also be quickly verified. Thus, the problem of P = NP questions whether every problem whose solutions are easy to check for correctness are also easy to solve. If one-way functions are proven to exist, then P is proven not to equal NP (since a one-way function is an NP problem - if it is proven not to be able to be solved easily it cannot be a P problem as well). On the other hand, if one-way functions are proven not to exist, then P = NP is confirmed and this discovery would immediately lead to improvements in computing efficiency and many problems would be solved much faster.

In conclusion, as long as P doesn't equal NP remains commonly accepted, one-way functions will continue to keep our online payments, messaging and data storage safe and secure because it would be nearly impossible for hackers to invert the function which is needed to decode the encryption.

Edited by Mann Patira



Compilation

By Jesse Luo (Y11)

Every time you use a website or a piece of software, be it the latest triple-A game, or something simple like Gmail or Spotify, you are using the work that hundreds, if not thousands of software engineers have painstakingly coded, often consisting of millions of lines of code across thousands of files in many programming languages. This complicated process might be even more complicated if not for the *compiler, a piece of software that converts high-level languages to machine code.*

What is a compiler?

Languages like Python are designed to be as easy to use as possible for humans, which is why the syntax for these languages looks a lot like everyday English. Put simply, a compiler is a piece of software that acts as a translator between these high-level languages and machine code, which consists of entirely ones and zeros. Compilers are used in computers just like how you might use Google Translate and converts a text file of code into an executable file of machine code [1].

How does a compiler work?

For compilers, three tasks need to be tackled. Firstly, the 'words' (or lexemes) written in the coding language need to be read, and each character in the code needs to be divided in a process called tokenising [2] .Secondly, these bits of code need to be re-ordered into the right order after analyzing the logical flow of the source code, parsing, done by referring to the context-free grammar of the source code, which is just like grammar in human languages. Finally, all lexemes are generated into machine code, optimized, and then re-generated into the final machine code.

To tokenise, we first need to perform lexical analysis on the source code. This means listing every single character/lexeme in a list of tokens, ignoring spaces and line breaks. Each token can be put into categories, like operators (==) and variables ('Tuesday').

Next, the tokens are parsed. This means that each token is checked against the context-free grammar to see if they are 'valid'. Then, they can be put into a tree-like data structure called an abstract syntax tree, which shows the logical connections between each token.

While doing this, the compiler checks the grammar of the tree structure and can return errors as needed in a process called semantic analysis. Three main things are checked in this step – flow structures (e.g., if loops), labels, and types. [3A symbol table is also created which lists all the named objects in the source code, like variables (day) and functions (print), and puts them against equivalent terms in machine code, which would be different strings of 0s and 1s [4] .

Mapping the AST

The next stage of the process is the generation of the intermediate representation. Think of this like planning a draft before writing the final essay. In this step, the compiler takes the symbol table and the AST and generates an initial, intermediate form of the machine code that will be returned. In computer systems, resources like the number of registers available in the RAM are always limited, and so the compiler now moves on to attempt to optimise this intermediate code as much as possible.

One way of optimisation is through deleting any duplicates in the code. For example, if a variable is assigned a value, and then assigned a different value later on in the source code, the compiler will simply optimise to have the variable be assigned the final value to start with.

Another way of optimisation is through not implementing all instructions in a loop. For example, if you have a looping set of instructions that are always executed as many times per second as possible unless one instruction results in the change of some other variable in the code, the compiler will simply execute that specific instruction once.

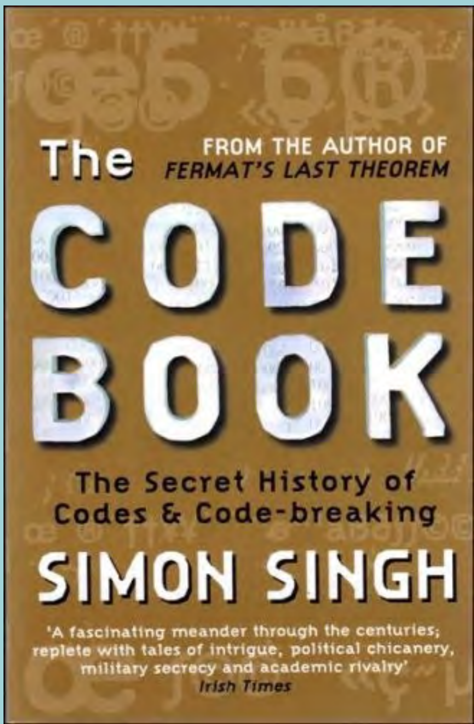
The final stage of the compiler is the final code generation. In this step, the compiler takes all optimisations that have been made and makes the final version of the machine code that is finally returned. The end of a laborious process.

Why should I care?

Good question. After all, a compiler isn't exactly a very exciting piece of software that everyone raves about. However, all software has to be coded, meaning compilers were coded in purely 1s and 0s.[5] Technology as we know it might not exist if not for people who developed the compiler, making it easier and accessible for everyone all over the world to use computers for hugely important reasons, like healthcare, education, and criminal justice.

Edited by Mann Patira

"THE CODE BOOK" by Simon Singh



Simon Singh aims to solve the unawareness about cryptography, introducing the fundamentals involved in developing encryptions and how they are decoded. His thorough explanation of this topic is intended to spark the reader's intrigue into mathematics and computer science by the end of the book since both these domains of STEM are shown to be important tools for cryptography. Not only this, the readers' perspective into these two domains are widened because it is easy for one to think mathematics is merely arithmetic and geometry and computer science is just for producing digital programs/applications.

Singh starts the book by taking us back to the 5th century BC where Greece was threatened by Persia, highlighting the importance of a secure form of communication. Thus, the first major form of cryptography – transposition and substation - were created. From here, Singh takes us on a trip through history, displaying how cryptography was used by the Egyptians, 16th Century England (Babington Plot) and finally cracking the Enigma during World War Two. Whilst showing the pivotal role cryptography played during these points in history, he also teaches how new, more rigorous forms of encryption were invented. For example, the rudimentary Caesar Cipher (made around 100BC) was made futile in the 16th century when Blaise de Vigenere built a polyalphabetic cipher. This was thought to be an "unbreakable cipher", but was easily superseded by the mechanical gadget called the Enigma (created by the German, Arthur Scherbius in 1918). Unsurprisingly, Singh then goes into great depth describing the heroic technical endeavours of Turning and his team at Bletchley Park to crack the Enigma. By doing so, he precisely emphasizes the crucial role cryptography played in shortening the war and as a result, saving millions of lives.

I believe that Simon Singh brilliantly encapsulates the field of cryptography, such that it left me a feeling of inspiration having been taken on this journey of technological advancements. By providing historical context to how cryptography has been used, the readers can, without a doubt, comprehend the sheer importance of encrypting data effectively when communicating. Furthermore, explains the concepts that enable encryption in depth by taking his explanation as easy to understand steps: from the underlying logic/mathematics used to example applications. He also examines each idea, providing their limitations and in what cases they excel. As a result, I found the way he structured the information to be very helpful to aid my understanding, bearing in mind that the concepts are quite complex.

By Jonathan Peter-Rajan

DID YOU KNOW?

The white trails, known as contrails, are the same as when you see your breath in winter. The much colder atmosphere condenses the hot humid exhausts causing streaks of condensed water vapour. This is often confused with jettisoning, which is the drop of large volumes of fuel from the plane.

Climate Engineering

What solutions can we create to solve this crisis? p20

Flying Cars

Are today's dreams tomorrow's reality? p22

"Scientists dream about doing great things. Engineers do them"

-James A Michener

Noise Cancelling Headphones

Can we finally free ourselves from the deafening world around us?

By Atharva Narkhede (Y13)

With active noise cancelling (ANC) headphones growing in popularity, despite their long existence, they have enabled you to relax and listen to music, intrusions-free. Arguably, all headphones cancel out noise to some degree due to the foam casing. However, ANC refers to this being done electronically.

The concept was conceived initially by Dr Lawrence Jerome Fogel, inspired by his involvement in the electrical and aerospace industries [1]. A few years later, on-board a flight from Zurich to Boston, in 1978, a man called Dr Amar Bose (the founder of BOSE) readdressed the concept. He came up with the idea due to his immense frustration with the loud noise from the jet engines disturbing his inflight entertainment. Bose then designed headphones that would listen and actively cancel out noise and by 1986 he had a prototype ready. He, like Fogel, intended to design them for pilots in the cockpit and military personnel, in order to improve communication and prevent ear damage. Eventually, the much desired product became available to first and business class customers on-board American Airlines and then, following economies of scale, the general public in the early 2000s [2].

How does active noise cancelling work?

All sound is transmitted in (longitudinal) waves and the mechanism for noise cancelling exploits this natural phenomenon. There are two microphones used: an internal one that detects the percentage of noise that enters through the foam or sound insulating properties and an external one that picks up external noise surrounding the headphones. Sound is erased when the microphones listen and signal to the internal speakers and electronics to generate a sound wave which is out of phase. They then feed this into the human ear, along with the desired audio from a device. This phase difference of π radians (or 180°), known as antiphase, means an oppositely shaped wave is generated and superposed onto the existing noise wave [3]. As a result, the two waves cancel each other out in another phenomenon which is known as destructive interference [4, 5]. The mechanism acts as a sound eraser. Only the desired audio remains!

However, ANC headphones are not perfect and come with their flaws. It needs a power source either in the form of disposable batteries, or nowadays, a recharge of the built-in rechargeable battery [6]. There are complaints about the noise cancelling, in which people hear the hissing of the technology. Also, not all undesired sound is eliminated and one reason for this is because noise (for example, that of loud cars) leaks through the headphones. This is because noise cancellation works best in environments with consistent background noise. Too much variation in sound means that it becomes increasingly difficult for the headphones to calculate and then generate a matching wave in antiphase. It may seem as though the problem is limited to this but that is not the case – frequency is also an issue. Timing the anti-sound wave perfectly with the ambient noise is quite difficult and so only around 70% of this is actually cancelled out [4]. Timing is so difficult because there are hundreds of compressions and rarefactions in certain frequencies so a lag of even five milliseconds will fail the active noise cancelling, hence proving higher frequency sound waves to be more difficult to cancel than lower frequency ones. To tackle this, engineers have integrated a high-powered digital processor within headphones to measure and calculate a close to exact anti-sound wave [7].

ANC headphones were mainly designed for pilots in aviation to deal with the loud repetitive noise of the jet engine. However, one can use them in regular commutes to block out noise from traffic or in formal settings like an office to block out background noise. However, in consumer markets, the integration into wireless instruments such as airpods pro, ANC seems to be used more for recreational purposes than its initially intended purpose.

Are active noise cancelling headphones worth it? Yes! They are a feat of engineering with exceptional execution. It is great to protect your hearing as you can listen to music at a healthy volume without the need to raise it to overcome environmental distractions. Overall, they offer a more enjoyable audio experience.

Edited by Aditya Jain

How Close are Flying Cars to Reality?

By Matteo Cascini (Y12)

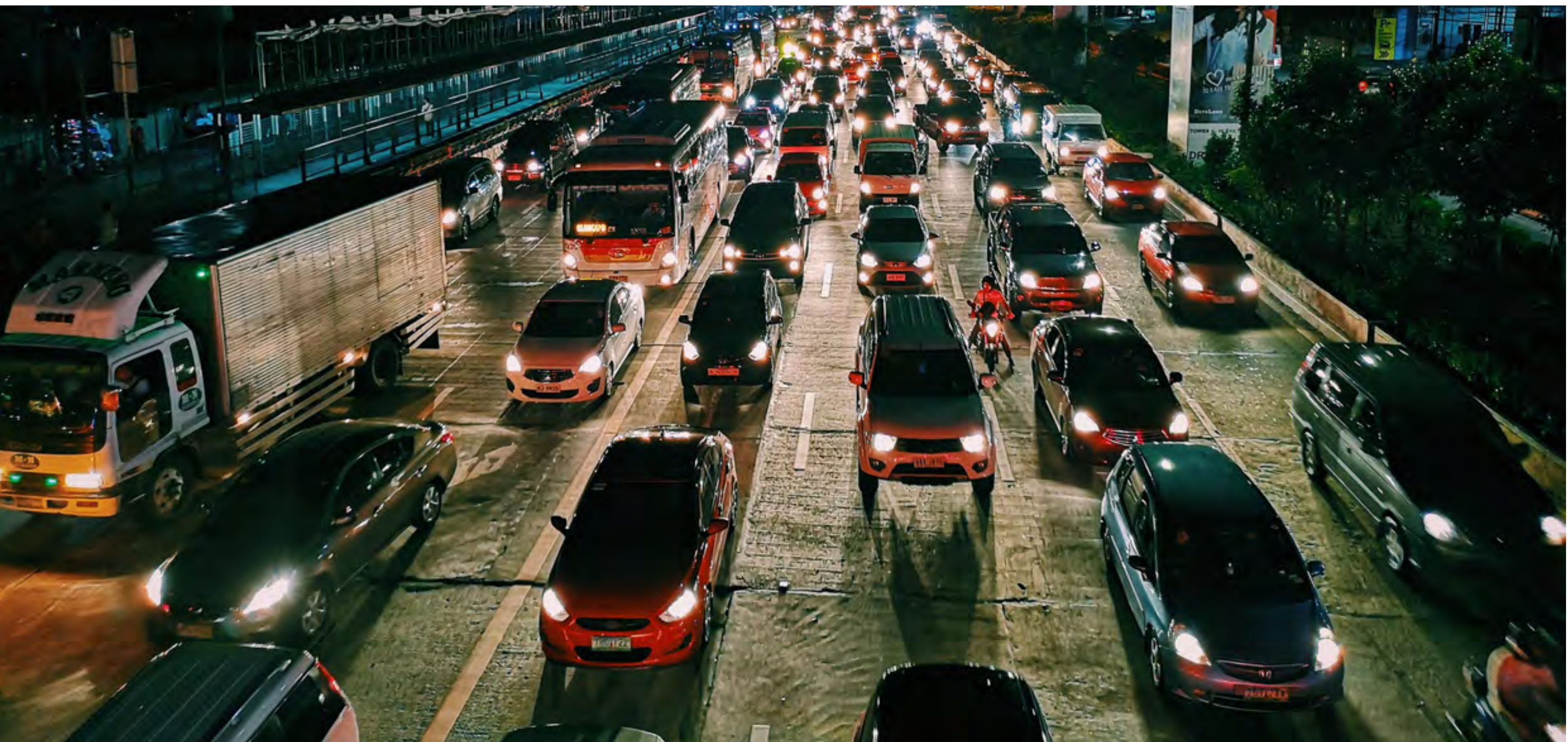
The 1947 ConVairCar Model 118

Roads? Where we're going, we don't need roads!" Many of us can probably remember watching the scene at the end of Back to the Future when the DeLorean leapt into the air, sending Marty McFly and Doc Brown thirty years into the future. However, nearly six years after the famous 21st of October 2015, could flying cars really become a reality in our near future?

In 1841, even before the Wright Brothers' first successful flight in 1903, William Samuel Henson and John Stringfellow patented the concept of a flying car. Unsurprisingly, a functional model of this monoplane never actually came to fruition. Indeed, there were many who experimented with the fantasy with projects such as the 1923 Pitcairn PCA-2 and the 1947 ConVairCar Model 118 (shown in the image above) which did manage to fly for over an hour, but an unexpected emergency landing ended their hopes [1]. The first promising road-to-sky vehicle came in the form of the Aero-Car (first flown in 1949). With its folding wings, this flying car was capable of reaching up to 60 mph on the road and over 110 mph in the air. It even managed to get certification from the CAA in 1956; however, due to a lack of interested buyers, only six of these were ever manufactured by the American aerospace company [2].

Over the remaining years of the 20th century, aerospace engineers continued to try and achieve the ultimate dream of flying cars. People saw the 1973 AVE Mizar – an invention that essentially saw a Cessna Skymaster being welded onto a Ford Pinto [3]. They also witnessed the M400 Sky-car: the first to try and use VTOL (Vertical Take-off and Landing) technology. While the VTOL idea had been around for many years, notably with the Harrier 'jump jet' used by many air forces around the world, the only successful civilian application of this has been the helicopter.

So why have we been so limited in the development of flying cars? Firstly, this type of new aircraft would be very expensive to fly – much more than the average Ford Fiesta. The large volumes of fuel would also greatly add to this cost in addition to the significant negative environmental impact which the combustion of this fuel would result in, such as the augmented production of CO_x and NO_x gases. Furthermore, it requires a much higher degree of training to pilot compared to a simple road car. On average, it takes a pilot over 55 hours of



training, which also comes at a very high private cost of over £8,000 usually, in order to receive their Private Pilot's Licence[4]. Therefore, for a flying car to work, it needs to be both affordable and as simple to fly.

However, the dream of being able to quickly transition from driving on your local roads to soaring in the sky has not yet ended. Major companies are starting to invest millions into developing our potential mode of transport for the future. For example, Uber has recently invested over $75 million (c. £55 million) into Joby Aviation's efforts for the Uber Elevate project. With over $820 million (c. £600 million) invested into the aviation company in total, it is trying to build an electric VTOL air taxi service that provides an alternative to overly crowded roadways in large urban areas, with the hopeful ambition to start services from the year 2023 [5].

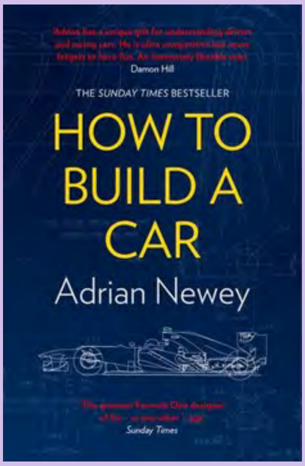
The Klein hybrid car-aircraft

Recently, we have also seen start-up companies such as Klein Vision experiment with their hybrid car-aircraft. On the 30th of June 2021, a prototype completed a 35-minute flight between international airports in Nitra and Bratislava, Slovakia. Using a standard BMW engine running on petrol fuel, its creator predicts it will have a range of over 1000 km, a maximum altitude of 2.5km and a cruising speed of roughly 170 km/h. It functions by having narrow wings which fold down the side of the aircraft in only two minutes and fifteen seconds. With the sector predicted to be worth over one trillion pounds within the next twenty years, the founder Prof. Stefan Klein is hugely optimistic for the future of travel [6].

Therefore, in line with Robert Zemeckis' dream in Back to the Future, the coming years seem highly promising for the development in the aerospace industry looking at flying automobiles. So, whether it be flying taxi services led by companies such as Uber or monoplane cars from start-ups like Klein Vision, let's hope that where we're going, we won't need roads.

Edited by Ishan Makkar

"HOW TO BUILD A CAR" by Adrian Newey



In addition to learning about his inspiring career as an engineer, the most fascinating part of this autobiography is the exploration of the technical design process of the cars and the challenges contributing to it, with various informative freehand drawings scattered amongst the pages.

As an aerodynamicist, Newey began by working in a quarter-scale wind tunnel in the University of Southampton as an undergraduate student, investigating how to improve the aerodynamic performance of racing cars, which he has continued to do across the rest of his career as well. His role as an engineer is to solve the problems regarding the handling and performance of the racing car, and to identify all the loopholes within the rulebook to maximise the amount of speed gained from the car compared to the other competitors on the grid.

From complicated technologies such as active suspension to evolving the chassis shape to reduce turbulent flow of air, Newey has had to consistently adapt and resolve possible threats with creative and determined problem-solving skills in order to be at the top of his game and to achieve the best results for his teams. Evaluating every possible solution and never giving up were critical to his success as a motorsport engineer. Moreover, throughout this book, he has managed to portray this cycle of consistent evolution effectively and inspire others to always think outside the box when facing challenges whether that be in an engineering situation or any other profession as there will always be obstacles to overcome in life.

By Matteo Cascini

How Will Engineering Keep Up with Climate Change?

By Sarin Kulatileka (Y12)

January 2022, the beginning of a new year and time to reflect on the chaos of 2021. We've seen a mass die out of over one billion animals in Canada, the energy and water security of around forty million people in the Southwest US threatened, floods killing 120 people in Western Europe and a beachfront condominium collapse killing at least ninety-seven people in Florida. The consequences of human induced climate change are being felt around the world and we don't need to wait to see if it will get worse. For decades we've been focused on stopping it when now we should really be asking how we minimise the damage done by it.

The world's average temperature has risen by 1.2 degrees Celsius since 1850 leading to an increase in the frequency and severity of extreme weather conditions [1]. 2021 was the seventh consecutive year during which a hurricane formed (Storm Anna on May 22) before the season officially began (June 1st). This trend is more than likely to continue, leaving millions of people living in soon-to-be uninhabitable areas and numerous questions to be raised concerning our existing infrastructure.

In most cases, there may be no other solution than moving elsewhere. A record setting heat wave near Las Vegas, during which temperatures reached 49.6 degrees and cooked shellfish alive, coupled with an ongoing drought, has left Lake Mead only 35% full and at its lowest levels since it was built in 1936 [2]. Those in charge have resorted to lowering five of the seventeen turbines on the Hoover Dam to limit the effects of the dropping water levels yet still hydro power generated by the dam has fallen by 25% leaving the Southwest, currently laden with water restrictions, facing the possibility of an electricity shortage that the entire US might feel. Draining the Colorado River to support megacities in deserts may have once been possible - but only back when Colorado itself wasn't facing a drought.

Yet too much water is also a concern. Although investigations are still underway, it is thought that a contributing factor to the tragic collapse of the Chaplain Towers South in June, was a rise in sea levels along Florida's East Coast [3]. The corruption of the building's concrete foundation caused by the introduction of sea water may have played a major role. Concerns are now being raised in San Francisco, another coastal city, where its iconic Millennium Tower has sunk eighteen inches and tilted 14 inches since its construction in 2008. Joe Biden's two trillion dollar infrastructure plan aims to address the issue of climate change by drastically reducing carbon pollution in the USA,

primarily by speeding up the transition from more polluting vehicles to electric, charger-based ones and using renewable energy - money better spent on defending or relocating coastal populations some argue [4].

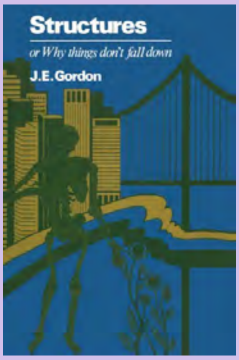
Whilst defensive techniques like sea walls and pumps have proven successful and could save cities like Miami and San Francisco, a more sustainable solution is needed for poorer nations if we are to stop 800 million people in at least 570 cities globally from losing out to rising oceans. In Germany, intense flooding has killed more than 100 people [5]. Warmer temperatures lead to more water evaporating. A warmer atmosphere means more moisture can be stored leading to a greater intensity and volume of rainfall. Towns in valleys and along riverbanks, especially those more densely built, will have to look towards river widening or barriers to combat such issues.

Tactics aimed more towards reducing the damage done as opposed to simply dealing with it include carbon capture methods [6]. Capturing carbon in the process of cement production for example removes it directly from the atmosphere without hindering the construction of new buildings. As the cement hardens, it absorbs CO_2 which also happens to help strengthen it. However, this may not be the most practical solution as increased costs rule out its widespread use especially in newly emerging economies where infrastructural development is at its highest, yet funding is often sparse.

There is no one solution to any of the challenges posed by human induced climate change however one fact is clear – this is no longer a threat we will face in ten, twenty or forty years, even if major nations managed to go net zero on carbon emissions by 2050 or even 2030. The damage is done. Protective measures need to be put in place and funding for infrastructure prioritised. COP26 sought to make game changing promises, yet some may argue it failed to deliver with major culprits like China and Indonesia pulling out of key deals and not even turning up. Our future on this planet is in our hands and we are failing to do anything about it.

Edited by Ishan Makkar

"STRUCTURES OR WHY THINGS DON'T FALL DOWN" by J.E .Gordon



I first picked up 'Structures or Why Things Don't Fall Down' since it promised an insight into the type of problems I will be trying to solve when studying engineering at university. I not only wanted to explore the subject of structures, but also understand its applications in nature, in technology and in everyday life. I have found it to be a well-written book that guides us through the history of the development of structures, providing key analysis and thoughts from the author, who is a prestigious professor of materials science at the University of Reading.

In a particularly interesting chapter, Gordon discusses the application of strain energy in weapons such as bows and catapults. He then suggests how the efficiency of these weapons has improved over time, which I found intriguing. Another topic I was enthused by was on bridges, and the advantages and problems arising from the use of different types of bridges: arch, cast-iron, suspension and the bowstring girder. This is followed by the chapter 'The advantage of being a beam', which offers a humorous insight into human creation through Gordon's observations on roofs, trusses and masts. Towards the end of the book, Gordon gets more philosophical when talking about the efficiency and aesthetics of structures, which I quite enjoyed, since it provided a nice contrast to the more practical approach earlier on. He criticises the relentless pursuit of profits and efficiency that in turn leads to a lack of beauty and culture, as one can so distinctly see when one looks around themselves in an urban built-up environment.

By Shanjeev Mathialagan

Quantum Dots - Minuscule in Nature, but Boundless in Potential

By Shanjai Mathialagan (Y12)

What are quantum dots?

Quantum dots are synthetic atoms that do not occur naturally in the world. These atoms are manufactured in a process called colloidal synthesis, involving nucleation, growth, and transformation, and are made from semiconductor materials such as silicon, lead selenide, or cadmium sulphide[1]. They are examples of nanomaterials, and so they are exceptionally small [2]. This gives them a unique set of properties which standard materials do not possess.

When ultraviolet light shines onto these artificial atoms, the high energy electromagnetic radiation causes an electron to be excited, and the electron moves to a higher energy level. When the electron moves back down to a lower energy level, it emits a photon of light with an identical wavelength and frequency as the electromagnetic radiation that was absorbed.

Quantum dots with the largest radius emit the longest wavelengths and lowest frequencies (red), while the dots with the smallest radius emit shorter wavelengths and higher frequencies (blue). This is because a small quantum dot has a larger band gap (which is the minimum energy required to excite an electron so that it can conduct electricity). Larger dots have a greater number of closely packed energy levels, so they produce lower frequencies of light, as they have a smaller band gap [3].

Solar Panels

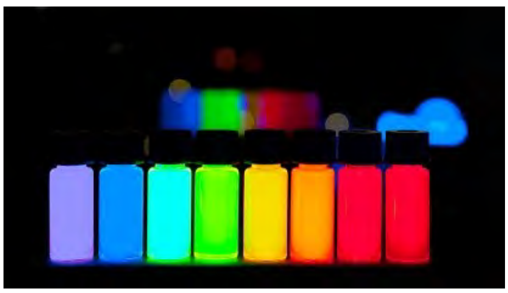
Quantum dot solar cells

In the rapidly evolving solar photovoltaic market, quantum dots have transformed the functionality and utility of solar panels across the globe. In standard solar panels, each photon of light is only able to produce one delocalised electron, whilst the rest of the energy is transferred into less useful stores, such as heat. Comparatively, the properties of silicon quantum dots enable each photon of light to produce up to three electrons, increasing the average efficiency of standard solar panels from 33% to 65% [4]. The consequences of this can be far-reaching in an increasingly environmentally conscious world. Flaunting its low power consumption, increased electrical performance and efficiency, quantum dot solar panels can be one of many solutions to our global environmental problems. The lower long-term costs and improved electrical output can encourage more homes and businesses to adopt solar panels on a small scale, but these solar panels can also be implemented centrally by governments for more widespread impact.

Quantum Dot Displays

With a market share of over 20%, Samsung has dominated the television industry for the last decade or so and their recent success and development of QLED and 8K technology relies heavily on advancements in quantum dot technology.

In a normal LCD (liquid crystal display) TV there is a blue LED (light emitting diode) coated in yellow phosphor, which gives off a white light. When this light reaches the RGB filters, the television can emit a range of colours. In a QLED TV, quantum dots are applied to a thin sheet of film, which is situated in front of the LED backlight, which illuminates an LCD. The quantum dot colour filter enables the LCD to reveal a wider, brighter, and more saturated range of colours [5]. In addition, since these quantum dots are so small, the resolution of the images are also significantly greater. The use of quantum dot technology has also



Quantum Dot Colours

enabled companies like Samsung and other television manufacturers to reduce the thickness and weight of large display televisions, whilst enabling them to enhance the performance, colour, sharpness, and contrast of their displays. Some other benefits that quantum dot displays exhibit include a longer lifetime, lower manufacturing cost, and lower power consumption.

Biological applications of quantum dots

With their fascinating optical and physical properties, quantum dots have proved useful in the medical and pharmaceutical industry. Their unique photoluminescence and electric characteristics make them very efficient fluorescent labels in drug delivery systems. For example, quantum dots can be used to deliver cancer-killing drugs. Bioconjugation means that we can attach drugs to these artificial atoms and we are able to deliver these drugs to the site where they are needed - there is high specificity and reduced side-effects as drugs are not delivered to healthy tissues. In addition, they could also potentially be used for cancer cell imaging. Specific antibodies can be attached to the quantum dots, so that when they are injected into the body, the quantum dots will be able to detect and bind to the cancer cells, illuminating them.

On the contrary, there are various hazards with using quantum dots for biological applications. For example, cadmium sulfide – commonly used in quantum dots - is a toxic substance and it could catalyse harmful reactions in the body. Hence, these types of quantum dots cannot be used for medical purposes, and alternatives may be necessary.

The unique set of properties that come with such small atoms provide beneficial advantages, whether this may be in the energy industry, medical industry or even the entertainment industry. The discovery of quantum dots can prove to be a ground-breaking invention, and their potential is yet to be reached.

Edited by Aadin Patel

ARKWRIGHT SCHOLARSHIP by Matteo Cascini

The Arkwright Scholarship is a prestigious award which aims to encourage young people to help change the world as future engineers. This year 289 students were awarded with the scholarship from an initial 1,300 following an intensive selection process, including a personal statement and a virtual interview. This involved completing an engineering-related project which I had to present to the board of interviewers: with my project being a product to assist remote music lessons during the pandemic, which I had designed as part of my GCSE DT NEA.

The Arkwright Engineering Scholarship scheme is a great opportunity for aspiring future engineers as not only do they provide you with both mentorship and funding, but there are also many rare opportunities as a scholar, including planned Connect Days at McLaren Technology Centre, Virgin Atlantic's Gatwick HQ and many more. For those interested in taking a career from a wide range of engineering disciplines from civil to aerospace to even chemical engineering, I would thoroughly recommend applying for the scheme as it will provide one of the strongest possible foundations for a future career in engineering.

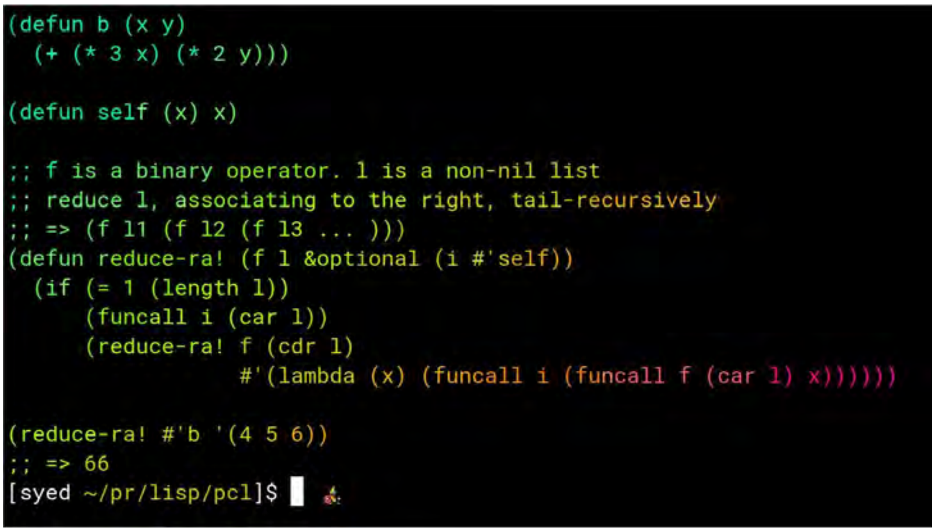
DID YOU KNOW?

Hexagons are the best shape to fill a plane with equal sized units with no wasted space, whilst keeping structural integrity (shapes like triangles and squares create rows and this makes them weak to shear forces). Hexagonal packing also minimises the perimeter for an area.

Disliking Maths
Why do so many people not like it? **p29**

Gabriel's Horn
A painter's paradox **p31**

> *"Maths is the only place where truth and beauty mean the same thing"*
>
> -**Danica McKellar**



Propositions in the Natural Number Game and Group Theory

By Syed Shah (Y13)

In our previous article on the Natural Number Game, we looked at how to prove statements of the form *LHS* = *RHS*. However, some statements are of the form *P* implies *Q* or "*P* is true". In this article, we look at how to prove them.

Propositions vs. Proofs

Lean - a functional programming language that is used to formalise pure mathematics - distinguishes between a proposition and its proof [1]. Fermat's claim in 1637, that $x^n + y^n \neq z^n$, is a proposition, and its proof is the paper Wiles published in 1995.

If *h: H*, then *h* is, internally, a *term of Type H*, but we interpret this mathematically to mean a proof of the proposition *H* [1].

Implication arrows as functions

Recall that the general structure of a proof in Lean is the following:

```
theorem <name>
<assumptions> : <goal> :=
begin
  <proof>
end
```

Consider example1:

```
theorem example1 (P Q R : Prop)
(p : P) (h : P → Q) (i : Q → R) : R :=
begin
  have q : Q := h(p),
  have r : R := i(q),
  exact r,
end
```

The first line of example1 states the assumptions: we have three propositions, *P*, *Q* and *R*, and a proof, *p*, of *P*. Furthermore, we have a function, *h*, which takes as input a proof of *P* and returns a proof of *Q*. This is the formal way of saying that *P* implies *Q* in Lean. Similarly, *i* is of the Type *Q* → *R*.

In our previous article about Peano's Axioms, our goal was to show that the left-hand side of an equation was the same as the right. However, our goal here is to show that *R* is true, given the assumptions in line one.

To prove *R*, we can now either start from *p* and work forwards or work backwards from *R*.

Working forwards, the command have q : Q := h(p) tells Lean we have a proof, *q*, of the proposition *Q*, and that we created this proof using the function *h*, acting on *p*.

At the end, the exact tactic indicates that we have found a proof of *R*, namely *r* [1, 2].

The have tactic only exists for readability. We could instead prove *R* with the command exact i(h(p)), because *h(p)* is a proof of *Q*, and *i(...)* is a proof of *R*.

Working backwards

If we instead work backwards, we use the apply tactic. This works on the principle that it is sufficient to prove *Q* in order to prove *R*, because we know by *i* that *Q* implies *R* [1]. Similarly, *h* tells us that *P* implies *Q*. Since we have a proof of *P*, *p*, we can close the Goal with exact p.

```
1. theorem example2 (P Q R : Prop) (p : P) (h : P → Q) (i : Q → R) : R :=
2. begin
3.   apply i,
4.   apply h,
5.   exact p,
6. end
```

Below is the `Goal state' after Lean runs each line above. Notice how the Goal changes from *R* to *Q* to *P*.

2. P Q R : Prop, p : P, h : P → Q, i : Q → R ⊢ R
3. P Q R : Prop, p : P, h : P → Q, i : Q → R ⊢ Q
4. P Q R : Prop, p : P, h : P → Q, i : Q → R ⊢ P
5. no goals

$(P \longrightarrow (Q \longrightarrow R)) \longrightarrow ((P \longrightarrow Q) \longrightarrow (P \longrightarrow R))$

Here is a more interesting example.

```
theorem example3 (P Q R : Prop) : (P → (Q → R)) →
((P → Q) → (P → R)) :=
begin
 intros f h p,
 exact (f p) (h p),
end
```

P → (Q → R) is equivalent to saying that *P* and *Q* together imply *R*. Assuming this is the case, is it true that *(P → Q) → (P → R)*? I.e. if we further assume that *P* implies *Q*, is it the case that *P* implies *R*?

The line intros f h p lets us name these assumptions. *f* is the assumption that *P → (Q → R)*; *h* that *P → Q* and *p* that *P* is true.

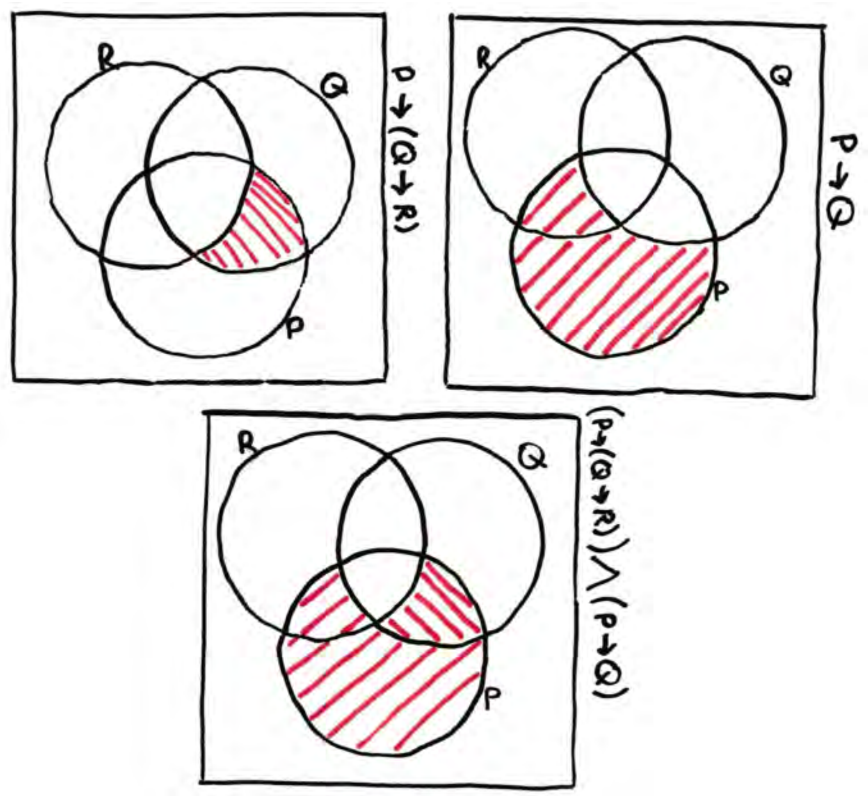
exact (f p) (h p) closes the goal. A lot is going on in this line. Remember that *f* is a function which takes as input a proof of *P* and returns another function of Type *Q → R*. This function takes in a proof of *Q* and returns proof of *R* [3].

We give to *f* the proof *p*, then give *(h p)* to the generated function. *h* is a function which takes in a proof of *P* and returns a proof of *Q*, so *h p* is a proof of *Q*. Therefore, *(f p) (h p)* is a proof of *R*.

(Note that *f p*, *f(p)* and *(f p)* are all the same thing: the function *f* acting on an input *p*.)

As an example, *P* could be the proposition that *n* is even; *Q* that *n* is a square number and *R* that *n* is a multiple of four. *P* does not imply *Q*, but that is fine, because our theorem asks the question, *If P implied Q,* would *P* imply *R*?

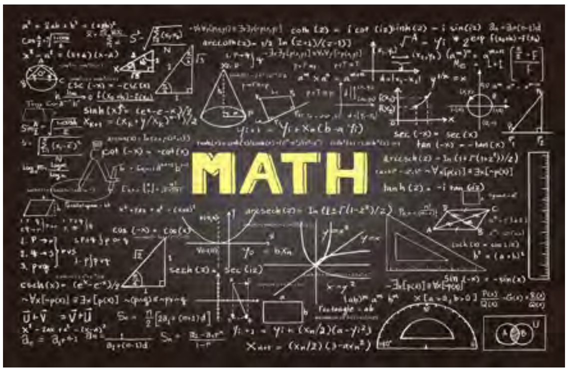
Edited by Nabeel Abdul Rasheed



The logical statement P → Q can be considered in the light of sets. Let P be the set of all situations in which p is true, Q be the set of those in which q is true and R be that for r. If P → Q, then it means that there are no situations in which p is true but q is false. Therefore, we exclude P → Q' from the Venn diagram. If P → (Q → R), then it means there are no situations in which p and q are true but r is false, so we must exclude P → Q → R'. Superposing the red, excluded regions shows us that, whenever p is true, r (and q) must be true as well.

Why do some people dislike learning Mathematics?

By William Lu (Y13)



Mathematical myths

Personally, I enjoy learning Mathematics as a subject. Unfortunately, not everyone else shares the same notion. Whether this is due to finding Mathematics boring, difficult, or even pointless; it is very clear that not everyone is excels at the subject. This may seem like a strange claim given that Wilson's is a "Maths school," yet in 2013 only 26% of American 12th graders (Year 13s) scored 'proficient' or better according to the 'Nation's report card' [1]. Does that mean 74% of American 17–18-year-olds are inherently bad at Mathematics, or is the education system to blame for a nationwide disinterest in the subject?

Obviously, the first statement is not true, after all 'hard work beats talent, when talent fails to work hard' (Kevin Durant, NBA player) [2]. This must mean that the education system is to blame for not doing enough to inspire people to enjoy exploring the 'incredible archipelago of knowledge' that is mathematics. However, that claim may not be entirely true either.

Maths Anxiety

It is rather common for people to classify themselves as 'not a Maths person;' and it is not exactly surprising, that some would say that they feel anxious before a Maths test. Across the 34 OECD countries, 61% of fifteen-year-olds say that they worry about getting bad grades in Mathematics [4] . Now underperforming in tests is a rational fear. However, with Maths anxiety many doubt their ability to solve questions well within their mathematical capabilities. It may seem that Maths anxiety is caused by being bad at Maths, yet often it is the other way round. Students avoid engaging with Maths, because they doubt their abilities, which in turn makes them underperform. This stems from a theory regarding 'working memory,' where the brain has a limited capacity to learn and process information [6,7]. Consequently, if a student is stressed and worried about a mathematical problem, they could end up limiting their ability to solve the problem.

This can lead to a student avoiding tacking Maths problems out of the fear of making mistakes, given that in Maths you either get the answer right or wrong. However, making mistakes is integral to a student's ability to learn in any subject, not just Maths. The problem may lie within society's perception of Maths as a subject, where one's performance at Maths reflects their mathematical ability, or the subject is a just a set of formulae to remember rather than a vast library of knowledge to explore. This could arise due to the linear nature of learning Maths; to progress to more 'challenging' topics, you need a good understanding of the basics. This can lead to the predicament when students with Maths anxiety avoid Maths, which leads to them 'falling behind.' The problem compounds if the student is too worried to ask for help, especially when under pressure to quickly solve Maths questions.

Unfortunately, there is no easy way to treat Maths anxiety. There are several practical strategies one could try, from writing about a past stressful experience to something physical like going for a walk. Furthermore, one of the most important ways to help overcome Maths anxiety is developing a growth mindset. This involves one being willing to take a risk, ask for help, and acknowledge that the notion that 'you're either good at Maths or not' simply isn't true.

Maths and its Applications in the *Real* World

People also dislike mathematics as a result of Mathematics being portrayed as too abstract or something for calculators to solve for us.

On the other hand, I would say that using a calculator without fully understanding the power of mathematics can be rather limiting. Georg Cantor (German mathematician) would even go as far and say that 'The essence of mathematics lies in its freedom [8].' Mathematics is extremely important to our everyday lives and having at least a general understanding of the subject can protect us from faulty mathematical models, misleading statistics, and the power algorithms have over us in this digital age.

Now as daunting as that may seem, there is a beautiful side to mathematics, in which complex problems can be answered with a simple and incredibly satisfying answer. An example of such would be the Möbius strip. For those not aware, a Möbius strip is a one-sided loop, which can be constructed by taking one end of a strip of paper, turning it over 180°, and gluing the two sides together. Besides being a cool party trick that you can show to your friends, the Mobius strip has a range of applications ever since its discovery in the mid-nineteenth century: old conveyer belts, recording tapes (doubles playing time), and even rollercoasters [10].

If we expand the scope of this field of mathematics (topology), we can learn about other wonderful non-orientable manifolds [11] (a shape from which you can translate the mirror image of a symbol on its surface onto the symbol's original position, only by sliding it around). A prominent example would include the Klein bottle, which is a four spatial dimension equivalent of the Möbius strip, where it only has one face. Technically, it can even exist in three spatial dimensions, where the closed loop intersects itself!

Should I learn Mathematics?

Now, obviously mathematics isn't the subject for everyone. Nevertheless, it is still a vital tool that is often underappreciated and overlooked by society. So many careers require at least a baseline understanding of the subject and it has a profound impact on our everyday lives, whether it be the algorithms behind Google search results, or even having fun on a theme park ride. Consequently, mathematics is a fascinating world of knowledge, which can not only be fun and exciting, but make us more aware about the way our ignorance can be used to misguide us.

Edited by Aadin Patel

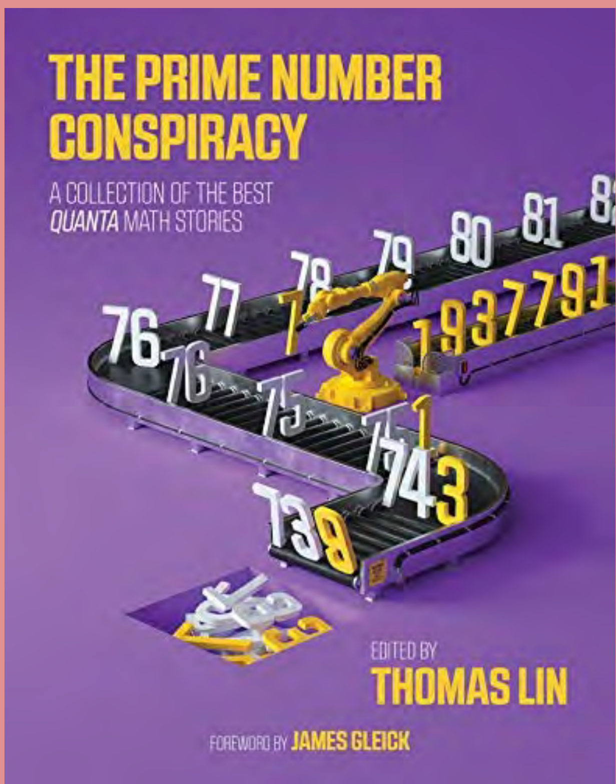
"THE PRIME NUMBER CONSPIRACY" by Thomas Lin

This was an amazing read that looks into lots of theories within mathematics, without the plethora of equations. Instead, for each theory, it looks at its development as a concept and the story behind it. This provides a narrative in our heads for understanding what can seem rather alien concepts.

My favourite story within this collection has to be the one about universality where the article seems to discover new information with you, as if you were part of the process in discovering it. This reinforces how maths can be for anyone whilst giving an experience of what it feels like to "discover" maths (something we don't necessarily feel when given formula sheet after formula sheet).

This is quite an accessible and intriguing read which I would highly recommend if someone wants to know more than just the theory but the backdrop to its discovery and the context to it.

By Divy Dayal



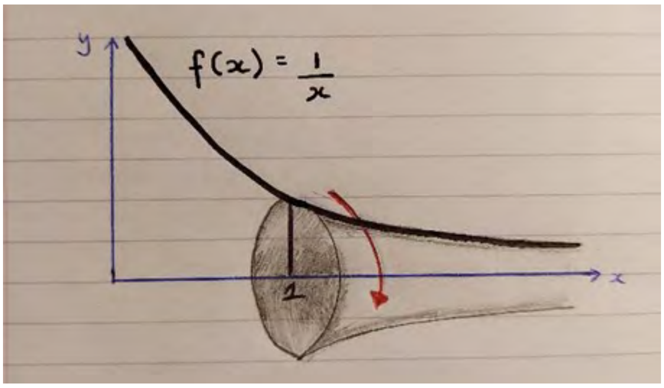
Gabriel's Horn

By Divy Dayal (Y13)

Gabriel's Horn is a paradox, a horn that you can fill with paint but never paint it. This is down to its finite volume but infinite surface area, and below we will go through the proof for this remarkable paradox. This paradox relies upon the converging nature of the sum of $1/x^2$ and the diverging nature of the sum of $1/x$.

Creating the horn

First we need to create a volume of revolution of $1/x$ from 1 to infinity. A volume of revolution is the equivalent of taking a graph and spinning it round the x-axis to produce a 3D solid. The horn is infinitely long but begins at one and this is very important to note.

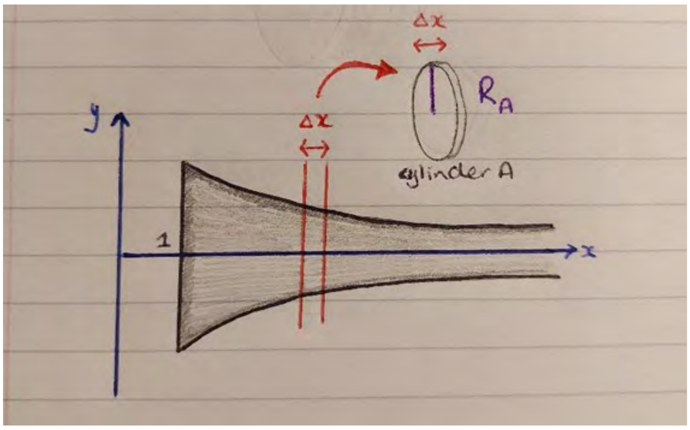


Volume of the horn

To find the volume of the horn, we need to split the horn into infinitesimally thin cylinders with a height of Δx. The volume for each cylinder is the radius (R_A) times the height (Δx) times π.

$$\text{Volume for cylinder } A:$$
$$V = \pi r^2 h$$
$$V = \pi R_A^2 \Delta x$$

We can add all these cylinders up, and take a limit of where the height of each cylinder tends to 0 to gives us a smooth sum (or an integral) between one and infinity to find the volume.



$$\text{Sum of all volumes of cylinders in the horn:}$$
$$\lim_{\Delta x \to 0} \sum_{r=1}^{\infty} \pi R_r^2 \Delta x \implies \int_1^{\infty} \pi r^2 \, dx$$

where subscript r represents the radius at the relevant *x* coordinate.

The radius of the horn at any point is the height of the graph at that point i.e. *at A, the height is f(A) where f(x) = 1/x*. Therefore, the volume can be expressed as:

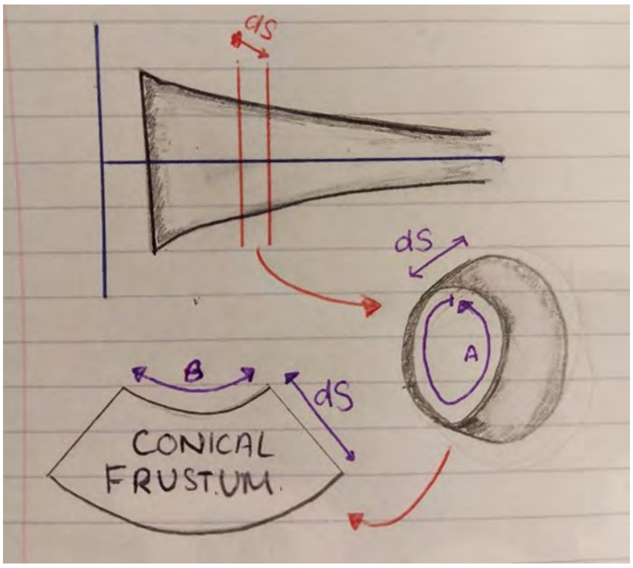
$$\text{Volume of Gabriel's Horn:}$$
$$\pi \int_1^{\infty} \frac{1}{x^2} dx$$
$$\implies \lim_{k \to \infty} \pi \left[\frac{1}{x}\right]_1^k$$
$$= \pi$$

When we put in the values for the integral, we once again have to take a limit as it does not mathematically make sense to have one divided by infinity, hence we use a dummy variable, *k*, as a limit.

Surface area of the horn

The surface area for the horn follows a similar process, where we slice up the horn into infinitesimally thin sections, but unlike last time, we will get almost a chopped off cone shape. When we unravel this shape, the net is called a conical frustum. To find the area of the chopped off cone, we need to find the area of the conical frustum.

We can find the area of the conical frustum by multiplying the inner arc (B) with the width (dS). Once again, we can note that the inner arc is the circumference of the smaller end of the chopped up cone, and the radius of that is also 1/x. Hence:



$$\text{Area of conical frustrum:}$$
$$A = 2\pi \frac{1}{x} dS$$

This means the smooth sum of all the conical frustums would give us the surface area of the horn. Therefore:

$$\text{Surface area of horn:}$$
$$\int 2\pi \frac{1}{x} dS$$

There are no limits here since this is currently not integrable, and we need to rewrite dS.

If we zoom into the top of the horn, we can see dS is almost a straight line, with its width being dx and height being dy. Hence we can rewrite dS as the following using Pythagoras:

$$dS^2 = dx^2 + dy^2$$
$$dS = \sqrt{dy^2 + dx^2}$$
$$dS = dx\sqrt{\left(\frac{dy}{dx}\right)^2 + 1}$$

By factorising out dx from the the square root, we can replace the dS in the integral for surface area with the expression above. You may also recognise we have a dy/dx, which we can calculate with basic differentiation, and it comes out as $-1/x^2$. Therefore, the overall surface area is:

$$\int_1^\infty 2\pi \frac{1}{x}\sqrt{\left(\frac{-1}{x^2}\right)^2 + 1}\, dx$$

We could do the integral here but it would be particularly long and involve multiple integrations by parts, substitutions and hyperbolic functions. Instead, since we know the bounds, we can create a small inequality for ourselves. The function inside the square root between one and infinity will always be more than one so we can say:

$$Surface\ area = \int_1^\infty 2\pi \frac{1}{x}\sqrt{\left(\frac{-1}{x^2}\right)^2 + 1}\, dx$$
$$Surface\ area > 2\pi \int_1^\infty \frac{1}{x} dx$$
$$\Rightarrow \lim_{k\to\infty} \pi[\ln(x)]_1^k$$
$$= \infty - 1$$
$$= \infty$$

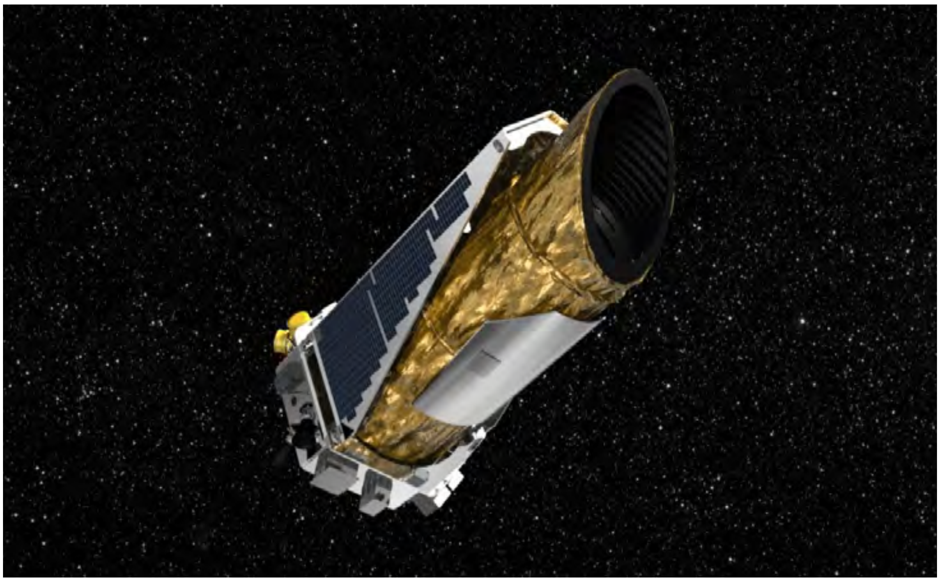
What we can now see is that the surface area is infinite but the volume is finite, hence the paradox. It begs the question, however, that if the horn was transparent and we filled it with π litres of paint, we would fill the horn but have we painted it? Paradoxes defy our expectations but mathematical rigour can prove what we cannot grasp intuitively.

You could play this horn, but you would need an infinitesimally small mouth!

Edited by Atharva Narkhede

DID YOU KNOW?

A Van de Graaf generator has a moving belt within the device that accumulates electrostatic charge. This creates very high electric potentials and produces very high voltage electricity at low current levels. This makes it very attracted to surfaces that donate electrons, such as a hand.



Intrigue Y8 Winner: Are We Alone in this Universe?

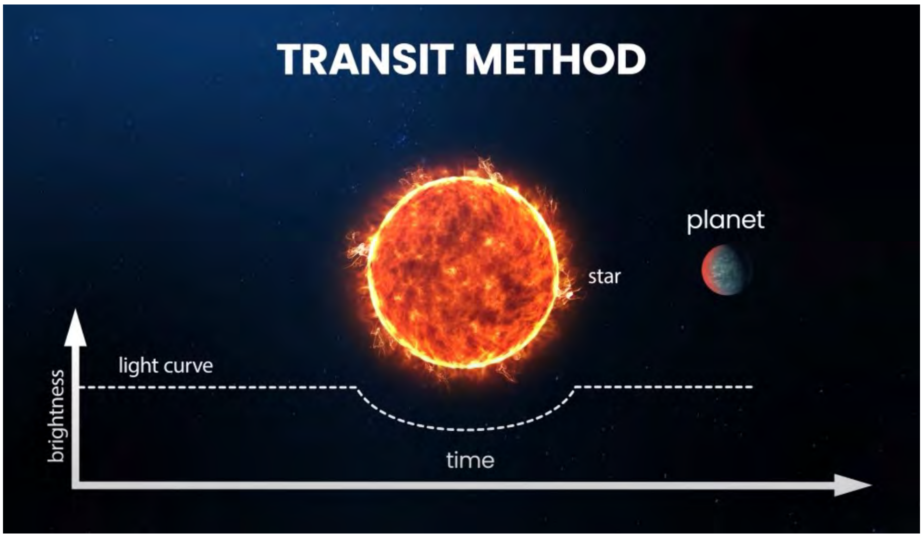
Could there be other life outside? What would it even look like?

By Shourya (Y8)

Have you ever wondered how ideal our planet is for life? We can easily breathe oxygen without fear of choking in the thick hydrogen gases and walk freely without suddenly floating in the air. Human beings are evolved creatures that live in a wonderful world where all we need for life is easily accessible in most places. However, are there other sapient-beings like us in the universe, who perhaps are more evolved than us and live on a planet like Earth?

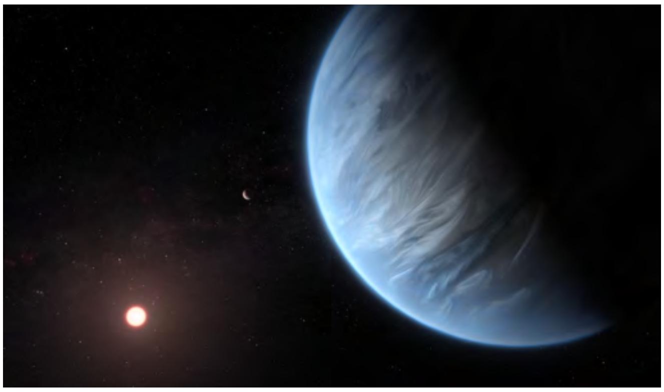
This question has puzzled us humans for many years and to find the answer, NASA had previously launched the Kepler telescope in 2009. Its aim, according to NASA, was to explore 'exoplanets' in some way like our own [1]. Here is an artist's impression of the Kepler Telescope.

An 'exoplanet' is simply a scientific word for a planet outside our Solar System that orbits around another star. One possible exoplanet which could be a suitable host for alien-life was 'K2-18b', discovered in 2015, perhaps a strange name at first, but it is an easier way to keep track of the more than four-thousand confirmed exoplanets discovered so far. Remarkably, the planet was in the 'goldilocks zone', the range of distance with the right temperatures for the water to remain liquid on a planet. After further investigation, two separate scientific teams announced that they had found signs of liquid water in the planet's atmosphere! This was a magnificent discovery since, out of the 2662 exoplanets discovered by Kepler, only sixteen lie in the goldilocks zone. Out of those sixteen, some are 'tidally locked' with their parent star, so only one hemisphere of the planet faces the star which is not ideal for life as one half would be permanent daylight, whereas, the other would be in complete darkness. The planet, according to Wikipedia, was about eight times the mass of Earth, thus making it a 'super-Earth' [2]. It orbited a red dwarf star named 'K2-18', hence the name 'K2-



18b' and was discovered by a clever method called the 'Transit Method'. In short, if a planet passes in front of the star, the light of the star dims slightly. The level of dimming and how long it lasts tells astrologists the important information of the size and orbit of the planet.

It also has water that builds in the atmosphere and is capable of rain. However, every great adventure poses a challenge. According to Space.com, one of the research teams, led by Angelos Tsiaras of University College London's Centre for Space Exochemistry Data (CSED), determined that water vapour makes up between 0.01% and 50% of K2-18 b's atmosphere, compared to Earth's mere 2% to 4% [3]. With such a big range, it is near impossible to characterise the exoplanet. For instance, it could be completely flooded with vapour, or a world with lakes and oceans but much exposed land. The planet's temperature is also uncertain. At Space.com, Tsiaras' team estimated a surface temperature of between -100 and -116-degrees Fahrenheit (-73 to -47 degrees Celsius). That means the surface could, on average, be colder than Antarctica or hotter than Earth's most blistering deserts! However, we should not lose our hope. According to the Scientific American, "this represents the biggest step yet taken toward our ultimate goal of finding life on other planets, of proving that we are not alone" [4].



Edited by Atharva Narkhede

THE PLANETS presented by Brian Cox

"The Planets" is a wonderful documentary series by the BBC which systematically looks at each planet exploring the conditions, features and astronomical observations of each planet. This coupled with the excellent narration of Brian Cox and state-of-the -art motion graphics makes it an excellent watch.

The most fascinating bit was understanding the moons of Saturn and how they create voids in the ring system. Here, there is also in depth discussion of the inter-tidal forces experienced on Saturn and Enceladus (one of Saturn's moons) that we cannot observe in our own moon.

This is a must watch for any bidding astronomer for it provides a unique insight not into the planets themselves but how they interact with each other, the forces at play that cause them to have the characteristics they do as well as an appreciation for the immense time and distances in space.

Key Information:

Produced: 2019

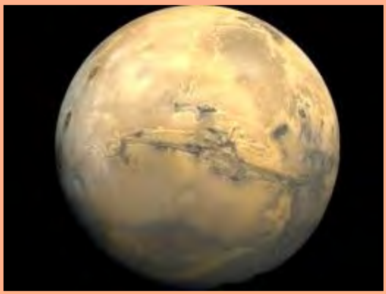
Genre: Documentary

Season: 1

Episodes: 1 to 5

Available on: BBC iPlayer

Presenter: Brian Cox



Intrigue Y10 Winner: The Kardashev Scale

By Poorwa (Y10)

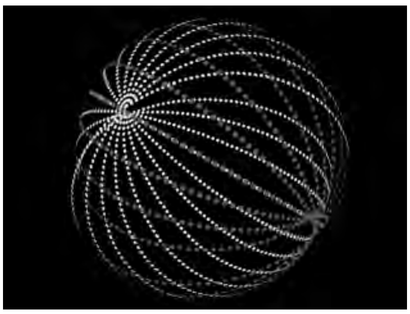
The Universe is one of the greatest mysteries ever encountered – an expanding void of space, dotted with trillions upon trillions of stars. As humans, we are part of it. Scientists assume there are around forty billion Earth-like planets in the Milky Way and new species could exist on any of them. It really is difficult to think there is nothing out there. Finding extra-terrestrial life would change the perception of ourselves forever. So, what could life other than that on Earth look like [1]?

Our 'Civilisation Sample Size' is only one. This means we are quite limited. Even so, it is better than having nothing to work with. We need to understand that humans are greedy and expansionist. Yes, we want space, resources and to dominate in whatever way we can. We have been doing this for the past few thousand years. Therefore, it would be logical to assume that aliens would possess the same traits. Assuming our laws of Physics apply to all areas of the Universe, there is one measurable metric unit we can compare by: energy [2, 4].

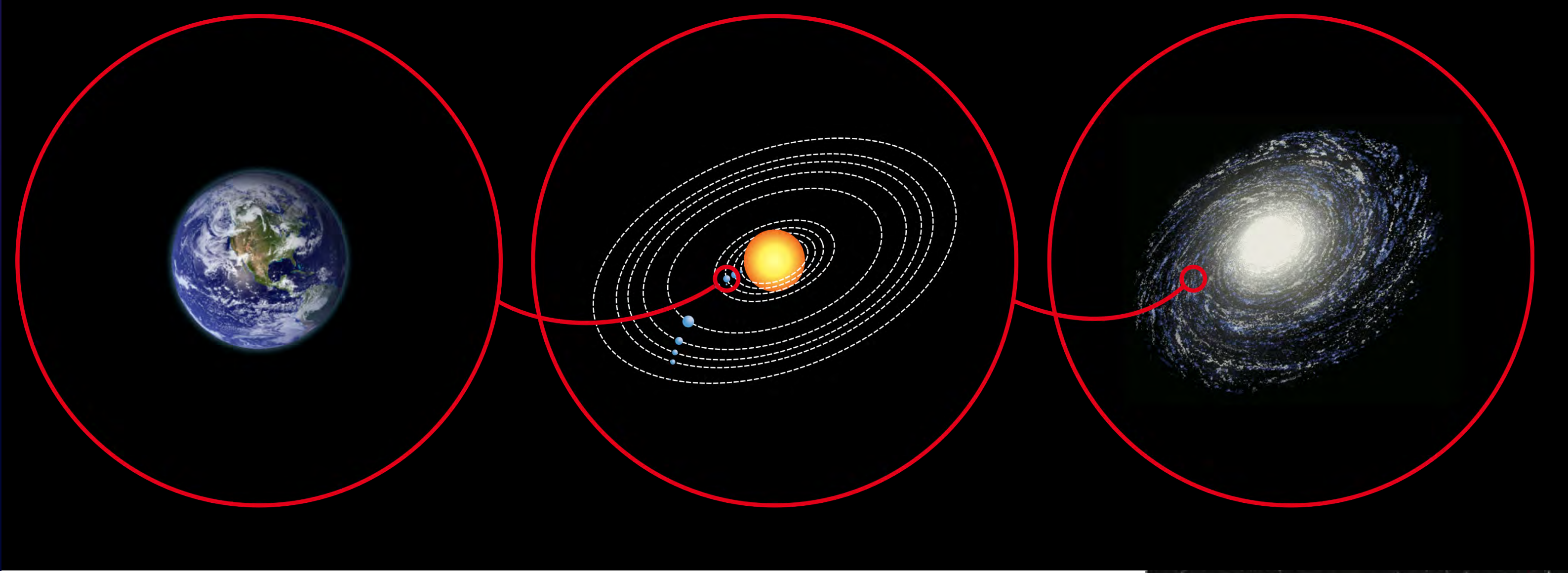
The more space we take up and the more resources we use, the more energy we consume. As our energy consumption grew exponentially, so did the abilities of our race. Between 1800 and 2015, population size has increased sevenfold, while humanity is consuming 25 times more energy. It is safe to assume that this process will continue into the far future. This is where the Kardashev Scale comes in, a system invented by Nikolai Semenovich Kardashev (in 1964) that measures a civilisation's level of technological advancement based on the amount of energy they are able to use, beginning with a type I civilisation [2].

Though the scale has been refined through the years by various scientists, these are the six main categories which differ in orders of magnitude. It is as if comparing an ant colony to a human metropolitan area. To them, we are so complex and powerful, that we may as well be Gods. Therefore, we would need to create subcategories to make the scale more useful. If a type I civilisation is able to fully use the available energy of their home planet, humanity would most likely be classified as a type 0.7 species as we have changed the components of our atmosphere and used natural structures such as volcanoes to our advantage. Whereas, ants may be around type 0.02 as they just use what the Earth provides.

Any fully type I civilisation is bound to expand outwards as they are likely to still be greedy, competitive and expansionist. And so, a type II civilisation can use the available energy of their star and planetary system. This moves on to creating colonies and terraforming other planets by changing their rotation or position.



The most advanced project that a lower type II civilisation can take on is creating a Dyson Sphere – a

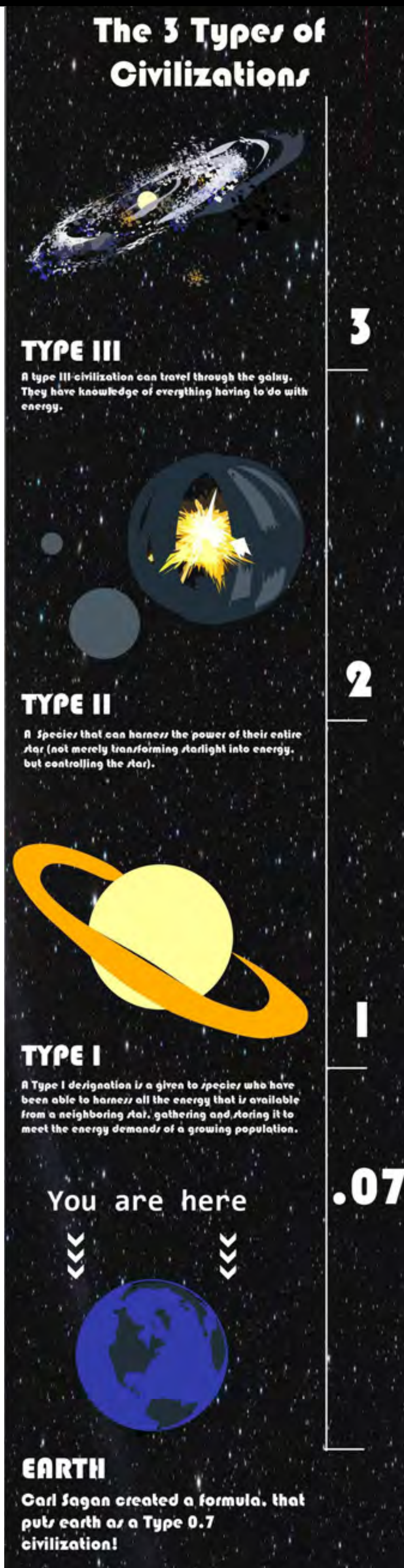


megastructure harnessing the Sun's energy output. Although this would take close to a billion years, it would provide virtually unlimited energy. This means that they would be able to advance to a type III in no time as they would be able to replicate this project at a much quicker rate due to no concerns over energy consumption. For type II civilisations, the distance to other stars which are light years away may feel like the distance from Earth to Pluto for us today: technically within reach but only with "large investments in time, ingenuity and resources" [3, 4].

A type III civilisation can use the available energy of their home galaxy and a type IV civilisation is able to use the available energy of multiple galaxies. It would be difficult to understand and to imagine how life would be at these stages: have they discovered new Physics? Or have they begun to control dark matter? If so, lower type III species may find humans 'too primitive' to speak to as we are not advanced enough. A type IV civilisation would most likely view us, as we view the bacteria in an ant colony – they may not even deem us conscious [4].

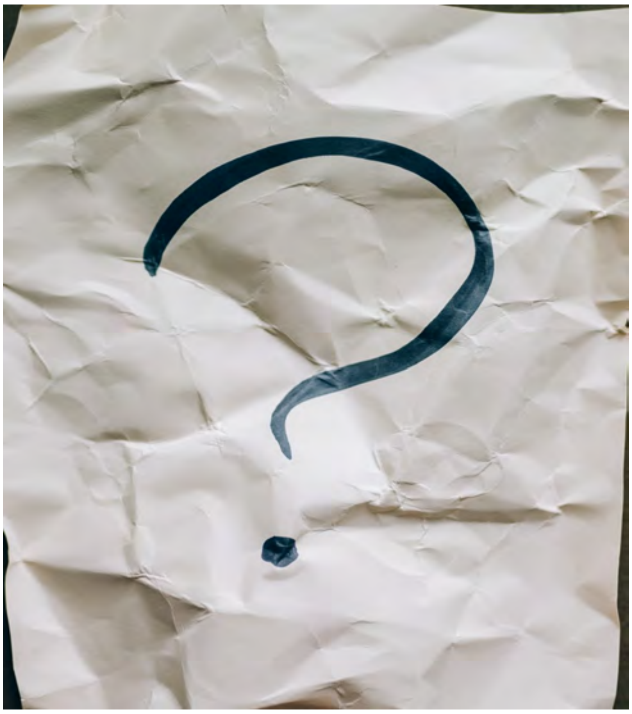
But the scale does not end here – some scientists think that there are more. Type V civilisations are ultra-advanced beings, Gods even, that rule over galaxy superclusters, comprising of trillions of stars and millions of galaxies. And finally type Ω (Omega): the ultimate beings, ruling over multiple Universes and even multiverses. Who knows, maybe we are just the minions of a supreme being that we call God – who, really, is a single blip in the vastness of the type Omega species. Maybe they created our Universe, for reasons beyond our comprehension. Or it is that we are too immature to advance, maybe being expansionist and greedy is not the way. Only time will tell [4].

Edited by Atharva Narkhede



The Last Question

By Boyu Xiang (Y13)



Sixty-five years ago, Multivac was asked 'the last question' that was asked for the first time ever, and at the time there was:

"INSUFFICIENT DATA FOR MEANINGFUL ANSWER."

Asimov's 'The Last Question' was first published in 1956 and the short story investigated how various stages of civilization and multiple evolutions of an AI named Multivac dealt with increasing entropy and the obsession over reversing it. Fifty years ago, Asimov could not imagine even an ideal society giving a convincing answer to the question in any reasonable timespan, but perhaps presently we may have sufficient data for a more optimistic answer.

Colloquially, entropy is described as a measure of energy disorder in the universe, where 'order' is a description of the complexity of energy. Pop science, of course, is always less than helpful, however, the claim that the universe is constantly moving towards a state of maximum entropy has been agreed upon for decades [3].

As with most concepts, thermodynamic entropy is more readily and accurately described as an equation, currently it is modelled with:

Where Ω represents the 'number of microscopic configurations', otherwise known as the number of microstates. A microstate refers to a possible configuration of all the particles in a system, given that it abides by the macrostates of said system. A macrostate refers to the observable characteristics of a system that can be used to describe the particles within it, for example in an inflated balloon, the macrostates would be pressure on the rubber, temperature of the air and the volume of the balloon itself. These macrostates describe the scalar kinetic energy of the particles inside and the vectors momentum and the forces acting on them [1,5,6].

Imagine a closed system with 'N' number of particles, with volume 'V' and total energy 'E' and 0 net momentum. Every particle can be in f(V) locations, with g(E) different velocities – 'v' and 'ε' respectively, a single particle then could have ε^v different states, and the system as a whole could have (ε^{v})^N number of microstates. This of course is oversimplified, there are far more variables that would affect the state of a particle, and in the real world we can only estimate at the value of 'N'.

The macrostates of the universe are total energy available and the size of the universe itself, and while, as far as we know, the former is constant and the latter is increasing. This means that given absolutely no interactions at all, the total entropy will always be increasing.

Entropy can be defined with a more experimental/demonstrable equation in:

$$\Delta S = \frac{Q}{T_I}$$

Where T_I is the initial temperature and Q is the thermal energy added to the system.

This means if a system reaches thermal equilibrium, the hot part of the system transforms thermal energy to the colder part of the system, so:

$$\Delta S = \frac{Q}{T_C} - \frac{Q}{T_H}$$

[1,2]

Where T_C is the colder temperature and T_H is the hotter temperature.

Since $T_H>T_C$, entropy increases.

In all reactions, temperature either increases, decreases, or remains constant. If temperature increases then firstly entropy increases as Q is positive, then it increases again as it cools down, reaching thermal equilibrium with the surroundings. If temperature decreases, energy is being stored in chemical bonds and it appears as if entropy is decreasing. However, that energy needs to come from somewhere and that, inevitable, comes from some kind of exothermic reaction which increases entropy more than the formation of chemical bonds decreases it. These bonds will also eventually break, and thermal equilibrium must be re-established.

As entropy increases, the energy within the system become less useful and therein lies the issue. For example, as hot air migrates to a cooler region, we can harness the kinetic energy through a generator. However, once the air is homogenous, that kinetic energy can no longer be accessed as easily, as the particles are no longer transferring kinetic energy in one direction and is instead random, so there is net transfer to the generator. Entropy has increased, and a chunk of the universe's energy can no longer be used.

In Asimov's book, when Multivac was created, the final question may not have been very important except in an abstract way. However towards the end of the short story, as energy has become less useful and as Multivac approached the time where none could be used at all, whether we can reverse the process of entropy became far more pivotal.

The increase of entropy is still generally accepted as an irreversible process to this day; however, some have theorized that there is hope at a local, microscopic level. Long before Multivac's conception, in 1867 James Clerk Maxwell proposed a thought experiment where a demon would only allow particles of a certain speed past a membrane, thereby decreasing entropy. While this is in essence how cooling devices work, the device is no demon and use energy and there is a net total increase of entropy. In isolated quantum spaces it has been hypothesized lately that this demon may actually exist [3.4].

Alternatively, there is always a probability that particles will move in such a way that entropy is randomly reduced. In a cup of water, the particles may interact in such a way that a lot of the energy is transferred to the glass cup, and the water spontaneously freezes, decreasing entropy. Of course, this has never been observed as it is infinitesimally unlikely.

Given that the best theories now center around impossible feats of luck and a slightly more solid foundation to a thought experiment centuries old, we can still extract no meaningful answer. Multivac took so long to answer the question that time itself had no meaning, so perhaps the marginal progress we have made already is more impressive than it may appear.

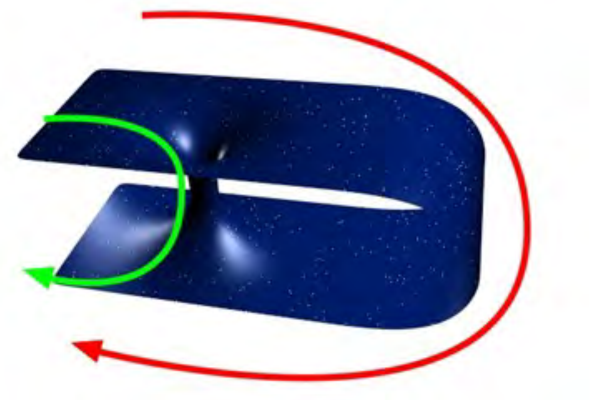
Edited By Aadin Patel

Is Time Travel Possible?

By Shanjeev Mathialagan (Y12)

Travelling through time, whether it is trying to change the past or exploring the distant future, has been a frequent occurrence in science fiction. From 'Back to the Future' to 'Doctor Who', the ability to travel through time has engaged millions of viewers and created successful stories. But how close are we to actually making time travel a genuine possibility? Although we haven't yet invented a time machine that we can just hop into and go whenever we please, physicists have actually considered time travel to be theoretically possible. Albert Einstein came up with his theory of relativity: his idea about how time works. According to his theory, time is relative, so the faster you travel, the slower you experience time.

This has been found out to be true, after scientists carried out experiments to provide evidence. For example, one experiment involved comparing two clocks that had been set to the same time - while one clock remained on Earth, the second flew in an aeroplane. After the second clock had flown around the world, it was observed that the clock on the aeroplane was slightly behind the clock on Earth [1]. Through this, it has been discovered that nature allows a way for unconventional time travel - the bending of time. This effect is known as time dilation - "the relative slowing of a moving clock with respect to a stationary observer". This time dilation is quite small for the speed



of planes, but it does show that significant time travel may be possible in the future if we were travelling very close to the speed of light (3×10^8 m/s), because the faster you travel, the greater the effect of time dilation. However, getting spaceships or even human beings close to the speed of light poses a great issue. It would require unimaginable amounts of energy. Enormous particle accelerators, for example the Large Hadron Collider, are needed to accelerate subatomic particles close to the speed of light, so with our current technology, all we could manage is jumping a few microseconds into the future. Thus, we would need to develop the tools necessary to accelerate matter, equivalent to the mass of humans, to the speed of light before we can send time travellers to the future.

So, what about travelling back in time? People want to explore the past as much as the future, visit certain moments in history, watch dinosaurs roam the earth, experience the ice age, the list is endless... But the truth is that it is easier to travel forward in time than backwards, theoretically, because we are all moving forward in time naturally. Backwards time travel seems extremely difficult, since we cannot use time dilation, but it is not exactly impossible... Einstein proposed that it would be possible only through a certain type of wormhole - a wormhole is a theoretical area of spacetime that is warped in a way that it connects two distant points in space - an Einstein-Rosen bridge (shown on the right is a visualization); he suggested that this bridge in space could connect any two points in time if it was stable enough and did not collapse [2]. Note, however, that this is just a speculative structure proposed by Einstein - it is still unknown to mankind if such a time bridge exists, since scientists have not observed them yet, meaning that time travel to the past does not seem possible [3]. Furthermore, physicists struggle with the scenarios posed by backwards time travel, in which time-travellers may alter events that have already happened in the past. What would the consequences be in the future? One very famous example of this is known as the grandfather paradox: imagine a time-traveller going back to the past kills a younger version of his or her grandfather before he has conceived a child. Since the grandfather then wouldn't have any children, this would inevitably erase one of the time-traveller's parents, and the time-traveller too. So, who would have killed the grandfather? Another example of this is in Back to the Future, when Marty McFly travels to the past and accidentally prevents his parents from meeting each other, nearly preventing his own existence [4]. But if he could no longer exist, how could he have travelled back in time in the first place?

Some researchers have tried to find the answer to this baffling paradox, by arguing that the universe will try to correct itself in order to avoid inconsistencies. In this case, we would never be able to alter events to create a different future, even if we could travel back in time, thus preventing any chaos or destruction a change may have caused. But this could also provide evidence as to why it may only be possible to travel forwards in time and not backwards. As the late Stephen Hawking said in his book 'Black Holes and Baby Universes', "The best evidence we have that time travel [into the past] is not possible, and never will be, is that we have not been invaded by hordes of tourists from the future".

To conclude, while time travel into the past may never be possible, we can still be hopeful as travelling into the future remains a possibility.

Edited By Aadin Patel

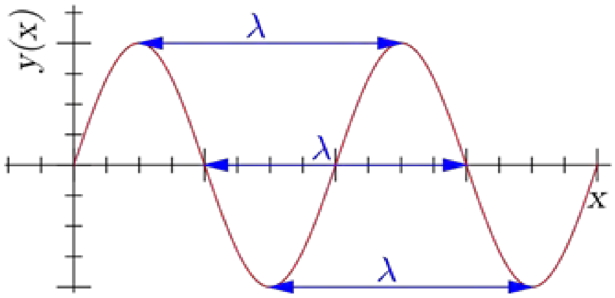
The Heisenberg Uncertainty Principle

By Bavithiran Jeyagoban (Y12)

In 1927, German physicist Werner Heisenberg articulated the Heisenberg uncertainty principle. Also known as the indeterminacy principle, it states that both the precise position and velocity of an object cannot be ascertained simultaneously. According to this principle, the concepts of exact position and exact velocity together have no meaning in nature.

Why does it occur?

A common misinterpretation of this principle is that the uncertainty is a result of flawed measurement (a practical limit): many believe that the act of measuring a quantum object's position changes its velocity or vice versa. The truth however is that it is a result of the wave-particle duality, an idea in quantum mechanics that was suggested by French physicist Louis de Broglie in 1924, as a result of the previous inability of the concepts 'particle' or 'wave' to fully describe the behaviour of quantum-scale objects [3]. The wave-particle duality enunciates that everything in the Universe behaves like both a particle and a wave concurrently.

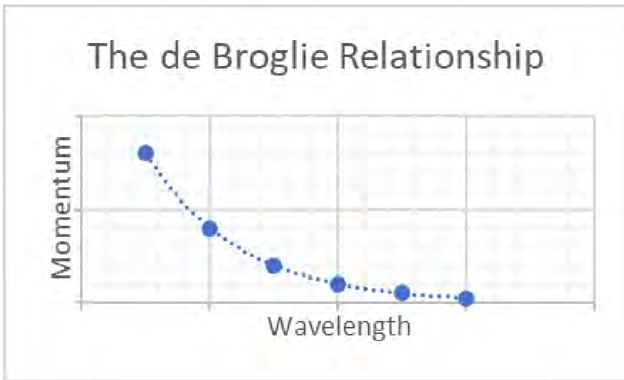


What does behaving like a particle or a wave actually mean?

Whilst a particle is always in a single place at any instant in time, a wave may be described as disturbances spread out in space. One can only clearly identify features of a wave pattern, such as its wavelength (the distance from one crest to the next).

The de Broglie Relationship

After proposing the wave-particle duality, De Broglie stated that the wavelength associated with a particle is inversely proportional to its momentum. The relationship is given by the de Broglie equation and can be applied to all particles with mass:



$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

where λ is wavelength, p is momentum, m is mass, v is velocity and h is Planck's constant or 6.63 x10^{-34} Js to three significant figures. This equation helps to clarify why we do not observe the wave nature of everyday objects: they are too large. As the mass of a particle increases, its wavelength decreases, so it becomes harder to observe wavelike properties. However, small things, such as atoms and subatomic particles (protons, electrons, neutrons, etc.) have wavelengths that are large enough to measure.

Combining the wave-particle duality and the de Broglie relationship gives us insight into the limitations of what we can know about a quantum object. If we have a pure wave (one that has only one frequency), we can measure its wavelength and thus, calculate its momentum from the equation $p = \frac{h}{\lambda}$, but we cannot assign the wave a single position because it has a good probability of being in many places. According to classical mechanics, any single particle travelling with a specific velocity will have a momentum. Therefore, if a wave has momentum, as explained above, then it should also be considered as a particle.

On the other hand, we can be certain about a quantum particle's position, but it does not have a wavelength. Therefore, we cannot calculate its momentum and so, we are uncertain about its velocity. Therefore, due to high uncertainty in the particle's velocity, the momentum of the particle's position will be uncertain.

Hypothetically, to find both the position and momentum of a quantum particle, we would need to combine these two pictures, to make a graph that has waves, but only in a small area (to decrease the position uncertainty). This can be done by combining waves that have different wavelengths. If we were to add two waves, so that some peaks line up (this would form a resultant wave with a larger wavelength) and other peaks fill in the troughs of the other wave, there would be regions where we see waves, separated by regions of nothing at all (i.e., the amplitude is 0). Hence, adding more waves would increase the size of the region where the amplitude is 0 and decrease the size of the region where waves are present.

Therefore, if enough waves are added, there would be a wave packet (a region where two or more waves exist simultaneously) with a clear wavelength in one small region. However, to accomplish this, we would lose certainty about the momentum of our quantum object because the wave packet was made by adding lots of waves and there is some probability that the object has a wavelength (and so, momentum) corresponding to any one of those.

At this point, both position and momentum would be uncertain, and we can see that these uncertainties are connected. To reduce the position uncertainty, one would need to make a smaller wave packet. This could be done by adding more waves, though this would result in a larger momentum uncertainty. Conversely, if you wanted to reduce the momentum uncertainty (and thus, the velocity uncertainty), you would need a larger wave packet, which results in a greater position uncertainty.

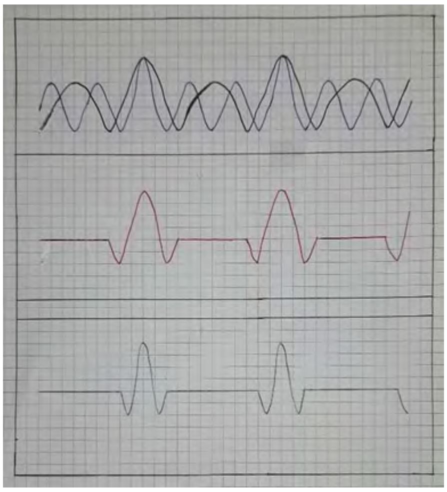
The Inequality

The inequality for the Heisenberg Uncertainty Principle is:

$$\sigma x \, \sigma p_x \geq \frac{\hbar}{2}$$

where σx represents the position uncertainty, σp_x represents the momentum uncertainty in the x-direction and $\hbar$ (h-bar) represents the reduced Planck's constant, which is $\frac{h}{2\pi}$. This tells us that the left-hand side of the inequality ($\sigma x \, \sigma p_x$) must at least be equal to the right-hand side ($\frac{\hbar}{2}$): we cannot have a small uncertainty in position and momentum because it would not satisfy the inequality (and the principle).

Therefore, the Heisenberg uncertainty principle is not a matter of flawed measurement, primitive technology or humans' lack of intelligence, but an inevitable result of the wave-particle duality ingrained into the fundamental structure and manner of the universe.



Wavelengths

Edited By Aadin Patel

THE EDITORIAL TEAM: REFLECTIONS ON ISSUES 1-7

In their last issue, the editors talk about how they got into the Wilson's Intrigue, their thoughts about the magazine so far and what drives them to pursue STEM subjects at higher education

Divy Dayal
Chief Editor
Economics

I remember going quite anxiously into S5 for the first ever magazine meeting, led by Devanandh Murugesan. I caught onto his dream of making the first ever student run magazine at Wilson's that lasted more than a term very quickly and it is this ambition that pushes me and the editors to make the Intrigue the way it is. The Intrigue has provided me with a vocation and role to play within the school, which I cherish and it pushed me to found the Humanities division as well. I must also say the feeling of holding and smelling a freshly printed Intrigue is quite an empowering moment, after working countless hours as a team to produce something like the this, and its very heart-warming when we see pupils dive into it in the foyer or form rooms.

My article choice has always been peculiar in the STEM magazine, from polishing to genetics to screws, unsure as to what I should really be writing about given my interest in Economics. However, the magazine has always been a motivator for me to find out, express and share research which frankly I would not have done without the notion of a magazine and the community at its centre.

Perhaps what I found the most interesting as an editor was the exposure to topics and examples, as well as gaining an appreciation for the scientific approach—both skills and memories I will use regularly as I explore the economy in the future.

Atharva Narkhede
Deputy Chief Editor
Engineering

I joined the Intrigue in the Year 12, following my interest in aviation, upon being tempted by Divy and to indulge in a new experience. Initially, I signed up wanting to write and edit articles for the Engineering section only, however, I soon found myself immersed in editing both the Engineering section and the new Maths section. Watching the magazine grow out of its infancy has been incredibly rewarding. Over the past year and a bit, I have grown as an editor and transforming articles so that they look appealing to the reader was fulfilling. It has been delightful to work alongside such a cooperative and enthusiastic team of editors and writers and juggling unending WhatsApp messages with them, particularly in Issue 6 due to the remarkable turn-around time and a lockdown!

Undoubtedly, I have developed my communication skills, be that with my writers and when liaising with teachers or new skills such as researching, tackling deadlines and familiarising myself with Publisher. I got the opportunity, with Divy, to interview successors for our magazine, judge the STEM Intrigue competition and edit the COP26 Edition and this particularly enhanced my editor experience and improved my interpersonal skills.

At university, I will be studying Aeronautical Engineering. This fascinates me due to my interest in aviation and cars, the former of which I got to explore during my Intrigue journey in the form of V-shaped aerofoils and circular runways. Technological evolution in this field is exciting and inevitable as we seek sustainable energy sources to power our aircraft.

Aditya Chougule
Editor
Medicine

I joined the magazine because I wanted to improve my academic writing and express my interest in the subject I'm pursuing at university (medicine). In particular, I am very grateful for the experience I have gained as an editor and the various skills acquired in this role, most notably the ability to ruthlessly critique a piece of work to transform it into the best version of itself.

I would like to thank Divy and the rest of the editorial team for creating such a driven environment where we push each other to improve through constructive criticism, whilst also balancing this ambition with tomfoolery and good cheer. The last few years have made for an incredible journey and I will cherish my memories with the Intrigue team as I head off to study medicine.

THE EDITORIAL TEAM: REFLECTIONS ON ISSUES 1-7

Aditya Jain
Editor
Engineering

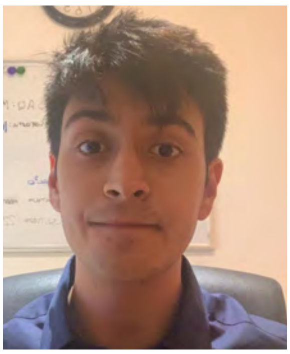
I initially joined the science magazine to spread my fascination of the sciences with others in the school community. Through this process, I learnt valuable lifelong skills such as editing and writing concise articles as well as citing references. As an editor, I have really enjoyed helping others research their areas of interest and working with them to develop their articles.

My research in robotics and machine learning for one of my articles in the science magazine actually sparked my interest in electronic engineering and I hope to read the field further at university! Thanks to the amazing work of our founder Dev and now our chief editor Divy, as well as the teams of teachers and editors, the magazine has grown exponentially since its inception. Just like the magazine intrigued me into the wonderful world of STEM; I hope it will continue to inspire the minds of Wilsonians in the future!

Nabeel Abdul Rasheed
Editor
Medicine

I joined the Science Magazine at the start of Year 12 because I liked the freedom of being able to dip my finger into whichever pot of biomedical syrup seemed most interesting or, dare I say it, intriguing. In other words (and to cover the cracks in my loosely constructed metaphor), I was eager to discover and zoom in on aspects of Medicine I never previously had a chance to appreciate. I found great satisfaction in exploring the inner workings of RNA vaccine technology and the surprising link between Alzheimer's and Down Syndrome. Even cursory glances at ultimately fruitless ideas contributed in some way towards my understanding of biochemical phenomena and the process of scientific research; the latter proved to be a particularly helpful baseline from which to kickstart my Templeton Scholarship Project.

From an editorial perspective, it has truly been a pleasure for me to witness the transformation of Wilson's Intrigue into the consummate template it serves as today; the professional content and design produced on a clockwork basis is a tribute to the toil and ever-watchful eyes of Dev, Divy and their respective editorial teams. I hope their efforts inspire the next generation of keen scientists and help set a successful blueprint for the future of Wilson's Intrigue.

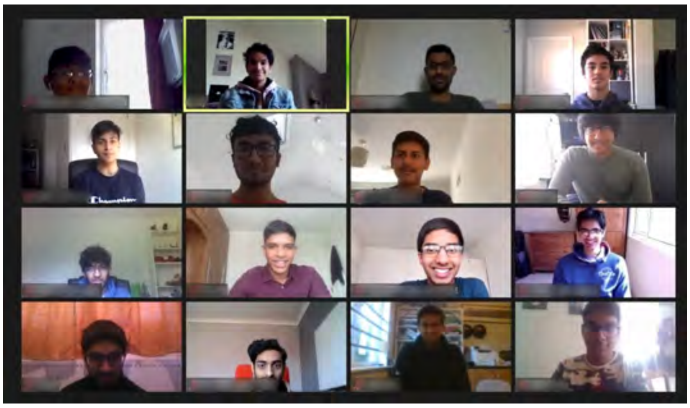


Mann Patira
Editor
Computer Science

Being a part of the editing team behind the Science magazine has been a true privilege. I first joined to diversify my knowledge in STEM and I have come to learn more than I ever imagined I would. Having the opportunity to read and scrutinize the work of the many writers that have given articles to the magazine has allowed me to gain an in depth insight into so many different concepts that I never would have thought to independently research.

I will study Computer Science at university and being an editor in this magazine has enabled me to be exposed to so many different parts of the subject. It is through this magazine that I developed a true appreciation of the breadth of Computer Science. I am excited to learn about Quantum Computing and what role this will play in the future since it is this type of computing power that might enable the wildest fantasies of science fiction to be made a reality. I am really looking forward to being a part of an industry that drives real change in people's lives.

THE CHIEF EDITOR: REFLECTIONS ON ISSUES 1-7



The Wilson's Intrigue Team

The first meeting in October 2019 for the newly formed, unnamed magazine was a quiet gathering, of a few intrigued pupils enthusiastically led by Devanandh Murugesan. Soon the community of journalists grew, and now with over a 100 writers over both the STEM and Humanities Wilson's Intrigue Magazines, it is an integral part of Wilson's life. Despite national lockdowns, exam seasons and university applications, the team has persevered and produced three issues and a special climate edition with Miss Denison in the last year. The last few issues have seen a refining and standardisation of the editorial process whilst evolving to be more accessible and useful to the reader (through book reviews and TV recommendations). To see the Intrigue in every form room in the lower school, to have so many entries for the Intrigue Essay Competition and to even have our own display board in the sixth form has been a true pleasure to witness and participate in.

I would also like to take this opportunity to thank my team of editors (Atharva, Nabeel, Adi J, Adi C, Mann, Aadin and Ishan) for supporting me, even with the tightest of deadlines and riding the highs and lows of the editorial process with me. I would also like to thank all the writers who think of wonderful topics to share with the wider school community and craft such excellent articles that further broaden our awareness. We simply would not have a magazine without you. I would also like to thank all the subject specialist teachers acknowledged at the start of every issue for giving up their time outside of lessons, to assess the scientific accuracy of the articles and providing additional support to writers alongside the editors. Lastly, I want to thank Mr Lissimore for giving the team the opportunity to publish the magazine and for his meticulous proofreading of each issue.

I want to conclude this section by wishing all the best of luck to the new STEM editorial team: Matteo Cascini, Ishan Makkar, Shanjeev Mathialagan, Aadin Patel and Jonathan Peter-Rajan and also to our sister organisation—the Humanities division of the Wilson's Intrigue, which shares all the same aims and values as we do.


THE WILSON'S
INTRIGUE
Issue 1: Friday 20th December 2019
The first issue of the student STEM magazine
BIOLOGY | COMPUTER SCIENCE | PHYSICS | ENGINEERING


THE WILSON'S
INTRIGUE
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INTERVIEW WITH PROFESSOR JINDANI
HUMAN POWERED FLIGHT
SPACE TRANSPORTATION
Issue 2: Friday 14th February 2020
BIO-CHEMISTRY | ENGINEERING | PHYSICS


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ISSUE 2 – February 2020
'Founded' 30th September 2019


THE WILSON'S
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Cancer-killing Viruses
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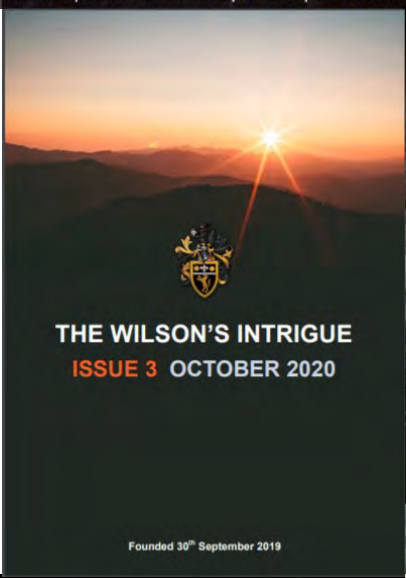
Artificial Creativity
ENGINEERING
The Ground Effect
PHYSICS
Asteroid Mining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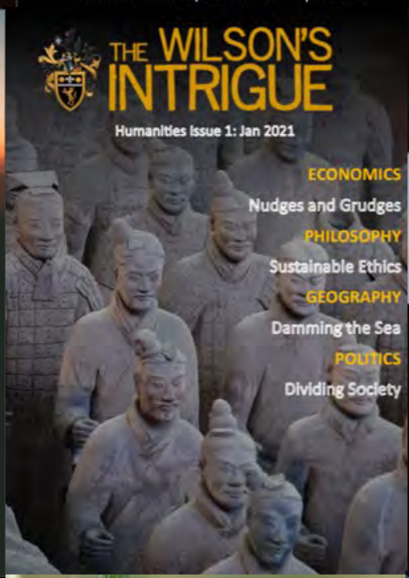
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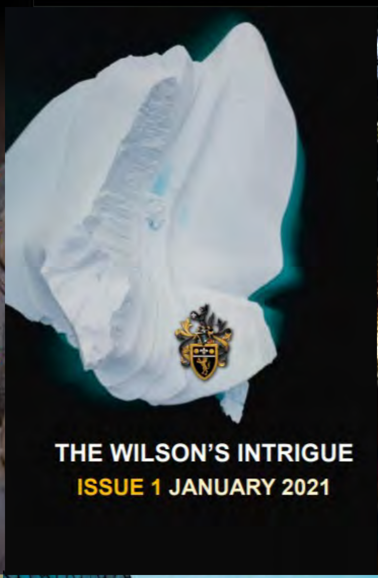
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PHYSICS
Rising Entropy


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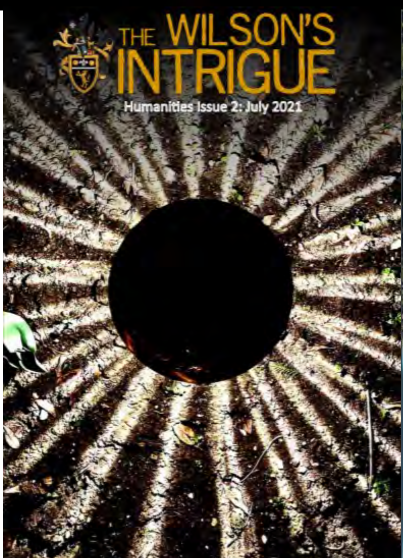
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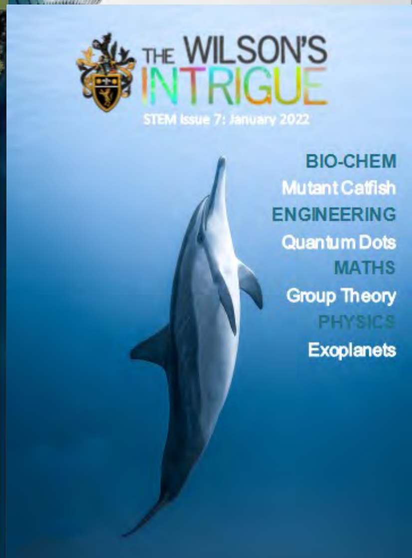
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Jesse Luo—Compilation

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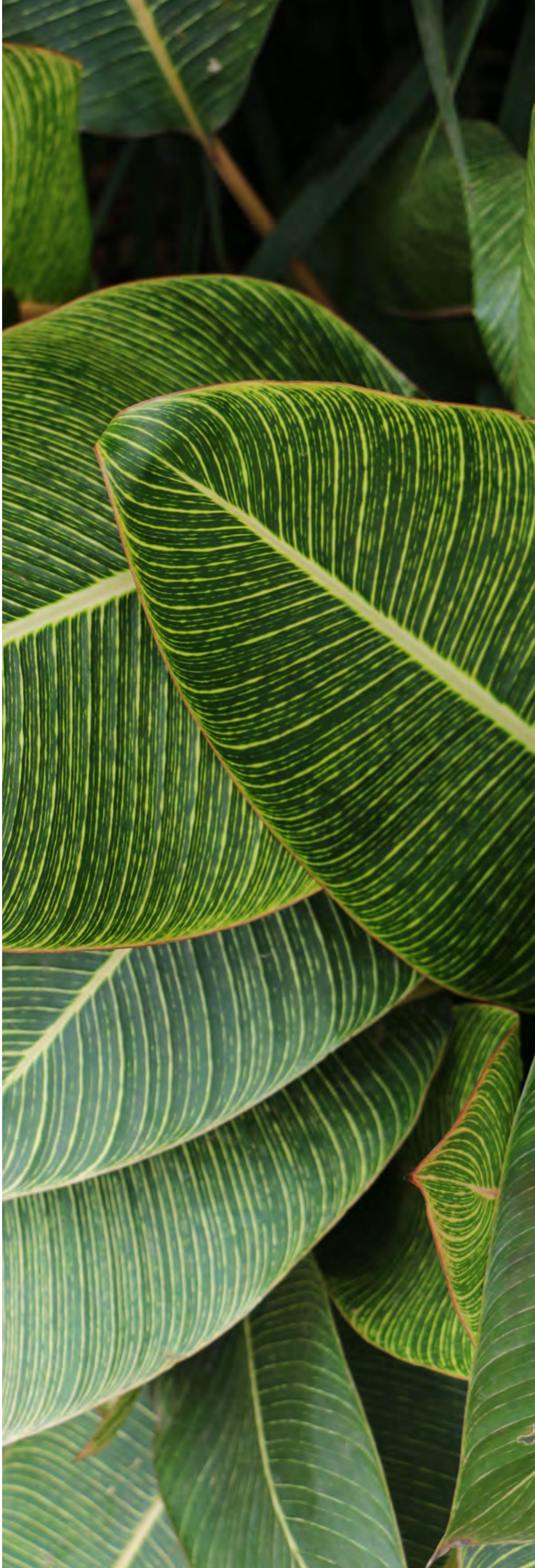

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