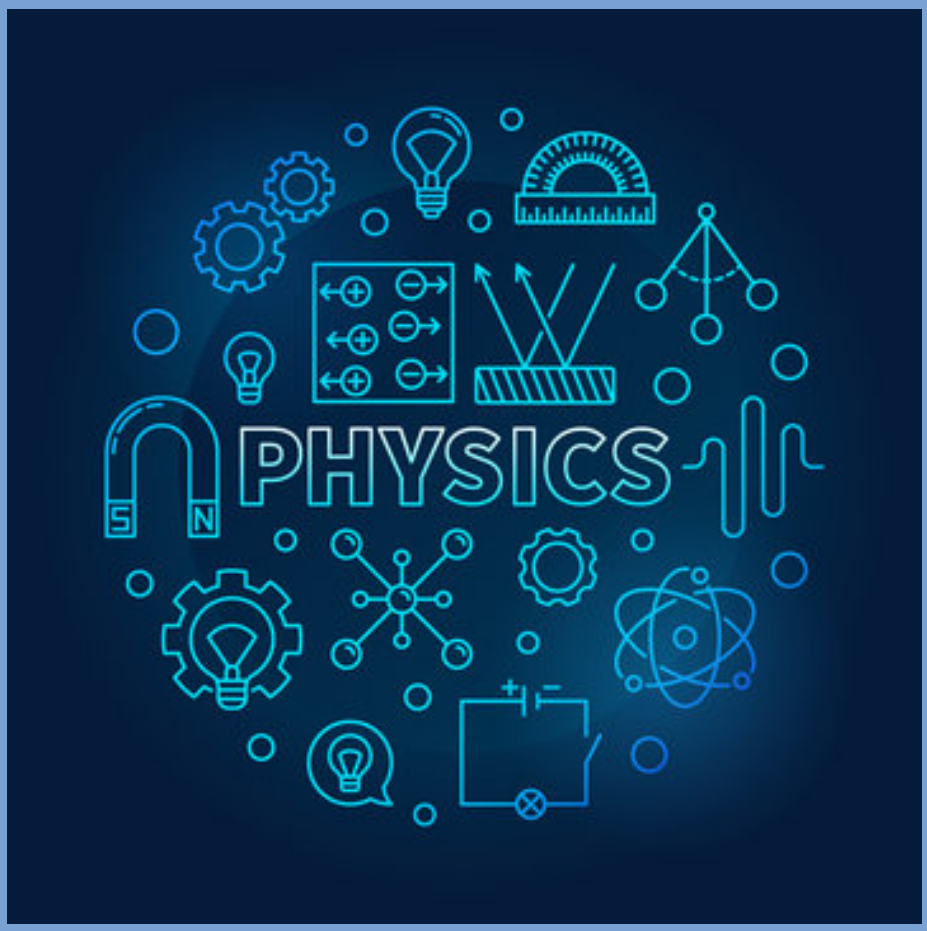
Physics A Level Essays 2023



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Contents

Snell's law

Introduction

Snell's law is an equation used to describe how light waves refract when they pass through a boundary between two different transparent media with different refraction indexes. A common example of this is when light passes through water and the waves refract, making objects in the water seem squashed or distorted. Some of the applications of Snell's law are in optical fibre communications, designing optical lenses, biometric technology, travel time tomography and medical imaging.

Derivation of Snell's law

Heron's shortest distance formula:

Below is a diagram of light travelling from point A to B and being reflected from a plane.
Because of the Law of Reflection, the angle of incidence is equal to the angle of reflection. So ∠ACE = ∠A'CE = ∠BCD [1]
Maths is used all the time to find solutions to optimisation problems. One such problem is finding a path with the shortest distance from a given point to another. If you have two points, A and B and you want to find where point C should lie on the plane to minimise the distance, Heron found that you could find the shortest distance by reflecting one of the points, A to A', in the plane and joining the two points to make a straight line. Where the line crosses the plane is where the point C should lie for the distance to be minimised.

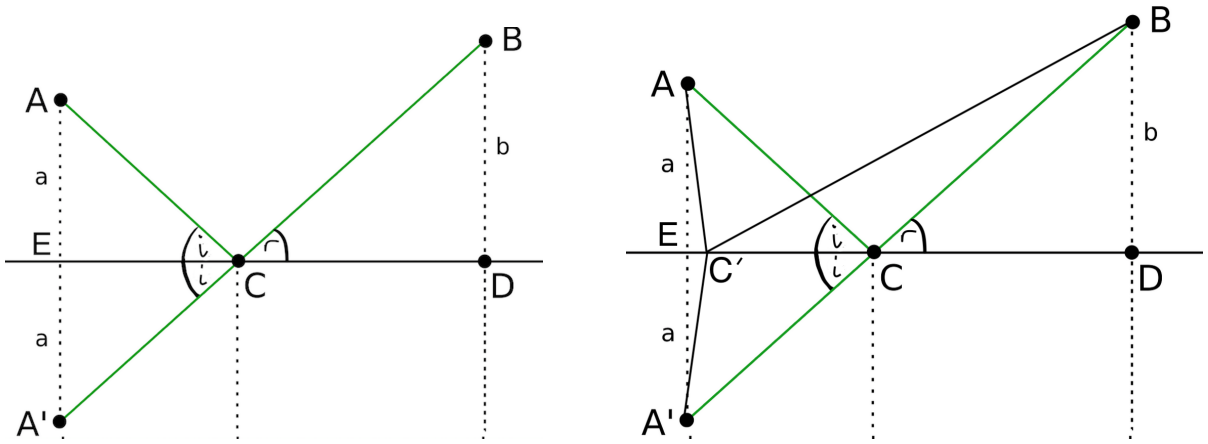


Image retrieved from Cantor's Paradise. Heron's Shortest Path Problem (2018). https://www.cantorsparadise.com/herons-shortest-path-problem-80396c68d5e9 date 8/4/2022

[2] If C was to be moved across to the left or right, the angle of incidence would no longer equal the angle of reflection. This is shown in the second image where the angle $\angle AC'E \approx 80°$and the angle $\angle AC'B \approx 30°$. This goes against the principle that the angle of incidence is equal to the angle of reflection therefore the light can't take any other path than the one shown in the first image.
Therefore Heron was considered to be the first person to show that the Law of Reflection implies that light always takes the shortest path.
However, this only applies for when light travels through homogeneous media with the same refraction index. In reality, light passes through many different materials, all with different refraction indexes. When light passes through one medium to another, it's velocity changes, and it refracts towards the normal if it enters a more dense material or away from the normal if it enters a less dense material.

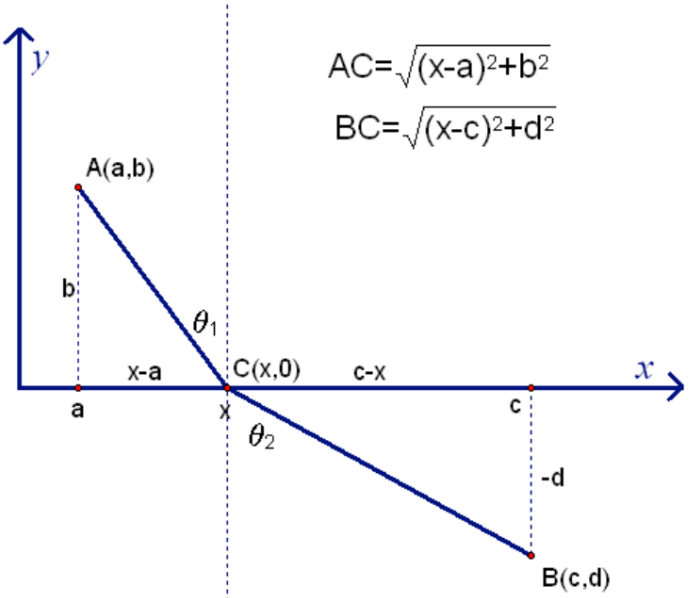
References:
1. Herons shortest path theorem: https://www.cantorsparadise.com/herons-shortest-path-problem-80396c68d5e9
2. Image retrieved from Cantor's Paradise. Heron's Shortest Path Problem (2018). https://www.cantorsparadise.com/herons-shortest-path-problem-80396c68d5e9 date 8/4/2022

Snell's Law:

The Dutch physicist Willebrord Snell conducted experiments on refraction. His observations were that when the light entered a denser medium, its velocity decreases and its path bends towards the normal. This led to him comping up with the relationship:

$$n_1 sin_1\theta = n_2 sin_2\theta$$

During this time, Pierre de Fermat became interested in the derivation of Snell's law and he came up with the 'least time principle'. This improved upon Heron's theory and stated that light doesn't always travel in the path with the shortest distance but that light travels the path which takes the least time.



[3]

Let T be the time taken for the light to travel from point A to point B, through point C. Then $T = \frac{AC}{v_1} + \frac{CB}{v_2}$

$$T = \frac{\sqrt{(x-a)^2+b^2}}{v_1} + \frac{\sqrt{(x-c)^2+d^2}}{v_2}$$

to find the minimum time we can differentiate T with respect to x

$$\frac{dT}{dx} = \frac{\frac{1}{2}[(x-a)^2+b^2]^{-\frac{1}{2}} \times 2(x-a)}{v_1} + \frac{\frac{1}{2}[(x-c)^2+d^2]^{-\frac{1}{2}} \times 2(x-c)}{v_2}$$

$$\frac{dT}{dx} = \frac{x-a}{v_1\sqrt{(x-a)^2+b^2}} + \frac{x-c}{v_2\sqrt{(x-c)^2+d^2}}$$

$$sin\theta_1 = \frac{x-a}{\sqrt{(x-a)^2+b^2}} \quad \text{and} \quad sin\theta_2 = \frac{c-x}{\sqrt{(c-x)^2+d^2}}$$

$$\frac{sin\theta_1}{v_1} - \frac{sin\theta_2}{v_2} = 0$$

$$\frac{sin\theta_1}{v_1} = \frac{sin\theta_2}{v_2}$$

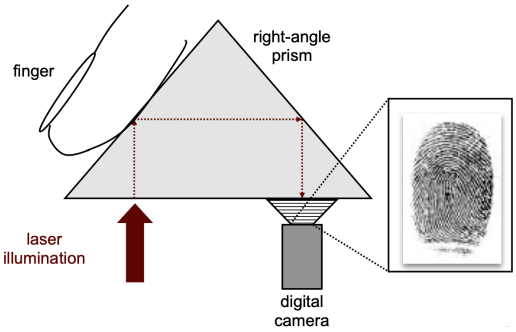
References:

3. Image from: Mathematical Association of America, Optimization- Snell's law and the Principle of Least Time, date: 13/04/22 https://www.maa.org/press/periodicals/convergence/historical-activities-for-calculus-module-3-optimization-snells-law-and-the-principle-of-least-time

Applications

Biometric technology: Fingerprint scanners

There are two types of fingerprint scanners; optical fingerprint scanners and capacitive scanners. [4] The way optical scanners work is by taking an optical image of the finger print and implementing algorithms to detect unique patterns on the surface. A row of LED's shine bright light over your fingerprint. The light is reflected from your finger, through the glass and onto a CCD or CMOS image sensor. An algorithm tests the level of detail by looking for ridges and alternating light and dark areas. The unique points and ridges on your finger are identified and converted to binary numbers (1,0). These numbers are then encrypted and stored.



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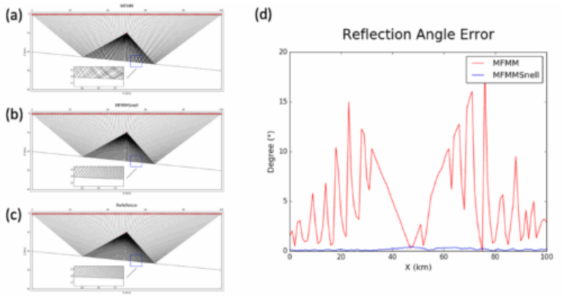
Travel time tomography

Travel time tomography is a method used to determine the Earth's seismic velocity structure. This is in order to determine the structure of the Earth.

Raypaths of reflection waves are significant for reflection travel time tomography. [6] For this, accurate calculations of travel times are needed. There are different methods for reflection wave raytracing such as MSPM (multistage shortest path method) or the MFMM which finds the solution by solving the Eikonal equation (nonlinear partial differential equation). The MFMM method is far more accurate than MSPM however, both methods hold some level of inaccuracy as the reflection angle has a large error as it does not follow Snell's law nearby the reflector. A new method (MFMM-Snell) was developed. This method uses linear interpolation to compute the incident travel time and uses Snell's law to compute the reflection time tomography above the reflector and also the reflection point at the reflector in order to provide a more accurate result for the angle. [7]

The figure below [8] shows represents the reduction in the angle error using the original MFMM method and the improved MFMM method which relies on Snell's law:



Conclusion

Despite Snell's law being considered a relatively easy equation, which is taught to A-level students, it's importance shouldn't be overlooked. Heron and Fermat provided the starting point, with Snell refining and improving the equation they were able to come up with this very important law which is used everyday. Snell's law is used from simple, everyday technologies such as fingerprint scanners, medical imaging and fibre optic communications to more complex applications such as in travel time tomography.

References:

4. https://www.androidauthority.com/how-fingerprint-scanners-work-670934/
5. Image taken from MIT open courseware Lecture 2: Reflection and refraction; prisms, waveguides, and dispersion
6. Infromation from 'Sciencedirect: Application of Snell's law in reflection raytracing using the multistage fast marching method'. and Earthdoc "Reflection Raytracing Using Snell's Law in Multi-Stage Fast Marching Method"
7. https://www.sciencedirect.com/science/article/pii/S2772467021000099
8. Image taken from: https://www.earthdoc.org/content/papers/10.3997/2214-4609.202010820dataandmedia 04/08/2023

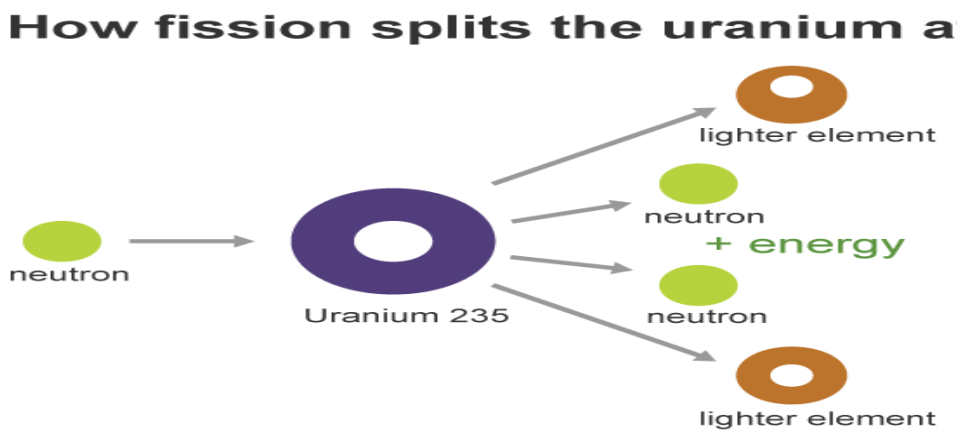
The History and Future for Nuclear Fusion and Fission By Bradley Fry

Introduction to Nuclear Fusion

Nuclear fusion is the process of which two light atomic nuclei combine to form a single heavier one whilst releasing a massive quantity of energy. These fusions take place in a state of matter called plasma - "a hot, charged gas made of positive ions and free-moving electrons with unique properties distinct from solids, liquids or gases". (1) This is how most stars are powered to produce their energy. To produce high energy, the nuclei combining must be under heavy gravity while exposed to extreme hot temperatures- "ten million degrees Celsius". This is important to scientists because and many others due to this being a high energy production, which could be used in the future for clean energy production. Due to fusion being powered by hydrogen the production of the energy is nothing to worry about and is clean due to no carbon dioxide emissions or other bad emissions for the environment being in the process of nuclear fusion. I personally believe that nuclear fusion can be used efficiently to help propel the world into a more advanced society that we currently live in with a way to produce more clean energy without many side effects which currently plague the planet right now. "Plasma, one of the four fundamental states of matter, consists of a gas of ions and free electrons. A burning plasma is one in which most of the plasma heating comes from fusion reactions involving thermal plasma ions. In the Sun, those fusion reactions involve hydrogen ions". (2). This text shows that it will be difficult to access nuclear fusion as the sure fine way of nuclear fusion happening is the sun which is very nearly impossible to access the sun's energy directly.

Introduction to Nuclear Fission

Nuclear fission is where atoms are split apart, and this releases energy. During this process a neutron must collide with a uranium atom, this splits the atom which in turn releases energy and radiation. more neutrons are released as the uranium atom splits. These neutrons keep colliding with the uranium atom and repeats this process. This is known as a "nuclear chain reaction". The reaction takes place in a nuclear power plant, where it is controlled and produces the right amount of heat desired (3). Currently the efficiency for nuclear fission is around 33%-37% and with advancements the efficiency could be as high as 45% soon with better generators (4). I think that these numbers can increase to where nuclear fission can be the main source of energy in the future if there is progress being made to make it a greater and more dependable as an energy source.



Source: Adapted from National Energy Education Development Project (public domain)

The discovery of nuclear fission

The two physicists Lise Meitner and Otto Frisch had discovered over December 1938 that neutrons were capable of splitting uranium atoms. And after discovering that the uranium had split into two drops and was driven apart at high energy at about 200 MeV. After using Einstein's formula of E=mc2. They had used this equation with the mass of the proton being about 1/5 of what a uranium nucleus would be. Soon after it was recognized that if the fission reaction emitted enough secondary neutrons, a "nuclear chain reaction" was possible, which released very high energy and could be used for two main purposes which were an energy source and an atomic bomb. (6)

Nuclear energy becomes commercial

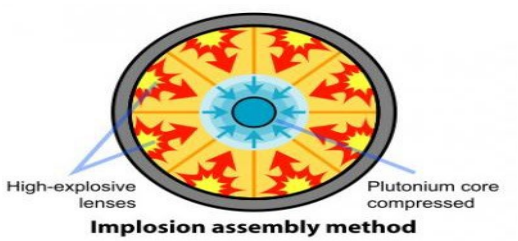
The first commercial use of nuclear fission was started in 1960, PWR 250 MWe, in USA, Westinghouse. "Meanwhile the boiling water reactor (BWR) was developed by the Argonne National Laboratory". (5).

The discovery of nuclear fusion

In the 1930's Hans Bethe had discovered that nuclear fusion was possible, and that the energy source of the sun was produced by nuclear fusion. The task to access the energy produced from fusion was next to impossible due to the reaction requiring the temperature to be at "ten million degrees Celsius". -(1). The physicists researching fusion had thought of containing plasma with magnetic fields, for example using the "pinch effect" where electric currents are moving in the same direction attracting each other through their magnetic fields. This was called the "magnetic confinement". (7).

The Atomic Bomb

The atomic bomb made during the 2nd world war was built upon using the principles of nuclear fission. "The isotopes uranium-235 and Plutonium-239 were selected by the atomic scientists because they readily undergo fission. Fission occurs when a neutron strikes the nucleus of either isotope, splitting the nucleus into fragments and releasing a tremendous amount of energy". (8). This is known as the implosion assembly method. The little boy was powered using uranium-235 isotope and due to 0.7% of uranium only existing naturally as the 235 isotopes of uranium. The first problem that the scientists had was converting uranium-238 to a pure amount of uranium-235. One separation metho that could be used was electromagnetic separation (8). This uses a mass spectrometer to send a stream of charged particles through a strong magnetic field and atoms of uranium-235 would be deflected more by the magnetic field than the heavier uranium-238 isotope, which resulted into two streams that could be collected by different receivers. However, in 1940 this method would have taken too long to be useful. (9). During the Modern era atomic bombs are not the primary source of nuclear weapons in the world so there was not much material on how they were developed over time.



Implosion assembly method

-(8)

Conclusion to how I believe nuclear fusion and fission will develop into the future

I personally believe that there will be many developments to make nuclear fission the most reliable energy source on the planet that will last 200-300 years until there are better process to harness nuclear fusion. During this time period I think there will be much more interest in how the powerplants function, and the innovative ways nuclear physicists make the generators more effective. Whilst more knowledge will be learnt about nuclear fusion as technology advances and more uses will unveil for it. I think that space travel will become more viable when we can use the energy transferred from nuclear fusion.

(1)- https://www.iaea.org/newscenter/news/what-is-nuclear-fusion - 08/09/2023

(2)- https://www.energy.gov/science/doe-explainsburning-plasma#:~:text=Plasma%2C%20one%20of%20the%20four,fusion%20reactions%20involve%20hydrogen%20ions -08/09/2023

(3)- https://www.eia.gov/energyexplained/nuclear/#:~:text=During%20nuclear%20fission%2C%20a%20neutron,itself%20over%20and%20over%20again – 08/09/2023

(4)- https://energyeducation.ca/encyclopedia/Nuclear_power_plant#:~:text=Typical%20nuclear%20power%20plants%20achieve,potentially%20reach%20above%2045%25%20efficiency – 08/09/2023

(5)-https://world-nuclear.org/information-library/current-and-future-generation/outline-history-of-nuclear-energy.aspx -08/09/2023- under nuclear energy goes commercial.

(6)-https://www.aps.org/publications/apsnews/200712/physicshistory.cfm - 08/09/2023

(7)-https://www.lppfusion.com/technology/brief-history-of-fusion-power/ -08/09/2023

(8)-https://ahf.nuclearmuseum.org/ahf/history/science-behind-atom-bomb/#:~:text=The%20isotopes%20uranium%2D235%20and,a%20tremendous%20amount%20of%20energy – 10/09/2023

(9)-https://ahf.nuclearmuseum.org/ahf/history/isotope-separation-methods/– 10/09/2023

Chernobyl and dangers of radiation

On the 26th of April 1986, the Chernobyl power plant experienced a major failure within nuclear reactor no.4 which caused the reactor core to melt.[1] Chernobyl is located near the city of Pripyat in the north of Ukraine and was in operation during Soviet Russia. Author B.J Garrick states that the main events which led to the failure in the reactor were a loss of external power paired with a major coolant leak, with the main cause for the explosion being written down as "steam explosions" due to the amount of coolant that was pumped into the reactor. Radiation released from the accident continued to be released from the reactor for around 10 days (about 1 and a half weeks). After the accident, 64 human deaths have occurred through acute radiation poisoning and cancer deaths related to radiation poisoning from the reactor were estimated to be between 4000-9335 and it was said that "predominantly it was workers who assisted with the cleanups of the Chernobyl reactors who suffered the most". [1]

 [6]

Exposure to radioactive iodine 131I gives off radiation that breaks the chemical bonds within DNA strands. From this exposure," Mutations can form when the body attempts to repair these bonds." [2]. It was this exposure that resulted in the estimated 1000 cases of thyroid cancer within Europe, alongside 4000 cases of other cancers, according to the US department of Health and Human services

[1] https://www.sciencedirect.com/topics/medicine-and-dentistry/chernobyl-nuclear-power-plant 21/04/23, Science direct – B.J Garrick

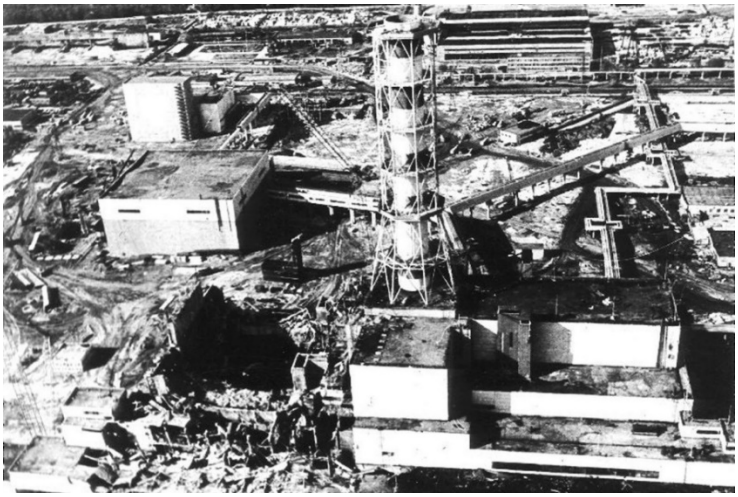
[2] https://www.nih.gov/news-events/nih-research-matters/genetic-effects-chernobyl-radiation-exposure#:~:text=Exposure%20to%20radioactive%20iodine%20(131,attempts%20to%20repair%20these%20bonds . 21/04/23, US department of Health and Human services.

[6] https://www.google.com/searchsca_esv=568147601&rlz=1CAZJQH_enGB1054&sxsrf=AM9HkKlRQqHOzQIM5wvKZwNpQGAm9MXwOQ:1695636733012&q=chernobyl&tbm=isch&source=lnms&sa=X&ved=2ahUKEwiroI6Jw8WBAxULQkEAHfqZAIEQ0pQJegQIDxAB&biw=1536&bih=788&dpr=1.25#imgrc=Sd_Ow-oqiV_laM

Why was there a nuclear meltdown?

World Nuclear.org [3] states that the accident was a result of a "flawed reactor design that was operated with inadequately trained personnel." The accident occurred due to poor communication between operating staff who prior to a routine shutdown, they began to prepare reactor 4 for a test which would determine how long turbines would spin and maintain a power supply to the main circulating pumps following a loss of main electrical power. New operator actions were to be used during this test of the reactor such as the disabling of automatic shutdown mechanisms, however by the time operators had moved to shut down the mechanism, the reactor had already reached an extremely unstable condition. Alongside this, an anomaly regarding the design of the control rods caused a dramatic power surge once inserted into the reactor. Once the extremely hot fuel and the cooling water began to interact, fuel fragmentation occurred alongside the production of steam and therefore a dramatic increase of internal pressure. The overpressure caused the 1000 tonne cover plate of the reactor to become partially detached, causing ruptures to some of the fuel channels. Scientists believe that it was these ruptures which caused "the majority, if not all, of the control rods to become jammed at only half of their desired positioning." [3]

The buildup of steam eventually resulted in a steam explosion, releasing fission products into the atmosphere. Two to three seconds after the first explosion, a second explosion threw out fragments of fuel channels and hot graphite. The combination of the fragments from the fuel channels and hot graphite resulted in several fires across the site, and it is believed by scientists and researchers that this is what caused the main release of radioactive elements into the environment. In total, around 14EBq (equivalent to 14x10^18 Bq) of radiation had been released into the environment, from biologically inert noble gases. [3]

 [7]

[3] https://www.world-nuclear.org/ukraine-information/chernobyl-accident.aspx#:~:text=The%20Chernobyl%20accident%20in%201986,in%20many%20parts%20of%20Europe. 20/08/23, World nuclear.org - Chernobyl accident 1986 -

[7]https://www.google.com/searchsca_esv=568147601&rlz=1CAZJQH_enGB1054&sxsrf=AM9HkKkR0HF4SdZjypJNmfxoIqTcaMG_Bw:1695636656695&q=chernobyl+reactor+4&tbm=isch&source=lnms&sa=X&sqi=2&ved=2ahUKEwjymdzkwsWBAxWbSvEDHZbsD2QQ0pQJegQIDBAB#imgrc=BCBsp2N6KFEirM

Although people believe that Reactor 4 has been cleaned up now, scientists say that it will take" at least 3000 years for the area to become safe again" [3] whilst others believe the number to be closer to as long 20,000 years.

Why is radiation so dangerous?

We are exposed to radiation all the time due to natural reserves. In the UK, half of the radiation we are exposed to comes from natural radon gas which is produced from the decay pf natural uranium deposits found within rocks and soil. [4] However, this background radiation has extremely little to no effect on our health and like with most other toxins, "it is the dosage that makes radiation so dangerous." [4] Alongside the size of the dosage that a person receives, the dose rate is vital as to how dangerous the radiation will be. Dose rate is the time taken for a dosage of radiation to be received, and if the dosage is over a long period of time it is much safer than receiving the same dose over a shorter period of time, as the body has enough time to recognise the radiation and work to break it down before it becomes too harmful.

When dealing with radiation, the primary target which it affects is our DNA and other forms of genetic material. The main ways that radiation damages our DNA is by directly breaking down bonds within the DNA, or by indirectly breaking the water molecules which surround the DNA. Once these water molecules have been broken down, they produce something called free radicals (unstable oxygen molecules capable of causing damage to both cells and organs).[4] Once radiation has damaged a cell, there are only three outcomes for the cell. These consist of repaired, altered, or dead. A repaired cell will simply repair itself and return to performing its standard function with no change. An altered cell can either be a cell which cannot be repaired but is still able to perform a function, but it is not the desired function, or a cell which has been incorrectly repaired and is now performing the wrong function within the body. In both cases the cell can lead to the development of cancerous cells.

[3] https://www.world-nuclear.org/ukraine-information/chernobyl-accident.aspx#:~:text=The%20Chernobyl%20accident%20in%201986,in%20many%20parts%20of%20Europe.
20/08/23, World nuclear.org - Chernobyl accident 1986

[4] https://ukinventory.nda.gov.uk/about-radioactive-waste/what-is-radioactivity/#:~:text=On%20average%2C%20about%2084%25%20of,power%2C%20industrial%20and%20defence%20activities.&text=In%20the%20UK%2C%20about%20half,comes%20from%20natural%20radon%20gas.
20/08/23, UK Radioactive Waste Inventory

The last outcome for affected cells is simply cell death, however scientists state that "this is not always the worst-case scenario for people exposed to radiation."[4] Cell death occurs when too much damage is sustained to the cell and it is unable to repair itself in any form, and if wide-spread cell death occurs within the body, then organ failure is a likely outcome and therefore the recipient is likely to die. On the other hand, local cell death may result in your body being able to make a recovery and the risk of affected cells developing into cancerous cells is mitigated.

Chernobyl now

Two months after the explosion within Chernobyl's reactor number 4 the Soviet cleanup team "scrambled to build a sarcophagus to contain the debris" [5]. On Business insider [5] it is said that around 60,000 workers were involved in the construction of this initial sarcophagus, and it was built to contain the estimated 220 tons of radioactive material presumed to be trapped within the downed reactor 4. The initial sarcophagus consisted of 400,000 cubic meters of concrete and 16 million pounds of steel, however in the haste of their construction, water had seeped into the holes within the roof and caused corrosion of the sarcophagus. Out of the 60,000 workers, it is believed that at least 31 died of acute radiation sickness (ARS) and in 1988, the Russian scientists revealed that the sarcophagus had only been designed to last "between 20 to 30 years" [5] which was nowhere near enough time for the levels of radiation to become safe again. After the collapse of the USSR, the Ukranian government launched an international design competition to produce a replacement sarcophagus. In 2004 a British design was approved by the Ukranian government, and the contract was given to a French consortium called Norvaka.

Construction of the new sarcophagus, designed to last 100 years, began in 2010, and the basic framework was complete and put into place by 2014. In November 2016, the completed shell was rolled into its final position, but construction of the new shell's internals lasted for 3 more years, as workers had to limit their radiation exposure. In 2019 the final structure was revealed to the public.[5]

[4] https://ukinventory.nda.gov.uk/about-radioactive-waste/what-is-radioactivity/#:~:text=On%20average%2C%20about%2084%25%20of,power%2C%20industrial%20and%20defence%20activities.&text=In%20the%20UK%2C%20about%20half,comes%20from%20natural%20radon%20gas. 20/08/23, UK Radioactive Waste Inventory

[5] https://www.businessinsider.com/chernobyl-disaster-sarcophagus-construction-dismantling-2019-9?r=US&IR=T#less-than-two-months-after-the-disaster-soviet-cleanup-workers-scrambled-to-build-a-sarcophagus-or-massive-covering-to-contain-the-debris-2 22/08/23, Chernobyl sarcophagus timeline – Aria Bendix

 [8]

However, only a few weeks after the public were shown the complete shell which encased reactor number 4, experts revealed that the sarcophagus had a “very high probability of collapse” [5], and that “only gravity had been keeping the structure tethered to its supporting blocks” [5]. Workers will now have to reinforce the structure of the sarcophagus, whilst simultaneously disassembling some of the parts. Once the sarcophagus has been torn down, workers will have to begin the humongous task of cleaning up the radioactive waste which will consist of vacuuming up radioactive particles and the removal of the ‘lava’ mixture created when the Soviets poured sand, lead, and boron into the burning reactor to extinguish the fires. The entire process is expected to continue through 2065, where scientists have predicted the number of cancer cases because of the radiation from the accident will exceed 40,000.

[5] https://www.businessinsider.com/chernobyl-disaster-sarcophagus-construction-dismantling-2019-9?r=US&IR=T#less-than-two-months-after-the-disaster-soviet-cleanup-workers-scrambled-to-build-a-sarcophagus-or-massive-covering-to-contain-the-debris-2 22/08/23, Chernobyl sarcophagus timeline – Aria Bendix

[8] https://www.google.com/searchsca_esv=568157848&rlz=1CAZJQH_enGB1054&sxsrf=AM9HkKk4OvTKmLmLuuThptght2LbnN974w:1695637941485&q=chernobyl+sarcophagus%23&tbm=isch&source=lnms&sa=X&ved=2ahUKEwjXz63Jx8WBAxVmUUEAHeABB4IQ0pQJegQIDRAB&biw=1536&bih=788&dpr=1.25#imgrc=PqHhVSzZYs-Q4M

Cortney Green

Einstein's Theory of Relativity:

Time Dilation

Introduction:

Albert Einstein received the Nobel Prize for Physics, 1922[1],for his contribution towards theoretical physics and the photoelectric effect. The global recognition of the award aided further in the support of his new theories.[2] The new theories being: the theory of special relativity, 1905, and his general relativity theories, 1915, which introduced gravity into "one of the most important papers ever published"[3]. His theories concluded "that particularly massive objects warp the fabric of space-time, a distortion that manifests as gravity"[4] The theory of general relativity was the first recorded proposal of an effect called time dilation.[5] Time dilation stated as " the slowing of time as perceived by one observer compared with another, depending on their relative motion or positions in a gravitational field."[6] This phenomenon conjoined with both Einstein theories, is credited as worldly fundamental and are still apart of many experiments and responsible for the advance of global applications.

Applications:

Time dilation has had varies applications and been the focused for numerous experiments, most focusing on more extreme conditions. Nevertheless experiments, surrounding more common conditions, show that all humans experience time dilation.[7] The National Institute of Standards and Technology confirmed this with a multitude of investigations, one being done in 2010. They concluded that people "age faster when you stand a couple of steps higher on a staircase.".[8] This connection was made through calculations showing that this

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[1] How I created the theory of relativity 'The nose as a reservoir for thoughts' cartoon by Ippei Okamoto. (Courtesy AIP Niels Bohr Library.). (n.d.). Available at: https://courses.physics.ucsd.edu/2022/Fall/physics2d/einsteinonrelativity.pdf.

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effect is detectable from a scale of 33 centimetres.[9] Another series of experiments including atomic clocks further proved the effects of time dilation on earth.

Hafele-Keating Experiment

In 1971 Joesph Hafele and Richard Keating demonstrated time dilation using caesium-beam atomic clocks that were place on circulating aircraft set to travel eastward and westward.[10] Each flight had four caesium beam atomic clocks with an additional four left on Earth, the prediction was that the eastward clocks would lose 40 nanoseconds and the westward clocks would gain 275 nanoseconds.[11] These predictions were made in the hopes of producing measurable evidence of Einsteins theories. After observing the clocks that had returned from the commercial airflight and making the comparison between them and the four clock that were stationed in the Washington lab the final conclusions were drawn. The eastward clocks had lost 59 nanoseconds and the westward clocks gained 273 nanoseconds.[12] And despite the discussions regarding accuracy, the results of the experiments were regarded as "unambiguous empirical resolution of the famous clock paradox"[13] and established that "time is not universal and absolute".[14]

https://www.nist.gov/news-events/news/2010/09/nist-clock-experiment-demonstrates-your-head-older-you [Accessed 23 August 2023].

[9] Chou, D.B. Hume, T. Rosenband and D.J. Wineland. (2010). NIST Clock Experiment Demonstrates That Your Head is Older Than Your Feet. [Online]. NIST. Last Updated: 2 February 2023. Available at: https://www.nist.gov/news-events/news/2010/09/nist-clock-experiment-demonstrates-your-head-older-you [Accessed 23 August 2023].

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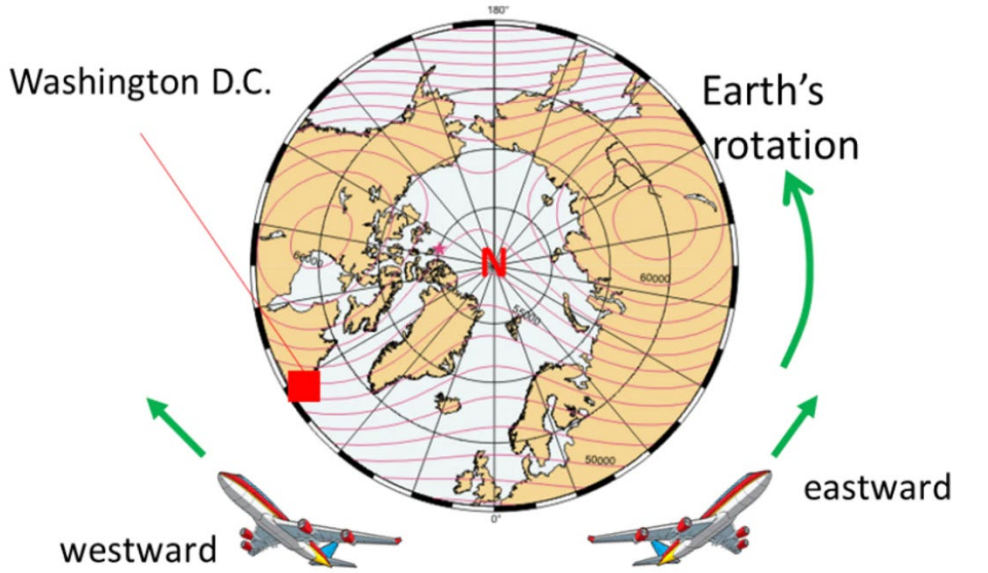

15

The Global Positioning System

The global positioning system is ubiquitous, it is used by the majority and is credited as a useful application. So much so that 93% of drivers use a GPS[16], "millions of drivers, hikers, sailors, and pilots" depend on it[17] and is generally considered a well-known concept even to school children.[18] The GPS is crepitated as an application of time dilation as it" is, in effect, a realization of Einstein's view of space and time." and utilizes the fundamental principles of relativity. There are 24 satellites in orbit [19] "four satellites in each of six orbital planes inclined at 55° with respect to earth's equatorial plane". This is done so that there are four or more satellites above the horizon. Each satellite is equipped with stable atomic clocks that aid in the transmission of (synchronous timing) signals. [20] These atomic clocks provide the means for accurate navigation with GPS, in the case of errors the clock must "deviate by less than about 4 nanoseconds from perfect synchronization with the other

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[15] HSC Resources. (n/a). Time Dilation and Length Contraction. [Online]. Science Ready. Last Updated: n/a. Available at: https://scienceready.com.au/pages/time-dilation-and-length-contraction#:~:text=In%201971%2C%20Joseph [Accessed 21 August 2023].

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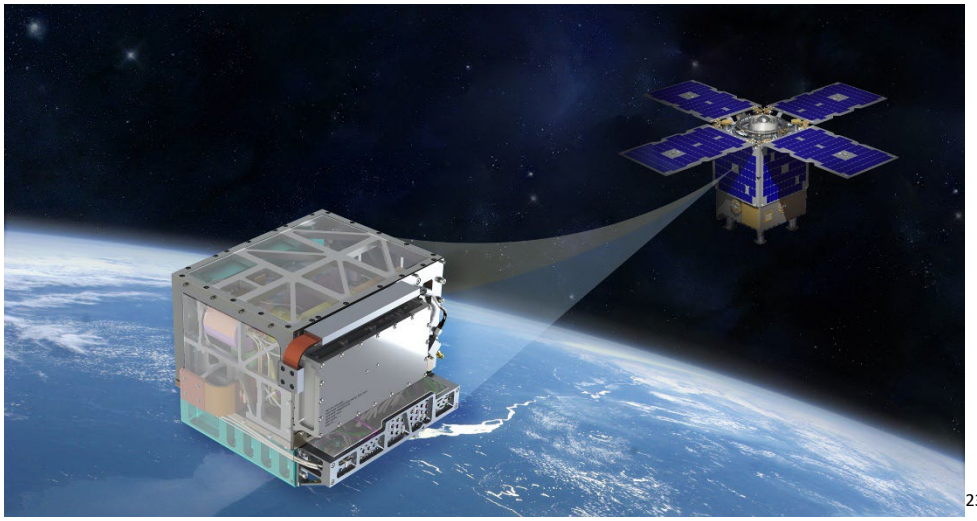
[19] Ashby, N. (2005) 'Relativity in the global positioning system', 100 Years of Relativity, pp. 257–289. doi:10.1142/9789812700988_0010.

[20] Ashby, N. (2005a) 'Relativity in the global positioning system', 100 Years of Relativity, pp. 257–289. doi:10.1142/9789812700988_0010.

satellite clocks."[21] Deactivation must be within 4 nanoseconds for efficient synchronization, this is only possible with atomic clocks since they use the Fondmetal's of relativity.[22]

 [23]

Conclusion:

Time dilation used to be a fictional belief with its earliest conceptions dating back to the 1930s.[24] However, through Einstein's theories, physicists have been able to adapt and prove its applications creating worldwide uses.

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Quantum Immortality and Its Controversies

Quantum Immortality (QI) is a thought experiment derived from the Many-Worlds Interpretation (MWI). In the simplest terms, in this thought experiment a living being will simultaneously live and die in separate worlds, continuing for an infinite number of repetitions. Quantum Immortality is the idea that the being will supposedly never die whereas Quantum Suicide (QS) is the inverse, where the being will die in every repetition. For this to take place each outcome must occur in distinct, co-existing parallel universes.

The MWI was initially presented by American physicist Hugh Everett who proposed this concept in 1957[i], known as the Everett Interpretation. He proposed the idea of the Everett Box[ii], in which there is an observer in a box alongside a quantum apparatus. If it goes off it causes the observer to die. From the observer's perspective the probability of survival decreases with each repetition. It is this decrease in the probability of survival combined with the repeated survival of the observer which Everett used to support the MWI. The continued survival in each repetition becomes so improbable within a single world that this thought experiment somewhat proved Everett's claims of a branching universe. His experiment has also been referred to as a "variation of the Schrodinger's cat experiment, from the cat's point of view"[iii], since both thought experiments rely on a state of superposition. However, since the publishing of Everett's MWI there have been multiple progressions from a wide range of contributors.

Whilst QI was never directly referenced by Everett in his works, the foundations he produced in the MWI allowed for the development of QI. Alongside this, as stated in Eugene Shikhovtsev's biography of Everett, he "firmly believed his many-worlds theory guaranteed him immortality"[iv]. Despite the potential outcomes from his works, Everett never promoted the MWI[v]; in fact after accepting a job at the Pentagon he withdrew (to an extent) from academia. It was not until the 1960s[vi] that his interpretation first began to gain an interest as physicists began to realise the potential of Everett's findings. One key contributor who developed Everett's works was Max Tegmark, a Swedish-American physicist. Tegmark published a paper in 1997 in which he proposed that if QI is true, then it must be possible to survive an accident which would usually end in fatality[vii]. Nevertheless, this suggestion generated many controversies which have since challenged Tegmark's claims.

One of the controversies regarding QI gained momentum when the conditions required for QI to be possible were developed. The first, and arguably most vital, condition is that there is an infinite number of copies of the observer, each with alternate lives[viii]. This is one of the only realistic conditions for QI, claiming the universe can account for the fact that for any experiment in which an observer does not survive, there is another copy of the observer which did survive. This is supported by the branching off of subsequent worlds, detailed in Everett's MWI.

On the other hand, QI is reliant on the fact that the MWI is the correct Quantum Mechanics theory, ignoring the opposing findings from other physicists. This leads to another flaw in the QI experiment. Its reliance on Everett's MWI was previously a minimal issue but as time has progressed the number of theories challenging his findings has significantly increased. Many of these were founded at a similar time to Everett's interpretation. One was the Copenhagen Interpretation, a theory worked on by many physicists including Neils Bohr, Max Born and Werner Heisenberg[ix]. Their findings led them to believe that observation results in the wave function collapsing into a single reality. This interpretation was used to challenge the MWI as claims were made that the state of superposition the MWI relied on did not apply at a macroscopic scale[x]. Furthermore, the Copenhagen Interpretation challenges the foundations of the MWI, as Copenhagen's explanation portrays how the state of particle trajectories will converge into the observer's timeline, causing a quantum

particle to exist in all possible states simultaneously. This is a direct contrast to the ideas of individual splitting into separate worlds explained in the MWI. The Copenhagen Interpretation is a key example of opposing ideas to the MWI which discredit Tegmark's claims of the ability to survive a fatal accident.

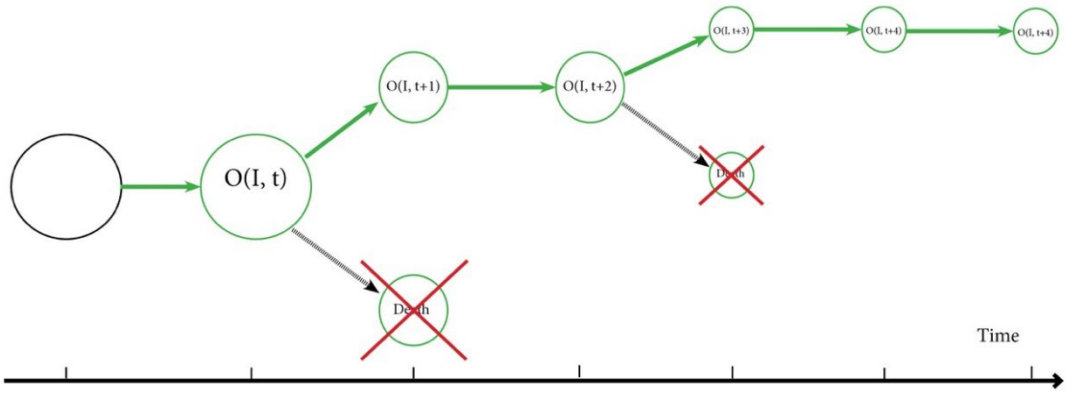

Figure 1[xi] Diagram showing the splitting of universes throughout the QI thought experiment.

In addition, there are physicalities which also oppose the idea of QI. For instance, whilst the MWI explains the splitting of worlds to account for separate beings, the consciousness of these beings is not accounted for. It is assumed that consciousness continues to exist even in parallel universes after death. However, consciousness is a trait of a living being, contrasting this assumption. The concepts of physical aging and decay are also not accounted for. For instance, if the observer continues down the path of QI, eventually the observer will die of old age[xii] (assuming there are no other fatalities encountered). This leads to the issue of the finite nature of human life. QI is reliant on infinite concepts like the infinite splitting of worlds with each experiment. For this to continue the observer must also be able to continue for infinity. The physical mortality of human nature begins to unravel the theoretical prospects presented by QI.

Following these points, more controversies arise. QI is an experiment in which an observer encounters a fatal accident, making this theory untestable. This is a reoccurring flaw within these theories. Everett's MWI was initially published with a much larger focus on the theory and possibilities this interpretation allowed for, rather than a mathematical explanation. It is this difference between the claims made in this theory and the lack of evidence to support it which underpins many controversies behind QI becoming feasible. Furthermore the great contrast between Bohr and Schrodinger's Copenhagen Interpretation in 1927[xiii] and Everett's MWI caused uncertainty in believing the MWI. The Copenhagen Interpretation relies on the existence of wave function collapse[xiv], whereas Everett described the universe as some form of enormous wave function which contained all possible realities within itself[xv]. This new understanding of wave function collapse made the MWI controversial.

There is also an ethical opposition to QI. Conceptually, QI is a vastly interesting theory with immense potential but its "untestable"[xvi] nature leaves it solely as a theory. This renders QI as nothing but a thought experiment but this does not mean it will remain that way. Recently, many videos have been shared on social media platforms, very briefly describing the basics of QI. As a result, this thought experiment has reached a much larger and very different audience than other interpretations within theoretical physics. Many of these videos simply highlight the concept of immortality and do not tend to mention the restrictions or assumptions made when considering QI, leading to a very false interpretation being spread throughout mainstream media. This could potentially lead to people considering or actually putting this thought experiment into real practice. However, the fantasy of

immortality that is somewhat present through this theory coincides with QS, which is an equally likely result to this experiment. Eugene Shikhovtsev even suggested in his biography of Everett that his daughter Liz's suicide in 1996[xvii] was related to her father's works in MWI and QI. While this an unsupported claim, it is not impossible. Furthermore, QI and QS are simply life and death experiments. The fact that it is somewhat self-inflicted is not relevant here, leading to claims that experiment of quantum survival could easily progress into other methods of death like "Quantum Murder"[xviii]. It is the progressions of these ides within society among people who are uneducated on the reality of the MWI which poses a threat, leading to many physicists debunking the fallacy that QI provides.

In conclusion, QI is an interesting concept which in the future could be developed or supported by more mathematical data but the controversies which follow investigating QI and QS may deter physicists from progressing this theory further. To a minimal extent, QI could be possible, but it is reliant on many circumstances being true and constant which is not maintainable. Alongside this, the untestable nature of this thought experiment renders it extremely difficult to progress with sufficient information. Moreover, the ethical issues provide an unfortunate dilemma for a theoretical physicist hoping to develop this idea. A promotion into believing in the MWI and QI further spreads the fallacy that this could be applied in any situation, eventually resulting in deaths unless the hysteria caused by the spread of misinformation on this theory is dismantled. It is the common belief from media that the MWI implies QI, combined with the many conditions required for QI to be true, which make its validity uncertain.

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[iii] Contributors, W. (2023b) *Quantum suicide and immortality*, *Wikipedia*. Available at:https://en.wikipedia.org/wiki/Quantum_suicide_and_immortality (Accessed: 22 August 2023).

[iv] Shikhovtsev, E. (2003) Biographical sketch of Hugh Everett, III, Home. Available at: https://space.mit.edu/home/tegmark/everett/everett.html#e08 (Accessed: 22 August 2023).

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[xv] Ball, P. (2022) Why the many-worlds interpretation has many problems, Quanta Magazine. Available at: https://www.quantamagazine.org/why-the-many-worlds-interpretation-has-many-problems-20181018/ (Accessed: 31 August 2023).

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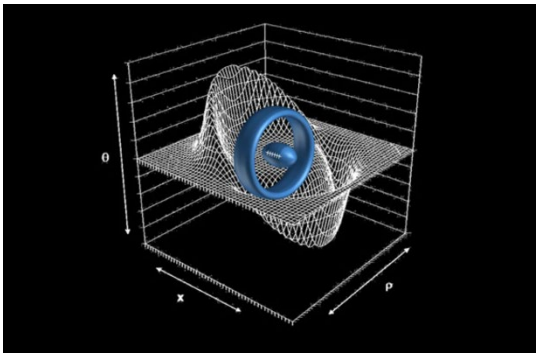
Reasearch into the problems of using a warp drive to traverse space.

-Ethan Aldous

Introduction

The universe around us in inexplicably large, with recent estimates for the size of the observable universe to be 93 billion light-years in diameter (Sottosanti, 2022). This distance is incomprehensible to the human mind and seems to completely dismantle any hopes of ever truly exploring the universe. With humanities' furthest probe into space (Voyager 1) that has been travelling through space since 1977 only travelling 161 AU as of September 2023 (California institute of technology, 2023). This has led many scientists to ponder the idea of a way in which we could far exceed our current capabilities of travel and even achieve FTL (faster than light) travel allowing inter-galactic travel to become a reality. The most interesting of such a device is one named the Alcubierre drive by theoretical physicist Miguel Alcubierre in 1994(Alcubierre,1994). This is the same principle as the more commonly known phrase “Warp drive” introduced by John W Campbell in a novel published in 1957 and popularised by many Sci-fi films and series such as Star Trek. As the name suggests, such a device literally warps space around it in order to traverse the cosmos magnitudes faster than what is currently possible with conventional means. However, this idea comes with a multitude of problems that pose extreme engineering challenges that may not be possible to overcome, which we will explore in this paper.



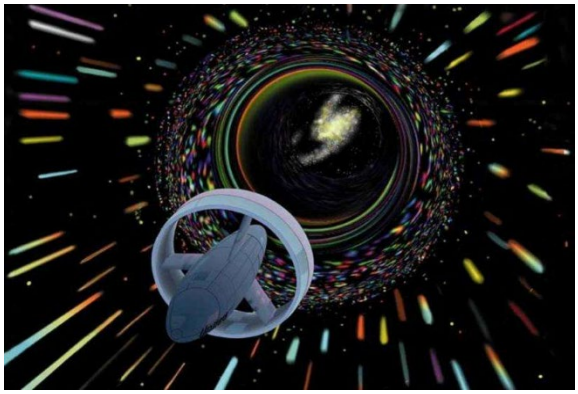
(NBC News, 2013)

Energy requirements of a Warp Drive

The first problem of a theoretical warp drive would be the vast amount of energy needed to launch such a space craft. As you would expect, with a monumental feat such as travelling through space at FTL speeds and bending the very fabric of space in such a manner, the energy required poses one of many seemingly insurmountable barriers for FTL travel. In a paper constructed by Chris Van Den Broeck (Broeck,1999), by taking the original paper by Alcubierre (Alcubierre,1994) and modifying the shape of the warp bubble, he managed to reduce the energy requirement from $E \simeq -6.2 \times 1062$vs kg which is “ten orders of magnitude bigger than the total positive mass of the entire visible Universe” to “the order of a few solar masses” (Broeck,1999) This is a seemingly great precedent in the formulation of a warp drive, as in just a few short years the energy requirement has been significantly reduced and is no longer one that seems completely unrealistic for civilisation, in a couple of centuries or even a millennium. However, the way in which this reduction of energy occurred poses a great problem in its own right. In order to achieve this feat, Broeck proposed that the actual wall of the warp bubble itself cannot be made thicker than “approximately one hundred

Planck lengths for velocities". A plank length is thought to be the smallest distance in the universe, "the shortest physically measurable distance" (Plank length, Wikipedia editors)

While many deem sub-atomic particles such as an electron to be unfathomably small and impossible to visualise, the plank length takes this feeling to new heights. To put it into perspective, the plank length is estimated to be 1.6×10^{-35} m (Plank length, Wikipedia editors), while one of the smallest distances that has been currently measured is the upper bound measurement of the radius of an electron, at 10-22 m or ten trillion Plank lengths (Koltz. A, 2015). This shows how incredibly small this wall would have to be. Not only would it not be visible to the human eye, but it would smaller than anything engineered by humans ever in history, a monumental engineering challenge that does not seem possible to produce in the near future. This displays how there really are no easy short cuts in building a working warp drive as if you solve or partially solve one issue, such as the energy requirement, there is another great challenge that arises due to those manipulations. This makes the idea of a warp drive seem not worth working towards for many scientists and is a cruel crash back down to the reality of our feeble position compared to the vast expanse of the universe.

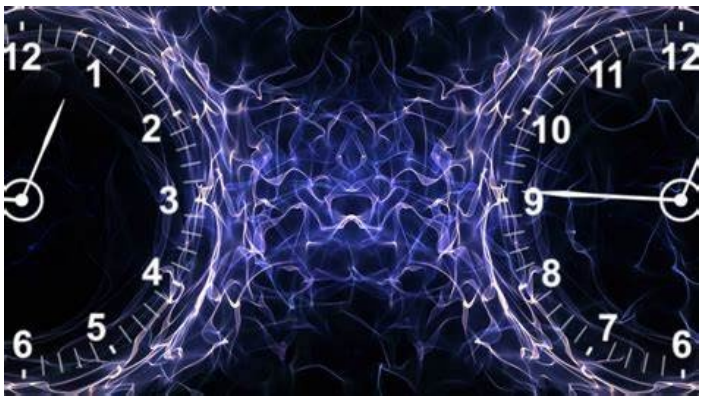


(B-cdn.net. 2023)

The requirement for exotic matter

The next issue regarding the Warp drive is that it seems to require the use of exotic matter, in this instance negative energy or mass. Dark matter or energy is thought to make up a large majority of the universe, and it has been theorised that "gravitationally repulsive negative masses" could be what is causing the constant expansion of the universe (Farnes, J.S 2018). However, while this could mean that negative masses or energy do exist, this is not yet proven, and we have not found any plausible way of isolating or using such exotic matter. The warp drive requires the use of such matter as, where it currently stands, it seems to violate the Weak Energy Condition (WEC). The WEC expresses the idea that for all time like observers (beings that always experience moving forward in time like us) the energy density must be positive, or at least non-negative (Kontou, E.A and Sanders, K 2020). Violating the WEC implies that there is negative energy or mass, and as explored by Alcubierre in his only follow up paper in 2021 along with Francisco S. N. Lobo, acknowledges that his equations for the drive do in fact violate the WEC and that "the energy density for this class of spacetimes is nowhere positive". This means that the Warp drive, in order to not violate a fundamental law of physics would have to utilise negative energy or matter; and yet we do not even have concrete evidence for its existence. This once again poses another key issue with the construction of a warp drive and begins to blur the line of science and science-fiction with ideas of harnessing exotic matter and shaping it within the outer wall of a warp drive whose thickness is no more than 100 plank lengths.

Time travel with FTL movement



(Healththoroughfare,2023)

A different kind of problem presented by the warp drive, that is not related to the actual construction of the ship, it is that in fact any method you use to travel faster than light can in principle be used to create a time machine including the warp drive itself (Alcubierre, .M 2019). This is problematic as it can create closed time like curves (CTC). CTCs would seem to theoretically allow you to travel back in time (Wikipedia, 2023). In Allen E. Everett's paper (Everett, 1996), he showed that either the warp drive would create a singularity, and the CTC's would be "hidden behind an event horizon" or that if no singularity is formed then there could be no CTC as the energy density would be positive which was proven to prohibit CTC's as it would mean that the WEC was not violated (S. W. Hawking 1992). However, with the current warp drive model, as previously explored in this paper, we know that the WEC will be broken without negative energy and so a CTC will occur. There are many different paradoxes which can occur as an effect of traveling backwards in time with FTL travel. One of the most famous examples is the grandfather paradox, which explores the consequences of changing something in the past and how this can seemingly break causality (Wikipedia, 2023). For example, if you were to travel through the universe at an FTL speed, and then turn back around and land back on Earth, it is possible that you will have arrived before you embarked, or perhaps before you were even born. In this case, what would happen if you killed your grandfather before you were born. If that happened, then he would not be able to create your parents and thus you would never be born. However, if you were never born then you could not have travelled back in time to commit that act, and so he would not have died, and you would have been born, and thus the cycle would begin again. This would seem to create an infinite causal loop with no obvious solution. This is known as a consistency paradox and occurs whenever you attempt to change the past. With this we see that even if we were able to overcome the immense engineering challenge of creating the warp drive, there may be unforeseen consequences to using such a device.

Summary

The idea of a warp drive is one popular in both scientific research and Science fiction, proposing a way in which humanity can explore the cosmos within our lifetimes, by warping the very fabric of space. However, this paper has highlighted three major problems with such a device that have been outlined in scientific research. For such a device to exist, not only does it require a huge amount of energy (3 solar masses) which humanity has not even begun to reach close to; but it also requires

the use of negative energy or matter which is only theoretical in nature, as without this it will violate the Weak energy condition. In addition, it also requires an outer wall of diameter no more than one hundred plank lengths in order to drastically reduce the energy requirements to the aforementioned 3 solar masses. Finally, it also facilitates the creation of a time machine as a side effect of faster than light travel. Overall, the idea of a warp drive poses the greatest engineering challenges ever faced by humanity and could break causality as we know it. However, if there is one thing mankind always does, it is push the boundaries of what is perceived to be possible, and so the idea of a warp drive remains a distant hope, an elusive goal that may yet be achieved in the very distant future.

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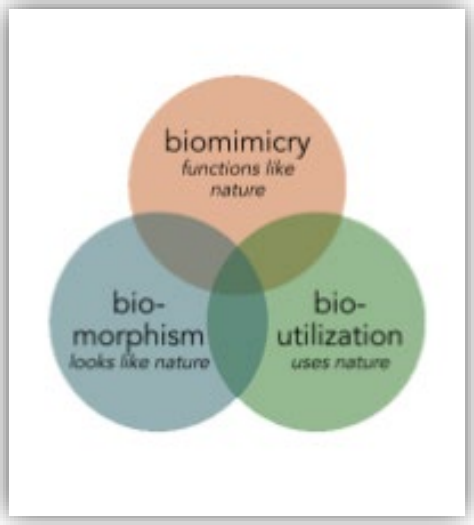
How engineering and nature work simultaneously to enhance modern aircraft and aerodynamics.

In this essay I will be exploring the study of how animals and nature have adapted to maximise their aerodynamics and how this is incorporated into modern technologies such as commercial airlines, military aircraft, drones and micro drones.

Aeronautical engineers have been learning from nature on how to create new aircraft designs, concepts and modes of travel [1]. Biomimicry is 'a practice that learns from and mimics the strategies found in nature' [2] this can be used to solve human design challenges and achieve new feats of innovation. this study of nature has helped inspire the innovation in aerodynamics in flight with leaders such as Airbus modelling concepts inspired by the eagle which incorporates individual moving 'feathers' [1] into the wings and a tail inspired by the tail structure of nature's fastest birds. All to improve aerodynamics which in turn will decrease flight time, decrease fuel consumption, reduced noise and increase flight range. This increase in interest in biomimicry started with birds but have also expanded into insects, scientists study insects such as dragonflies and bees to create smaller and more mobile drones that are being tested in the US military. The University of Arizona have been studying the aerodynamics of bees whilst Oxford university have designed double winged micro drones which mimic dragonflies that can hover in 20mph winds.

Before looking at the similarities shared between nature and today's technology it is important to understand not all bioinspired design is biomimicry, although it has adopted the umbrella term for this type of research. There are three types of bioinspired design which all lend certain aspects to the design process, such as-



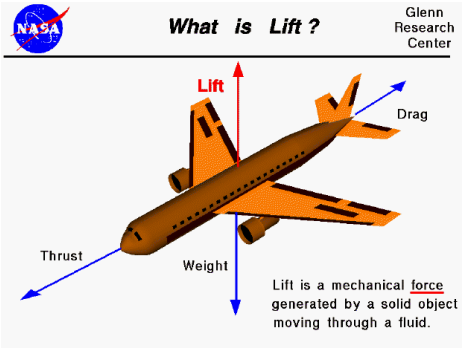
- Biomimicry- this emphasises learning from and emulating regenerative solutions for specific challenges found in nature.
- Bio-morphism- refers to designs that visually resemble nature and use the aesthetic as a solution.
- Bio-utilisation- refers to the use biological materials or living organisms in design, such as plants in an office space to clean the air. (Image 1, [2])

It is clear to see why biomimicry takes the mantle of being the umbrella term as it encompasses the other two terms in its description and use, but for creating and advancing with designs to aid aerodynamics and aircraft travel it is vital a divide can be made to allow more precise advancements in this technology.

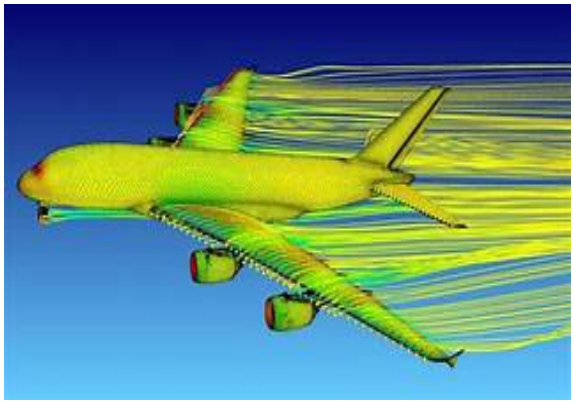
The premise of aerodynamics and its use in aircraft and drones is to minimise the effects of air resistance also known as drag, this is all to increase lift which is one of the basics of how aircraft fly (image 2, [3]).

[1] https://www.aerosociety.com/news/engineering-nature/, 31/03/23, Bill Read 19/01/21

[2] https://biomimicry.org/what-is-biomimicry/, 31/03/23, Biomimicry: innovation inspired by nature (1997)

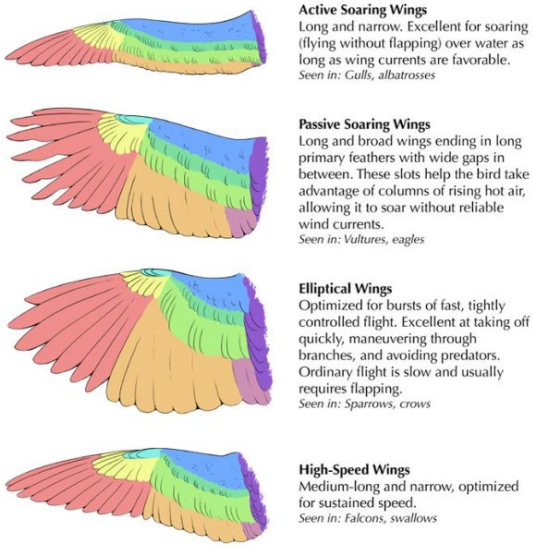


Lift occurs when a flow of gas is turned by a solid object [3] lift can be generated by any part of the aircraft which is why the plane as a whole is made more aerodynamic but lift is mainly generated by the wings which are flat on the bottom and curved on top. This is an intentional design which in a way splits and 'turns' the fluid (air) by



pushing more air over the top of the wing quicker than under the wing therefore creating less air pressure on top of the wings which pushes the wing and the plane up.

This is where aerodynamics come into play as the definition is "of or having a shape which reduces the drag from air moving past" [4]. The plane's wings shape can be almost entirely credited to the natural formation of birds wings which follow a similar concept. As seen in the picture [5] a plane wing is long and this with a curved top and a flat bottom hence creating fundamental lift like explained prior. To reduce air resistance the plane wing needs to have a small surface area and be streamline and in the current design of the aircraft wings they have a slim surface area with the front facing segment being curved up, also as seen in the resistance simulation [5] the wings are streamline and not causing major collisions of air particles to the plane moving in the opposite direction which would increase air resistance.



Now understanding the basics of aerodynamics and lift on aircraft we can explore how nature has inspired the development of this technology. In the left picture [6] it explains the different types of bird wings which are adapted for different flying experiences. The first wing which is the most similar to a aircraft wing is the best adaptation of soaring long distances without the need for constant propulsion which is ideal for an aircraft as there is no current technology for plane wings to flap. This is a clear action of biomimicry in modern technology and copying one of natures most sophisticated evolution paths.

[3] https://www.grc.nasa.gov/www/k-12/VirtualAero/BottleRocket/airplane/lift1.html#:~:text=Lift%20can%20be%20generated%20by,a%20fluid%20past%20an%20object. 31/08/23, Nasa: what is lift?, Tom Benson 13/05/21

[4] https://uk.search.yahoo.com/search?fr=mcafee&type=E211GB1562G0&p=aerodynamic+definition

[5] https://aviationweek.com/aerospace/week-technology-jan-2-6-2019?NL=AW-05&Issue=AW-05_20190102_AW-05_494&sfvc4enews=42&cl=article_8&elq2=48aea9963c1640c2aff3d4e9b24d2fb5 1/02/19,

[6] https://www.pinterest.com/pin/26669822781688075/ image

Although typical airliners have chosen wings that are more inclined to gliding there are many other specialist aircraft which have studied and choses different wing structures. The most notable changes in aerodynamic plane build and structure are all in the following aircraft – the Concord which because of its streamlined nose, body and wings could travel from London Heathrow airport to New York in 3 hours and 40 mins as against any typical commercial aircraft (i.e. Boring 747 , A380 etc) making the flight in 8 hours.

Another major change in wing mechanics was the introduction of the American F-111 Aardvark and EF-111A fighter's and air radar jammer plane (EF-111A). Both these planes had full wing movement front to back for slow and high speed intercepting of enemy aircraft. These planes were based of the "fastest diving bird in the world" the peregrine falcon reaching speeds of up to 200mph in ideal conditions [8]. When a falcon dives it folds it wings into its body to create a triangular like shape which decreases overall air resistance on its body and in turn increases speed [7] (image). The F-111 Aardvark can fold its wings inwards to mimic the natural process of falcons all to increase its speed when traveling long distances quickly or to produce ground breaking acrobatic manoeuvres mid-flight.

Another example of planes designed like this is the fixed wing American B-2 spy, intel and bomber aircraft. This aircraft is an example of peak modern engineering and maximum use of biomimicry and human intellect. This plane is triangular shaped and is designed to glide, for speed and to not be detected by enemy radars by gliding at high altitudes. Thus explaining the combined wing design of typical airliners and a retracted wing of the peregrine falcon. This fusion of different wing types in nature and human technological advancements has created one of the most unique and threatening plane in the current air forces. [9] (image)

[7] https://www.pinterest.com/pin/847028642407942406/ image

[8] https://guinnessworldrecords.com/world-records/70929-fastest-bird-diving no date, no author

[9] https://www.wallpaperup.com/435810/Northrop_B-2_Stealth_Bomber_aircrafts.html image

The Disappointing Reality of Faster Than Light Travel

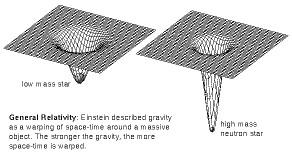
- Harry Dyer

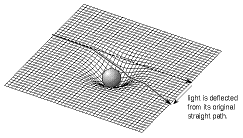
Faster than light travel (FTL) is a large topic that has been used in many media throughout the last century, largely being seen in shows such as Star Trek and Star Wars, both examples using very different ideas however for their own shows. The theoretical ideas around FTL are based upon how to avoid breaking Einstein's theory of relativity (Einstein, 1905). This theory means that mass requires more energy to move the faster it travels; meaning, to accelerate a single electron to the speed of light would require more energy than is currently stored within the entire universe. Furthermore, practical application of FTL travel in space travel is a genuine concern, with despite the speed of light being the fastest anything can go, to reach even the nearest neighbouring star would require around 4 years traveling at the speed of light for one way. This has edged scientists to create ways to travel faster than light, but also in ways that would avoid using methods that would require an infinite amount of energy to achieve. The main types of FTL travel theories revolve around two different basic ideas. The first would be either teleportation or something similar as seen in Star Trek that makes a perfect reconstruction of the copied item in a different location, therefore traveling anywhere instantly. The second basic idea is manipulation of space itself. This idea is based on the theory that if space itself moved around you, then technically you are not traveling but instead everything else is moving around you, therefore abiding by Einstein's theory of relativity. Or, if you manipulate the space in front and behind you, you could shorten the distance that would have to travel by condensing the space ahead. Lastly, there are other theories around how to achieve a form of FTL travel using other, more obscure methods that are vastly different from the basic two.

Einstein Rosen Bridge Theory -

Starting with the idea of space manipulation. The most basic way of achieving this would be through the use of black holes, and then the theorised resultant worm hole that would attach one part of the universe to another. This abides by Einstein's theory as not only are you not moving at any high velocity, but also it allows you to travel anywhere instantaneously throughout the universe.

Again, returning to the theory of relativity, space is manipulated by the effect of gravity, with the heavier objects, distorting space in a more noticeable way. This effect explains the distortion of light around the horizon of black holes, or how you can see something behind an incredibly massive object. As seen in the images, the bending effect of gravity grows as mass grows. Therefore, using a black hole, an object with infinite density, how far does this distortion reach? The theorised resultant behaviour is something as seen below, bending space to an extreme amount.





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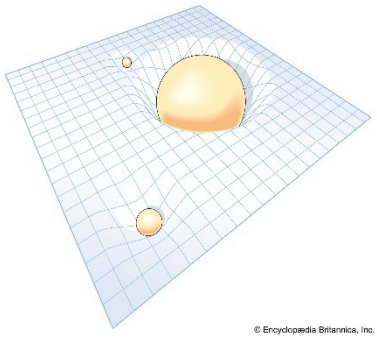


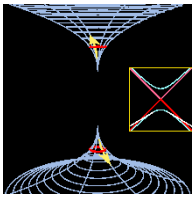
Encyclopædia Britannica (26/06/23)

The possible application of this is that due to its extreme bending of space, that maybe it bends so much that it reconnects elsewhere within the universe. This produces a theory of white holes also, or for our purpose, the position that we will find ourselves after 'teleporting'.

This theory is labelled the Einstein Rosen bridge theory (Einstein & Rosen, 1935), connecting two places in the universe with an opposing black hole and a white hole at the resultant point. However, this theory collapses at many points in being any form of useable in a realistic way.

White Holes – the theorised idea of white holes is simply that, theoretical, as we hold genuinely no proof at all of their existence. The mathematical proof of their possibility is due the double result of the Schwarzschild metric (Hamilton, 2001), with the solutions either being a positive or a negative square root, with the result of a negative producing a white hole. Furthermore, due the second law of thermodynamics as matter and energy

will be moving out not in, the resultant white hole cannot exist in our own universe (Hamilton, 2001). Therefore, the Einstein Rosen Bridge (ERB) does not simply connect one point of our universe to another, but instead of another universe, with time traveling in the opposite direction as so that the laws of thermodynamics also act in the opposite direction. For reference, antimatter travels backwards in time in respect to its positive matter reciprocal. This is similar in how the universe that we would be found in works. That is also why we could leave any form of black hole in the first place (Morris & Thorne, 1987).



Hamilton A (24/06/23).

Black Holes – the theorised inside pf a black hole ends in an infinitely dense point of space named a "singularity" in which all the matter that is consumed by said black hole is stored. Or in the case of a spinning black hole, a "ringularity" as seen in Morris's reference. Either way, both result in a complete shut off at the end of all black holes, meaning that the wormhole itself to actual traverse through is not even open in the first place to start reaching the white hole on the other side. To prevent the resultant point of singularity, the "throat" of the black hole must be threaded with a stress and energy sufficient to keep the wormhole open (Micheal S Morris et al., 1988). However, the more mass you feed any black hole, the stronger the gravity of the singularity, effectively making it impossible to hold it open.

The solution to the issue of singularities holding the throat closed of the ERB would be through the use of a theorised material named "exotic matter" (Micheal S Morris et al., 1988). This matter holds negative mass and therefore repels gravity instead of attracting it. Using this as a shell to hold open the throat of a wormhole could not only remove the issue of a singularity but also open the wormhole to any desired size to stretch and allow our future spaceships to travel through. This does still however pose the issue of our resultant location being in a different universe and one of which where time is reversed. Furthermore, the issue of finding and then producing enough of this material to create a sizable gateway through the ERB creates even further problems.

Quantum Teleportation –

Moving away from spatial manipulation, the use of quantum theory in mainly the idea of quantum entanglement is the basis of how quantum teleportation works. However, it is less of a teleportation of an object, and more of a deconstruction and instantaneous transfer of information for a reconstruction anywhere in the universe. This uses the basis of how entanglement of particles works to allow for information to be transferred anywhere in the universe immediately.

Quantum entanglement (Wong, 2019) is the idea that once produced, every particle has a paired particle to go along with it, one of opposite spin and momentum. These particles are as such so that both charge and momentum are conserved upon their being conceived. For example, if one particle has the spin of up then the other must have a spin of down to counteract the spin of the other particle. This also means however if you change the spin of one particle, the other then must also change accordingly to maintain the counteraction of spins. To allow for the information to transfer instantaneously throughout the universe despite any given distance, the particles instead of acting as individual, work as a singular wavefunction of which both lie upon. If one point of the wave function changes, then since the wave function can be seen as one singular very large entity, then the information to change the other part of the function to account for the change in spin or momentum is instantly given to the pairing particle, no matter the distance. This, for sense of purpose, can act as a sort of teleportation of information across space.

How we use this in teleporting entire bodies is seen in a byproduct of manipulating this entanglement. (Bennett et al., 1992) By using two already entangled particles with both known states, and a third particle of an unknown state not entangled in the first pair, we can transfer the state of information from the third particle (lets call this 3) into the states of either of the other particles (lets call them 1 and 2, in which 1 is with the particle that we wish to teleport and 2 being the position of which we want particle 3 to be teleported to).

Measuring both particles 1 and 2 to create an entanglement between their quantum states. The measurement however is indirect as to not completely collapse the quantum states of the particles as so that the

entanglement between particle 2 and 3 is maintained. The information collected from the indirect measurement of particle 1 is then transferred to the person with the 3rd particle as so that they can perform changes on particle 3 to replicate the quantum state of the first particle. This then collapses the state of the first particle destroying its state and giving it a new one, therefore in effect destroying the first particle and cloning it in the position of particle 3.

Negatives: the issues with this are that the method of transportation is current limited to particles, with most experiments limited to photons or protons. Furthermore, the need for classical transfer of information as seen in Bennett's explanation, limits this as a method of true teleportation due to the limit of the speed of light for electromagnetic waves used for communication. Finally, the last limitation to this method is within the fact that particle 2 and 3 must be entangled, requiring them to be in the same position as some point, meaning initial transfer of the particles to create a location for teleportation.

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History of nuclear energy

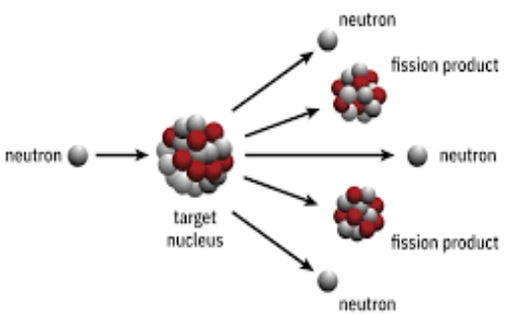
Igor Zbiciak

Introduction

As the second world war devastated the whole world, the USA was developing a new kind of weapon.[5] Soon, the first self-sustaining nuclear chain reaction was initiated in a university basement in Chicago[1], bringing humanity into the nuclear age. Despite being developed as a part of a much more sinister project[5], it paved the way for the future of clean, safe and virtually endless energy. Just over a decade later, behind the iron curtain, the first nuclear reactor, *Atom Mirniy* (Peaceful Atom), supplies electricity to the local power grid[2], by splitting atoms. As time went on, nuclear energy continued to evolve rapidly. This wasn't however an easy journey. A catastrophical accident in the USSR[14] caused the support of such controversial projects to plummet and some people would forever regard nuclear energy as unsafe and dangerous. In this time of contemplation about the climate and the future of our planet as well as energy supply for the continuously increasing population, this matters more than ever before.

History – the beginnings

In the late 19th century, many discoveries in the physics field were made[7] - in 1895, Röntgen discovered the X-rays, a year later, in 1896, Becquerel discovered spontaneous emission of radiation from uranium salt - radioactivity. Researching into this newly discovered idea, in 1898, Pierre and Maria Curie discovered Radium and Polonium.[7]



More work was being done in the early decades of the 20th century when physicists have been investigating the atoms thoroughly – this is the period which saw the proposal of the atomic model by Rutherford, the improved model by Bohr and the discovery of the neutron by Chadwick. In 1938, Otto Hahn and Fritz Strassmann discovered nuclear fission by splitting uranium atoms using neutrons. In 1933, Szilárd calculated that a nuclear chain reaction was possible, and theorised that Uranium could be used to generate vast amounts of energy, which could be used for civilian energy generation, but also military purposes.

History – WWII

Following great advances in research, there was concern that this knowledge could be used with bad intentions – in August 1939, Einstein wrote a letter to US president Roosevelt[21], warning that the Germans were working on a weapon like no one has seen before. Not long until on the 1st September 1939, Germany invades Poland, marking the beginning of WWII. As the war rages on in Europe, it soon escalates into a global conflict with several different front lines across the world. One of them is the Pacific War fought between Imperial Japan and the USA, initiated by the Japanese attack on Pearl Harbor in 1941.

Soon after, in 1942, the Manhattan Project, one of the most ambitious projects was initiated. The goal was simple – build a successful atomic bomb before the Germans do, and maybe use it to end the war. And already on the 2nd December 1942, the first man-made self-sustaining nuclear reaction took place in the basement of a university building in Chicago, Illinois. The secret project led by Enrico Fermi, the Chicago Pile-1 (CP-1), was a *crude pile of bricks and timber*, a very basic reactor - built using 45,000 ultra-pure graphite blocks which weighed 330 tonnes, fuelled by 4.9 tonnes of uranium metal and 41 tonnes of uranium oxide, the reactor achieved an output of half a Watt.[1]

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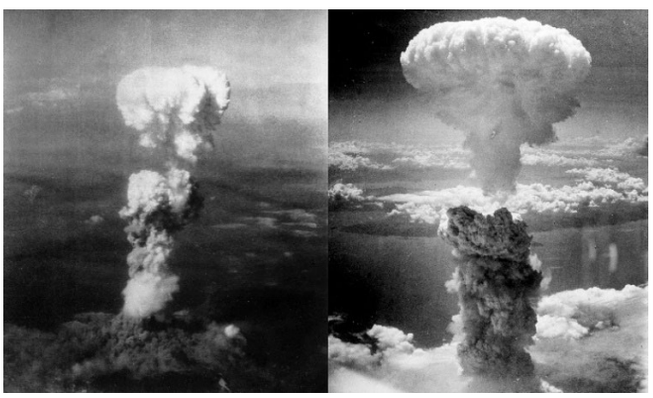
This success paved the way for the Manhattan Project to continue full steam ahead – secret towns were built in Oak Ridge, Tennessee, where the uranium was enriched, Hanford, Washington, where the plutonium was produced, and Los Alamos, New Mexico[5]. The main research laboratory was in Los Alamos, led by Robert J Oppenheimer. The secret town was the site where research and construction of the atomic bomb took place, and it housed thousands of engineers, physicists, chemists, metallurgists and other experts in the field, as well as their families, all of that hidden from the public.

The development of the bomb was giving good results. Not even whole 3 years later, in July 1945, the first ever detonation of a nuclear bomb was going to take place in NM in the "Trinity" test. The bomb used was an implosion-type bomb[6] with a 6.2kg Plutonium-239 pit surrounded by Uranium-238. The bomb worked by detonators around the U-238 detonating and causing shockwaves to travel inwards, causing pressure on the Pu-239 core, causing the explosion. The bomb, called "Gadget", exploded with 20 kilotons of force, producing a 13 km tall mushroom cloud, leaving a crater approximately 3 metres deep and 300 metres in diameter in the New Mexican desert.[5]

On the early morning of August 6th, 1945, much to Oppenheimer's surprise[23], the device he made to kill hundreds of thousands did precisely that. Flown in onboard a B-29 Superfortress, the Little Boy was dropped on the Japanese city of Hiroshima, instantly obliterating everything in the radius of 1.6 km. Over 200,000 people were killed in the attack due to burns, radiation sickness and cancer. Three days later, the second bomb, the Fat Man, was dropped on the city of Nagasaki. 150,000 further people were killed. On 2nd September 1945, Japan surrendered, ending World War II.



Mushroom clouds over Hiroshima and Nagasaki

History – energy use

It did not take long for nuclear energy to be investigated alternatively, not as a weapon of mass destruction, but as an abundant source of energy, as already in 1951, the Experimental Breeder Reactor, EBR-1[8], started operation in Arco, Idaho, successfully powering 4 200-Watt light bulbs on its first run, eventually powering its whole building. However, it would be behind the iron curtain where the first nuclear reactor supplied energy to the energy grid to be used by the ordinary man; in June 1954, the AM-1 reactor, which stood for *Atom Mirnyi,* "Peaceful Atom", supplied electricity the *naukograd* of Obninsk[2], 110 km from Moscow. Albeit the power output was very small, it marked the beginning of nuclear power used for good, used for peace. But as many projects made in the Soviet Union, the design of the AM-1 was not made with safety in mind, and its design would eventually serve as the base for the RBMK reactor.

How a reactor works

Nuclear fission is a process where a neutron is fired into a heavy nucleus[3], for example Uranium-235. The Uranium nucleus then gains some energy before splitting into 2 lighter nuclei and releasing 3 neutrons which collide into more heavy Uranium nuclei and the whole process repeats in a chain reaction, harvesting extremely high levels of energy from a relatively straightforward process. When left alone and uncontrolled, this becomes a very powerful bomb. However, using control rods, fission can be controlled and used to generate lots of clean energy – this is how a nuclear reactor works.

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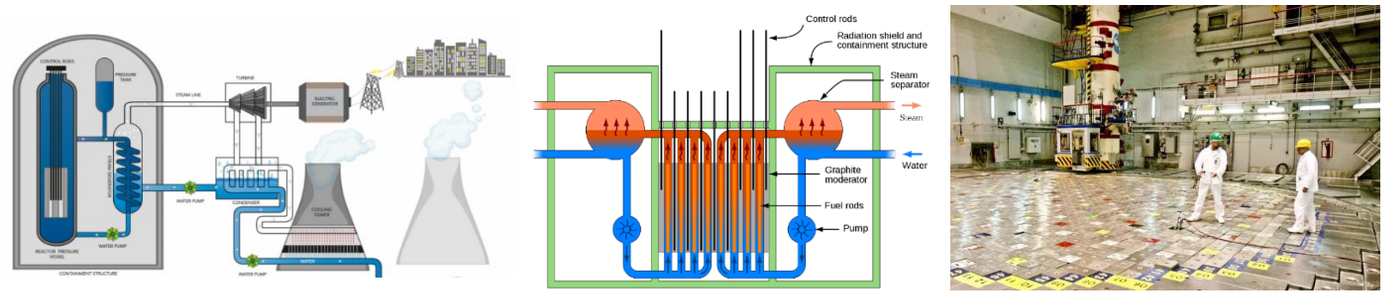
A nuclear power plant is no more than a thermal power station[9], in which heat is produced by the reactor, the heat evaporates water into water vapour, or simply steam, and this steam turns a turbine which turns a generator which generates electricity. The most common fuel used is Uranium, specifically the U-235 isotope. The problem is that most naturally found uranium isotope in the world, at 99.3%, is the U-238 isotope, which is practically useless as it does not undergo fission, and therefore the uranium first has to be enriched in order to be of any use in generating clean electricity. Enriched uranium can provide the same electricity output as 160 tonnes of coal, making it incredibly efficient.[24]



Left: diagram of a typical PWR reactor. Centre: diagram of an RBMK reactor core. Right: RBMK reactor hall (Ignalina, Lithuania), note the crane that can be used for refuelling the reactor thanks to extra space gained by a lack of a containment structure.

There are many different reactor types which work in slightly different ways[11]. The most common Western types include PWR (Pressurised Water Reactor) and BWR (Boiling Water Reactor). These types are what is known as a light water reactor, meaning that they are cooled by normal water. However, they require special enriched fuel, which can be expensive and difficult to obtain. An alternative is the Canadian CANDU reactor (Canada Deuterium Uranium), which does not require special enriched fuel, and can be fuelled by natural uranium, which makes it a suitable choice for developing nations[18]. It is cooled by deuterium oxide (heavy water). The most popular type in the United Kingdom is the AGR, Advanced Gas-cooled Reactor, a different type of reactor, using carbon dioxide gas as a coolant instead of light or heavy water.[12]

In the Soviet Union, the popular choice was the RBMK – *Reaktor Bolshoi Moshchnosti Kanalniy,* "High Power Channel-type Reactor". The reactor was designed to be fast and cheap to put into service and was meant to produce a lot of power from not a lot of resources – the fuel used was only 2% enriched, making it the most economic reactor ever. Using a crane in the hall, the reactor could even be refuelled while in operation, as it did not have a containment building.

Where it went wrong – the Chernobyl disaster (1986)

In 1977, a newly commissioned nuclear power plant opens in the new city of Pripyat in the Ukrainian SSR. By 1983 it had 4 brand new RBMK-1000 reactors, and 2 more reactor blocks were under construction. Chernobyl NPP the third power plant to use the new reactor type, first one being Leningrad (now Saint Petersburg), producing an output of 12,800 MW, supplying energy for around 10% of Ukraine.[15]

After a partial meltdown of reactor 1 in 1982, and a major incident of reactors 3 and 4 in 1984, it quickly gained a reputation of being unsafe[15]. In 1982, a safety test on the reactor 4 was meant to be conducted, but it was unsuccessful. After modifications, the test was repeated in 1984 and 1985 but was still unsuccessful[19]. Finally, during the day on the 25th April 1986, it was meant to be attempted again, before a planned reactor shutdown for maintenance, however due to higher energy demand, Kiev energy grid dictated that the safety test had to be rescheduled to take place at night, on the 26th. The test was going to involve reducing the reactor's power and getting the emergency backup generators to come online to supply sufficient cooling for the reactor, for example in case of a blackout. The test would take place under the supervision of deputy chief engineer Anatoly Dyatlov, a very experienced nuclear engineer. In the control room of reactor 4, the power output was being lowered to the required range of 700-1000 MW, however, due to a phenomenon known as xenon poisoning, the power quickly dropped, and the reactor was in a near shutdown stage.

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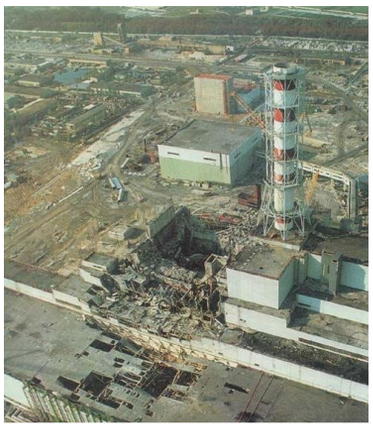


Destroyed reactor 4 building – it is now covered under a sarcophagus structure as well as the recent new safe confinement, the biggest moving structure on Earth[16]

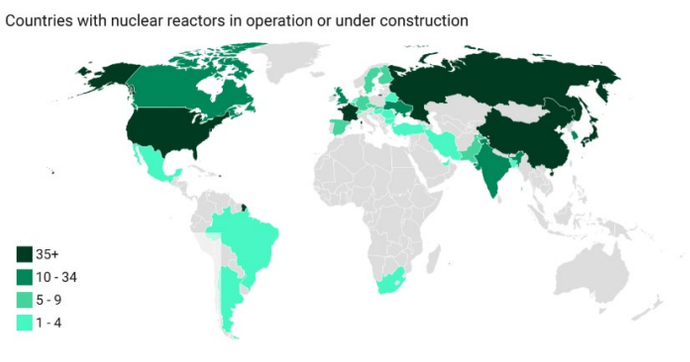
Nearly all the control rods have been raised. The power rapidly rose again, and the emergency shutdown, *AZ-5*, was initiated, which started to reinsert all of the control rods into the reactor. The tips of the boron control rods were made of graphite, which massively accelerated the reaction, instead of slowing it down, defeating the point of what a control rod is supposed to do. Seconds later, the core overheated, fracturing fuel rods and jamming some control rods. The reactor output exceeded 30,000,000 MW; 30 times more than the plant was designed for[14]. The reactor suffered a steam explosion, ejecting the 1000 tonne upper biological shield through the roof of the building, and seconds later, a nuclear chain reaction started, turning reactor 4 into a nuclear bomb. Ultimately the people were blamed for the disaster, despite it actually being a serious design flaw[25] which was held secret from the people who worked with it. As Anatoly Dyatlov argued in an interview, the disaster happened during the safety test, but not because of the safety test.[19]

The consequences

While accidents like the Three Mile Island partial meltdown[13] and the Fukushima meltdown in Japan in 2011 had significant environmental and social consequences, it is without a doubt that Chernobyl was the worst nuclear accident as well as the worst (and most expensive) accident in the history of mankind[14]. Many power plant constructions were cancelled after the Chernobyl accident due to public fear and opposition, for example Żarnowiec in Poland[17] , forcing many countries to rely on worse sources of energy like coal or gas. The Chernobyl disaster exposed the Soviet Union's complete lack of interest in safety and safety culture, major cost cutting and dangerous design, withholding crucial information that could explain the behaviour characteristics of the RBMK reactor, as well as major disorganisation, ultimately being one of the factors that contributed to the dissolution of the USSR. The official death toll for the Chernobyl disaster is 31.[14]

The present and the future

As of 2023, around the world there are 436 operational nuclear reactors, providing over 10% of the world's electricity supply[20] ,with many more under construction in more and more countries. In a time where climate change is a relevant topic, it is crucial that nuclear energy is considered, as many countries are reluctant given that it's not exactly a *renewable* source of energy. The next major step is fusion, which as opposed to fusion, joins hydrogen particles into helium, which generates a lot of energy, which could be used in the same way, to heat water, turn it to steam and turn a turbine, however, as of 2023, there is still no working reactor[22] which generates more electricity than it uses. For the time being, fission is still the only way, and given the rigorous safety standards and low emissions, this should be the source of energy of the future.



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Origin of The Universe

By Jayden Hughes

The origin of the universe is a puzzling yet fascinating idea that our entire universe, including all existing matter and space considered as a whole (which is believed to be at least ten billion light years in diameter[1] all originated from a single point or time. There are in fact many theories on the origin of the universe with the most popular being the Big Bang theory believing to take place about 13 billion years ago. However, many scientists have challenged this idea such as British astronomer Fred Hoyle who, alongside Tommy Gold and Hermann Bondi, developed the steady state theory in 1948, with another theory being the pulsating theory introduced by scientists J.C Boyle in 1923[2].

The pulsating theory

The pulsating theory was first proposed as an explanation for the origin of the universe as far as 1879 however it was not until 1917-18 where the theory began to develop with the help of physician Arthur Eddington whose ideas on the pulsating theory resulted from his study of the stars. According to zebra academy, The pulsating theory is a variation of the big bang theory in which the universe is expanding and contracting through successive periods. When a compressive stage is complete in a small volume of high density it results in a bang, also known as a 'break up.' According to this theory the universe is endlessly switching between the big bang and the big squeeze and adheres to the understanding that our universe is in fact expanding constantly[3]. However, according to Stanley W. Angrist in his book "perpetual motion machines" published January1968, the pulsating theory is also flawed and criticised for the theory behaving like that of a perpetual motion machine, which is impossible through the proof of science[4]. Therefore, many scientists claim the pulsating theory is purely hypothetical as it claims the universe can do work infinitely without an external energy source, which would violate either the first or second laws of thermodynamics, or even both.

Steady state theory

The steady state theory suggests, like the pulsating theory, that the universe is constantly expanding. The theory claims the universe maintains a constant average density as new

[1] [22/09/23] https://universe.nasa.gov/universe/basics/#:~:text=Bang%20and%20Nucleosynthesis-,Big%20Bang%20and%20Nucleosynthesis,soup%20of%20light%20and%20particles

[2] [19/09/2023] https://www.britannica.com/science/astronomy/Cosmology (origin of the universe)

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matter is created to create new stars and galaxies at the same rate old ones are unobservable[5]. A steady state universe has no beginning or end in time[6]. The theory was first introduced in 1948 but was firstly predicted by Albert Einstein himself in 1931 after he proposed that rather than the universe being a single explosive event, the universe expanded steadily and eternally according to a 1931 manuscript in the Hebrew university archive[7]. Einstein in his description of the formation of the universe wrote "for the density to remain constant, new particles of matter must be continually formed."[8] which is the same principle behind the steady state theory. However, Einstein quickly abandoned this idea after recognising a mistake in his calculations and has not mentioned his opinion on the origin of the universe since. Furthermore, much evidence proposed ion the 50's and 60's led to much controversy around the steady state theory – most notably the cosmic radiation background observation which was predicted by the big bang model- have produced significant evidence contradicting the steady state model and supporting the big bang model, greatly contributing to the big bang theories popularity among astrologists worldwide. After the steady state theory had weakened and had fallen out of the favour of most cosmologists, Sir Fred Hoyle (the creator of the steady state theory) continued to defend the theory, despite having to alter several of his conclusions due to observations by other scientists disproving aspects of the theory.

Big Bang theory

The Big Bang theory is the leading explanation for how the universe originated. The theory states the universe as we know it all began from a singular point in time and space and expanded at unimaginable speeds due to an infinity hot and dense "bang" which took place approximately 13.7 billion years ago. According to physician Alan Guth in 1981, After the first split seconds (10^-32 of a second) after the Big Bang, there was a temporary period of cosmic inflation[9]. Once the cosmic inflation suddenly came to a stop (which scientists are still confused as to why) there began a flood of matter and radiation, also known as "reheating." The reheating process populated our universe with everything we know today from particles, atoms down to the protons and neutrons in which stars, galaxies and all matter are made of. This all happened extremely fast (within the first few seconds) and because of this immense energy, temperatures reached around 10 billion degrees Fahrenheit - according to NASA's CMB (Cosmic Microwave Background) explorer satellite in 1992. Whilst the Big Bang may sound like a beautiful explosion, it would actually be impossible to see since visible light was unable to be held. NASA stated ""The free electrons would have caused light (photons) to scatter the way sunlight scatters from the water

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[9] [23/08/2023] https://www.space.com/25126-big-bang-theory.html (what is the big bang theory)

droplets in clouds." It was not until 380,000 years after the Big Bang in which light was able to shine through[10].

The Big Bang suggests the universe we know today is still ever expanding as the cosmos is forever inflating. The expansion of the universe is very significant in the evidence for the Big Bang theory as astronomers don't yet have the technology to literally peer back to the birth of the universe, therefore astronomers must study the "echo" of the expansion through a process known as cosmic microwave background (CMB) and , which is sometimes named the "afterglow" of the Big Bang and is the first visible light (380,000 years) after the Big Bang. This light was predicted to exist in 1948 by Ralph Alpher and other scientists, however it was not until 20 years later till this phenomenon was accidentally confirmed by two men (Arnos Persiaz and Robert Wilson) whilst building a radio receiver in 1965[11]. According to a NASA article, the men picked up "higher than expected temperatures." At first, they believed the anomaly was a result of pigeons roosting by antennas, however the anomaly continued to exist after they killed and removed all the pigeons. In the meantime, a team at Princeton university was trying to find evidence for the CMB but realised that Penzias and Wilson had already stumbled across it after they published their strange observations in the Astrophysical journal in 1965.

The CMB is one of the 3 most important observations supporting the Big Bang theory. This is because "The properties of the cosmic microwave background radiation (CMB). This shows that the universe went through a transition from an ionised gas (a plasma) and a neutral gas. Such a transition implies a hot, dense early universe that cooled as it expanded. [12]This transition happened after about 400,000 years following the Big Bang," stated by Jason Steffens, assistant professor of physics and astronomy at the university of Nevada.

Another observation for the Big Bang theory is the Hubble law (also known as red shift) which shows that objects in the universe are accelerating away from us at a rate proportional to its distance. This only occurs when there is an expansion in all directions and therefore confirms the universe is expanding. We can also observe objects moving further away by studying their wavelengths which increases, and frequency and photon energy decreases as distant galaxies move further away from us. This implies that in history everything was once close together.

Conclusion and analysis

Whilst the pulsating theory creates an interesting explanation for the expansion of the universe through the continuous switching between periods of squeezing and inflating, the theory seems more hypothetical than realistic due to the lack of relevant observations resulting in the theory lacking any popularity. This is most likely due to the theory first being introduced as far back as 1879 where technology was significantly inferior to those of today,

[10] [23/08/2023] https://www.space.com/25126-big-bang-theory.html (what is the big bang theory)

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therefore the theory (alongside many others around this time) were simply wrong- especially since the pulsating theory broke several laws of physics which was not known at the time.

This is same for the steady state theory was proposed in a 1948 where the technology was archaic in comparison to that of today. The steady state theory suggests the universe has no beginnings or end in time and that all matter is created at the same rate where it becomes unobservable. However, this is false as it contradicts the law of conservation of mass as new matter cannot be created or destroyed but only transferred. This theory is almost a direct juxtaposition to the Big Bang theory which signifies the universe has a specific point in time in which the cosmic microwave background (CMB) discovered in 1964 prove there was a beginning in time for the universe, therefore disproving the steady state theory.

Whilst the Big Bang theory is (so far) the most realistic theory reinforced with the most evidence and observations, it is still not yet perfect and there are a few flaws. For example, the Big Bang violates the first law of thermodynamics which states that matter cannot be created or destroyed, whereas the Big Bang theory suggests all matter was created out of nowhere, which is scientifically impossible. Secondly, the universe is too big to have been formed in only 10-20 billion years which the Big Bang theory claims. This is because there is a temperature uniformity (According to NASA's satellite readings in 1992) which requires matter to have moved beyond the speed of light to become universally uniform which is impossible according to Einsteins general theory of relativity, because nothing can move faster than the speed of light. Another question surrounding the Big Bang theory is, where did the energy for the bang come from? And what was the universe before the Big Bang? Some scientists describe the universe as "desolate and cold" [13]however the energy fuelling the Big Bang remains a mystery. So, whilst the Big Bang theory is the strongest theory to date, it is still criticised for its imperfections and flaws with some claiming the Big Bang to be "philosophical viewpoint" and not a scientific fact[14].

A new, disturbing theory?

Whilst researching theories I came across a relatively new and shocking theory proposed by physics professor James Gates who specialises in theoretical physics with two bachelor's degrees, an MIT and a PHD who, according to the James Gates biography[15] found a discovery when investigating string theory in the 1970's (he was one of the earliest workers in the field of string theory). Like Einstein's theory of relativity is the theory of everything big, such as planets and galaxies all the way back to the Big Bang, quantum physics is the theory of everything small such as particles and molecules where general laws of physics such as gravity no longer apply. Due to the Big Bang, everything that is now big was once small so therefore if what was small can become big (such as atoms and molecules) then quantum physics and general relativity needs a theory which can unify the two, which is string theory. When looking at the quarks inside a neutron, string theory suggests there is tiny filament (or a string) of pure energy which exists inside of them, whereas conventional science states there is nothing. These strings vibrate like that of an instrument and produce matter in the form of particles meaning every particle in the universe is just a string vibrating

[13] [22/09/23] https://www.buffalo.edu/news/releases/2022/03/033.html (what came before the big bang?)
[14] [22/09/23 https://techreader.com/top-ten/top-ten-scientific-flaws-in-the-big-bang-theory/ (10 flaws in the big bang theory by James Watson)

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at different frequencies to form matter. When Doctor James Gates looked at a set of equations derived from string theory, he found binary code. This code was error correcting code made of 1’s and 0’s used for compressing data in computers. Doctor James gates claims that if we break matter down far enough etched into the very fabric of reality and proposes an idea that this code could have been written by someone and that this universe could just be some sort of program in a potential supercomputer. Whilst this is just a theory, with string theory being a very new idea which is yet to be proven true, could string theory answer the mystery of the Big Bang? Perhaps the mysterious energy fuelling the explosion was just that of a computer starting…

Is commercial interplanetary travel possible?

Introduction

As we know, interplanetary travel is possible. We know this from when the USA landed Neil Armstrong on the moon during the Apollo 11 mission in 1969 which 'won' them the space race. However, the USSR was able to put Yuri Gagarin (1) into space and do a full orbit of the earth in April of 1961 (they should have won the space race). Currently companies such as Space X have a way to commercially travel to space, such as to the International Space Station (2). Similarly other organisations have landed spacecraft on mars ,that do not contain human pilots, such as Nasa landing a rover on mars and Russia landing craft on mars in 1971 (3) and there may soon be attempts to send people to Mars considering Elon Musk's Mars mission, seeing as there have been many rovers landed on mars and many discoveries have been made through this technology it seems quite possible that we could see this happening within the next 50 years. Recently SpaceX's Starship was launched and ended in an explosion, however they said that the launch was an overall success considering they were able to get the craft off the ground. This is a step in the right direction as they were able to get the largest rocket to ever launch 'Starship is the largest and most powerful launch vehicle ever flown' (4) this shows that there could eventually be large developments in travel into outer space and other planets, since it was the largest and heaviest it could lead the way for passengers and sustenance for those passengers if there are more huge developments such as this there could be passenger space craft launching within the next 50 years.

What technological advancements have helped this to be possible?

Recently we have seen many advancements in technology which could be particularly important when discussing sending spacecraft accommodating people who want to travel and potentially without all the years of specific training to do so. For example, we have reusable space craft which can be launched and after coming back down they can be re used after slight repairs and configurations which would (5) 'reduce the launch cost significantly' which overall would make the feasibility of having spacecraft travel commercially more likely as they would be able to launch craft more often if they are able to make craft that can successfully land efficiently and lower the cost more than they already can. Advances in AI could also be beneficial to making this possible as it can help with automation of important processes such as navigation as the delay between transmissions while travelling (6). Private companies have been able to launch craft into space such as amazon and their blue origin 'mission' where they launched to the atmosphere and were able to experience low gravity for a short while before returning to the earth's surface in July of 2021 (7) developments and events such as these are vital and huge steps toward making this possible. Other developments that could be beneficial are new insulation materials such as aerogel which is a great insulant and quite inexpensive to make on a large scale which would reduce costs of manufacture (8). Even recently India was able to launch a rocket that landed on the south pole of the moon and made discoveries such as ice on the southern lunar pole to 'support future human exploration' (9) this brings potential for a lunar base which could be used commercially after there is development in human space travel. Furthermore, India is planning to launch a craft to study the sun at a closer point (10) which would be the first ever sun-studying craft leading towards progress for future piloted exploration that goes past the moon.

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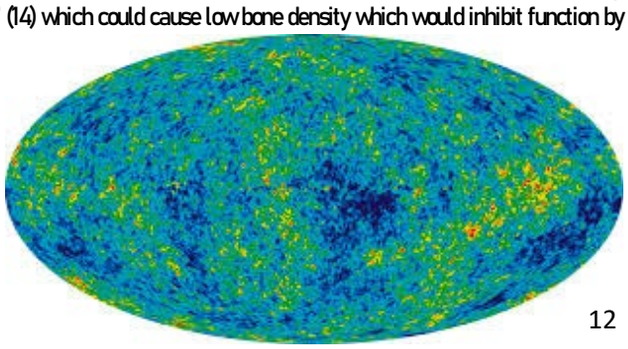
(11) https://techcrunch.com/2020/11/24/spacex-targeting-next-week-for-starships-first-high-altitude-test-flight/?guccounter=1&guce_referrer=aHR0cHM6Ly9sZW5zLmdvb2dsZS5jb20v&guce_referrer_sig=AQAAALfGPakKyWwRjiPDJZ09cYeH1SNTCP0nszuXq765m0g4FHyvLNnB4sri3Z6h3p_h9t_PwuA1-dEdEIovv2eiCvC32eWrpSdd4kgCB- 26.09.23

what challenges are there?

There are many challenges that are and will be faced when discussing the potential of commercialising this such as the effect of microgravity on people and the exposure of background radiation in space whilst travelling these problems could potentially cause minor or major harm to people travelling if the craft doesn't have precautions to help stop the potential problems also being able to travel would have to accommodate the people who are travelling which means that there will have to be established bases on the planets that are being travelled to which will require much exploration before it is possible for this to happen. Problems with radiation in space could cause terrible sickness 'Beyond Low Earth Orbit, space radiation may place astronauts at significant risk for radiation sickness' (13) and future problems for those who are exposed to it which will mean there will have to be accommodations that will be able to help prevent issues like this. Similarly, microgravity can cause 'negative calcium balance' (14) which could cause low bone density which would inhibit function by a significant amount. Furthermore, there would be a requirement for advanced propulsion for the craft as it would have to travel very vast distances without being able to stop to get to another planet, this could change requirements for fuelling or could change the method of propulsion altogether. However, there could be a huge breakthrough in the next 15-20 years that could potentially solve this this would be hugely beneficial to this problem



12

Conclusion

In conclusion, commercial interplanetary space travel is possible, in theory, but would only be possible after 20-30 years of scientific progression. Moreover, we could not currently accommodate this since it would cost millions to get a ticket as the craft taking people would cost that much to build as well as the fact that we do not have any accommodation or such on any other planets right now. If SpaceX's mars mission goes to plan this will be different and we would only need the efficiency to have spacecraft that can be reused to make it cheaper overall.

(13)https://pubmed.ncbi.nlm.nih.gov/11536970/#:~:text=It%20is%20well%20known%20that,plasma%20volume%3B%20and%204)%20cardiovascular 13/08/23

(14)https://www.nasa.gov/analogs/nsrl/why-space-radiation-matters 17.08.23

(15) https://cosmology.unige.ch/topics/cmb 26.09.23

RUEBEN GORDON

Exploring Time Dilation

Introduction:

With a simple search on google, one of the first definitions to pop up for the concept of time dilation is as follows; "*the slowing of time as perceived by one observer compared with another, depending on their relative motion or positions in a gravitational field"*[1]. There are two types of time dilation; gravitational time dilation, the idea that where gravity is stronger time passes more slowly, and kinematic time dilation, the idea that the passage of time (typically when referring to clocks) depends on the speed the clocks move[2]. The time dilation theory was first proposed by Albert Einstein between 1907 and 1915 in his theories of relativity, where he explained that the effect can be observed by placing atomic clocks at different elevations at which they would experience different levels of gravitational forces[3]. The phenomenon of time dilation is also the conceptual foundation of the widely known 'twin paradox', an infamous example of relativity[4] – however, being a paradoxical situation, it is purely hypothetical. The existence of gravitational time dilation was first directly confirmed by the Pound-Rebka experiment in 1959, and later confirmed again by the 1971 Hafele-Keating experiment that also confirmed the existence of kinematic time dilation. The concept of time dilation has been represented in pop culture a few times – the most notable being Christopher Nolan's space epic *Interstellar*, released in 2014. In the blockbuster however, it is portrayed to quite an extreme degree, and required guidance from the American theoretical physicist Kip Thorne to represent the concept in a realistic, yet digestible way on the big screen to global audiences.

Twin Paradox:

The twin paradox experiment involves identical twins – one travels into space in a rocket and upon returning home discovers the twin who stayed has aged more[5]- it is not exactly paradoxical however as it follows the laws of relativity – the idea of the paradox comes from the fact that nothing would feel different for the twin who travelled in space, although he ages slower[6]. In Einstein's theory of Relativity, one of the many implications that arose was the idea that time moves relative to the observer of the motion. This means that if an object such as a human were moving extremely fast, close to the speed of light for example, they would experience time more slowly than when at rest[7]. Back then, and currently in modern day, testing the concept to such a degree is not

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[1] May, A. (2021) *What is time dilation?*, *LiveScience*. Available at: https://www.livescience.com/what-is-time-dilation#:~:text=Time%20dilation%20is%20the%20slowing,positions%20in%20a%20gravitational%20field. (Accessed: 19 April 2023).

[2] Szostek, R. (2022) *Explanation of what time in kinematics is and dispelling myths allegedly stemming from the special theory of relativity*, *MDPI*. Available at: https://www.mdpi.com/2076-3417/12/12/6272#:~:text=Time%20dilation%20is%20described%20by,time%20in%20the%20same%20way. (Accessed: 19 April 2023).

[3] *Einstein's general relativity and your age* (2022) *NIST*. Available at: https://www.nist.gov/education/einsteins-general-relativity-and-your-age#:~:text=Albert%20Einstein's%201915%20theory%20of,clocks%20located%20at%20different%20elevations. (Accessed: 19 April 2023).

[4] Sutter, P. (2022) *The 'twin paradox' shows us what it really means for time to be relative*, *Space.com*. Available at: https://www.space.com/time-is-relative-twin-paradox#:~:text=The%20infamous%20%22twin%20paradox%22%20showcases,hard%20fact%20of%20the%20universe. (Accessed: 19 April 2023).

[5] Sutter, P. (2022) *The 'twin paradox' shows us what it really means for time to be relative*, *Space.com*. Available at: https://www.space.com/time-is-relative-twin-paradox#:~:text=The%20infamous%20%22twin%20paradox%22%20showcases,hard%20fact%20of%20the%20universe. (Accessed: 19 April 2023).

[6] Sutter, P. (2022) *The 'twin paradox' shows us what it really means for time to be relative*, *Space.com*. Available at: https://www.space.com/time-is-relative-twin-paradox#:~:text=The%20infamous%20%22twin%20paradox%22%20showcases,hard%20fact%20of%20the%20universe. (Accessed: 19 April 2023).

[7] Stein, V. (2021) *Einstein's theory of special relativity*, *Space.com*. Available at: https://www.space.com/36273-theory-special-relativity.html (Accessed: 06 September 2023).

possible as we did not have the means to accelerate people anywhere even close to such speeds. Despite this, Einstein explained that the phenomenon is still available to be tested with atomic clocks however; by placing them at different altitudes where they experience different gravitational strength, a difference in the speed they tick at is able to be observed[8] - his was one of the first instances of the twin paradox. French physicist Paul Langevin studied the idea of the twin paradox in 1911, where he proposed the idea of a traveller making a trip at a Lorentz factor (the factor commonly used in time dilation formulae that expresses the dilated time of a moving clock when observed in a stationary frame[9]) of 100. If the clock speed is low relative to the speed of light, then the Lorentz Factor is typically observed as being close to the value of 1; the Lorentz Factor of the Earth when orbiting at $3x10^4$ ms^{-1} is 1.000000005, and the LF of an object moving 99.9% of the speed of light is 70.71[10]. Langevin explained that the traveller with a Lorentz Factor of 100 would spend one year as a projectile, before reversing his course and returning to earth, and upon his return, he would find that he had aged only 2 years whereas 200 years had passed on earth. This is yet another example of how the differing rates of ageing result from the traveller experiencing a significant value of absolute acceleration close to the speed of light[11].

The Pound-Rebka Experiment:

In 1959, American physicists Robert Pound and Glen Rebka Jr. conducted an experiment at Harvard University that proved the existence of gravitational redshift, the effect in which light appears red due to the increase of wavelength of a light particle as the particle gets further from the influence of gravity[12]. A 74-foot vertical tower was constructed, and the radioactive isotope Iron-57 was placed at the bottom. According to the theory of relativity, gamma rays lose energy as they travel upward - at the top of the tower, an iron-57 absorber was designed to absorb the emitted gamma rays only when their energy matched the resonant absorption energy of the Iron nuclei[13]. To compensate for this, the duo employed the Mössbauer effect; a nuclear process that allows for the resonance absorption of gamma rays by fixing the atomic nuclei in a lattice of solids so that no energy is lost in recoil during the emission and absorption of the radiation[14]. So the particles were emitted upwards, and the received atoms moved downwards, allowing them to correct for the redshift due to the gravitational dilation as a result of the doppler effect[15]. By vibrating the iron-57 source as it emitted gamma rays upward, they were subsequently able to change the energy of the emitted rays, allowing them to match the energy to the resonant absorption of the absorber at the top of the tower. As a result, they were able to find the frequency at which the gamma rays were most efficiently absorbed by adjusting the level of vibration on the iron-57 source – this

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[8] Vedantu (2023) *Twin paradox - definition, history, role, analysis and example*, *VEDANTU*. Available at: https://www.vedantu.com/physics/twin-paradox

[9] *What is the Lorentz Factor* (no date) *What is Lorentz factor*. Available at: http://www.herongyang.com/Physics/Time-Dilation-What-Is-Lorentz-Factor.html (Accessed: 06 September 2023).

[10] *What is the Lorentz Factor* (no date) *What is Lorentz factor*. Available at: http://www.herongyang.com/Physics/Time-Dilation-What-Is-Lorentz-Factor.html (Accessed: 06 September 2023).

[11] Vedantu (2023) *Twin paradox - definition, history, role, analysis and example*, *VEDANTU*. Available at: https://www.vedantu.com/physics/twin-paradox (Accessed: 06 September 2023).

[12] Gohd, C. (2020) *Effect predicted by Albert Einstein spotted in a double-star system*, *Space.com*. Available at: https://www.space.com/einstein-gravitational-redshift-observed-double-star-system.html (Accessed: 06 September 2023).

[13] Author (2023) *Pound-REBKA experiment definition & example*, *Nuclear Power*. Available at: https://www.nuclear-power.com/pound-rebka-experiment/ (Accessed: 06 September 2023).

[14] *Mössbauer effect* (no date) *Encyclopædia Britannica*. Available at: https://www.britannica.com/science/Mossbauer-effect (Accessed: 06 September 2023).

[15] Cyril (no date) *Gravitational redshift part III - experiments*, *Einstein Relatively Easy*. Available at: https://einsteinrelativelyeasy.com/index.php/general-relativity/42-gravitational-redshift-part-iii-the-pound-rebka-experiment (Accessed: 06 September 2023).

frequency corresponded to the expected gravitational redshift value proposed in the theory of relativity[16]. However, despite the experiment's success, it only tested time dilation with respect to gravity.

The Hafele-Keating Experiment:

The 1971 Hafele-Keating Experiment conducted by J.C. Hafele and R.E. Keating, two experimenters from the U.S Naval Observatory, proved the existence of both gravitational time dilation and kinematic time dilation. The pair flew around the world for about three days twice on commercial airline flights with caesium beam atomic clocks – one flight headed west, and the other headed east. They then compared the clocks against those of the Observatory. Before they carried out the experiment, their calculated predicted net loss for the eastward journey clock was 40+/-23 nanoseconds (144+/-14 nanoseconds of gravitational dilation and -184+/-18 nanoseconds of kinematic dilation[17]) and the predicted net gain of the westward journey was 273+/-7 nanoseconds (179+/-18 nanoseconds of gravitational dilation and 96+/-10 nanoseconds of kinematic dilation[18]). The equations used are seen below (see left for gravitational time dilation, see right for kinematic time dilation);

$$T_A - T_S = -T_S\left[\frac{2R\omega v + v^2}{2c^2}\right] \qquad T = T_0\left[1+\frac{gR}{c^2}\right] \quad \text{or} \quad T - T_E = \frac{gR}{c^2}T_E$$

The predicted values of 144 nanoseconds on the eastward flight corresponds to an altitude of 8900m of the flight, whilst the value of 179 nanoseconds for the westward flight corresponds to *an altitude of 9400m[19] – this demonstrates that the lower altitude flight aged slower than the westward flight at a higher altitude, proving that gravitational time dilation occurs to a stronger degree when the effect of a gravitational well is stronger.

Table 1. Observed relativistic time differences from application of the correlated rate-change method to the time intercomparison data for the flying ensemble. Predicted values are listed for comparison with the mean of the observed values; S.D., standard deviation.

Clock serial No.	Δτ (nsec)	
	Eastward*	Westward
120	- 57	277
361	- 74	284
408	- 55	266
447	- 51	266
Mean ± S.D.	- 59 ± 10	273 ± 7
Predicted ± Error est.	- 40 ± 23	275 ± 21

* Negative signs indicate that upon return the time indicated on the flying clocks was less than the time indicated on the MEAN(USNO) clock of the U.S. Naval Observatory.

The above figure shows the net results of the flights; the observed deviation was very close to the pairs predicted results, once again proving the success of the ideas proposed in Einstein's theory[20].

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[16] Author (2023) *Pound-REBKA experiment definition & example*, *Nuclear Power*. Available at: https://www.nuclear-power.com/pound-rebka-experiment/ (Accessed: 06 September 2023).

[17] *Hafele and Keating Experiment* (no date) *Hafele-Keating Experiment*. Available at: http://hyperphysics.phy-astr.gsu.edu/hbase/Relativ/airtim.html (Accessed: 06 September 2023).

[18] *Hafele and Keating Experiment* (no date) *Hafele-Keating Experiment*. Available at: http://hyperphysics.phy-astr.gsu.edu/hbase/Relativ/airtim.html (Accessed: 06 September 2023).

[19] *Hafele and Keating Experiment* (no date) *Hafele-Keating Experiment*. Available at: http://hyperphysics.phy-astr.gsu.edu/hbase/Relativ/airtim.html (Accessed: 06 September 2023).

[20] https://einsteinrelativelyeasy.com/index.php/general-relativity/87-the-hafele-keating-experiment
Cyril (no date) *Hafele–Keating Experiment (1971)*, *Einstein Relatively Easy*. Available at: https://einsteinrelativelyeasy.com/index.php/general-relativity/87-the-hafele-keating-experiment (Accessed: 06 September 2023).

Time Dilation in Mainstream Media:

One of the most well-known science-fiction blockbusters, Interstellar, released in November 2014 to widespread critical acclaim and praise from audiences worldwide for its emotional and grounded story, fantastic visuals and, most importantly in this case, its meticulously accurate representation of space and the concepts behind it. The film's director, Christopher Nolan, directly consulted with astrophysicist Kip Thorne throughout the production to keep its physics as accurate as possible - Kip laid down some guidelines concerning his involvement early in the process that would prevent concepts being introduced in the film from violating any established physical laws and from "any ideas from springing from the mind of a Hollywood screenwriter rather than a scientist"[21]. Time dilation plays a major role in the later acts of the film - after the characters are stranded on a planet close to a supermassive blackhole for what they experience as a few hours, it is revealed that 23 years on earth had passed during their mission. Nolan made it clear to Kip that the dilation had to have a specific ratio of 1 hour: 7 years on earth. He ultimately concluded that, if the black hole was spinning incredibly fast, the ratio could occur without the planet being close enough to the point where it is torn apart by Gargantua's gravity[22]. So, with incredibly high velocity and incredibly high gravitational force, by being close enough to the event horizon of the black hole, the characters experience time dilation in an extreme manner[23]. It is unlikely that we will see time dilation to such an effect in current day society, but the possibility of it occurring in the future isn't too far out of reach.

Conclusion:

Time dilation is an extremely interesting concept that was first theorised by one of the most renowned scientists in history. Its effects have successfully been observed and proved numerous times, most notably in the instances mentioned above, and have given scientists across the globe insight into the fundamental laws of our universe. Despite this however, we are yet to see time dilation in an extreme case, where its effects are more clearly noticeable and digestible for us to see. This may become possible in the future, as humanity continues to advance technologically with regard to space travel and interstellar transport, where we may see space travellers return from grand space expeditions only slightly aged whilst the earth's clock has kept on ticking.

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[21] (No date) *Physicist who inspired interstellar spills the backstory—and the scene ...* Available at: https://www.science.org/content/article/physicist-who-inspired-interstellar-spills-backstory-and-scene-makes-him-cringe (Accessed: 06 September 2023).

[22] Cofield, C. (2014) *'interstellar' science: Physicist Kip Thorne writes the book*, *Space.com*. Available at: https://www.space.com/28075-science-of-interstellar-book-review.html (Accessed: 06 September 2023).

[23] LUMINET, J.-P. (2016) *The warped science of interstellar (4/6) : Time Dilation and Penrose Process, by Jean-Pierre Luminet*, *e-LUMINESCIENCES: the blog of Jean-Pierre Luminet*. Available at: https://blogs.futura-sciences.com/e-luminet/2016/01/16/warped-science-interstellar-46-time-dilation-penrose-process/ (Accessed: 06 September 2023).

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