SCIENTIFIC INVENTURER

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Our Team

Vibha Reddy

I am a passionate Biology major with a deep love for exploring the wonders of life sciences. Alongside my academic pursuits, I enjoy exploring UI design, combining creativity and functionality to craft visually engaging experiences.

Tejas Singh

I am a passionate designer with a keen eye for both graphic and product innovation, enjoying the blend of creativity with purpose. I also have a deep appreciation for geography, which fuels my curiosity and broadens my perspective. Driven to bring ideas to life, I strive to make each project visually impactful and thoughtfully crafted.

Manini Nair

I am a passionate student interested in interior design, with a creative flair for baking and art. Driven by my love for aesthetic spaces and innovative design, I constantly explore ways to blend functionality with beauty. My hobbies fuel my artistic vision, shaping my aspirations in design.

Teachers/Mentors for SbC

Inventure Teacher Mentors

As a team of science teachers, we've had the privilege of guiding students through the Science Beyond Curriculum (SbC) program, which has been an incredibly rewarding experience. SbC offers students a chance to explore science beyond the classroom, dive into research, and develop key skills in communication and critical thinking.

Our role was to mentor students throughout the process, from helping them choose research topics to guiding them in writing research papers and presenting their findings. We worked closely with them to refine their academic writing and presentation skills, helping them express their ideas clearly and confidently.

The collaboration with experts from GenWise has also been a valuable addition, providing students with further insights to improve their research and communication skills. Watching students grow as independent researchers and confident communicators has been truly fulfilling.

Through SbC, our students have not only gained scientific knowledge but also developed important skills that will help them in any future endeavor. It's been a rewarding journey, and we look forward to seeing how they use these skills in the future.

Science team

Genwise Mentors

Radha Gopalan
Chemistry

Radha is senior mentor and course designer at GenWise. Her view of the world is one of hidden connections and she believes that a significant part of learning is to unearth these connections. She is an environmental scientist by training, with a deep interest in exploring and practicing "transformative education for sustainable living". Towards this effort she is engaging actively with rural and urban communities to further the idea of food sovereignty. After 18 years as a global environmental consultant, Radha also wore the teacher's hat for several years at the Rishi Valley School, teaching Environmental Sustainability. She is a Visiting Faculty at the School of Development, Azim Premji University, Bengaluru and engages actively in popular education efforts around sustainability. Radha has a bachelor's degree in Genetics from the Madras University, a Master's from Osmania University, and a Ph.D from IIT Bombay in Environmental Science. Radha has facilitated several pioneering courses on Sustainability and related thems at various GenWise summer and year-round programs. In May 2022, Radha will be facilitating the course "Life, The City, and Changing Climate".

Dhanya K
Biology

Dhanya is an education consultant and science communicator with a strong foundation in research and pedagogy.

With a Ph.D. in Neurogenetics from NCBS, Bangalore, she brings deep scientific expertise to her work in education. She has taught Biology to grades 8–12 at Rishi Valley School, focusing on inquiry-driven learning and curriculum design. As a domain expert in the MANAV Human Atlas Initiative at IISER Pune, she contributed to scientific literacy programs, public engagement, and national-level outreach.

Currently, Dhanya works on designing innovative science curricula, mentoring educators, and fostering scientific inquiry to make learning more engaging and meaningful for students.

Genwise Mentors

Sukanya Sinha
Physics

Sukanya sees the world as an endless wonder, a world where children are excited and curious about learning science. She was the founder director of Curiouscity Science Education with the mission to enable children to look at science as a special way of viewing the world. Since 2004, she has been a visiting scientist at the Indian Statistical Institute, Bangalore. Sukanya also writes (in English and Bengali) to share her passion for science with her readers. She was awarded the prestigious Rabindra Smriti Puraskar in 2010 for science writing in Bengali. She has M.Sc., M.Phil. degrees from the University of Delhi and a Ph.D. from the University of Maryland College Park.

Sukanya has facilitated numerous courses at the online and residential programs at GenWise, over the years, including those on Intelligent Estimation, and Scientific Enquiry.

About SbC (Science Beyond Curriculum)

To enhance students' proficiency in science communication and academic writing, the science curriculum for grades 9 through 12 has incorporated a program called Science Beyond Curriculum (SbC). This initiative provides students with a platform to go beyond traditional coursework and engage in scientific exploration and write a research essay.

The program is structured into two levels of engagement:
Level 1 offers an immersive experience, equipping students with a solid foundation in the subject matter while encouraging deep engagement and curiosity.

Level 2 gives the students an opportunity to collaborate in groups, select an area of interest for research, and produce a research paper. This aspect of the program allows students to explore topics they are passionate about, promoting ownership and enthusiasm for their work.

To further support these efforts, the school organizes two webinars led by subject experts from our partner organization, GenWise. The first webinar, focused on Academic Writing, provided students with essential strategies for structuring and presenting their research effectively. The second webinar, centered on Academic Talk, helped students develop verbal communication skills to present their ideas with clarity and confidence. Both webinars were open to all students, offering valuable tools to support their academic growth.

Through this initiative, we aim to equip students with the skills needed to excel in their research and communicate their findings effectively, preparing them for future academic and professional success.

About CERN Experience

From June 23 to 29, 2024, twelve senior school students from Inventure Academy embarked on a unique experience to visit CERN, the world's largest Physics laboratory. Through the CERN Masterclass, they gained hands-on exposure to Particle Physics, engaged with world-renowned scientists, and witnessed firsthand how STEM education translates into real-world impact, from advancements in cancer research to cutting-edge technology.

Beyond the lectures and lab visits, this experience ignited curiosity, deepened scientific inquiry, and reinforced the significance of interdisciplinary learning. Upon returning, the students channeled their insights into their Capstone Projects—research-driven explorations spanning Particle Physics, cosmology, nanotechnology, and computational modeling. From analyzing Dark Energy's role in the universe's expansion to designing algorithms for tracking fast-moving nanoparticles, these projects showcase their ability to apply scientific principles to complex, real-world challenges.
Reviewed by eminent physicists on a global platform, these Capstone Articles stand as a testament to their academic growth and passion for STEM. We are proud to share their work, which reflects not only their technical acumen but also their curiosity, innovation, and commitment to pushing the boundaries of scientific discovery.

We are especially proud to share that Krish Kakkar's work was rated EXCELLENT, while Ameya Saxena and Advit Arora received a COMMENDATION for their outstanding contributions.

These articles reflect not only the students' technical acumen but also their curiosity, innovation, and commitment to pushing the boundaries of scientific discovery.

Editor's Note

Welcome to the latest edition of Scientific Inventurer!

In a world driven by curiosity, innovation, and the constant quest for answers, science stands at the very heart of progress. With this issue, we aim to celebrate the power of discovery, highlighting breakthroughs that inspire, challenge, and redefine the boundaries of possibility.

As a team, we have worked collaboratively to curate an exciting collection of articles that delve into the wonders of the natural world, cutting-edge technology, and the thought-provoking ideas shaping our future. Each piece has been selected with care, ensuring it reflects the magazine's mission to ignite curiosity and foster a deeper understanding of science in all its forms.

From unraveling the mysteries of the universe to exploring groundbreaking innovations, Scientific Inventurer invites you to embark on a journey of learning and inspiration. Whether you're a lifelong science enthusiast or just starting to explore its wonders, we hope you find this issue as engaging and thought-provoking as we did while creating it.

We would love to hear from you! Your feedback and insights fuel our passion and help us grow. Feel free to reach out with your thoughts, questions, or ideas for future editions.

Thank you for joining us on this journey of discovery. Together, let's continue to explore, question, and invent the future!

Happy reading,
The Editorial Team
Tejas S, Manini N, Vibha R.

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Tracking of Fast Moving Nanoparticles and Nanomachines

Krish Kakkar

Tracking fast moving nanoparticles and nanomachines (Npm) is complex due to their high speed and small size. Reliable information about the Npm's velocity and position is calculated by combining image processing techniques, and tracking algorithms. This framework aims to reduce these difficulties while offering a technique for locating and tracking a Npm.

Process Flow Algorithm

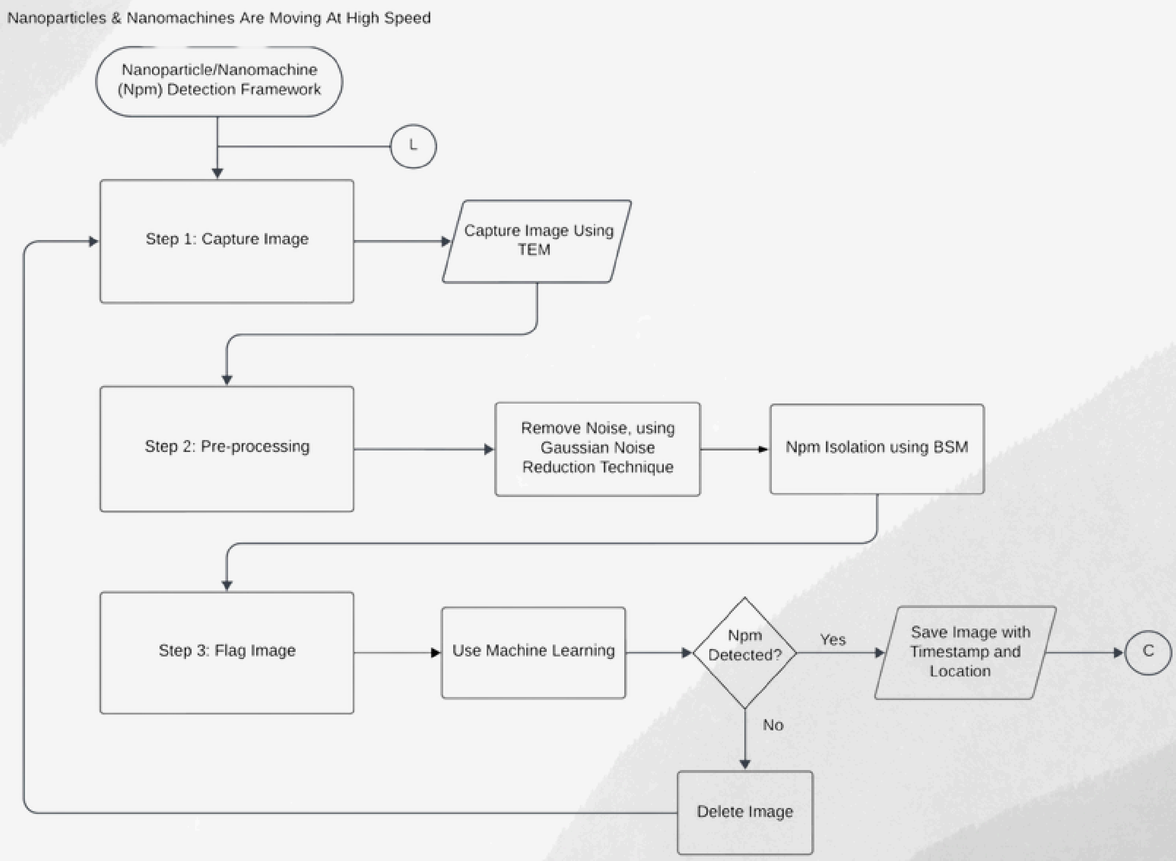


Figure 1: Process Flow (a)

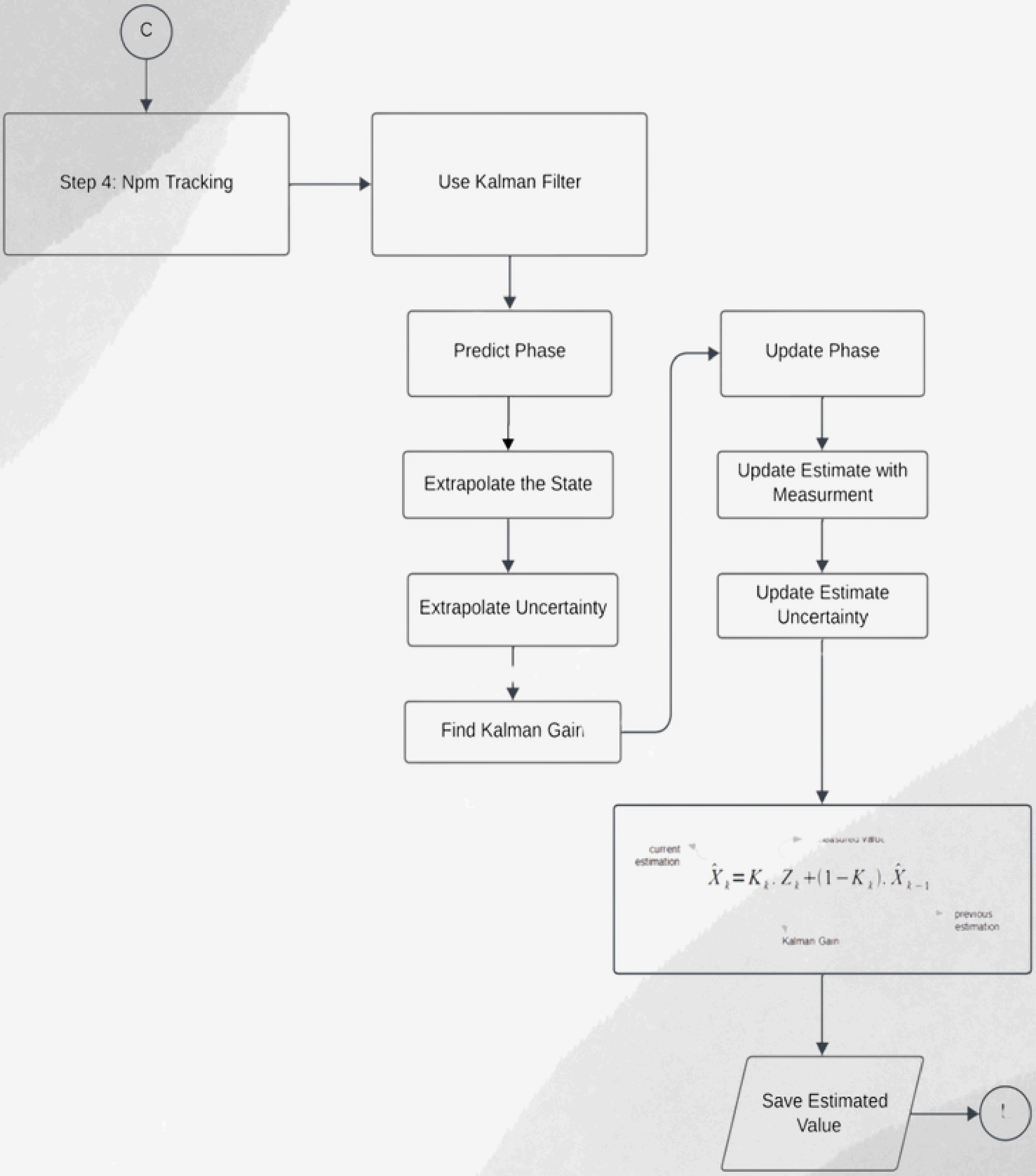
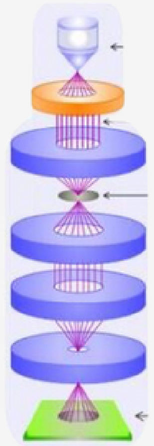


Figure 2: Process Flow (b)

Methodology

<u>Step 1: Image Capture</u>
TEM1 with electron microscopes can be employed for high resolution imaging, specialized equipment is needed to capture Npms at high speed.



Step 2: Pre-processing

A captured image would have to be pre-processed to remove unwanted details, enhance image quality, and prepare the image data for further tracking and detection steps.

Image Quality

Gaussian noise2 can obstruct Npm signals. Gaussian filters3 using Gaussian Smoothing Operator4 produces a clearer image.

$$\frac{1}{2\pi\sigma^2}\exp\{-\frac{x^2+y^2}{2\sigma^2}\}$$

Figure 4: Gaussian Filter

---

1 Transmission Electron Microscopy (TEM) - is a technique that uses a beam of electrons to take an image of Npm, with an high accuracy compared to a light based image.

2 Gaussian noise - arises when the images are taken under low light.

3 Gaussian filters - each element in the resultant matrix, new value is set to a weighted average of that element's neighbourhood.

4 Gaussian smoothing operator - performs a weighted average of surrounding pixels based on the Gaussian distribution. It removes Gaussian noise by smoothening the pixels.

Image Isolation

Next, using BSM5 the image is isolated and background is removed.

Step 3: Flag Image

Using machine learning models on the image, Npm detection check is done. This would be done based on the appearance and size of the object.

Step 4 : Particle Tracking

Npms travel at very high random speeds, determining the exact position is difficult. Therefore, a mathematical (Kalman Filter) model is used.

Kalman Filter

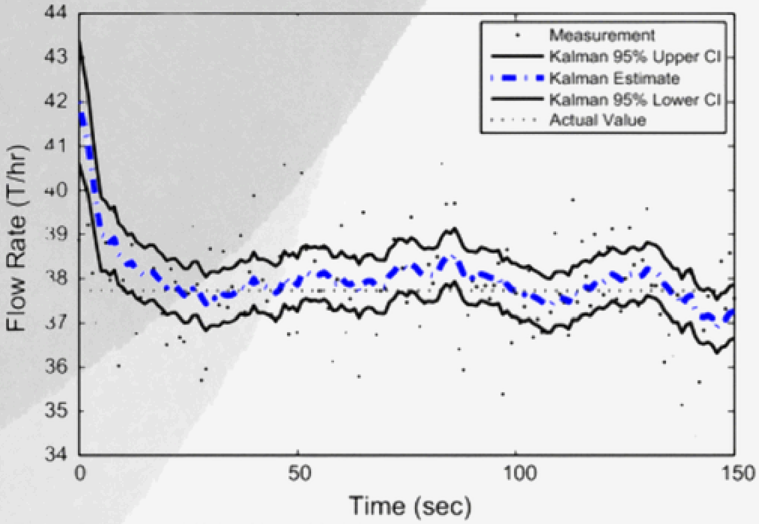


Figure 5: Estimated Value Using Module

The Kalman filter[6] has two phases:

1. **Predict phase**: Predicts Npm location.
2. **Update phase**: Using portion of Npm's measured flow, adjust measurements with lower error variance.

With Kalman Gain[7], a weightage of accuracy of the prediction is calculated.

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5 Background subtraction method (BSM) - is an algorithm that is used to extract foreground objects from a video stream by removing stationary and static backgrounds.

6 The Kalman filter - is a mathematical models that combines both the predictions and the actual measurements to predict an estimated location.

7 The Kalman Gain - the measurement's weight and the prior estimate's weight when forming a new estimate.

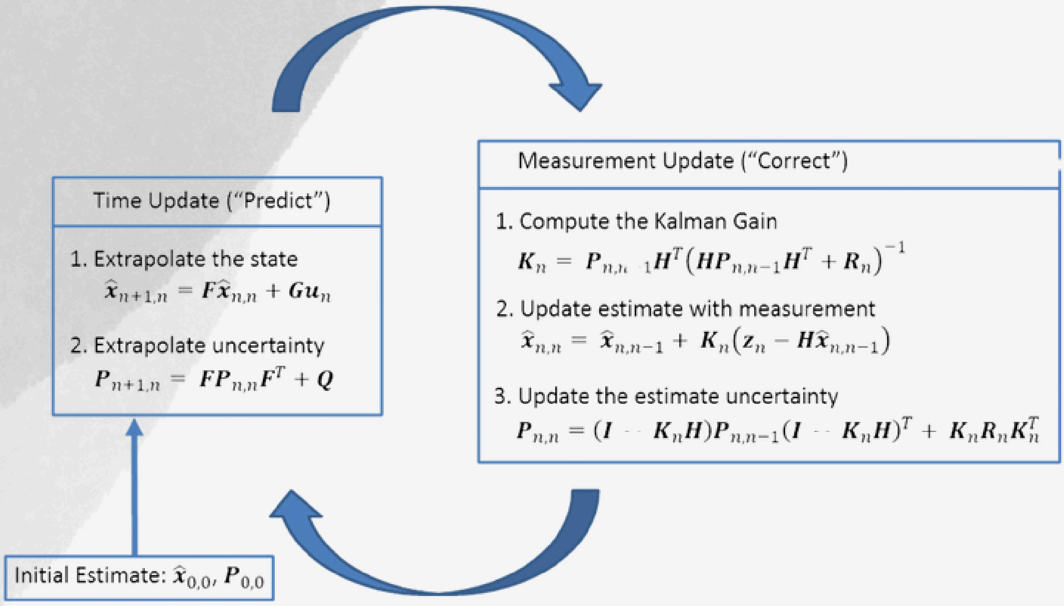

Figure 6: Kalman filter

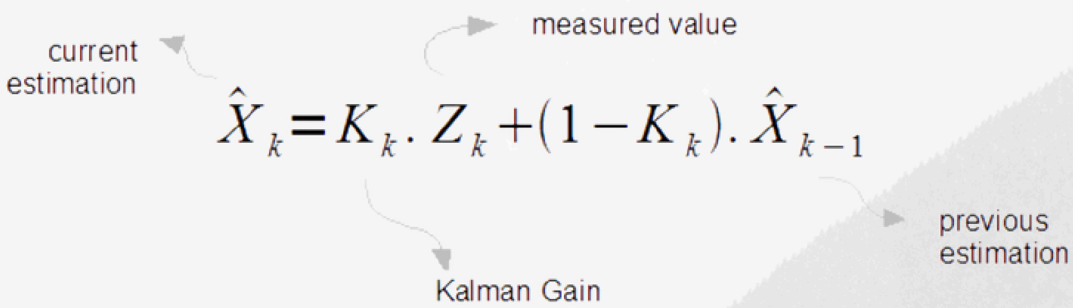

Figure 7: Kalman equation

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Dark Energy and Its Influence on the Expansion of the Universe

Advit Arora

Abstract
The discovery of the accelerating expansion of the universe has fundamentally transformed our understanding of cosmology. This paper delves into the role of dark energy in driving this acceleration, exploring its definition, discovery, and impact on the universe's expansion. By examining historical context, observational evidence, and theoretical implications, we aim to highlight why dark energy is a compelling explanation and its significance in the field of astrophysics.

1: Introduction:

The universe has been expanding since the Big Bang, approximately 13.8 billion years ago. Initially, it was believed that this expansion would slow down due to the gravitational pull of matter. However, in the late 1990s, observations of distant supernovae revealed that the universe's expansion is accelerating. This unexpected phenomenon has led to the hypothesis of dark energy, a mysterious force that constitutes about 68% of the universe's total energy content. Understanding dark energy is crucial as it profoundly impacts our comprehension of cosmology and the ultimate fate of the cosmos.

The objective of this paper is to explore the influence of dark energy on the expansion of the universe. This paper will delve into the historical context of the discovery of dark energy, explain what dark energy is, discuss how it was discovered, and examine its impact on the expansion of the universe.

The paper is structured as follows: Section 2 discusses dark energy's historical context, its theoretical underpinning, and the observational evidence that led to its discovery. Section 3 explores the impact of dark energy on the expansion of the universe. Section 4 concludes the paper by summarising the importance of dark energy in cosmology and its implications for the future of the universe.

2: Dark Energy

2.1 Historical Discovery of Dark Energy

For much of the 20th century, it was believed that the universe's expansion, initiated by the Big Bang, would eventually decelerate due to the gravitational pull of matter. This view was challenged by the groundbreaking work of astronomers in the late 1990s. Teams led by Saul Perlmutter, Brian P. Schmidt, and Adam G. Riess observed Type Ia supernovae, which served as standard candles to measure cosmic distances.

Their observations (Figure 2) revealed that these supernovae were farther away than expected in a decelerating universe, indicating that the expansion rate of the universe is accelerating. This discovery led to the hypothesis of dark energy, fundamentally altering our understanding of the universe's dynamics.

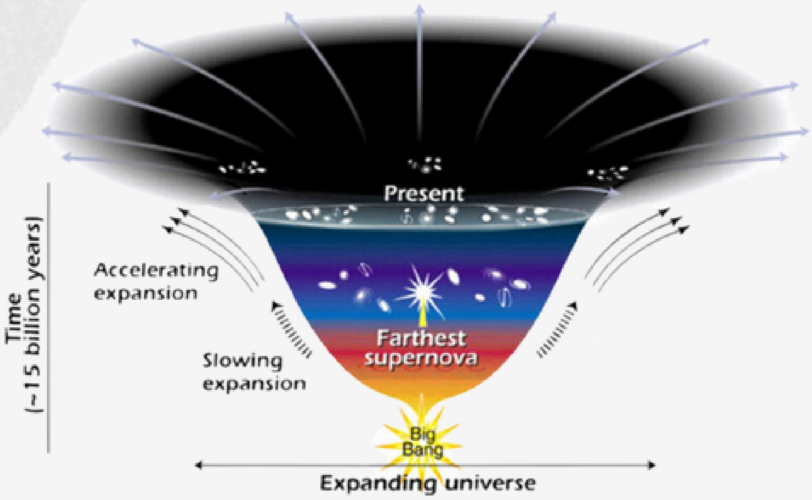


Figure 1: *Dark Energy and Universe Expansion. This diagram shows the expansion of the universe, illustrating how dark energy causes the accelerated expansion.*

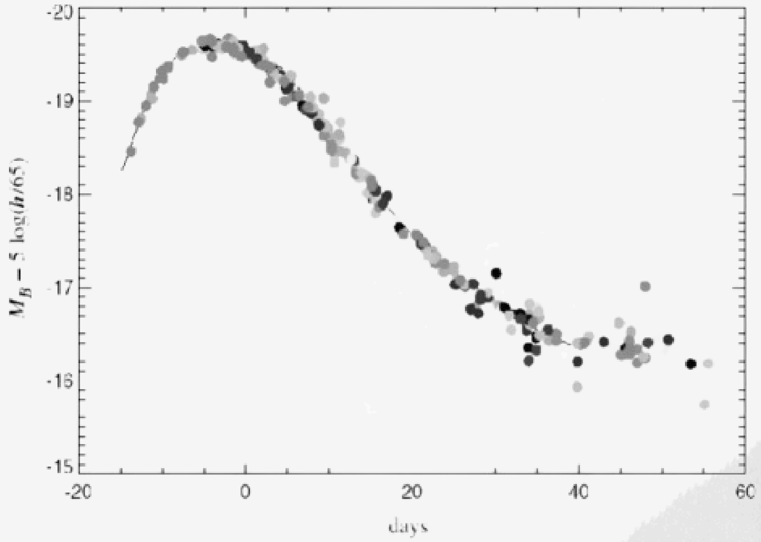
2.2 Definition and Theoretical Basis of Dark Energy

Dark energy is a mysterious form of energy that permeates all of space and tends to increase the rate of expansion of the universe. It is hypothesized to make up about 68% of the total energy content of the universe, with dark matter and ordinary matter comprising the remainder. The most widely accepted explanation for dark energy is the cosmological constant (Λ), introduced by Einstein in his general theory of relativity. The cosmological constant represents a uniform energy density that fills space homogeneously. According to Einstein's equations, this constant exerts a repulsive force, counteracting the gravitational pull of matter and causing the accelerated expansion of the universe.

Einstein's field equations describe how matter and energy in the universe influence its curvature. The inclusion of the cosmological constant mod-ifies these equations to account for the observed accelerated expansion. The equation is given by:

$$R_{\mu\nu} - \frac{1}{2}g_{\mu\nu}R + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4}T_{\mu\nu}$$

Equation 1: Einstein's field equations with the cosmolog-ical constant. This equation shows how the presence of dark energy (represented by Λ) leads to a repulsive force that drives the accelerated expansion of the universe.



2.3 Discovery and Observational Evidence

The discovery of dark energy was primarily driven by observations of distant Type Ia supernovae. In 1998, two independent research teams, the Super- nova Cosmology Project led by Perlmutter and the High-Z Supernova Search Team led by Schmidt and Riess, published their findings showing that the uni-verse's expansion was accelerating. These results were unexpected and required an explanation beyond the existing models of cosmology. Subsequent observations, including detailed measurements of the Cosmic Microwave Background (CMB) radiation by the Wilkinson Microwave Anisotropy Probe (WMAP) and the Planck satellite, provided further evidence supporting the existence of dark energy.

The presence of dark energy is supported by multiple lines of observational evidence:
1. Supernova Observations: Type Ia supernovae serve as standard candles to measure cosmic distances. Their observed brightness indicates that the universe's expansion is accelerating (Figure 2).
2. CMB Measurements: Detailed observations of the CMB, such as those by WMAP and Planck, show temperature fluctuations that provide evidence for the conditions of the early universe and support the presence of dark energy (Figure 3).
3. Large-Scale Structure Surveys: Surveys of the large-scale structure of the universe reveal patterns of galaxy distribution that align with the influence of dark energy on cosmic expansion.

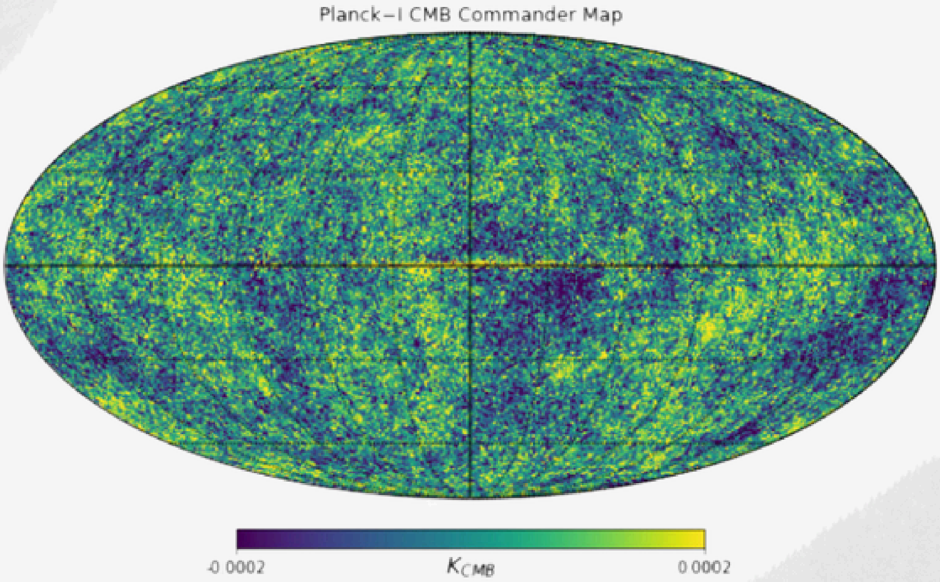


Figure 3: *Cosmic Microwave Background (CMB) Map. This image shows the temperature fluctuations in the CMB, which provide evidence for the conditions of the early universe and support the presence of dark energy.*

3 Impact on the Expansion of the Universe

Dark energy has a profound impact on the expansion of the universe. Its repulsive force accelerates the rate of expansion, counteracting the gravitational attraction of matter. This acceleration affects the large-scale structure of the universe, influencing the formation and distribution of galaxies and galaxy clusters. Observations of the CMB, large-scale structure surveys, and supernovae provide consistent evidence that dark energy dominates the energy content of the universe and drives its accelerated expansion. The evidence behind dark energy causing expansion is robust and comprehensive. Supernova observations, particularly of Type Ia supernovae, show that distant supernovae are dimmer than expected in a decelerating universe, implying that the universe's expansion is speeding up. CMB measurements reveal tiny fluctuations in temperature that correspond to the density variations in the early universe, supporting a model where dark energy drives the accelerated expansion. Large-scale structure surveys indicate that the clustering of galaxies and the distribution of cosmic structures align with predictions that include dark energy. Another important concept in this context is Hubble's Law, which relates the velocity of a galaxy to its distance from us:

$$v = H_0 \times d \tag{2}$$

Equation 2: Hubble's Law, which relates the velocity of a galaxy to its distance from us, providing evidence for the expanding universe and supporting the idea of an accelerating expansion driven by dark energy.

Hubble's Law can be visually represented in a Hubble diagram, where the velocity of galaxies is plotted against their distance from Earth. The slope of the line in this diagram is the Hubble constant, and deviations from a straight line indicate changes in the expansion rate of the universe, which can be attributed to the influence of dark energy (Figure 4).

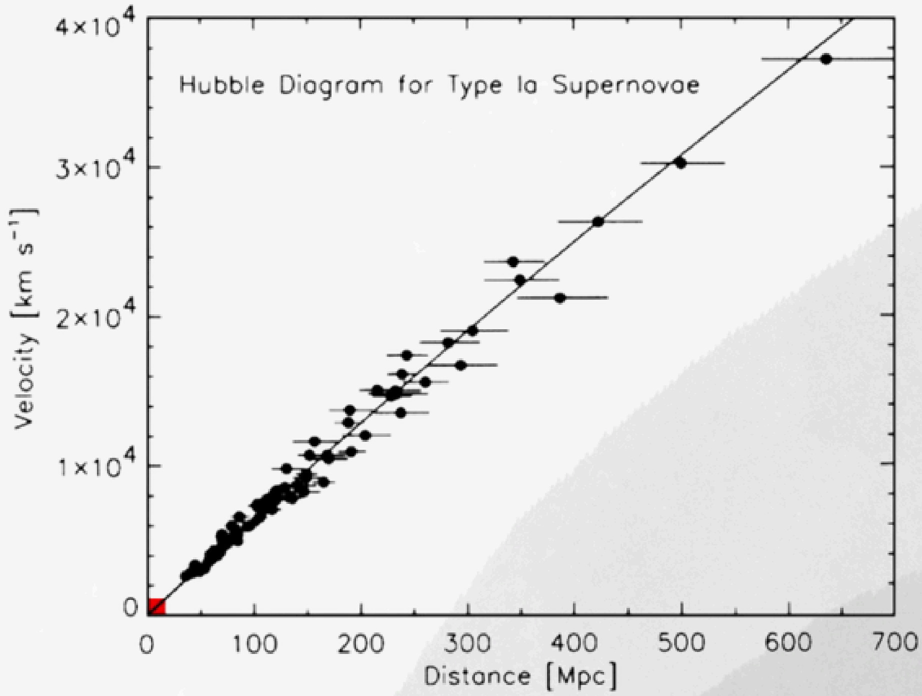


Figure 4: *Hubble's Law Diagram. This plot shows the relationship between the velocity of galaxies and their distance from Earth, demonstrating the concept of the expanding universe.*

4 Conclusion

Understanding dark energy is crucial for modern cosmology. It not only explains the current accelerated expansion of the universe but also has significant implications for its ultimate fate. If dark energy con- tinues to dominate, the universe will expand forever at an accelerating rate, leading to a "Big Freeze" scenario where galaxies, stars, and eventually atoms are spread thin across an ever-growing, increasingly empty cosmos. This understanding challenges our perception of the universe and raises fundamental questions about the nature of space, time, and the fundamental forces that govern the cosmos.

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The Hubble Tension

Ameya Saxena

The Hubble Tension is the significant discrepancy between the measurements of the Hubble constant from the cosmic microwave background and other local observations.

The Hubble constant is measured in 2 primary ways:

1. Using measurements that come from the Planck satellite's observations of the CMB, which give a value of approximately H0 = 67.4 ± 0.3 km/s/Mpc.

2. Local measurements using the cosmic distance adder, which involve Cepheids and Type 1a supernovae, have a higher value of around 73.5 ± 1.5 km/s/Mpc. This is a significant difference for such a fundamental constant, leading to many questions about the universe's expansion.

The Planck satellite has precisely mapped the CMB, allowing astronomers to determine parameters like the Hubble constant. This method fits the data to the ΛCDM (Cold Dark Matter) model, yielding a value of $H_0 \approx 67.4$ km/s/Mpc

$$H_0 = H(z)\sqrt{\Omega_m(1 + z)^3 + \Omega_\Lambda + \Omega_k(1 + z)^2}$$

Where H(z) is the Hubble parameter at redshift z, and $(\Omega_m, \Omega_\Lambda, \Omega_k)$ are density parameters derived from CMB data.

Conversely, local measurements use the cosmic distance ladder with Cepheid stars, whose distances are determined using their apparent and absolute magnitudes:

$$d = 10^{(m-M+5)/5}$$

Where d is the distance, m is the apparent magnitude, and M is the absolute magnitude of the Cepheid

Once these distances are known, they are used to calibrate the luminosity of Type 1a supernovae. These supernovae have a consistent brightness and are used for measuring interstellar distances. The Hubble constant is then calculated by plotting galaxy distances against their redshifts and applying Hubble's Law:

$$v = H_0 d$$

where v is the recessional velocity of a galaxy, d is the distance, and H_0 is the Hubble constant This method yields a value of $H_0 \approx 73.5$ km/s/Mpc.

A plausible solution to the Hubble Tension involves the concept of Early Dark Energy. This suggests that a form of dark energy, not like the dark energy driving the current accelerated expansion of the universe, was present at an earlier time. This early dark energy could have temporarily altered the expansion rate of the universe, leading to a higher value of the Hubble constant when measured through local observations. This would modify the physics of the early universe, affecting the CMB measurements and potentially bridging the gap between the two values.

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What is the Fermi Paradox?

Reyansh Sudhir

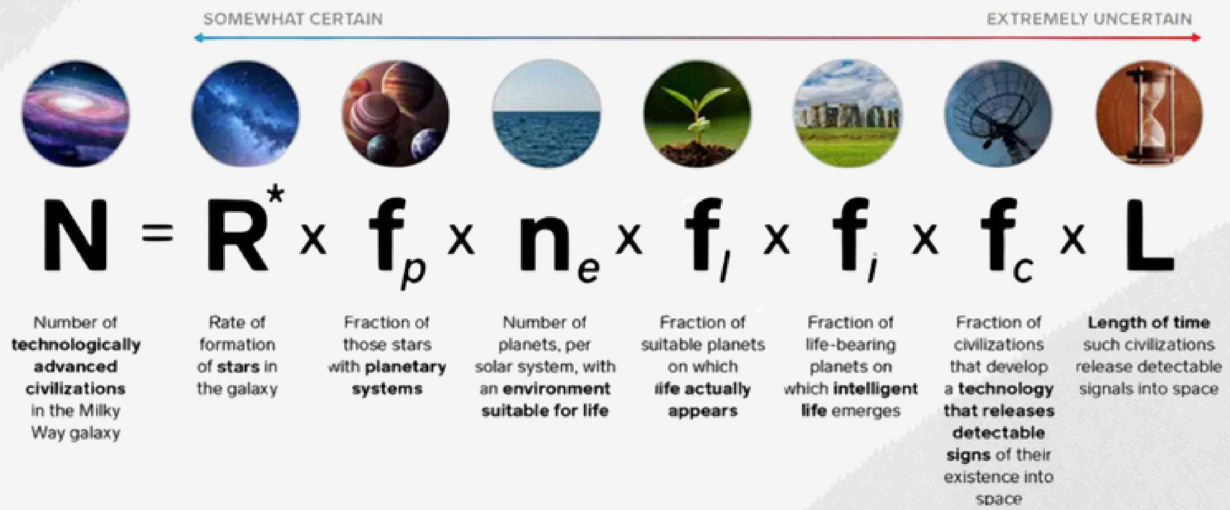
In 1950, during a discussion about extraterrestrial life at Los Alamos National Laboratory, physicist Enrico Fermi famously asked- “Where is everybody”.

The Fermi Paradox highlights the contradiction between the high chances of extraterrestrial civilizations and the complete lack of evidence for such civilizations.

There are approximately 200-400 billion stars in the Milky Way alone; and most of them have Earth-like planets in the Goldilocks zone, which result in roughly 100 million habitable planets; just in the Milky Way.

Surely we can’t be alone?

Drake Equation



Astronomer and SETI co-founder Jill Tarter had said, “The Drake Equation is a wonderful way to organize our ignorance”.

While the first three variables of The Drake equation have fixed values, the last four can only be guessed; hence rendering it largely inaccurate. However, till date it remains our most effective tool towards calculating the probability of extraterrestrial life.

Kardashev Scale

Earth is 0.7 on the Kardashev Scale. A type 1 planet would have harnessed all of its own resources, type 2 has colonized its star’s energy and type 3 has harnessed its galaxy. If humans can build generation spaceships in the next few thousand years, we could potentially colonize the galaxy in 1-2 million years. Why haven’t civilizations with older stars achieved this?

Theories

There is no way of knowing whether we are alone. This has encouraged speculation, both plausible and far-fetched.

There might have been glorious civilizations over extended periods before us. Considering intelligent humans have only been around for a short period of time, it is possible that signals were sent to us; we just weren't there to receive it.

However, one of the most widely accepted theories is the Great Filter. It states that there might be a barrier preventing any civilization from reaching a certain potential. Perhaps the filter is a fundamental challenge with intergalactic travel, or the inevitability of climate change.

The probability of extraterrestrial life is littered with maybes. There's no way to actually verify whether theories are right. But the scariest theory is that we're truly alone in a universe that's roughly 93 billion light years in diameter. This highlights how precious and fragile our existence is. Whether or not we have company, this journey of discovery seconds our human spirit and resilience.

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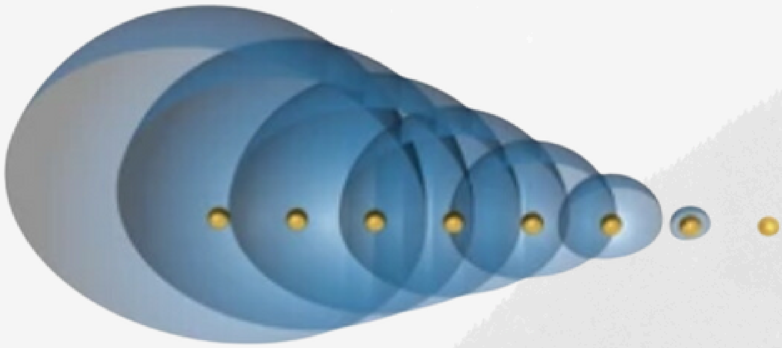
Tachyons

Arvin karthik Madhava

Tachyons are hypothesized subatomic particles with a velocity greater than light. Although it hasn't been proven experimentally, the existence of the tachyon seems to be consistent with the theory of relativity, which was initially believed to only apply to particles moving at or slower than the speed of light. Tachyons can only exist at speeds greater than light, at which time their mass would be real and positive, just as regular particles like electrons can only exist at speeds less than light. A tachyon would accelerate as it lost energy; the faster it moved, the less energy it had. Tachyons were first theorised in 1967 by physicist Gerald Feinberg in his seminal paper "On the possibility of faster than light particles.".

Properties of tachyons

Tachyons, unlike other particles, would lose energy as they accelerate. This means that a tachyon with no energy would accelerate infinitely. The consequences of such an event can be catastrophic. One such example is in the case of charged Tachyons. Since they move faster than light and lose energy, they emit a form of radiation known as Cherenkov radiation (energy emitted when charged particles move at speeds greater than that of light). This release of energy would further increase their velocity and cause them to accelerate more, thus causing the tachyon to emit large amounts of radiation as it propagates



Tachyons have the ability to convey information back in time due to their faster-than-light flight, which could disrupt causality. Imagine utilising tachyons to transmit a message; paradoxically, the recipient might receive it before it is sent, resulting in situations where a question is answered before it is asked. The cause-and-effect relationship that is essential to our comprehension of reality is broken by this backward temporal communication.

Is it possible to detect ?

Since tachyons always travel faster than light, the accompanying photons are outrun by them, making it impossible to detect their approach. Once they were gone, they would reappear as two pictures, coming and going at the same time. Even though they are "anti-mass," their gravitational effects may allow for detection. An additional means of detection could come from tachyons, which are electrically charged, travel faster than light in a near vacuum, and produce Cherenkov radiation.

Conclusion

Tachyons continue to bewilder scientists to this day, and the possibilities they offer are intriguing. Future advancements in particle physics and cosmology will shed light on the existence of Tachyons.

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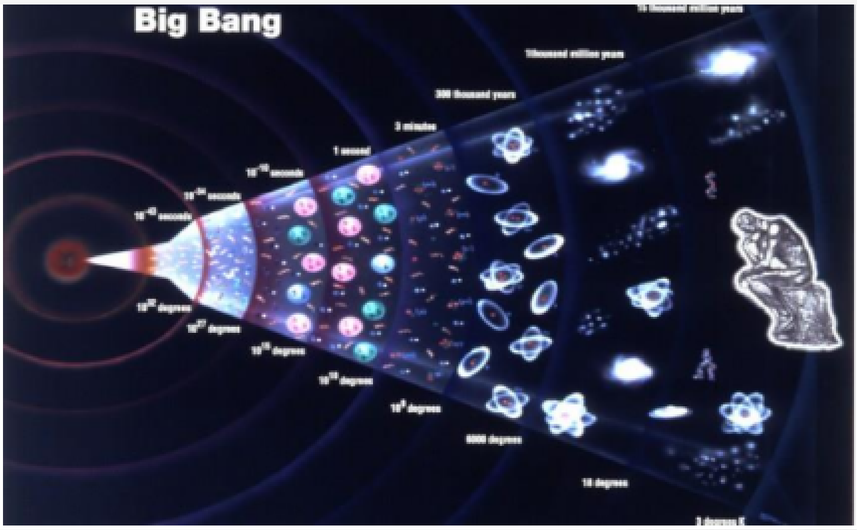
What happened before the Big Bang?

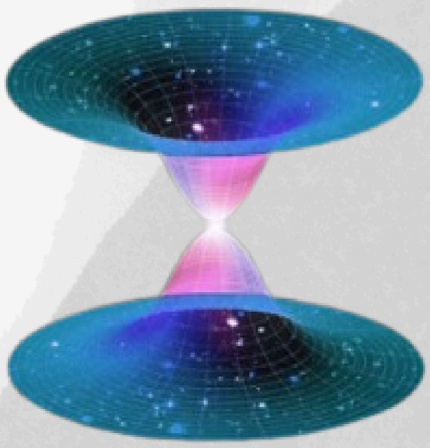
Agastya Kartikeyan

One of the biggest unsolved mysteries of the universe is how it came into being. The common theory explaining the beginning of the universe is known as the Big Bang Theory. According to the theory, the universe was concentrated into a small point (a singularity.) However, we still do not know what happened before this - how did the universe really start? How did our universe start from nothing or something? What really initiated the Big Bang?

The Big Bang Theory is justified largely by the Inflation Theory of the Universe, where it has been observed that the universe is gradually expanding, and as we go back in time the universe contracts to the point that it becomes a singular point, which brings us back to the Big Bang. The concept of a singularity is contradictory to Einstein's theory of General Relativity, meaning that the cause and the behaviour of the Big Bang has to be on a quantum level, and unify General Relatively and Quantum Mechanics.



One of the many hypothetical, theorized solutions to what happened before the Big Bang is called the Big Bounce. The concept of the Big Bounce is that the universe expands and contracts in phases. Our universe is currently expanding, and according to the Big Bounce, it will continue to expand until a certain point, at which the conditions will cause a reversal in dark energy, or the fundamentals of physics and cause the universe to contract. The universe however will not become a singularity, and instead, according to Loop.



Quantum Cosmology (a branch of Loop Quantum Gravity, and a theory that suggests the universe is made of quanta packets, and forms a quantum bridge between expansion and contraction), the universe will experience a Big Bounce – a switch from contraction to expansion. This is a solution to both the problem with the Big Bang (formation of a singularity) and what happened before it. This theory that describes a cyclical formation and destruction of universes in an endless loop.

However, the drawback of Quantum Loop Gravity is that it needs substantive evidence. At this stage, there is no experiment that can prove it. To find evidence,larger hadron colliders might have to be built, more observations on Cosmic Microwave Background Radiation maybe required, and Gamma Ray Bursts would have to be measured more effectively.

Although this theory needs further exploration, it does allow asking the right questions: What was before the Big Bang?

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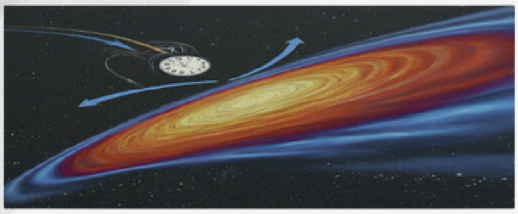
What time is it?

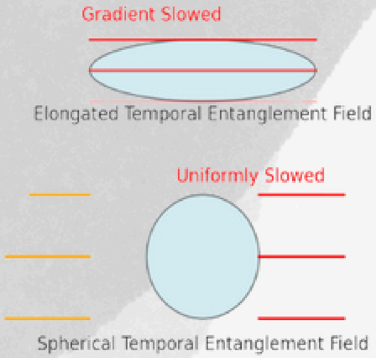
Daksh Mathew

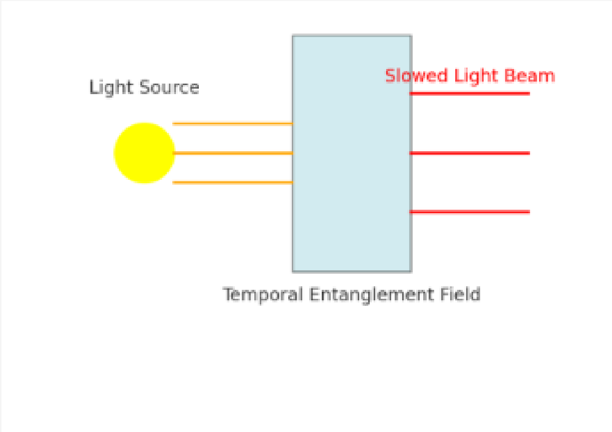
We all have felt the 2 faced nature of time . Sometimes it flies by in a blink, but in maths classes it goes for an eternity. This seems to apply even more broadly to our universe. It behaves differently in certain places - instead of moving uniformly forward as it should, in those areas time either moves faster or slower than expected. These locations are known as Cosmic Time Anomalies (CTAs). It's like all the clocks of the universe are not synchronised!



Imagine the universe as a big trampoline with great elasticity. When enormous celestial bodies like galaxies or black holes fall onto this surface they leave behind depressions and waves. CTAs could possibly emerge from those distortions in spacetime. Only very precise astronomical measurements can detect these minuscule space-time irregularities.

All CTAs have Temporal Entanglement Fields or TEFs. Some TEFs work in the way of speed breakers or boosters actually interfering with the time cycle. Thus, different regions get connected in a way that time is interrelated through TEFs and entanglement. Entanglement means that change in the state of one part of the TEF immediately influences another no matter how far it is located. This results in time loops hence time paradoxes and general time travel like phenomena. On the other hand, it can fluctuate, accelerate at one moment and then slow down. Temporal states become entangled in TEFs, producing effects that are not limited to temporal acceleration or deceleration, new temporal dimensions are produced. Its form and intensity might greatly influence time as well. Indeed, while inside a spherical TEF the time might be uniformly dilated, an elongated one would result in a gradient where within its length different parts of time flow at different rates. However due to mutual interaction among several TEFs, intricate temporal distortions give rise to sophisticated designs on the fabric of space-time.





Detecting and comprehending these cosmic temporal anomalies is critical to uncovering the underlying rules that govern our world. For example we could determine what happens visually with light, specimens under high energy fields acting like magnets (e.g., black holes), but that would only answer a portion of the question. One way is to detect light blue or red shifted by means such as infrared observing systems since TEF can also affect the speed of light rendering it differently coloured.

Interpreting CTAs could help in finding out the secrets of the universe. For instance, they may be linked with dark matter, black holes or even the inception of the universe itself. Thus, solving this mystery will be a titan in scientific advancement.

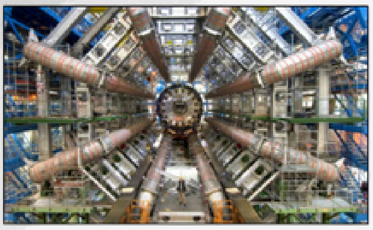
Citation :
arXiv.org
https://www.esa.int

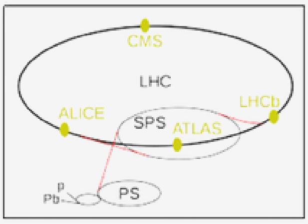
Synchrotron Radiation

Ekaansh Balaji

Introduction

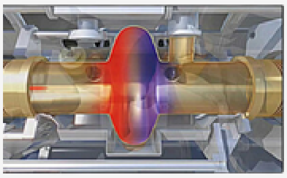
The universe we live in has so many unknowns that physicists are attempting to solve. Particle accelerators are one of the experimental techniques that is used to unravel these mysteries. They are devices that speed up the particles that make up all matter in the universe and collide them together. This allows scientists to study those particles. While trying to reach the speed of light,scientists encountered problems, one of them being Synchrotron radiation.

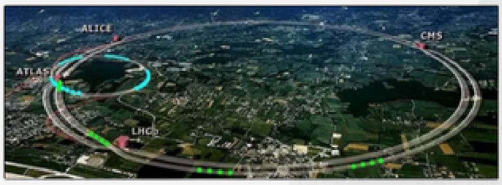


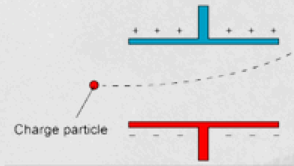


Particle Acceleration

All accelerators are mainly used to speed up charged particles and then collide them. Charged particles in this case are just used as carriers of energy to create new particles. They are used because they can be bent and sped up by magnetic fields. There are mainly 2 types of particle accelerators, a linear and a circular accelerator. Circular are superior to linear as the same particle can be spun many times hence reaching the same speed using a smaller space. A solenoid bends the particle based on their speed. To be sped up, they are attracted again using a magnet and move to the opposite charged side which repels it and kicks the particle away, accelerating it.







What is Synchrotron Radiation ?

Synchrotron radiation is the electromagnetic radiation emitted by a fast moving charged particle when it is accelerated perpendicular to its velocity. The general formula for this is the mass of the particle to the power -4.

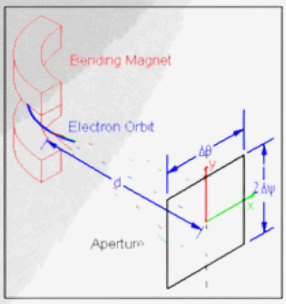
$$P(\lambda,\gamma,\psi_0,\Delta\lambda,I_B,\Delta\psi,\Delta\theta) = \int_{-\psi_0-\Delta\psi}^{+\psi_0+\Delta\psi} \frac{2}{3}\frac{e_0\Delta\lambda\Delta\theta I_B\rho^2}{\varepsilon_0\beta\lambda^4\gamma^4}\left[1+(\gamma\psi)^2\right]^2 \times \left[K_{2/3}[\xi(\lambda,\psi)]^2 + \frac{(\gamma\psi)^2}{1+(\gamma\psi)^2}K_{1/3}[\xi(\lambda,\psi)]^2\right]$$

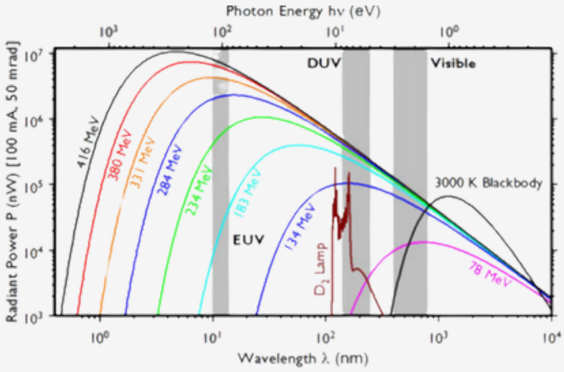
$$P_\sigma(\lambda,\gamma,\psi,\rho,\Delta\lambda,I_B,\Delta\theta) = \frac{2}{3}\frac{e_0\Delta\lambda\Delta\theta I_B\rho^2}{\varepsilon_0\beta\lambda^4\gamma^4}\left[1+(\gamma\psi)^2\right]^2 K_{2/3}[\xi(\lambda,\psi)]^2$$

$$P_\pi(\lambda,\gamma,\psi,\rho,\Delta\lambda,I_B,\Delta\theta) = \frac{2}{3}\frac{e_0\Delta\lambda\Delta\theta I_B\rho^2}{\varepsilon_0\beta\lambda^4\gamma^4}\left[1+(\gamma\psi)^2\right](\gamma\psi)^2 K_{1/3}[\xi(\lambda,\gamma)]^2$$

Why does it happen ?

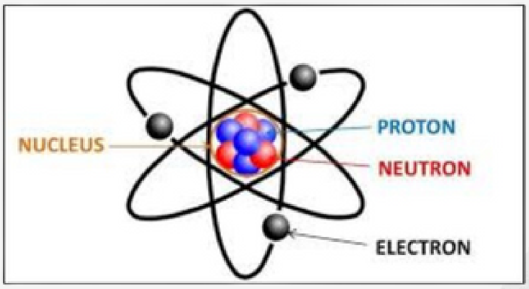
As the particle is moving in a circular motion, there is a constant electric field around the particle. Similar to in a dc motor as the particle is bent in said field, electromagnetic radiation is emitted. The amount of radiation given out is further emphasized by the speed of the particle.

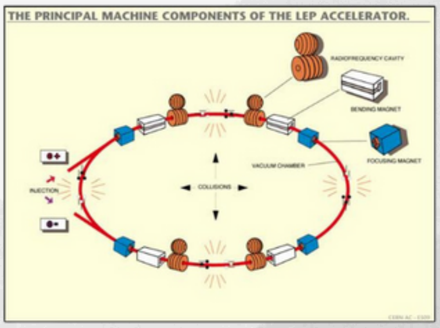




What's the problem and examples ?

Synchrotron radiation is the limiting factor in some particle accelerators. This is because as the particles are sped up, sometimes the radiation emitted by the particle is equal to the energy supplied to accelerate it per turn. A heavier particle can be used so that the particle can be accelerated to a higher speed before synchrotron radiation becomes the limiting factor. The LEP (Large electron positron collider) accelerated particles 11200 times around the 27 km tunnel every second. Here there were 8 points of acceleration. At the LHC (Large hadron collider) protons could be accelerated 11245 times around the same 27 km tunnel every second. However in this case, there is only 1 point of acceleration hence using less energy overall.





Particle	Relative Mass	Relative Charge	Charge / C	Mass / kg
Protons	1	+ 1	$+ 1.6 \times 10^{-19}$	1.67×10^{-27}
Neutrons	1	neutral	0	1.67×10^{-27}
Electrons	0.0005	- 1	$- 1.6 \times 10^{-19}$	9.11×10^{-31}

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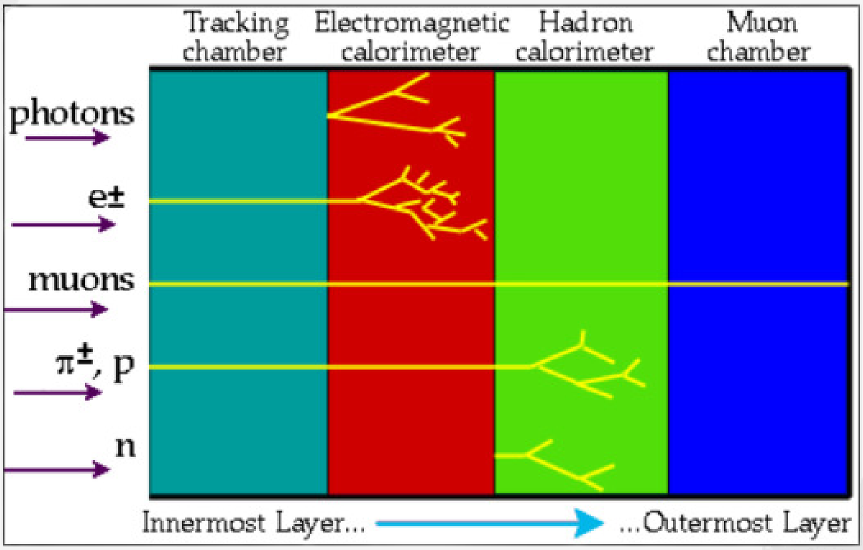
Tracking the Invisible: Developing an Algorithm for Tracking Nanoparticle Movement

Samrud Reddy

Tracking fast-moving nanoparticles is essential in particle accelerators to detect the paths and energies of known particles and thus solve for and find new particles and their behaviour. This paper outlines a descriptive algorithm for developing a computer program to track such particles' positions and types within a particle accelerator.

Inputs for the Algorithm

All algorithms need to have inputs and in the case of tracking nanoparticles, the input comes in the form of sensors in the particle accelerator. The 3 main sensors in particle accelerators are the silicone tracking chamber, the electromagnetic calorimeter, and the hadron calorimeter.



The first chamber is the silicone tracking chamber, this chamber detects the presence of charged particles. When a charged particle travels through the silicon an electron is knocked out of its shell, this can be detected. Since the silicone tracking chamber is very simple and small they can be placed very densely and in many layers. This gives us a very high-resolution path of charged particles.

Next is the electromagnetic calorimeter, which detects the energies of electrons, positrons, and photons. It achieves this by having a high-density material that causes the photons to turn into electrons and positrons and vice versa. Converting energy into matter to form a shower of collisions which are detected in the end by a scintillating layer.

Hadron calorimeters work very similarly to electromagnetic calorimeters but in the case of hadrons, they form longer showers and use different materials that are better suited to stopping hadrons. Also, hadron showers consist of pions, kaons, neutrons, and protons.

Putting the data together

Using the signals from the tracking chamber we can trace a particle movement in high definition and thus see its curvature. Its curvature tells us whether the particle is positively or negatively charged.

In the electromagnetic calorimeter by measuring how many particles the shower created we can calculate the initial energy of the particle and in the tracking chamber if we see a particle we know its charge and thus whether it's a positron or an electron. If there was no track we know it was a photon.

In the hadron calorimeter, we can use similar calculations and deduction to figure out the charge and energy of the hadron. Another metric used to help differentiate between hadrons is the time of flight, we can measure how long a hadron takes to travel from the tracking chamber to the hadron calorimeter and thus figure out its speed.

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The Expansion of the Universe

Sarang Krishna

One of the first cosmological mysteries I ever heard about was the expansion of the universe. An omnipresent war between the gravity in the universe against this mysterious and inexplicable resistance we like to call dark energy.

Currently what I understand is that dark energy is winning, causing the accelerated expansion of the universe. For me to understand this question, I needed to review the basic fundamental rules of the universe.

It started with the big bang, the massive explosion that propelled all the matter, anti-matter and energy into the universe which led me to the question of what did it get propelled into? Did the big bang stretch from a point causing space to be stretched out like a ballon getting filled up.

Since we don't know what was there before the big bang, I considered this explanation when I came to another situation where the analogy had to evolve. It comes because the universe is expanding at an accelerated rate.

If you are blowing a ballon with roughly the same amount of air getting pumped in per time, the bigger you blow the ballon, the more time it would take to expand each time.

This is because the volume increase would demand more air (energy in our analogy) for the ballon to be expanding at the same rate, much less at an accelerating rate,without taking into account that this balloon might be elastic which means there is more and more resistance the more you stretch it out.

Unless the air that you are pumping into has properties of its own. This is where I stopped relating it to that analogy.

The energy required for the amount of space to expand increases exponentially, perhaps because of the space itself.

The word vacuum was explained to me as the absence of anything, but I found that out to be false at my time in CERN.

Vacuum or space has temperature, radiation, particles like neutrinos even perhaps a WIMP particle as what we call dark matter. Beyond all of this, a physical factor of space can be this dark energy.

A vacuum energy. The more space created, the more dark energy exists along with it. This is turn would create a constant value that makes up for 68% of the universe.

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Cosmological Mystery on Inflation of the Universe

Yashvardhan Sanghi

Inflationary Theory Overview:
The inflationary theory suggests that the universe went through a short burst of exponential growth right after the Big Bang. This stage marked by a high-energy state called the "false vacuum," explains several features we see in the universe, like its homogeneity, isotropy, and flat geometry.

Hypothetical Mechanism: Holographic Duality in Inflation
One complex idea to shed light on the inflationary stage involves holographic duality, a principle that suggests we can describe all the information in the universe on a lower-dimensional boundary surface. This idea, which is inspired from string theory and the AdS/CFT correspondence, puts forward that our 3D universe might be a projection from a space with fewer dimensions.

Mechanism Details:
1. Holographic Inflation Framework: This model sees the early universe's quick growth as the change of a 2D boundary that holds all the needed information. As this boundary gains more information, it creates a 3D universe that expands exponentially. This approach gives a new look at the usual inflation idea hinting that the growth happens because of changes in how much information the boundary holds.

2. False Vacuum and Negative Pressure: The false vacuum state has a high energy density with a negative pressure component. This drives the inflationary expansion. In holographic duality, we might see this negative pressure as a boundary condition effect. It makes the boundary expand inflating the universe. This idea is like inflating a holographic image from a 2D surface into a 3D projection.

Theoretical Implications and Evidence: The holographic view of inflation might help us understand tricky issues in cosmology. These include what started inflation and how the phase ended. This idea is new and based on ideas from string theory and black hole physics. However, it could help unite gravity and quantum theories. It also fits with the growing interest in the universe's information-based properties.

Challenges and Further Research: The holographic model of inflation is still a guess and faces certain challenges. It's hard to find proof and make clear predictions that can be tested. Scientists are working to build a stronger math base for this theory. They also want to spot signs that could set holographic inflation apart from regular models. This study of inflation using holographic ideas shows how rich and complex our universe's early stages were.

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Experimental determination of Planck's constant

Sohan Chakravarthy Talla

INTRODUCTION

Planck's constant, denoted by "h", is one of the fundamental quantities of the universe, with many applications in quantum physics. It is used to describe the relation between the energy of a photon and its frequency, through the equation:

$$E = hf$$

where E is energy and f is frequency. It is through this equation that we can experimentally determine the v alue of Planck's constant.

Max Planck, a German physicist, discovered this constant as a part of his work with black-body radiation (the light emitted by a body due to its thermal energy), where he discovered that energy was emitted in packets of fixed size, suggesting the idea of photons. It finds use in many parts of modern physics.

Max Planck suggested the use of a system of units now known as the "Planck units", which include Planck's constant, made up of a set of universal constants that would allow us to standardise our units further. For example, Planck's constant was used in the 2019 redefinition of the kilogram. Earlier, the kilogram was defined based on the International Prototype of the Kilogram, a mass made of platinum and iridium.

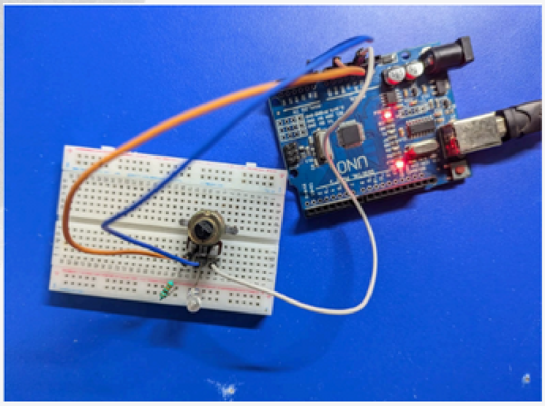
This led to difficulty in checking the calibration of instruments as very few had access to the IPK and hence most had to calibrate using copies and copies of copies, which led to compounding error, and also led to variations in the exact definition of the kilogram as the IPK's mass varied over its lifespan by a few dozen micrograms (the variations in the IPK are not known, only the variation in its copies, as the others were measured relative to the IPK). Using the modern redefinition, the kilogram now has a standard value that does not depend on any physical object, making it easier to calibrate instruments precisely and eliminating variation.

MATERIALS

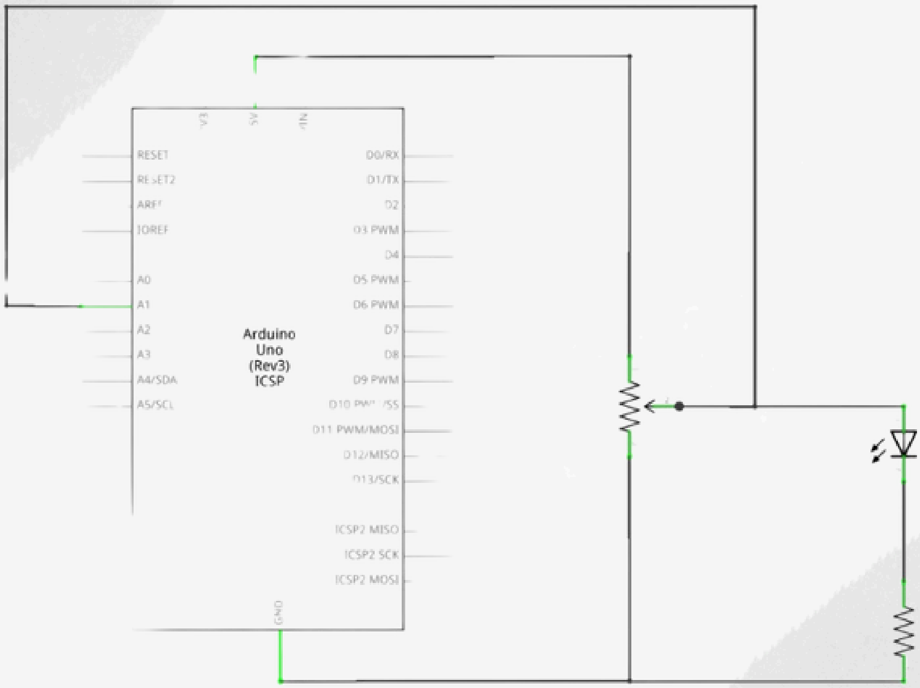
1. Monochromatic LEDs of various colours
2. Potentiometer
3. 300-500 Ω resistor
4. Arduino Uno
5. Jumper Wires

SETUP

In this setup, the Arduino Uno is used as both a voltage source and voltmeter. Voltage can be measured through its analog pins, and it is easier to take these readings compared to a multimeter or analog voltmeter. The potentiometer is connected to both 5V and ground, with the middle leg onnected to the positive leg of the LED. The negative leg of the LED is connected to ground through a resistor, which serves to limit current to prevent the LED burning out.



A circuit diagram can be seen below:

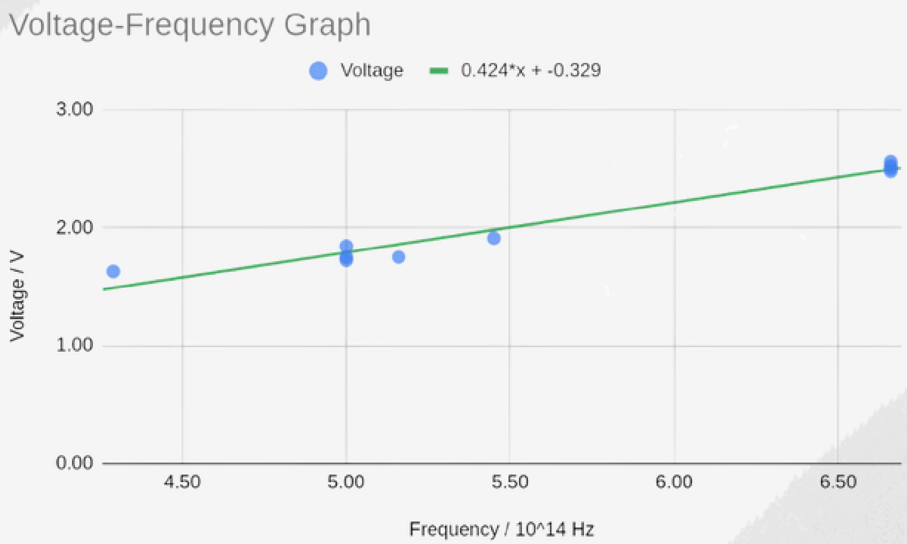


PROCEDURE

1. An LED is inserted into the breadboard as described in the circuit diagram above
2. The potentiometer is slowly turned clockwise until the LED just turns on, as at this voltage the energy used by the LED follows the formula
3. The voltage being outputted from the Arduino is recorded
4. The potentiometer is turned fully anti-clockwise to switch off the LED and the reading is repeated 2 more times
5. The LED is removed and the procedure repeated for different LEDs

DATA

Colour	Frequency / 10^14 Hz	Voltage needed to switch on / V			
		Reading 1	Reading 2	Reading 3	Average
Yellow	5.16	1.72	1.79	1.74	1.75
Blue 1	6.66	2.49	2.44	2.50	2.48
Red	4.29	1.63	1.64	1.62	1.63
Blue 2	6.66	2.52	2.50	2.49	2.50
Orange 1	5.00	1.87	1.84	1.82	1.84
Blue 3	6.66	2.53	2.50	2.54	2.52
Orange 2	5.00	1.74	1.79	1.72	1.75
Blue 4	6.66	2.56	2.54	2.58	2.56
Orange 3	5.00	1.72	1.75	1.7	1.72
Green	5.45	1.9	1.94	1.89	1.91



We look up the frequency for each LED from its colour using the Encyclopaedia Britannica. Using the equation E = hf, as we know that potential difference is energy per unit charge, we can multiply it with the elementary charge of an electron, e (1.6*10 -19 C), to get energy as follows:
eV = hf

Then, we can rearrange for h, giving us the following equation:

$$h = \frac{eV}{f}$$

V/f is the slope of the above voltage-frequency graph, which is multiplied with e to get our value of h.

$$h = 1.6 * 10^{-19} C * \frac{0.424}{10^{14}} Vs = 6.78 * 10^{-34} Js$$

CONCLUSION

Using this method, I was able to experimentally determine the value of Planck's constant as being 6.78*10 -34 Js, the actual value being 6.63*10 -34 Js, giving an error of 2.3%. Possible sources of error include:

- Measuring the point when the LED switches on by eye. A more precise method to do this would be to plot the LED's I-V characteristic (the amount of current flowing through the LED at a given voltage) and finding its knee voltage - the minimum voltage at which the LED begins conducting heavily in the forward direction
- Using standard values for the frequencies of the LEDs rather than measuring the actual values of their frequencies, for example by using a spectrometer or diffraction grating

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Exploring Redshift: Calculating the Motion of Stars

Tavasya Rao

INTRODUCTION

The mysteries of the cosmos have fascinated humans for centuries. Since the dawn of humanity, thinkers and scientists, as well as average people, have questioned the wonders of the universe and attempted to explain them. In this essay, I will endeavor to satisfy one of these curiosities. How does one calculate the motion of stars? More specifically, the speed at which they travel, and whether they travel towards the Earth or away from it. This essay will cover how scientists use their knowledge of the Doppler effect and spectra lines to calculate redshift values and determine the motion of a star.

WHAT IS THE DOPPLER EFFECT?

A piece of scientific knowledge crucial to understanding the motion of stars is the Doppler effect. The Doppler effect is the change in observed frequency of a wave due to the relative motion of the source of the wave and the observer. This can be easily understood with the example of the siren of a police car. If a car is moving towards you, the wavefronts of the sound created by the siren appear to "bunch up," and you perceive a higher frequency of sound, which your ears interpret as a higher pitch. When the car moves away from you, the wavefronts "spread out," and you perceive a lower frequency as a lower pitch.

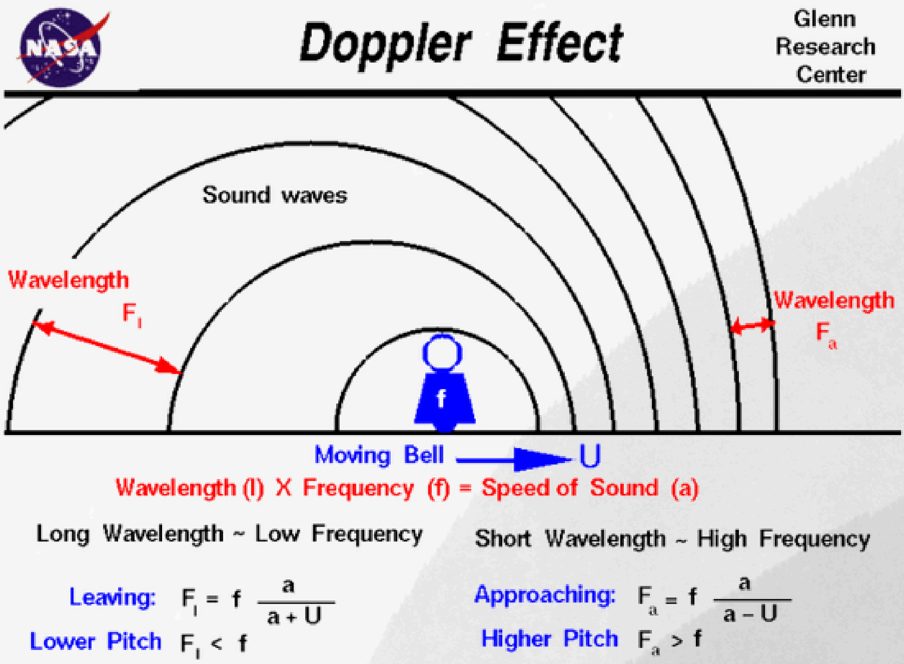


Fig 1. A diagram from NASA illustrating the Doppler effect, as well as the formulae used to determine the observed frequency of the waves from a moving source.

The Doppler effect similarly applies to light, which is a wave, like sound. While the frequency of sound determines its pitch, the frequency of light determines the colour we perceive. Each colour has a unique frequency, and in turn wavelength. Redshift occurs when the wavefronts of light end up "spacing out" as the star moves away from us, meaning we perceive a colour with a longer wavelength and lower frequency. Therefore, due to the Doppler effect, light emitted by a star is "shifted" towards the red end of the spectrum.

SPECTRAL LINES AND STARS

But how do scientists determine the extent to which light has undergone redshift? They make use of discrete spectral lines, which are lines in an otherwise continuous electromagnetic spectrum where more energy is either absorbed or emitted. These exist due to the electrons “jumping” from one shell to another. The energy the electron needs to jump to a more distant shell corresponds to the wavelength of light it absorbs. The energy an electron emits when it jumps back down closer to the nucleus corresponds to the energy it needed to jump up—therefore, the emission lines are the inverse of an element’s absorption lines.

Spectral lines can be classified by element, as each element has its own unique spectrum, much like a fingerprint. For example, a set of spectral lines emitted by hydrogen are called the Balmer series. They refer to the jumps made when an electron moves between the shell n=2 and n≥3. The Balmer series is commonly used to calculate the redshift of a star, as hydrogen is a common element in stars.

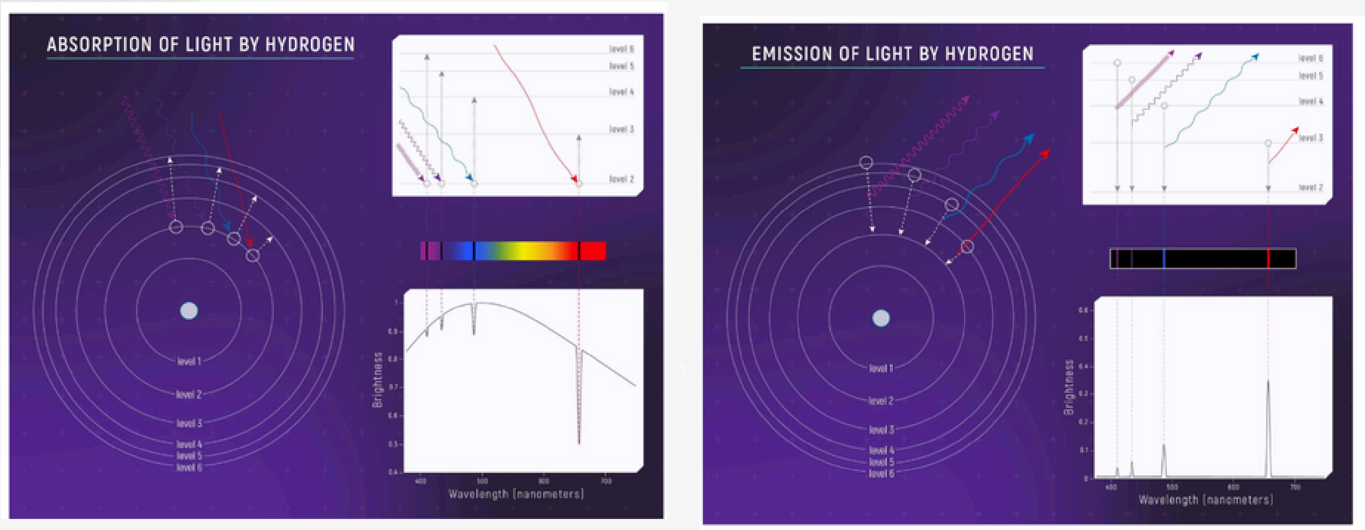


Fig 2. Diagrams from Webb Space Telescope illustrating the absorption and emission spectrums of a hydrogen atom, and how each “jump” corresponds to a certain wavelength. This particular set of “jumps” is the Balmer series.

name	wavelength (Angstroms)
H_α	6563
H_β	4861
H_γ	4341
H_δ	4102

Table 1. The table lists the rest wavelengths of the Balmer series,

Spectral lines can provide a variety of information about stars, from their composition to their temperature. However, they can also be used to determine the direction and speed of a star.

WHAT CAN WE CALCULATE?

By comparing the spectral lines of the stars with the spectral lines of the same series in a lab setting, scientists can calculate the redshift of a star. The spectral lines of the star are determined using spectrographs, which split light from an astronomical object into individual wavelengths so that its spectrum can be analysed.

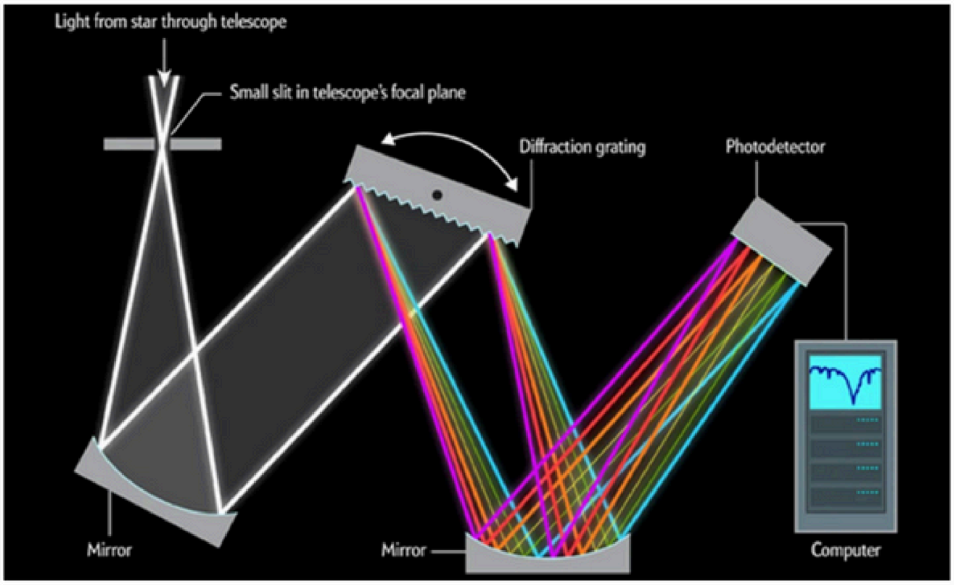
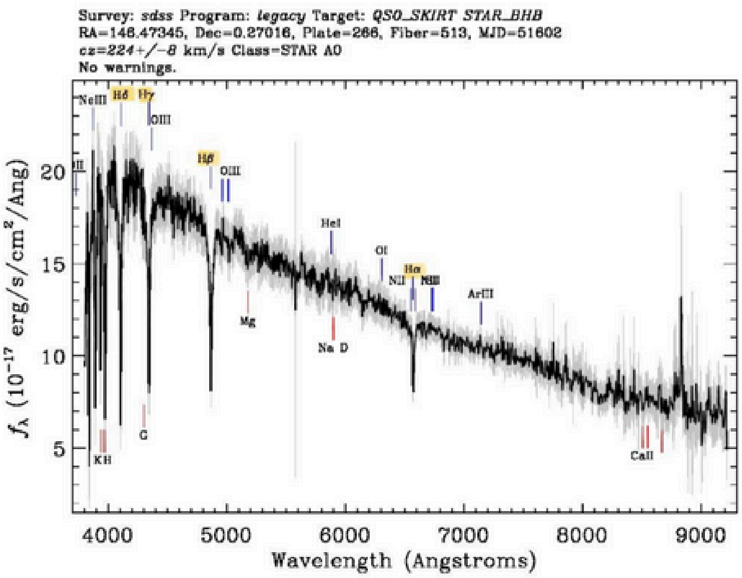


Fig 3. This diagram illustrates the working of a spectrograph, which splits light into its component wavelengths and

Once the star's spectrum is recorded, the wavelengths are graphed against the flux density. From the graph, the absorption lines are identified by finding the valleys, and the emission lines are the peaks. The Balmer series can be easily identified by finding the peaks and valleys whose wavelengths are the same intervals apart as the rest Balmer series. The rest wavelengths are the wavelengths of the Balmer series as measured in a lab. Through this comparison, we can identify the shift in the wavelength of the spectral lines.



Graph 1. Pictured above is the graph of flux density against wavelength for a star. The peaks are wavelengths with a higher flux density (emissions lines) and the dips or valleys are wavelengths with a lower flux density (absorption lines.)

To calculate the velocity of a star, one must first understand where the formula for the velocity of a star comes from.

λ_o - observed wavelength (m)
λ_r - rest wavelength (m)
v_w - wave velocity (ms^{-1})
v_s - source velocity (ms^{-1})
t - time (s)
z - redshift
c - speed of light (ms^{-1})

$$\lambda_o = v_s t + v_w t$$
$$\lambda_r = v_w t$$

$$\lambda_o/\lambda_r = (v_s t + v_w t)/v_w t$$
$$\lambda_o/\lambda_r = t(v_s + v_w)/v_w t$$
$$\lambda_o/\lambda_r = (v_s + v_w)/v_w$$

$$\lambda_o/\lambda_r = (v_s + v_w)/v_w$$
$$\lambda_o/\lambda_r = v_s/v_w + 1$$
$$\lambda_o/\lambda_r - 1 = v_s/v_w$$
$$v_w(\lambda_o/\lambda_r - 1) = v_s$$

The wave is light, therefore $v_w = c$.

$v_s = c(\lambda_o/\lambda_r - 1)$

If we let $z = \lambda_o/\lambda_r - 1$

$v_s = cz$

Hence, the velocity of a star is the speed of light times the redshift value.

The formula for redshift exists as it simplifies the formula for the velocity of a star to the simple multiplication of a dimensionless quantity and the speed of light.

The redshift value remains the same regardless of the spectral line chosen, as long as it corresponds to the correct rest wavelength. For redshift values which are small compared to 1.0, the speed of the star can be calculated by multiplying the redshift value with the speed of light.

$$z>0$$
$$\lambda_o/\lambda_r - 1>0$$
$$\lambda_o/\lambda_r >1$$
$$\lambda_o >\lambda_r$$

As the observed wavelength is greater than the rest wavelength, we can tell the light has undergone a positive redshift, and the star is moving away from us.

$$z<0$$
$$\lambda_o/\lambda_r - 1<0$$
$$\lambda_o/\lambda_r <1$$
$$\lambda_o <\lambda_r$$

As the observed wavelength is less than the rest wavelength, we can tell the light has undergone a negative redshift (blueshift,) and the star is moving towards us.

With all the information necessary, we can now calculate the velocity of a star with reference to graph 1 and table 1.

On the graph, Hα is a valley, and therefore is an absorption line. The wavelength is approximately 6568Å. The rest wavelength for Hα is 6563Å.

$$\lambda_o \approx 6568Å$$
$$\lambda_r \approx 6563Å$$
$$z = \lambda_o / \lambda_r - 1$$
$$z \approx 6568Å/6563Å - 1 \approx 0.0007618$$

$$v_s = cz \approx 3 \times 10^8 ms^{-1} \times 0.0007618 \approx 2.285 \times 10^5 ms^{-1}$$

CONCLUSION

Using our knowledge of the Doppler shift and spectral lines, we can calculate the star's redshift. The speed is also simple to calculate if the redshift is small compared to 1.0. As for larger redshift values, special relativity would need to be taken into account as the star moves at a speed nearer to the speed of light. Special relativity is a branch of physics that deals with motion at very high speeds and the effects on mass, space and time.

However, interpreting a star's redshift solely through the lens of the Doppler effect may be misleading. Stars experience both dynamic redshift and redshift due to cosmological expansion.

Dynamic redshift is due to the motion of the star itself. However, cosmological redshift occurs when the original wavelength is lengthened due to the expansion of space as light travels through it. Therefore, one might begin to wonder how to distinguish between these causes of redshift: the motion of the star itself, and the expansion of space itself. The distance of the star from us is a factor—the further the star, the more the cosmological redshift prevails over the dynamic one. One thing I would like to explore is the different causes of redshift. As humanity continues to explore the depths of space, and our calculations start to grow more accurate, I have faith we shall continue to learn more about the distant stars that caught the admiration of our civilisations so long ago.

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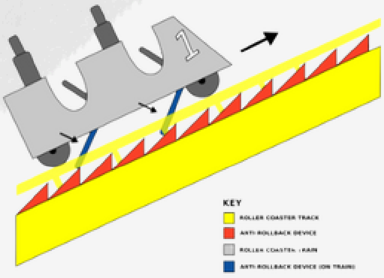
The Physics of Roller Coasters

Vedanth Sairam, Shishir Saripalli

Abstract

The roller coaster is one of the most famous theme park rides in the world that almost every kid has experienced. They thrill the rider with loops and turns and steep drops and bring sheer euphoria. There are lots of physics concepts at work behind the roller coaster like the conversion of energy,conservation of energy, and braking mechanisms that will be explored in this paper. [Srivatsan and Singh 2023 Reviewing the Physics of Roller Coasters]

Roller coasters rely on the simple physical concept of potential energy and kinetic energy. They don’t have an engine - instead, they use a chain lift/launch system [How a Chain Lift On A Roller Coaster Works!] that pulls the roller coaster to the top of a hill using a large bicycle-like chain that loops around the whole system.This initial hill has to be large enough to generate enough gravitational potential energy to propel the coaster for the rest of the journey [aided by the conservation of energy]. The rest of the ride is propelled by the kinetic energy produced by the drop, and the momentum that the roller coaster gains helps it to stay in motion. m



Chain lift mechanism in roller coasters

Mechanical Energy Conversion

Roller coasters make use of the conversion of mechanical energy[Kinetic energy and Gravitational Potential energy] to maintain motion and achieve the dynamic thrill they give without the use of an engine. Mechanical energy is subject to resistive forces like friction and air resistance, that lower its value throughout the ride.

Potential Energy[PE]

Potential energy is given by the formula PE = *mgh,* where m is the mass of the roller coaster, *g* is the acceleration due to gravity, and *h* is the height of the roller coaster. PE is directly proportional to height, and thus as a roller coaster climbs a hill it gains potential energy. The maximum potential energy occurs at the highest point of the roller coaster, usually towards the beginning of the ride to ensure the maximum mechanical energy in the system. The chain lift/ launch mechanism helps the roller coaster achieve this maximum potential energy.

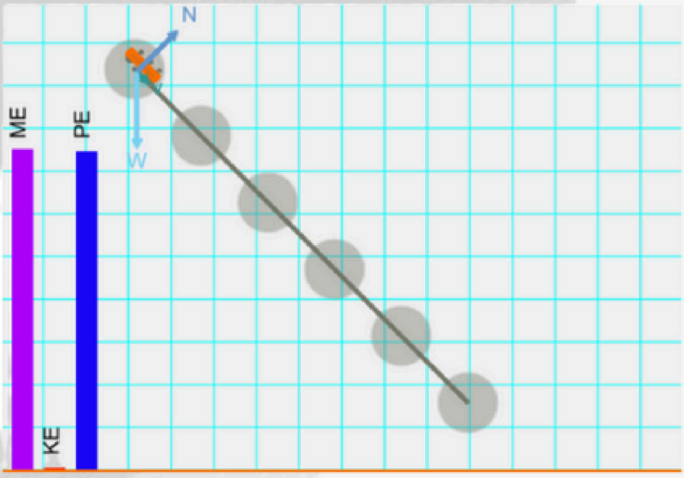


Diagram showing Mechanical energy in roller coaster at top of hill

Kinetic Energy [KE]

Kinetic energy is given by the formula KE = ½mv^2 where m is the mass of the roller coaster and *v* is the speed of the roller coaster. KE is directly proportional to the square of velocity, thus the roller coaster faces the highest KE when it is in the lowest points. At these points, all the Gravitational PE is used up to accelerate the coaster, resulting in the largest magnitude of KE. The steepness of the drops directly affect the force of gravity, and increase the KE at the bottom.

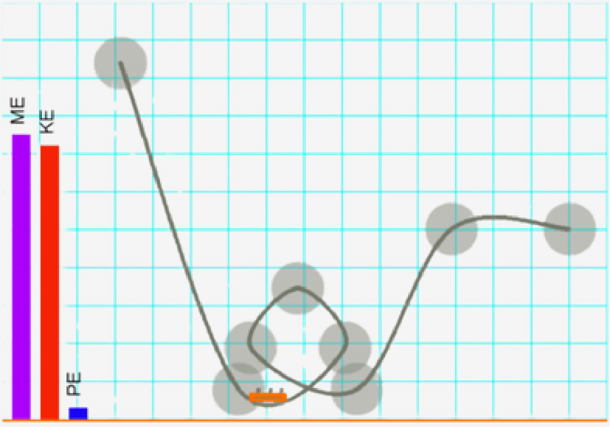


Diagram showing Mechanical energy in roller coaster at bottom of hill

Energy conversion process

Physics Simulation: Roller Coaster Model

This simulation effectively demonstrates the conversion of mechanical energy in a roller coaster. In a drop, the PE can be seen decreasing as the KE increases, due to the decrease in height as the roller coaster descends. The PE is highest at the top of the hill, while the KE is highest at the lowest point of the ride. Similarly, as the coaster ascends using the available KE, it decreases, while GPE increases as height increases. The total mechanical energy of the system is kept constant throughout the ride as can be seen, highlighting the conservation of energy. [Mechanical Energy Conservation KEi + PEi + Wnc = KEf + PEf]

The KE and PE levels move inversely - as one peaks, the other is at 0. However, when drag/friction is added, the total mechanical energy reduces throughout the ride as a result of the conversion of some of the energy into heat that dissipates into the environment, due to friction from the tracks, braking, and the extreme heat caused by the tracks as the coaster descends. [Kaushick 2020 (PDF) Impact of friction on the energy conservation of a roller-coaster]

The conservation of mechanical energy[in an ideal frictionless system] can be summed in the formula:
E total = PE + KE = constant

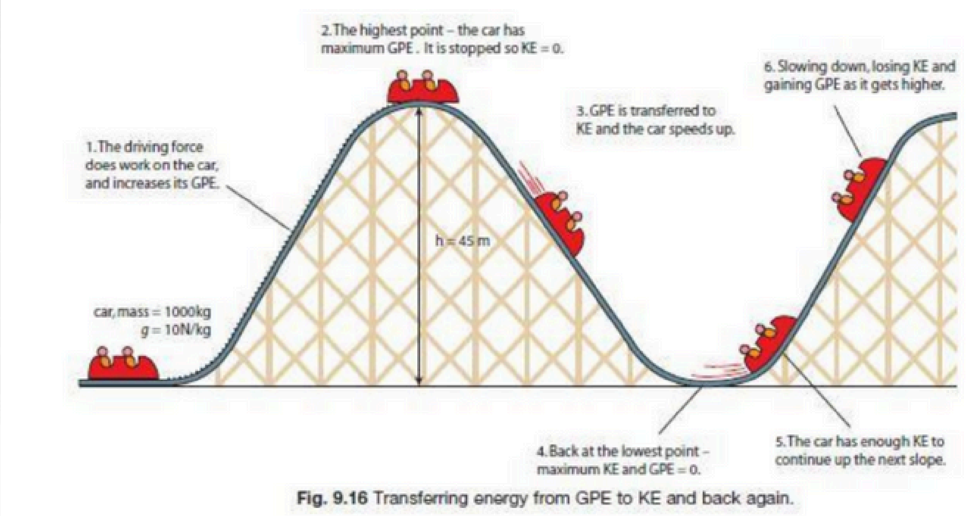


Fig. 9.16 Transferring energy from GPE to KE and back again.

Diagram explaining the conversion of mechanical energy in a roller coaster ride

Safe Braking Mechanisms

Safety brakes serve as crucial parts of roller coasters; they provide safety for the passengers and control the speed by allowing for a gradual reduction of the rollercoaster's velocity whenever the roller coaster must stop abruptly or a similar requirement is encountered in a section of the track. Braking mechanisms are designed in such a way that there are no discomforts or speed disruptions due to forces and speeds related to sensible decelerations. They constitute one crucial part of the safety system for a ride, ensuring that passengers feel safe and comfortable all the time. [Stopping a Roller Coaster Train.]

When a roller coaster brakes, mechanical energy is converted into heat energy. Friction brakes use high friction materials that restrict a roller coaster's wheel rotation. As the brakes press against the moving wheels, friction is created, which converts the roller coaster's kinetic energy into thermal energy. This heat is then absorbed by the braking mechanism and dissipates. [Dennis 2018 Wooden Coasters: braking systems part 2 | ParkVault]

Friction brakes in a roller coaster

Many modern roller coasters use magnetic braking, which does not require physical contact to slow down the roller coasters. Strong magnets [usually neodymium] help create an eddy current in the metal fins. This produces an opposing magnetic field that slows the coaster down. In this case, the kinetic energy of the moving train is converted to heat due to electromagnetic resistance from the magnets and metal fins. This heat is then dissipated. [Stopping a Roller Coaster Train.]

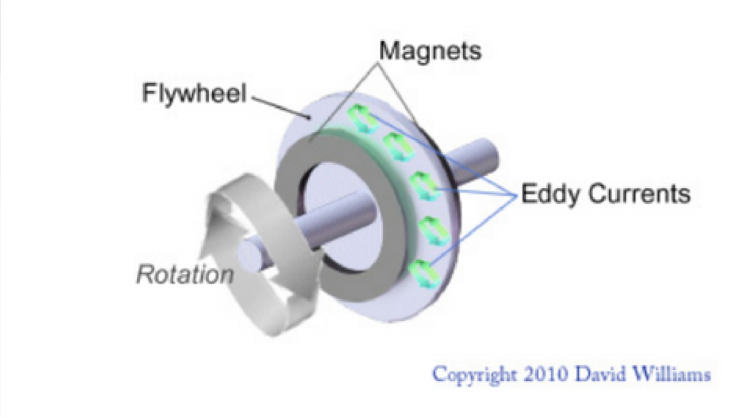


Diagram explaining the workings of magnetic braking

Comparison of Braking Mechanisms

Roller coasters depend greatly on their braking systems to ensure the safety of riders and provide a ride by using mechanisms, like friction brakes.

Friction brakes.

Friction brakes function by creating friction and generating resistance between brake pads and a metal track to slow down the trains motion effectively and cost effectively. They are an option for roller coasters that value reliability and affordability despite requiring maintenance, and part replacements due to natural wear and tear over time

Magnet brakes

Magnetic brakes use currents generated by magnets interacting with plates to slow down the roller coaster without any direct contact needed between them. These brakes minimize wear. Need maintenance compared to traditional friction brakes while ensuring a smoother deceleration. However they tend to be pricier to set up. May not be as efficient, for bringing the coaster to a stop as they necessitate additional braking mechanisms.

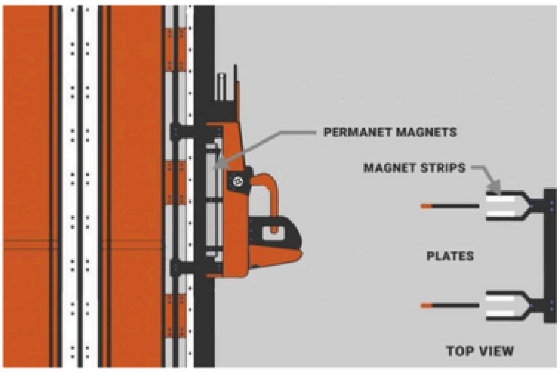


Diagram explaining the working of magnetic brakes.

Hydraulic brakes

Hydraulic brakes rely upon pressure to manage the braking force effectively and provide control along, with strong stopping power capabilities. Hydraulic brakes amplify pedal force with Pascal's principle. Pressing the pedal moves fluid through brake lines, causing pressure to be applied at each wheel to pistons. The pistons then push pads or shoes against a disc or drum, thereby creating friction. This friction converts kinetic energy into heat, which dissipates and thus slows the roller coasters. They are commonly utilized in high speed roller coasters; however these systems are intricate and vulnerable to leaks, necessitating more advanced maintenance procedures.

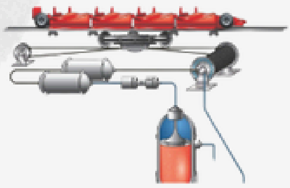
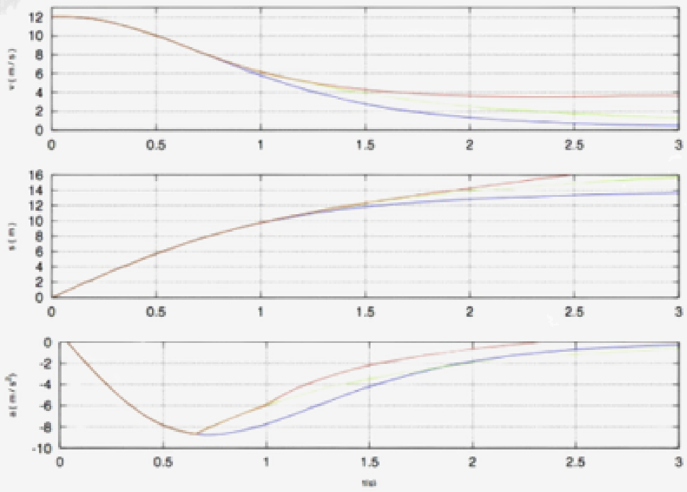


Diagram of the inside working of a hydraulic brake.



"Time dependence of speed, distance and acceleration after the roller coaster train enters the magnetic brake. The blue curves would hold if the train and brakes were sufficiently long for the train to come to a stop without reaching the end of the train or brakes. The green curve accounts for the finite length of the brakes and the red curve also takes into account the finite length of the train"

Conclusion

In conclusion, roller coasters are a great example of the work of physics and its related engineering that translates to conversion of energy and also to elements of safety for a thrill. They capture gravitational potential energy when they start ascending; then this is converted to kinetic energy that catapults the ride without an engine. The motion of the coaster in all cases, with either rising or falling potential energy, results in competition between kinetic energy, resistive forces such as friction and air resistance, that keep the mechanical energy conserved. Safe braking is highly relevant, as it encompasses friction, magnetic, and hydraulic braking systems to control speed and guide so that the riders get absolutely safe. Friction brakes are inexpensive and reliable; magnetic brakes ensure smooth deceleration with negligible wear on the moving parts while hydraulic brakes ensure effective stopping power with high rides. Together these three systems combine all the elements of excitement with their applied physics. Roller coasters are likely to continue developing in the series of evolution, with periods of rapid growth in innovation.

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Determining the Efficacy of Biodegradable Adsorbents in Improving Lake Water Quality

Dia Maheshwari, Pranoy Mathur, Neha Bhati, Vanya Nath, Kriti Murugan, Vivaan Chaudhri

I. Introduction

A.Background

Contaminated water is defined as that which contains a physical, chemical, biological, or radiologicalsubstance or matter.

As long as the contaminants are not harmful to health and are within limits prescribed by regulatory agencies, the water is safe for humans and aquatic ecosystems alike. The types of contaminants present in the water determine the impact they can have on ecological and human health.

Polluted lakes are increasingly posing severe environmental concerns, especially in highly populated cities such as Bangalore.There are various methods through which such lakes can be cleaned in ways that cause less harm to the surrounding environment, such as using biodegradable adsorbents. Adsorbents are insoluble materials with a liquid coating on their surface, such as capillaries and pores. When asubstance, like a sponge, can hold a certain amount of liquid in tiny chambers, it is said to be anadsorbent.For our experiment, we chose to test four adsorbing materials:

- Crushed Eggshells: wherein the eggshells are ground and mixed in the sample so that the calciumcarbonate present in them is available for an (increased rate of) reaction with the contaminants(due to the greater surface area provided by the crushed eggshells).
- Coconut Fibres: they are porous and have significant adsorption potential for the removal of various aquatic pollutants.
- Dry powdered orange peel: orange peels have been shown to aid in the removal of turbidity and the reduction of heavy elements in contaminated water.
- Granular activated carbon: this form of activated carbon is highly porous, providing a large surface area to absorb contaminants from water.

These methods were chosen because they are eco-friendly, which means that they do not harm the environment when carrying out the treatment. Additionally, their materials are readily accessible, safe, and simple to use in a school lab, making them more feasible than many other alternatives, such as biosand filter, phytoremediation and groundwater recharge.

For this experiment, we took our samples from Agara Lake, a lake in Bangalore located near a busy area of HSR layout. This lake dates back to the 8th century C.E. and has played a vital role in the surrounding ecosystem and community by supporting families, accommodating irrigation, and replenishing groundwater over the years.

In our experiment, we propose the usage of three criteria to assess the effectiveness of the treatment of polluted lake water:

1. pH: pH measures the acidity or alkalinity of a solution. The ideal pH for lake water in Bengaluru is 6.5 to 8.5, which provides favourable conditions for the local aquatic life.

2.Total Dissolved Solids (TDS): TDS measures the amount of solid matter dissolved in lake water, including organic and inorganic compounds. Thus, it can indicate the presence of harmful contaminants in lake water ,which can have significant implications for aquatic ecosystems.

Experiments on lake water, specifically Agara Lake in HSR layout, Bangalore, suggest that their average TDS lies between 50 and 250 ppm.

3. Electrical Conductivity (EC): EC measures water's ability to pass an electrical current. Distilledwater, lacking any minerals, cannot conduct electricity, so a higher EC suggests it contains more significant impurities. According to the USA's Environmental Protection Agency and othergovernment websites, such as those published by the Government of Canada, the most desirable EC for lakewater is 200µS.

B. Objectives

The experiment aims to identify the most effective biodegradable adsorbent in bringing the lake water quality within the prescribed limits mentioned above.

C. Hypothesis

We hypothesised that all the adsorbents would result in:
1. The pH level of the lake water moving closer to 7.
2. The Total Dissolved Solids in the lake water shifting towards the range of 50 to 250 ppm.
3. The Electrical Conductivity of the lake water reducing to the range of 150 to 500 µS

Additionally, we hypothesised that activated carbon would be the most effective adsorbing material since it provides a large surface area (due to its high pore volume), allowing for the increased adsorption of contaminants.Furthermore, activated carbon is less likely to decompose in water over time, which may be likely in the case of the other adsorbents used in the experiment. This may mean it may be more likely to bring the TDS and EC of the sample down.

II. Materials and Methods

A. Sample Preparation

The lake water samples were collected from 4 different corners of Agara Lake, Bengaluru, using four sterile plastic bottles to collect each 1L sample. Each was poured into one sterile plastic bottle, thoroughly shaken, and mixed to achieve a composite sample. The sample was collected in the evening, at 4 P.M.,and stored in a refrigerated environment to ensure that little to no degradation or change occurred in the sample before the experiment. Cooling preserved the sample by lowering the rate of reaction, which would slow down any metabolic or chemical reactions in microbes and bacteria present in the sample.A composite sample was taken to try and get a representative sample of the Agara lake water.
Below are pictures of the four sites of the collection:

Fig. 1: Sites of collection from Agara Lake.

The composite sample was divided into 25 containers, each containing 100mL of the sample. Five beakers were allocated for each biodegradable adsorbent, and five were allocated as controls. This was to identify anomalous results and increase the accuracy of the experiment. The diagram below depicts the setup for each of the 25 containers.

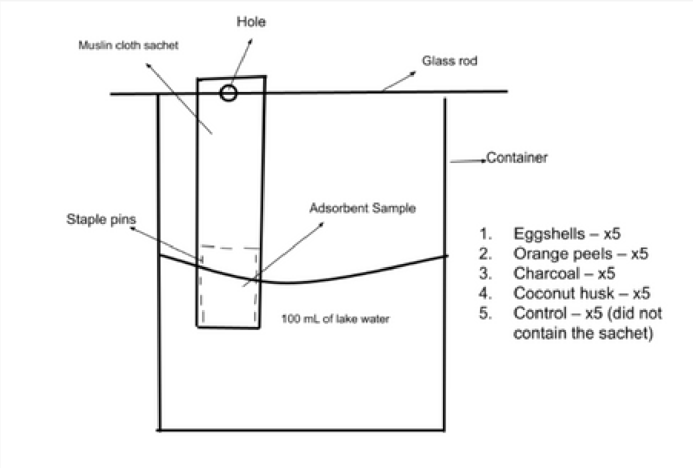


Fig. 2: Schematic diagram of the experimental set-up.

B. Equipment for Sample Collection & Testing

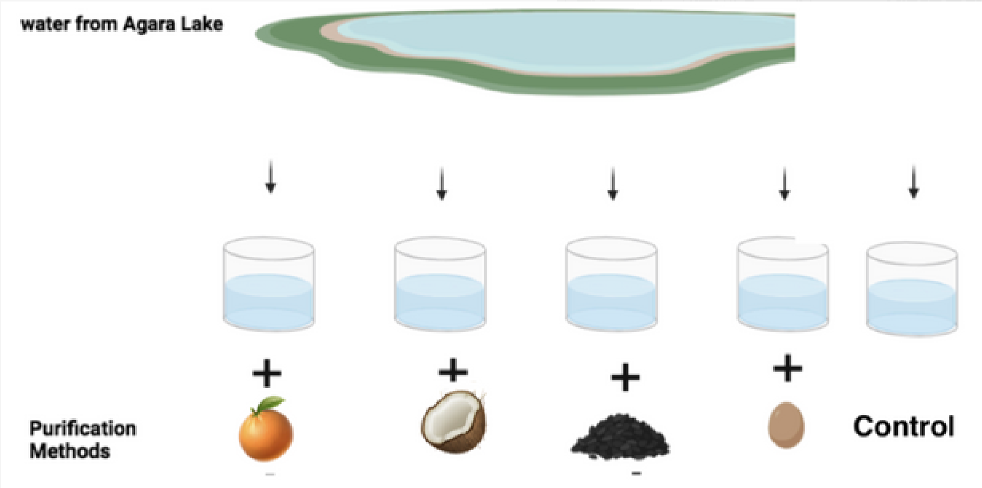


Fig. 3: Graphic portraying the 5 dif erent types of beakers used in this experiment.

The lab equipment required to test for:
1. Sample Collection & Preservation
   a. 4 plastic sampling bottles (having a total volume of 5L)
   b. Fridge/apparatus to maintain low temperature to ensure a slow rate of reaction of any existent bacterial or chemical reactions in the lake water

2. Experimental setup
   a. Identical tumblers/cups x25 (200 ml)
   b. Measuring cylinders x2: For measuring equal samples of water.
   c. Clamp and Stand x1: For holding the funnel and containers in place during the transfer of water.
   d. Funnel x5: For transferring of lake water into tumblers.
   e. Electric balance x1: To measure precise amounts of adsorbents.
   f. Biodegradable adsorbents
   i. Coconut fibres
   ii. Granulated activated carbon
   iii. Eggshells
   iv. Orange peels
   g. Muslin cloth: to create a sachet with a permeable membrane.
   h. Glass rod x20: To ensure even mixing of adsorbents in the water samples and to suspend 'tea bags'.
   i. Stapler x1: For stapling the muslin cloth to create a sachet.
   j. White tiles x10

3. Impurity Testing
1. pH Testing
- pH meter (to compare the pH of the sample in the duration of the experiment)
2. TDS Testing
- Total Dissolved Solids meter (for comparison)
3. EC Testing
- Electrical conductivity probe (for comparison)

C. Procedure for Testing

1. Experimental procedure
(1) Calibrate the pH meter using the pH 7 buffer solution.
(2) Measure using an electric balance and add the biodegradable adsorbents, namely coconut fibres (2.6g), granulated activated carbon (5g), eggshell powder (5g), dried orange peel powder (8g) into muslin bags and create a sachet-like device. Each sachet must be sealed well using staple pins.
(3) Suspend the sachet in the beaker using a glass rod.
(4) Repeat this 5 times for one biodegradable adsorbent.
(5) Divide the 4L composite lake water sample into 25 beakers, with 100 mL each measured using a graduated measuring cylinder (see Fig. 1)

Fig. 4: shows the experimental setup, including the lake water samples and apparatus.

(6) Measure each beaker's initial pH and TDS and note the values in a tabular format.
(7) Keep five beakers aside as the control and cover them with tiles until the next reading.
(8) Add one type of adsorbent sachet into each of the five beakers. Repeat this process for each type of adsorbent and cover each beaker with a white tile until the next reading
(9) Measure water quality parameters at the end of days 1, 2, 3.

2. pH Testing Procedure

(1) Measure the pH of the sample using a calibrated pH meter for each of the three days of testing.

3. TDS Testing Procedure

(1) Measure the TDS of the sample for each of the three days of testing using a calibrated TDS meter.

4. EC Testing Procedure

(1) Measure the EC of the sample using a calibrated EC metre for each of the three days of testing.

III. Results

Beaker Type	A	B	C	D	E
Adsorbent material	Dry Powdered orange peels	Coconut fibre	Crushed Eggshells	Granulated activated carbon	Control
Mass in each beaker/g	8	2.6	5	5	N/A

(2) Dry Powdered Orange Peels

Beaker	A1			A2			A3			A4			A5		
Time/hr	*TDS/ ppm*	*pH*	*EC/µS*	*TDS/ ppm*	*pH*	*EC/ µS*	*TDS/p pm*	*pH*	*EC/ µS*	*TDS/ ppm*	*pH*	*EC/ µS*	*TDS/ ppm*	*pH*	*EC/µS*
0	910	8.5	1200	974	8.9	1300	890	8.1	1150	960	8.3	1250	980	8.8	1100
24	1340	5.5	2370	927	5.5	1850	911	5.2	1930	894	5.0	1830	928	5.4	1870
48	1490	4.4	2850	1090	4.1	2170	1060	4.5	2080	1010	5.0	2140	1020	4.3	2030

(3) Shredded Coconut Fibre

Beaker	B1			B2			B3			B4			B5		
Time/hr	*TDS/ ppm*	*pH*	*EC/μS*	*TDS/ ppm*	*pH*	*EC/μS*	*TDS/ ppm*	*pH*	*EC/μS*	*TDS/ ppm*	*pH*	*EC/μS*	*TDS/ ppm*	*pH*	*EC/μS*
0	960	9.5	1000	890	9.3	1400	920	8.1	1250	1025	8.4	1300	890	8.2	1856
24	585	7.6	1160	625	7.5	1260	710	7.5	1420	1130	7.2	2180	669	7.6	1350
48	595	5.5	1200	636	5.2	1280	734	8.8	1490	1100	8.3	2260	709	8.5	1390

(4) Dry Crushed Eggshells

Beaker	C1			C2			C3			C4			C5		
Time/hr	*TDS/ ppm*	*pH*	*EC/μS*	*TDS/ ppm*	*pH*	*EC/μS*	*TDS/ ppm*	*pH*	*EC/ μS*	*TDS/ ppm*	*pH*	*EC/μS*	*TDS/ ppm*	*pH*	*EC/μS*
0	985	9.1	1350	950	8.5	1100	910	8.3	1050	974	9.4	1200	950	8.7	1300
24	613	8.1	1370	619	7.9	1360	645	7.9	1300	687	7.6	1370	716	7.4	1440
48	707	9.2	1480	715	8.8	1440	721	8.5	1470	731	8.4	1460	798	8.2	1610

(5) Granulated activated carbon

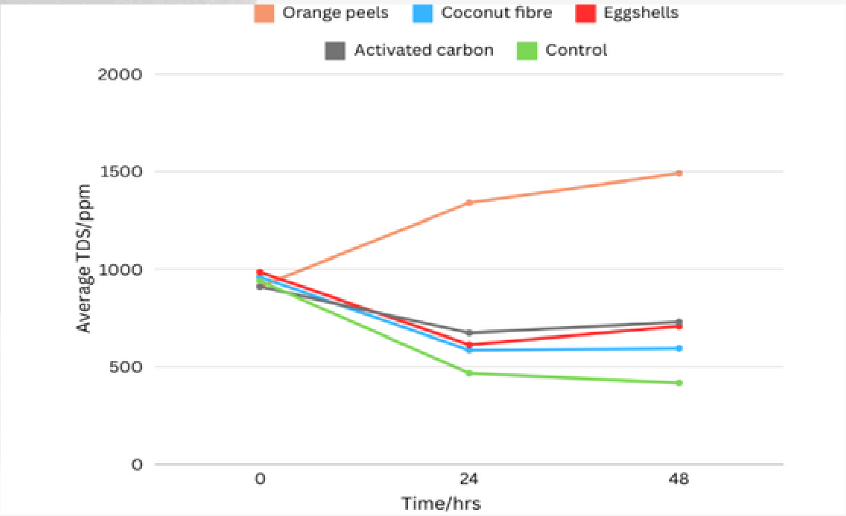
Beaker	D1			D2			D3			D4			D5		
Time/hr	*TDS/ ppm*	*pH*	*EC/ μS*	*TDS/ ppm*	*pH*	*EC/ μS*	*TDS/ ppm*	*pH*	*EC/ μS*	*TDS/ ppm*	*pH*	*EC/ μS*	*TDS/ppm*	*pH*	*EC/μS*
0	910	8.2	1403	930	8.9	1450	975	8.4	1000	887	8.0	1100	940	8.7	1250
24	673	7.5	1400	724	7.5	1460	773	7.3	1460	612	7.2	1370	784	7.3	1590
48	729	8.9	1430	745	8.8	1480	766	7.2	1560	713	7.2	1450	859	7.1	1770

(6) Control

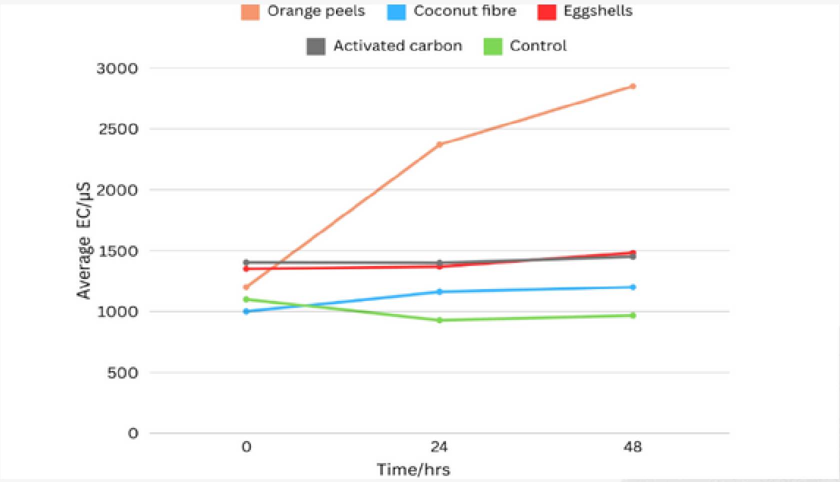
Beaker	E1			E2			E3			E4			E5		
Time/hr	*TDS/ ppm*	*pH*	*EC/ μS*	*TDS/ ppm*	*pH*	*EC/ μS*	*TDS/p pm*	*pH*	*EC/ μS*	*TDS/ ppm*	*pH*	*EC/ μS*	*TDS/ ppm*	*pH*	*EC/ μS*
0	940	9.2	1100	990	8.8	1300	880	8.1	1200	930	9.0	1000	950	8.3	950
24	466	8.2	929	454	8.3	937	456	8.3	936	455	8.3	934	455	8.3	938
48	418	9.4	967	467	9.3	954	464	8.5	938	462	8.5	930	468	83	952

6. Statistical Comparison

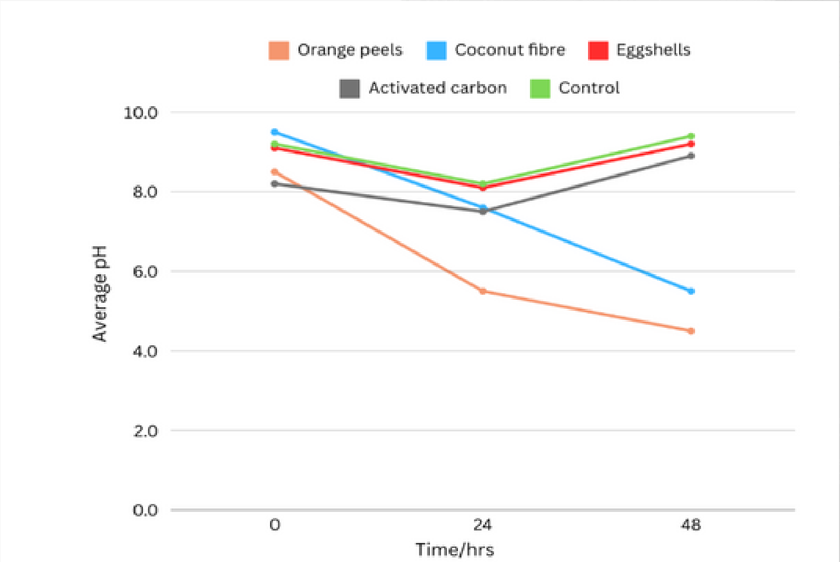
i) TDS:


Orange peels
Coconut fibre
Eggshells
Activated carbon
Control
2000
1500
1000
500
0
Average TDS/ppm
0
24
48
Time/hrs

ii) EC:


Orange peels
Coconut fibre
Eggshells
Activated carbon
Control
3000
2500
2000
1500
1000
500
0
Average EC/µS
0
24
48
Time/hrs

iii) pH:


Orange peels
Coconut fibre
Eggshells
Activated carbon
Control
10.0
8.0
6.0
4.0
2.0
0.0
Average pH
0
24
48
Time/hrs

7. Pictorial Evidence

IV. Observations and Discussion

1. Dry Powdered Orange Peels

Beaker(s) type A contained dry powdered orange peels. In beaker(s) type A, the TDS reached and average of approximately 900 ppm after 24 hours. The observations indicated a slight increase in TDS in two of the beakers, while three others showed very little decreases in TDS levels. Across all beakers, the pH lowered, producing a weakly acidic solution, which is likely due to the natural acidity of the oranges. However, the EC increased in all beakers, indicating the presence of dissolved ions, which suggests that the water quality decreased.

2. Shredded Coconut Fibre

Beaker(s) type B held coconut fibres. The TDS significantly decreased in nearly all beakers, reaching a range of 585-711 ppm, which displayed the promising efficacy of coconut fibres in removing dissolved solids from lake water. However, Beaker B4 was an outlier, showing anomalous results. The pH in all beakers moved from alkaline levels (8.1-9.5) to near-neutral (7.1-7.6) conditions, which also showed the effectiveness of this method. Notably, EC remained stable or increased in all beakers except for beaker B5, where Electrical Conductivity did not follow this upward trend, suggesting some efficiency in reducing conductivity.

3. Dry Crushed Eggshells

Beaker(s) type C contained dry, crushed eggshells. Across all beakers, TDS dropped significantly, reducing from an initial range of 910-985 ppm to 613-716 ppm, showing potential effectiveness of eggshells in reducing dissolved solids. The pH also decreased, moving towards acidic levels, while EC exhibited only minor variations, with all changes indicating a slight increase.

4. Granulated activated carbon

Beaker(s) type D contained granulated activated carbon, with reductions in TDS in all cases by about 200 ppm, closely matching our initial hypothesis that charcoal would be very successful at treating the water. The pH in these beakers also shifted towards neutral conditions, indicating efficient pH stabilisation. While EC showed minimal change, a slight increase was observed in a few cases, though granulated activated carbon's performance on TDS and pH remained notably consistent.

5. Control

The control beakers; type E, to which no treatment was added, had an initial TDS averaging 938 ppm at hour 0, which dropped to an average of 457.2 ppm after 24 hours. Despite this reduction, these values are well outside the optimal TDS range of 50-250 ppm, as mentioned in Section 1A. Initially, the average pH was 8.68, beyond the ideal range of 6.5 to 8.5. By 24 hours, the pH of the five beakers averaged 8.28, falling within the acceptable range. The initial average EC of the control beakers was 1110 µS, which lowered to 934.8 µS after 24 hours, still notably above the optimal 200 µS.

V. Conclusion

A.Result of Hypothesis

Our hypothesis predicted that granulated activated carbon would be the most effective biodegradable adsorbent in bringing TDS, pH, and EC ranges within the desired limits, but this hypothesis was invalidated by the evidence from the experiment. While most beakers showed favourable pH outcomes, which may have benefited aquatic ecosystems, the electrical conductivity and total dissolved solids increased relative to the control, indicating that the adsorbing materials were inefficient. Thus, our hypothesis was invalidated because activated carbon could reduce only pH, not all three metrics: pH, TDS, and EC. Despite disproving our hypothesis, we found that coconut husk was the most ideal adsorbent among the four materials. It achieved the most substantial TDS reduction, maintained a near-neutral pH, and had a generally favourable effect on EC. This combination of factors suggests that coconut husk has the best adsorption capabilities for improving overall water quality, as compared to the other adsorbents used in the experiment.

B. Interpretation of results

We noticed a general trend in all the results: the 24-hour results were the closest to the optimum conditions for aquatic life to survive. However, after 48 hours, the readings got worse, suggesting that leaving the adsorbents in for an increased time period is less advisable. Thus, in order to receive the best results, 24-hour usage of the adsorbents is recommended.

C. Author's Note

The experiment conducted by us was inaccurate due to multiple constraints including time, availability of apparatus and support, leading to us not being able to collect data for a wider range of more accurate measuring parameters that we would have otherwise wanted to, such as; dissolved oxygen, nitrate and phosphate concentrations, survival of Daphnia magna, water colour in True Colour Units and turbidity. The apparatus we lacked included a dissolved oxygen probe, nitrate and phosphate testing kits, colorimeters, samples of Daphnia magna, and a turbidity probe.

D.Recommendations

Suggestions for further research or improvements to experimental design:

(1) Test the samples within a shorter time frame after collection.

(2) Use equal masses of adsorbing materials, accounting for the porosity of each.

(3) Test the lake water for dissolved oxygen to measure the impact of the biodegradable adsorbents on the survival of organisms in the lake water. This could be further observed under a simple light microscope. An organism that could be monitored is the Daphnia magna, which are bioindicators for dissolved oxygen concentrations.

(4) Testing other water treatment methods to compare their efficacy in treating the lake water in comparison to the adsorbing materials.

(5) Repeat the experiment with different sets at different times to remove the possibility that data and readings in all the beakers might have been skewed simultaneously. This will make the results extremely accurate as we can get an actual average of the measurements.

(6) We could have considered other filtration and treatment methods that don't necessarily include the process of adsorption.

Such improvements can improve the quality of results and make the experiment more accurate.In conclusion, the treatment of lakewater is not only a problem that echoes through corners of the world but one that we see affecting us locally. Its cleanliness and purification are pivotal as it affects our city's ecosystem and biological gene pool. In addition, it is key to perform this purification sustainably, such as maintaining a balance between human activities and preserving our environment. The water we dispose of should be treated in a manner, if not recycled, such that the environment is not damaged in the process or aftermath. Thus, the proposed experiment considers one possible purification method, whose efficiency is measured by pH levels, TDS and electrical conductivity to help track the progress and practicality of water treatment by biodegradable adsorbents.

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VII. Acknowledgements

Our team would like to express our appreciation for the help and support provided by our teachers: Dr.Radha Gopalan, Dr. Dhanya K, Ms. Rupa Debnath, Ms. Augustina Queen Mary and Ms. Mary Raj.

Wewould also like to thank our school lab assistants, Shankar Sir and Nayak Sir for providing us with the resources we needed for our experiment.

Ooho balls

Shravya Sureka , Anahita Saurabh Agarwal, Neel Sanyal, Advay Chirayu Patel, Amvi Singh, Pranav Srinivasan

Imagine a future in which popping a bubble, rather than twisting a bottle cap, is how you quench your thirst! Presenting Ooho balls, the edible water balls that are revolutionizing hydration through a wave of environmentally responsible creativity. Pure, bite-sized refreshment that is both surprising and sustainable—no trash, no plastic..

This essay explores the effect of changing the ratio of reactants while making the ooho balls. Ooho balls' structural integrity, texture, and rate of hydration release are all greatly impacted by changing the ratio of sodium alginate to calcium lactate during production. This highlights how crucial exact ingredient ratios are to obtaining the best possible edibility and durability in sustainable water encapsulation. Read our essay to know more about the impact of various ratios on the structure of Ooho balls.

Why did we choose this topic?

This research problem is interesting because it discusses how the molecular structure and mechanical characteristics of Ooho balls are affected by the stoichiometric differences between calcium chloride and sodium alginate. We wanted to discover more about the resulting modifications to the structure of this sphere by investigating the effects of various reactant ratios. To add on, our curiosity about the chemistry underlying these water spheres and whether there is a chance to use them in the actual world motivated us.

Are Ooho balls sustainable?

Ooho balls are a more sustainable alternative to plastic bottles because they're made from renewable, biodegradable seaweed extract, which has a much lower environmental impact than plastic. Unlike plastic, they break down naturally and are compostable, helping reduce long-term plastic pollution. However, there are some practical challenges—Ooho balls are fragile, have a short shelf life, and cost more to produce, which limits their scalability and widespread use. While they're a promising step in the right direction, their overall sustainability depends on things like production processes, proper disposal, and whether they can replace plastic in everyday packaging. Overall, Ooho balls are definitely more sustainable than plastic, but they still face hurdles that need to be addressed for them to become a truly global solution.

Materials and equipment we required:

1. Water
2. 1 gram sodium alginate
3. 5 grams of calcium lactate
4. Large bowl
5. Smaller bowl
6. Hand mixer
7. Spoon with a rounded bottom (soup spoon or round measuring spoon works great)
8. Food coloring - 2 colors at least

Method:

1. Add one gram of sodium alginate to one cup of water in a small bowl.
2. Use a hand mixer to ensure the sodium alginate combines with the water. Let the mixture sit for about 15 minutes to remove any air bubbles. The mixture will transform from a white liquid to a clear substance.
3. Stir five grams of calcium lactate into four cups of water in a large bowl. Mix well to dissolve the calcium lactate.
4. Use your rounded spoon to scoop up the sodium alginate solution.
5. Gently drop the sodium alginate solution into the bowl containing the calcium lactate solution. The mixture will immediately form a ball of water. You can drop more spoonfuls of sodium alginate solution into the calcium lactate bath, just be careful the water balls don't touch each other because they'll stick together. Let the water balls sit in the calcium lactate solution for three minutes. You can gently stir around the calcium lactate solution if you like. (Note: The wait time determines the polymer coating's thickness. Less time gives your balls a thinner coating and more produces a thicker one.)
6. Use a slotted spoon to gently remove each water ball. Place each ball in a bowl of water to stop any further reaction. Now you can remove the edible water bottles and drink them. Remember, the water is, of course, consumable but the bottle is edible too—it's an algae-based polymer!

What went well?

While we conducted the experiment, we were very precise with the measurements and ratios. Even though after 2 failed attempts, we were patient to give it another try and learn from our mistakes. We followed the experimental method very well, although due to loopholes the product did not form as desired. Our team collaborated effectively, sharing ideas and troubleshooting in real-time, which strengthened our understanding of the process. Overall, the experiment gave us practical experience, strengthening our problem-solving skills and resilience in handling unexpected results.

What could have been done better?

As a team, we realized that through the process of making the Ooho balls required more precision which could be one of the reasons which caused the experiment to fail.However, if we did this differently we would have been more precise.. There are several areas where improvements could have been made. First, a more thorough pre-experiment research phase might have highlighted potential issues earlier, allowing us to adjust our approach proactively. Additionally, we could have refined our setup to ensure that all variables were tightly controlled, as slight inconsistencies may have impacted the results.

Our conclusion from experiment:

To conclude, we found out that the process to make ooho balls is not refined as small errors can change the product and not make ooho balls. Changing the ratio does not make the process easier, or form the products. Ooho balls are not the future of packaged water, as there is no easy or simple way to make it. Ooho edible water balls have a bright future as a creative way to cut down on plastic waste, but there are several obstacles in the way of its general acceptance. Ooho, a sustainable substitute for plastic bottles, is made from a seaweed-based membrane that encapsulates water in a way that permits the packaging to be consumed or biodegrade organically. However, because of the complicated procedure, producing these edible water balls on a large scale is difficult.

Data Collected:

In conclusion, altering the ratio of sodium alginate to calcium lactate in the production of Ooho balls has a substantial impact on their structural integrity, texture, and rate of hydration release. The findings emphasize the importance of precise ingredient ratios in achieving optimal edibility and durability for sustainable water encapsulation. This research underlines how careful adjustments to these ratios can improve the functionality and appeal of Ooho balls, advancing them as a viable, eco-friendly alternative to traditional packaging.

How does this connect back to chemical bonding?

Ooho balls are made from seaweed extract, mainly a substance called alginate, which is a type of sugar polymer. The sugar molecules in alginate are connected by covalent bonds, which are strong and keep the chain together. To create the gel-like structure of the Ooho ball, calcium ions are added, forming ionic bonds with the alginate, which helps the ball hold its shape and stay flexible. The material also forms hydrogen bonds with water, which allows the ball to hold liquid without leaking. These different chemical bonds—covalent, ionic, and hydrogen—work together to give Ooho balls their strength, flexibility, and ability to hold water, making them a more sustainable option than plastic packaging.

How does the ratio impact the structural integrity of Ooho balls?

The structural stability of Ooho balls, which consists of sodium alginate and calcium lactate, is heavily impacted by the components' ratio. An appropriate combination of sodium alginate and calcium chloride is required to create a membrane that is both robust and flexible, avoiding rupture during handling. This balance also affects the balls' longevity during shipping, reducing leaks and waste. Furthermore, the texture experienced by consumers is influenced by this ratio; a thicker membrane may improve durability but sacrifice mouthfeel. Finally, fine-tuning this ratio is critical to ensure that Ooho balls remain a safe, pleasant, and ecologically beneficial substitute for plastic bottles.

To conclude, our main purpose of this experiment is to change the ratio of reactants while making the ooho balls. The major thing that we concluded from this experiment is that altering the ratio of sodium alginate to calcium lactate in the production of Ooho balls has a substantial impact on their structural integrity, texture, and rate of hydration release. We could improve this experiment by having more precise measurements and also redoing the experiment more times. By encasing water in edible, biodegradable membranes, the Ooho edible water ball experiment investigates a sustainable substitute for plastic packaging; nevertheless, durability, scalability, and practical application present difficulties.

The Role of Cryogenic Fuels in the Energy Transition of Aviation

Divya Balamurugan

Abstract

The aviation industry faces a critical challenge in mitigating its significant contributions to global greenhouse gas emissions. This research explores the potential of cryogenic fuels, specifically liquid hydrogen (LH2) and liquefied natural gas (LNG), as viable alternatives to traditional kerosene-based jet fuels. Key factors addressed include technological advancements, scaling production, infrastructure development, regulatory and policy frameworks, and economic considerations. The research highlights that while cryogenic fuels offer promising pathways toward sustainable aviation, significant challenges must be overcome. The integration of these fuels into aviation will require coordinated efforts in technology development, infrastructure investment, and regulatory adaptation. This research provided a deeper understanding of classroom concepts like thermodynamics, as it required analysing the energy efficiency and heat transfer properties of cryogenic fuels compared to traditional jet fuels. It also emphasised the importance of simple concepts such as states of matter in the real world - it is critical to consider the state at which various fuels exist at room temperature to determine whether they would be a viable fuel option.

1. Introduction

Climate change, driven largely by the release of CO2 and other greenhouse gases (GHGs), is one of the most urgent environmental challenges of our time. The transportation sector is a large contributor of greenhouse gases, with the aviation sector being a significant contributor. As aviation continues to grow, its impact on climate change becomes increasingly critical. In 1960, it is estimated that only around 100 million people travelled by flight. However, this number grew to 4.56 billion by 2019, requiring more flights to operate and increasing the overall emissions due to the aviation sector. Therefore, addressing the CO2 emissions from aviation is vital for mitigating the broader impacts of climate change.

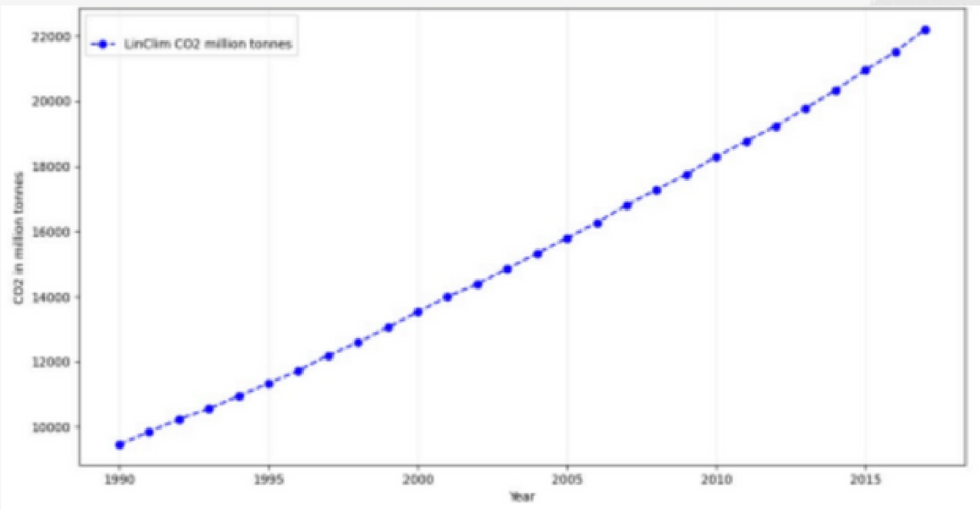

Figure 1. Annual CO2 emissions from aviation (1990 – 2017) [1].

Jet-A and Jet-A1, the most commonly used kerosene-based fuels for commercial and military aviation, release substantial amounts of CO2 upon combustion. To put this into perspective, the average domestic flight that makes use of Jet-A fuel releases about 246g/kilometre travelled, while petrol and diesel cars emit around 170g/kilometre and 171g/kilometre respectively [16].

The CO2 emissions from aviation have been on a rising trajectory, as depicted in Fig. 1, and this trend is expected to continue. This situation is exacerbated by the increasing price of jet fuels over the years as seen in Fig. 2, adding an economic imperative to the environmental urgency.

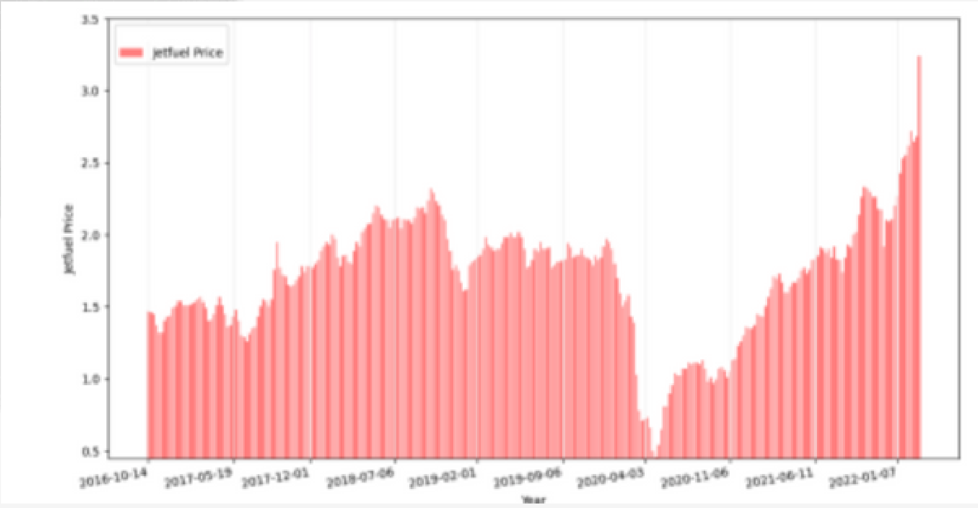

Figure 2. Jet-A fuel price (2016 – 2022) [S&P Global, 2024].

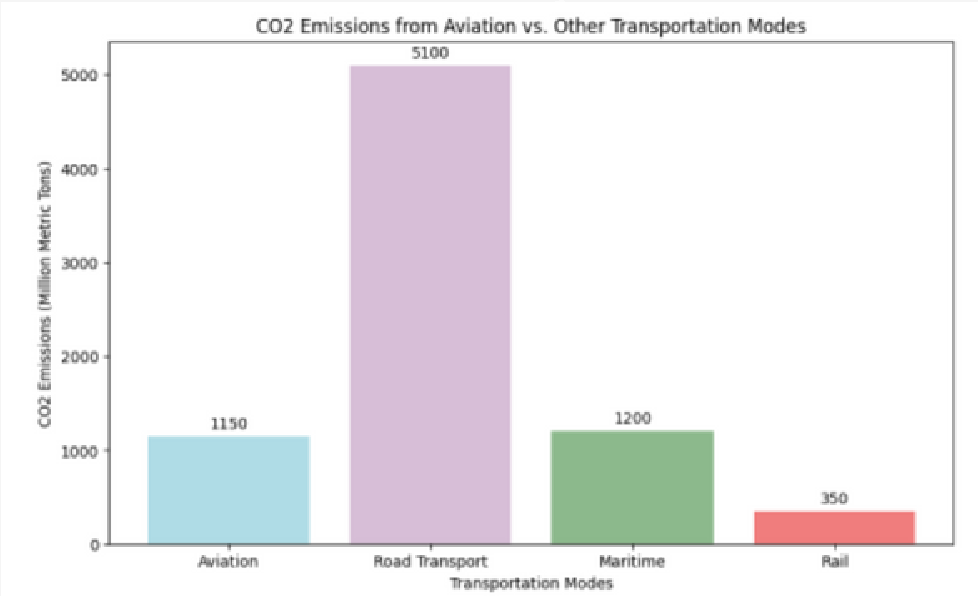

Figure 3. CO2 emissions from various transportation modes (Our World in Data, 2024)

Addressing the climate change impact of aviation requires a significant energy transition from traditional carbon-based fuels to more sustainable alternatives. The urgency of this transition is underscored by the growing environmental and economic costs associated with continued reliance on fossil fuels. Prospective sustainable fuel alternatives include hydrogen, ammonia, and biofuels. Hydrogen and ammonia, in particular, are promising because they produce no CO2 during flight. However, they are non-drop-in fuels. These are fuels that cannot substitute the currently used fuels directly and will require changes to the infrastructure to be made. Hydrogen and ammonia require substantial changes to the current aviation infrastructure for storage and transportation due to their gaseous state at room temperature and pressure.

Biofuels, on the other hand, are drop-in fuels. This means that they can be used as substitutes for the currently used fuels without changing the existing infrastructure [2]. However, they also have their drawbacks, including significant changes in farming practices and land usage required for their production.

This research aims to explore the potential of cryogenic fuels in the energy transition of aviation by assessing the current state and challenges of aviation energy use, evaluating alternative cryogenic fuels such as liquid hydrogen (LH2) and liquefied natural gas (LNG), examining the practical applications and feasibility of these alternative fuels, and projecting future prospects and developing a roadmap for the adoption of cryogenic fuels in aviation. Cryogenic fuels are unique due to their properties, including their high energy density, storage density and most importantly, their ability to reduce greenhouse gas emission when used as a fuel. Hence, the avenues for their applications are endless and are likely to play a vital role in the emerging technologies and the transition to a net zero emissions world. The significance of this research lies in its potential to identify sustainable alternatives to conventional aviation fuels based on a broad exploration of the impacts and overall capability to reduce carbon dioxide emissions from the aviation sector.

2. Current State and Challenges of Aviation Energy Use

The industry's efforts to improve fuel efficiency have led to innovations in aircraft design, engine technology, and operational practices. Modern aircraft are more fuel-efficient than ever, thanks to advancements such as lightweight materials, aerodynamic improvements, and more efficient engines. However, these improvements are often incremental and insufficient to offset the growing demand for air travel, which continues to rise steadily, further increasing overall emissions. Worldwide, aviation currently uses over a billion liters of jet fuel each day and this is expected to rise by 3% each year despite the advances in aircraft technology and efficiency [1].
Another major challenge is the existing infrastructure, which is deeply entrenched in the use of traditional jet fuels. Airports, refueling stations, and maintenance facilities worldwide are all designed to support conventional aviation fuels, making the transition to alternative energy sources complex and costly. Upgrading or replacing this infrastructure requires significant investment, which can be a deterrent given the industry's narrow profit margins and high sensitivity to economic fluctuations.

The regulatory environment also poses challenges. Current regulations and standards are based on the use of conventional fuels, and adapting these to accommodate new energy sources requires comprehensive and coordinated efforts among international regulatory bodies. This process is often slow and can create uncertainty for industry stakeholders.

Furthermore, there is a need for substantial investment in research and development to explore and commercialise new technologies that can reduce the industry's carbon footprint. While private companies and governments have started to fund these initiatives, the level of investment required to achieve significant breakthroughs is immense.

The high costs associated with research and development, combined with the long timeframes needed to bring new technologies from the laboratory to the runway, add to the complexity of addressing the industry's energy challenges.

In addition to technological and economic barriers, there are also operational challenges. The aviation industry is highly regulated to ensure safety, and any new fuel or technology must undergo rigorous testing and certification processes. These processes are crucial for maintaining safety standards but can also slow down the adoption of new technologies. For instance, biofuels are possible alternatives, some of which have also been certified to be blended up to 50% into current jet fuels. However, only a very minimal proportion of all aviation fuel consumed currently is composed of biofuels due to the difficulties in scaling up the production of biofuels [1].

Lastly, public perception and consumer demand play a crucial role. While there is growing awareness of the environmental impact of aviation and increasing demand for sustainable travel options, consumers are often unwilling to pay a premium for greener alternatives. This creates a paradox for airlines, which must balance the pursuit of sustainability with the need to remain competitive in a price-sensitive market.

3. Alternative Cryogenic Fuels for Aviation

Alternative cryogenic fuels, such as liquid hydrogen and liquid natural gas (LNG), are emerging as viable options to reduce the aviation industry's carbon footprint. Liquid hydrogen, especially when used in fuel cells or burned in modified gas turbines, offers the potential for zero-emission flights, marking a significant step towards sustainable aviation (see Fig. 4).

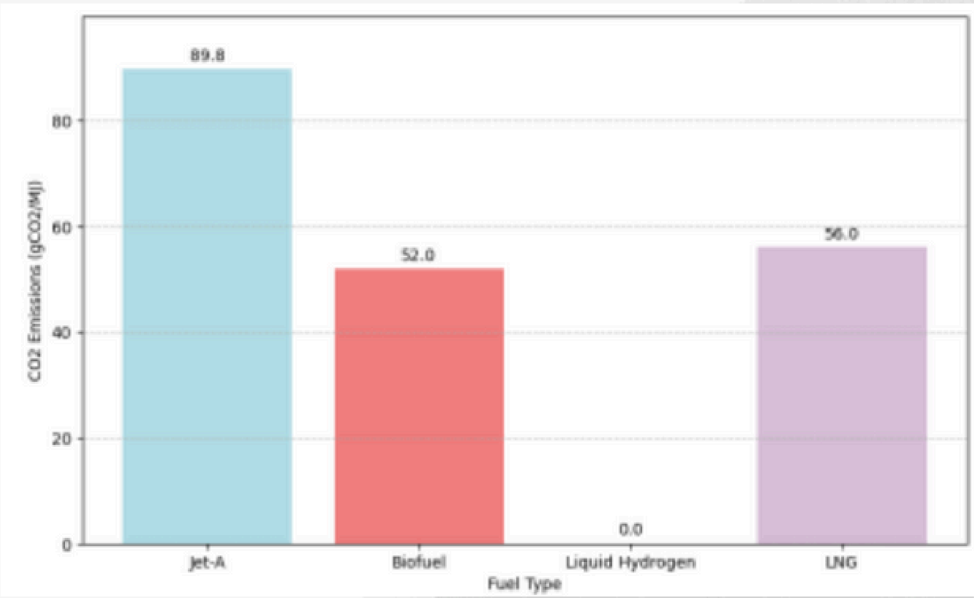

Figure 4. CO2 emission from the combustion of various aviation fuels (Carbon offset Guide, 2024)

When considering alternative fuels for aviation, a range of different factors need to be taken into consideration. These include the mass and volumetric energy densities, their carbon footprint throughout their life cycle, cost, availability, infrastructural compatibility, policy, etc. The mass and energy density of the fuel is especially important due to stringent restrictions regarding the weight and volume of fuel that can be accommodated within an aircraft. The weight of the fuel is crucial due to the stringent weight restrictions that aircraft have to comply with. Moreover, a high mass energy density generally translates to better fuel efficiency as more energy is available per unit mass of the fuel. It also supports long-distance flights as they would have to be refuelled less frequently. The volume of the fuel is critical as well as it affects the payload capacity of the flight. This would also impact the profitability of airlines, making the volume of the fuel a critical factor as to whether it would be a viable substitute. Fig. 5. depicts the mass and volumetric energy densities of various fuel alternatives that can be considered.

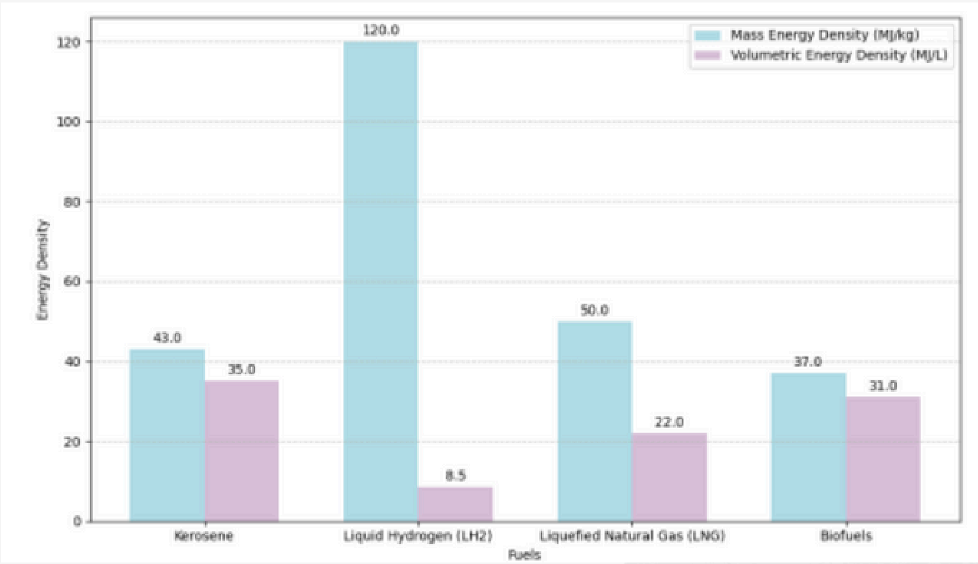

Figure 5. Comparison of possible fuel alternatives for aviation in terms of their mass energy density and volumetric energy density [2].

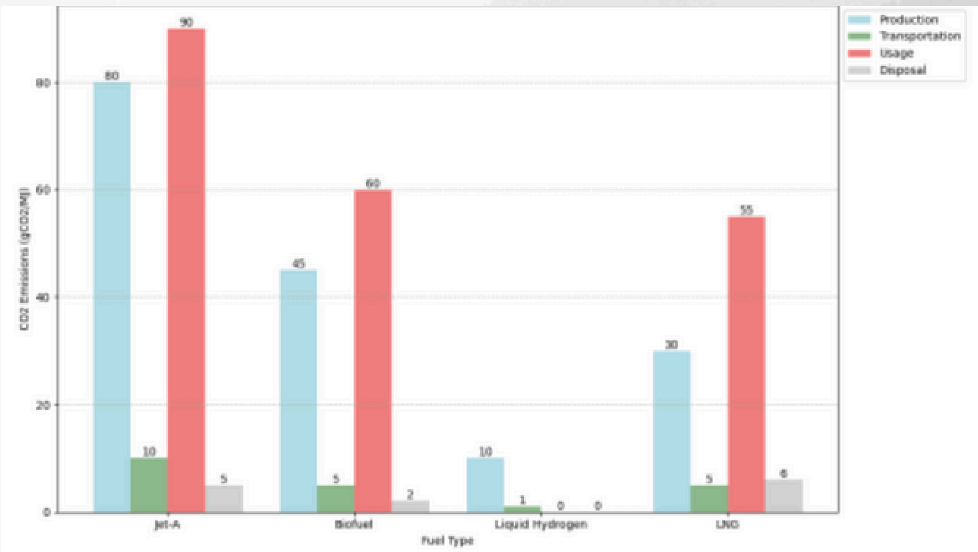

Figure 6. CO_2 emissions throughout the life cycle of various aviation fuel alternatives [14]

Liquid Hydrogen

Liquid hydrogen is a promising sustainable cryogenic fuel alternative as its combustion does not produce any CO_2, soot, CO, unburnt hydrocarbons (UHCs), and volatile organic compounds that are produced by the combustion of kerosene [1]. It is not just the combustion, but rather the entire life cycle of hydrogen which makes it a suitable alternative. In comparison with jet-A fuel, biofuel, and LNG, LH_2 has the lowest CO_2 emission levels in all stages of its life cycle, namely production, transportation, usage, and disposal (see Fig. 6).

LH_2 has a high mass energy density that is significantly higher than that of kerosene as well. This makes it an ideal candidate for use as an aviation fuel as it would add a much smaller amount of weight to the aircraft when compared to the other possible alternatives and kerosene itself.

Depending on the environmental impact of the method of producing hydrogen, it can be classified into 3 broad categories as depicted in Fig. 7. Grey hydrogen produces CO_2 during its manufacturing. Blue hydrogen is an improvement from that, where the CO_2that is produced is captured and stored to reduce its environmental impact. Green hydrogen is clean hydrogen and no $CO_2$is produced during any stage of its life cycle [3]. It is crucial to ensure that the hydrogen used is green hydrogen and is thus, carbon-neutral to reduce the climate impact of aviation.

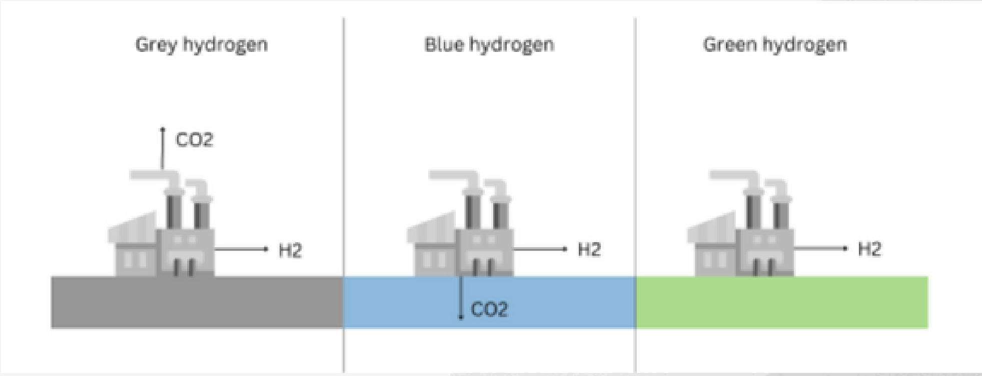

Figure 7. Classification of hydrogen as per their carbon footprint. The production of grey hydrogen causes GHG emissions, while blue hydrogen is an improvement from that where the GHGs produced are captured and stored to reduce their environmental impact. Green hydrogen is hydrogen that is produced without releasing any GHGs in the process and would be the most suitable to alleviate climate change.

Liquified Natural Gas (LNG)
Liquified natural gas is another potential cryogenic substitute for kerosene. LNG, at present, is one of the cheapest fuels available due to the large gas reserves that are available. It has a much higher boiling point when compared to LH2 and would thus, require less energy to liquify. This makes it an economically viable option as well [4]. Moreover, LNG is already traded globally and hence, has a well-established global network that would be able to support any upscaling that may need to be done to use it commercially as jet fuel. Alongside, the infrastructure required for the production and storage of LNG has also reached a good level of maturity.

The combustion of LNG, unlike LH2, does produce some amount of CO2, however, this is 25% lower than the amount of CO2 emitted by the combustion of kerosene. Additionally, LNG also reduced the formation of NOx within the combustor and soot [1].
LNG also has a slightly higher mass energy density when compared to kerosene. This makes it an improvement from kerosene in terms of the energy it can supply per unit mass and the overall weight it would add to the aircraft. It also has a volumetric energy density that is closer to kerosene than LH2, hence a smaller volume of fuel would have to be carried on board.

4. Practical Applications and Feasibility of Cryogenic Fuels in Aviation

The integration of cryogenic fuels into aviation represents a significant step towards reducing the sector's carbon footprint, yet it brings with it a set of complex challenges. Liquid hydrogen (LH2) and liquefied natural gas (LNG) are two key cryogenic fuels being investigated for their potential to mitigate greenhouse gas emissions from aviation. Assessing their practical applications and feasibility involves exploring infrastructure requirements, safety considerations, economic factors, and technological innovations [1].

4.1. Infrastructure Adaptation

Adapting current aviation infrastructure to accommodate cryogenic fuels is a major undertaking. Traditional jet fuel systems comprising refuelling stations, storage tanks, and aircraft fueling mechanisms are specifically designed for kerosene-based fuels. Transitioning to LH2 or LNG necessitates a comprehensive overhaul of these systems. Similarly, LNG, which is stored at about -160°C, demands its own set of infrastructure modifications. The refuelling infrastructure at airports would need to be revamped to support these new fuels, including new pipelines, storage facilities, and refuelling equipment. Adopting these fuels would also require significant infrastructural changes to be made to the aircraft itself. Additionally, there are several challenges associated with the storage of cryogenic fuels both at airports and onboard aircraft.

4.2. Safety Considerations

The handling of cryogenic fuels introduces distinct safety challenges. Both LH2 and LNG are stored at extremely low temperatures (see Fig. 9), which can cause severe cold burns and material brittleness. LH2, in particular, has a low viscosity and high flammability and makes leaks more likely, which can result in explosions when combined with air, and would hence, require stringent safety measures. Moreover, leaks of cryogenic fuels in confined spaces can cause pipes and values to freeze, which poses many safety risks. Advanced safety technologies and protocols are essential to manage these risks effectively. This includes robust leak detection systems, automated emergency shutdown mechanisms, and comprehensive staff training programs. Ensuring the safety of cryogenic fuel handling and storage is critical to preventing accidents and maintaining operational integrity.

Cryogenic fuels pose safety risks onboard aircraft as well. Hydrogen's high laminar flame speed increases the risk of flashbacks in the combustor [1]. It, hence, requires more stringent safety measures to prevent accidental ignition of the fuel.

4.3. Economic Viability

The economic feasibility of cryogenic fuels is a significant factor in their adoption. Currently, LH2 and LNG are more expensive as shown in Fig. 10 than traditional jet fuels due to the complex processes required for their production, liquefaction, and storage. Unlike kerosene and other forms of fuels currently used, LH2 cannot be found in its native form on Earth and must be synthesised from other substances, such as from the reaction between steam and methane. This method, however, produces CO2 and the most sustainable method to produce hydrogen would be from the electrolysis of water using electricity from renewable resources [7]. This is, however, energy-intensive and costly. LNG also involves high capital costs associated with its production and storage infrastructure. To make cryogenic fuels more economically viable, there needs to be progress in reducing production costs and achieving economies of scale. Government subsidies, long-term investment strategies, and technological advancements can help mitigate these costs and facilitate the transition to cryogenic fuels. The aviation industry must balance the higher initial costs with the long-term benefits of reduced greenhouse gas emissions.

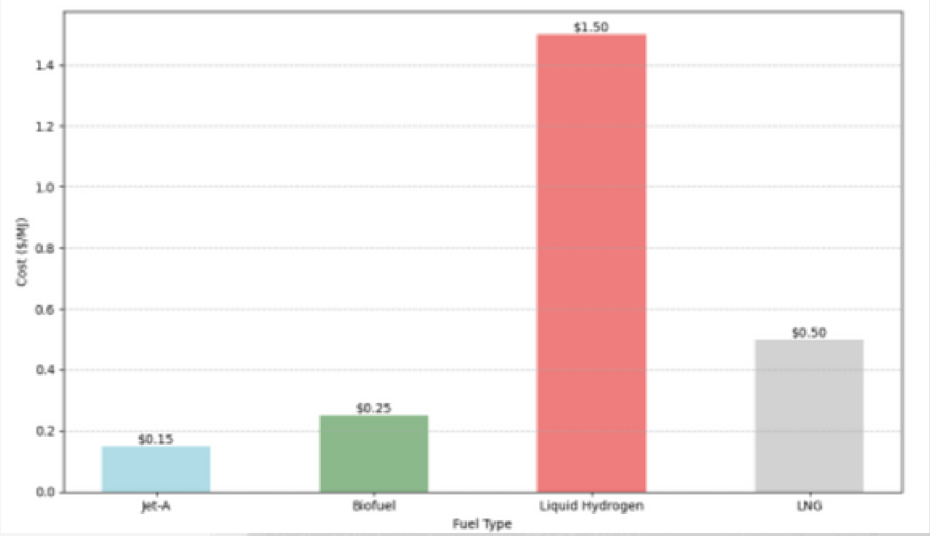

Figure 10. The cost of various aviation fuels per unit energy supplied [15]

4.4. Technological Advancements

Technological innovation is pivotal for the practical application of cryogenic fuels. The integration of LH2 and LNG into aircraft requires significant modifications to existing designs. LH2, with its low density, necessitates specially designed fuel tanks and modifications to aircraft engines. The use of LH2in fuel cells is a promising technology, as it generates electricity through a chemical reaction between hydrogen and oxygen, emitting only water vapour. Similarly, LNG requires adaptations to engines and fuel systems to handle its distinct combustion characteristics. Research is focused on developing new materials and technologies that can withstand the extreme conditions associated with cryogenic fuels. Advances in hybrid propulsion systems and fuel-efficient engine designs could further support the integration of these fuels into aviation.

Additionally, the use of LH2 reduces the production of the GHG CO2, however, increases the formation of water vapour and hence, contrails. Water vapour is also a GHG and is considered undesirable. This would require additional systems to be developed to reduce the formation of these ice contrails.

4.5. Operational Challenges

Operational challenges also play a critical role in the feasibility of cryogenic fuels. The global nature of the aviation industry means that the adoption of cryogenic fuels must be coordinated across different regions and regulatory frameworks. Harmonising international standards and regulations is essential for ensuring consistent safety and operational practices. Additionally, airlines must consider the practical implications of transitioning to cryogenic fuels, including changes in flight operations, refuelling procedures, and maintenance requirements. The transition process must be carefully managed to minimise disruptions and ensure a smooth shift to new fuel technologies.

The practical application of cryogenic fuels like LH2 and LNG in aviation presents several complex challenges but also offers substantial potential benefits. The need for infrastructure adaptation, stringent safety measures, economic feasibility, and technological advancements are central to the successful integration of these fuels. Addressing these factors through innovation and investment is crucial for realising the environmental benefits of cryogenic fuels and supporting the aviation industry’s transition towards more sustainable practices. While the path to widespread adoption is fraught with challenges, the continued advancement in technologies and infrastructure development holds promise for a greener future in aviation.

Conclusion

The transition to cryogenic fuels in aviation represents a crucial step towards reducing the sector’s environmental impact and advancing sustainability. Liquid hydrogen and liquefied natural gas, with their potential for significant reductions in greenhouse gas emissions, offer promising alternatives to conventional jet fuels. However, the path to their widespread adoption is fraught with challenges, including technological innovations, infrastructure adaptations, safety considerations, and economic feasibility.

Future prospects for cryogenic fuels in aviation hinge on overcoming these obstacles through continued research and development, strategic investments, and collaborative efforts among stakeholders. Technological advancements in storage and propulsion, coupled with scalable production methods and supportive regulatory frameworks, will be essential for integrating these fuels into the aviation sector. As the industry progresses towards greener practices, the successful adoption of cryogenic fuels will not only contribute to reducing aviation's carbon footprint but also drive innovation and sustainability across the broader transportation sector. By addressing the identified challenges and leveraging emerging opportunities, cryogenic fuels can play a pivotal role in shaping a more sustainable future for aviation.

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CERN PARTICIPANTS

Names	Certificate ID	Capstone Score
Krish Kakkar	SXP/CERN202406201/008	**Excellent**
Advit Arora	SXP/CERN202406201/003	**Commendation**
Ameya Saxena	SXP/CERN202406201/002	**Commendation**
Reyansh Sudhir	SXP/CERN202406201/007	**Good**
Arvin Karthik	SXP/CERN202406201/004	**Good**
Agastya Karthikeyan	SXP/CERN202406201/010	**Good**
Daksh Mathew	SXP/CERN202406201/011	**Good**
Ekaansh Balaji	SXP/CERN202406201/005	**Good**
Samrud Reddy	SXP/CERN202406201/009	**Good**
Sarang Krishna	SXP/CERN202406201/001	**Good**
Yashvardhan Sanghi	SXP/CERN202406201/006	**Good**

SBC PARTICIPANTS

Category - Poster			
Name	**Grade**	**Position**	**Topic worked on**
Aira Bisen, Devina Mitra, Adya Ajmera	Grade 9	First	The effectiveness of invisible ink based on pH Simple, clear presentation of the concepts.
Shreyas Narayan, Aryaman Chandilya , Aditya Manish Shah, Aaryan Kuppachi	Grade 9	Second	Explosivity
Tavasya Mizar Rao	Grade 11	First	Exploring Redshift: Calculating the Motion of the Stars
Ananya Jain and Aksh Prabhu K	Grade 12	Second	Correlation of Weight and Weight Distribution on Final Take-Off speed

Category - Essay			
Name	**Grade**	**Position**	**Topic worked on**
Shravya Sureka, Anahita Saurabh Agarwal, Neel Sanyal, Advay Chirayu Patel, Amvi Singh, Pranav Srinivasan	Grade 9	First	Ooho Balls
Vedanth Sairam, Shishir Saripalli	Grade 9	First	The Physics of Roller Coasters
Dia Maheshwari, Pranoy Mathur, Neha Bhati, Vanya Nath, Kriti Murugan, Vivaan Chaudhri	Grade 10	First	Determining the Efficacy of Biodegradable Adsorbents in Improving Lake Water Quality
Diya Balamurugan	Grade 11	First	Cryogenic fuels in Aviation
Sohan Chakravarthy Talla	Grade 11	First	Experimental Determination of Planck's Constant
Tavasya Mizar Rao	Grade 11	Second	Exploring Redshift: Calculating Motion of the Stars

SBC WINNERS

Category - Talk			
Name	**Grade**	**Position**	**Topics worked on**
Aira Bisen, Devina Mitra, Adya Ajmera	Grade 9	First	The effectiveness on invisible ink based on pH
Kiah Sinha	Grade 9	Second	Impact of Parabens on the Endocrine System
Vedanth Sairam, Shishir Saripalli	Grade 9	First	The Physics of Roller Coasters
Dia Maheshwari, Pranoy Mathur, Neha Bhati, Vanya Nath, Kriti Murugan, Vivaan Chaudhri	Grade 10	First	Determining the Efficacy of Biodegradable Adsorbents in Improving Lake Water Quality
Shambhavi,Anay, Adrika	Grade 9	Second	Battle of the Disinfectants: Which Formula Reigns Supreme
Jaahnavi Maheshwari, Nasha TK	Grade 12	First	Significance of Attitude Control and Control Systems in Satellites
Sohan Chakravarthy Talla	Grade 11	Second	Experimental Determination of Planck's Constant
Aadya Salwan, Hazel Chinku, Aanika Feagans, Arya A. Kenghe, Sunay Parish Mittal	Grade 11	First	Effect of sleep deprivation on reaction time