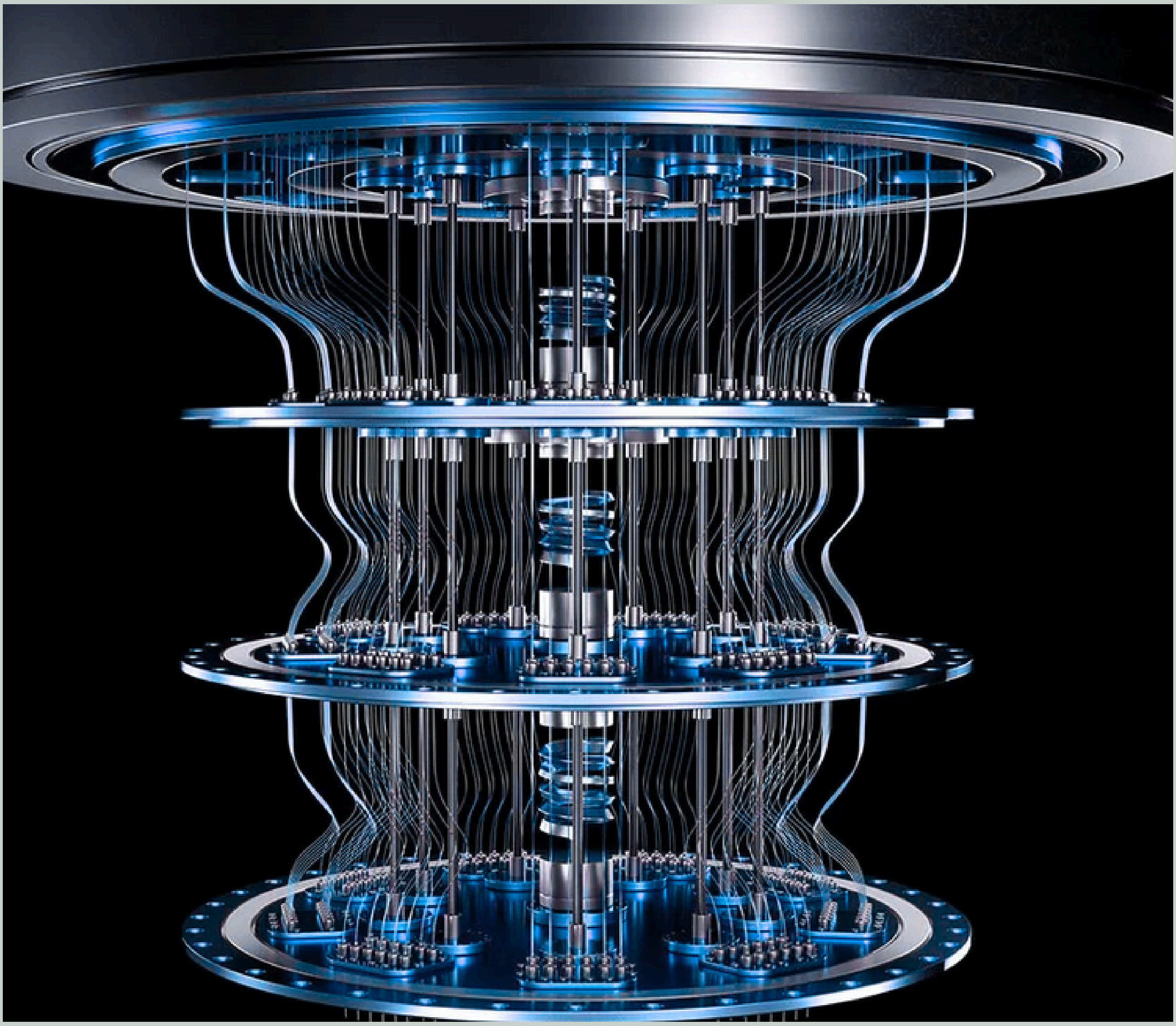
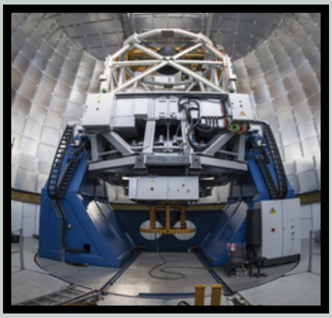
BHOUTIKI PRADNYA

Volume - 1 Issue - 1 March - 2025



Quantum Computer



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BHOUTIKI

Wadian Physics Association & Department of Physics, MES's Nowrosjee Wadia College, Pune 411 001

We are thrilled to announce the inauguration of **'BHOUTIKI,'** the Physics Students Club, on **22nd March 2025**. This initiative stands as a testament to the remarkable talent, boundless curiosity, and ambitious spirit of our students, who have come together to create a platform dedicated to exploring the wonders of physics—one of the most fundamental and fascinating sciences.

.Prof. Nathan Rosen and Robert Andrews Millikan

The choice of this date holds special significance. It marks the birth anniversary of **Prof. Nathan Rosen**, the renowned American-Israeli theoretical physicist who, alongside **Boris Podolsky** and **Albert Einstein**, played a pivotal role in the famous 1935 debate on quantum mechanics, culminating in the publication of the Einstein-Podolsky-Rosen theory. Additionally, it is the birth anniversary of **Robert Andrews Millikan**, the distinguished American physicist celebrated for his iconic oil-drop experiment (1911), which determined the charge of the electron.

Arthur Schawlow and Charles Hard Townes

Interestingly, this date also commemorates a groundbreaking milestone in modern science. On **22nd March 1960**, the first laser was patented under the title "*Masers and Maser Communications System*" by **Arthur Schawlow** and **Charles Hard Townes** of Bell Telephone Laboratories.

Through 'BHOUTIKI,' we aim to honour this legacy of scientific excellence and inspire a new generation of physicists to delve into the mysteries of the universe.

Logo of the MES's Nowrosjee Wadia College, Pune and the logo of BHOUTIKI, The Physics Club

Physics is often described as the language of the universe, unravelling the laws that govern the smallest particles to the vastness of galaxies. It challenges us to think critically, question the known, and venture into the unknown. The **Physics Students Club** is a testament to these very principles, fostering a spirit of inquiry and innovation among students. This club is more than just an organization—it is a **community**, created ***by the students, for the students.***

The club operates under the esteemed Wadian Physics Association (WPA), a long-standing organization within the Department of Physics at Nowrosjee Wadia College. Drawing inspiration from the College logo, the club logo was meticulously designed to represent two key elements:

- **An Open Book:** Symbolizing the quest to understand the fundamental principles of nature, it embodies openness to discovery and the dissemination of scientific knowledge. It also reflects an inclusive approach to education, encouraging curiosity and exploration of physical phenomena.
- **The Sun:** Representing energy, light, and life itself, the Sun aligns with the essence of physics and its focus on the forces that sustain the universe.

Additionally, the logo features **an atomic model**, illustrating the building blocks of matter and the exploration of the microscopic universe. This element showcases the intricate nature of atoms and their significance in understanding physical phenomena.

The motto, "**प्रकाशस्य प्रसारार्थम्**" embodies a profound philosophy that resonates deeply with the principles of physics and education. The phrase signifies a mission to illuminate minds and encourage scientific thinking. Whether through organizing workshops, engaging lectures, or hands-on experiments, the club aims to empower members to grasp the intricacies of physics and inspire others to explore its wonders.

Through its efforts, the Physics Students Club aspires to create a vibrant and collaborative environment, nurturing curiosity and inspiring future physicists to explore the mysteries of the cosmos.

The term **'BHOUTIKI'** in the Physics Club logo likely signifies 'Physics' in Sanskrit, encapsulating the foundational principles of the natural sciences. It beautifully reflects the essence of exploring the physical universe, spanning phenomena from the microscopic to the cosmic scale.

Throughout the year, the club will host a wide variety of activities, each thoughtfully designed to spark curiosity and deepen participants' understanding of the intricate beauty of physics. These activities include:

- Guest Lectures and Seminars
- Workshops and Skill Sessions
- Experimental Demonstrations
- Science Outreach Programs
- Debates and Panel Discussions
- Physics Quiz Competitions
- Project Showcases
- Movie Screenings and Discussions
- Publication of Quarterly Digest
- Experiment Design Competitions
- Peer Teaching and Learning
- Problem-Solving Sessions
- Celebration of Physics Days
- Collaborations and Competitions
- Educational Visits
- PHYSIQUEST: The department's flagship annual event.

With this diverse range of initiatives, the Physics Students Club aims to foster a vibrant community that celebrates the pursuit of knowledge and the joy of discovery in the realm of physics.

We sincerely acknowledge the invaluable motivation and support provided by our esteemed Trustees, **Prof. Sachin Sanap Sir** and **Dr. Ashok Chandak Sir**. We are deeply grateful to our Honourable Principal, **Prof. V. V. Chabukswar Sir**; our Vice Principal, **Prof. Dr. B. B. Bahule Sir**; and **Prof. Dr. Samina Boxwala-Kale Ma'am** for their unwavering encouragement and guidance. A special thanks to **Prof. S. G. Jamdad**e for their unconditional support and other faculty members of the department in organizing and executing the

activities envisioned for this club.

Dr. Sneha Pandit, IUCAA, Pune

We would also like to extend our heartfelt appreciation to our honoured guest, Dr. Sneha Pandit, IUCAA whose inspiring presence on the inauguration day has greatly motivated us all.

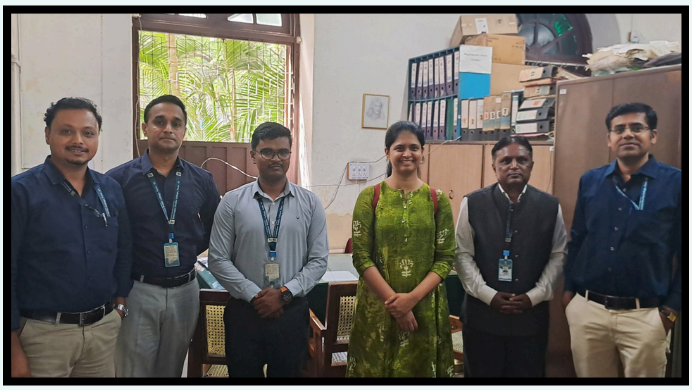
Together, we pledge to transform this club into a vibrant and thriving hub for learning, innovation, and collaboration. Let us, as a community, unite in unlocking the mysteries of physics and contributing meaningfully to the advancement of knowledge.

Connect with us

bhoutiki.nwc

Bhoutiki Physics Club

Event Gallery



Quantum Computing: The Bizarre Theory's Promise of a Powerful Regime of Computation

Sanket Gogte

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"The quantum moment reminds me of where AI was in the 2010s, …." - Sundar Pichai.

Quantum computers is a new regime of powerful computation. It exploits the non-trivial quantum effects and has great promises- solutions to problems in minutes, where even the most powerful supercomputers take time as long as life of the universe; or data encryption which are impossible to break. This is the reason that giants like IBM, Google, Amazon, Microsoft etc. are building the quantum computers and working hard to make the hardware technology better. While the development in hardware is relatively recent, physics community has anticipated the technology and has been proposing quantum algorithms and showing the superiority of these algorithms over their classical counterpart for more than three decades. What is physics behind quantum computers? What is the technology of gate-based quantum computers? What are the applications? What are challenges for advancing the technology? This article tries to briefly touch upon answers to these questions. Of course, it is not possible even to summarise the technology in a couple of pages. The article rather hopes to kindle the curiosity of a reader in the field. Moreover, the focus of this article is the gate-based quantum computers. There is other important technology for quantum computing- quantum annealing- that are not discussed here.

The Physics

"Those who are not shocked when they first come across quantum theory cannot possibly have understood it" - Neils Bohr.

At atomic level, nature is governed by laws of quantum mechanics. Therefore, even the classical computers follow the quantum mechanics. However, the quantum computing is a major shift as they exploit the direct non-trivial quantum effects. Let us consider two such effects:

1. Quantum Superposition and Interreference: The unit of information for classical computer is a bit, which assumes on of the two possible states- 0 or 1. At any instance, a classical bit is in one of the states and not both. Quantum Bit, or qubit which is the unit of information in quantum computers. Unlike classical bits, qubits can simultaneously exist in states 0 and 1. In quantum computers, the qubits are processed in this superposition state called as coherent processing. When measured, the qubits collapse to one of the states with certain probabilities- either measuring 0 or 1. Creating qubits with desired probabilities and manipulating the probabilities is the basis of information processing in quantum computers. Due to superposition quantum computers can explore all the possibilities simultaneously. This parallel processing gives quantum computers edge over their classical counterparts.

Along with the superposition, qubits mathematically behave like classical waves and produce interference pattern like them. This interference effect is also a non-trivial quantum effect that is used in information processing by quantum computers.

2. Quantum Entanglement:
Quantum entanglement is another unique phenomenon to quantum mechanics after superposition. In a nutshell, when two or more particles or qubits are entangled with respect to some degree of freedom; they lose individuality and behave as a single "superstate" pertaining to the degree of freedom. There is no parallel to quantum entanglement in classical physics. Therefore, quantum entanglement is another unique tool for information processing which classical computers completely lack in their toolbox.

The Technology
"The universe computes, and because the universe is governed by the laws of quantum mechanics, it computes in an intrinsically quantum-mechanical fashion; its bits are quantum bits." – Seth Llyod.

The technology for quantum computers requires creating and maintaining physical qubit states. Following are some of the qubit technologies which currently exist:

1. Superconducting Qubits
2. Trapped Ion
3. Neutral Atoms (e.g. Strontium) Qubit
4. Spin Qubits
5. Photonic Qubits
6. Topological Qubits

Today, most of the existing quantum hardware uses superconducting qubits as it is more matured as compared to other technologies. However, each of them has its perks and flaws over the others and it may happen that it's different technologies are utilized based on the applications.

Another important aspect of quantum computers are the quantum gates which are analogous to logical gates in classical computers. Quantum gates are basically operations performed on qubits to manipulate them for information processing. Mathematically the quantum gates are unitary operators and are inherently reversible. The reversibility is perhaps fundamental difference between quantum gates and classical logical gates. This difference in information processing in quantum computers differentiates them in their abilities as compared to classical computers.

As briefed above, quantum computers have unique way for processing the information that classical computers cannot mimic; at least not efficiently. Therefore, as anticipated for long by physicists, and now with advent of the technology, being proved experimentally; quantum computers have the advantage in certain computation task over the classical computers.

The Challenges

"Quantum computers are a theorist's dream and an experimentalist's nightmare" – John Preskill.

Quantum states are very fragile and are destroyed when interact with the environment, even when the interaction is very weak. This is one of the major challenges for engineers designing quantum computers. Achieving so called coherent states for sufficiently longer time requires that the qubits are cooled to near absolute zero and shielded from other interaction with the surrounding. (The coherent times are of the order of millisecond to a few seconds at best!) Thus, the cryogenics takes most of energy and efforts for engineering a quantum computer.
Apart from the coherence time during which qubits are to be processed, fidelity of quantum gates is other major challenge. The quantum gates, especially the gates which act on two qubits simultaneously to produce the entanglement are very noisy and

introduce errors in the final state than what is expected. The error correction is one of the fronts where scientists are working for making quantum computers more reliable and consequentially more useful.

The Applications

"Nature is quantum, goddamn it! So, if we want to simulate it, we need a quantum computer." – Richard Feynman.

Today's quantum computers are in so called NISQ (Noisy Intermediate Scale Quantum) era. And even in the early stage they have shown advantage over classical computers at least in some of the applications. While most of the experts agree that it would take some time to develop a full-fledged quantum computer, a lot of efforts are being made and funds are being poured for the development by many governments and corporate companies. Indian government has also announced National Quantum Mission (NQM) in 2023, allocating a cost of Rs.6003.65 crore from 2023-24 to 2030-31. NQM aims to seed and nurture scientific and industrial research & development of the technology. Obviously, there are many applications of quantum computers and in diverse fields behind this race. To list a few:

- **Cryptography:** Quantum computers could break current encryption methods but also create virtually unbreakable quantum encryption.
- **Drug Discovery:** By simulating molecular interactions at an unprecedented level, quantum computers could accelerate the development of new medicines.
- **Optimization Problems:** Industries like logistics, finance, and manufacturing could benefit from quantum computing's ability to find optimal solutions much faster.
- **Artificial Intelligence:** Machine learning algorithms could be significantly enhanced, leading to breakthroughs in pattern recognition and data analysis.

To summarize, quantum computers are promise of the futures with a lot of applications which are beyond reach of classical computers even in principles. They use the non-trivial quantum effect. While it may never happen, that classical computers are completely replaced by quantum computers due to the complex technology and cost of running them, they are game changer when it comes to certain applications. The development has already started rolling and it would be nice to see the technology changing the world for better in next couple of decades. The future seems to belongs to quantum computers and their engineers!

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Astronomy: Telescope

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रात्री सहज कधी फिरायला गेलो की आपली नजर सहज आकाशाकडे जाते. आकाशात चंद्र, तारे तसेच ढग सहज नजरेस पडतात. शहरात असाल तर दिसणाऱ्या ताऱ्यांची संख्या फारच कमी असते आणि जे दिसतात त्यातले काही टीम टीम करतांना दिसतात तर एखाद दुसरा तसा दिसत नाही. कधी चंद्र आपल्याला कोजागिरी पौर्णिमे सारखा खूप प्रकाश देतो तर कधी फक्त चंद्रकोर दिसते.

तुम्ही या सर्वांकडे पाहून लगेच उत्सुक होऊन प्रश्न विचारायला लागाल की काही तारे कमी दिप्तीमान (less bright) का दिसतात तर काही खूपच का जास्त दीप्तीमान (more bright) दिसतात. त्यातले काही twincle का करतात तर काही एकदम स्थिर का असतात. चंद्राचा तसेच ताऱ्यांचा प्रकाश नेमका कुठून येतो आणि ते आपल्या पासून किती दूर आहेत. शहरापासून दूर गेलात जिथे एकदम काळोख आहे तिथे तुमची उत्सुकता शिगेला जाईल कारण तुम्हाला अजून खोलवर आणि जास्त प्रश्न विचारावेसे वाटतील. काही तारे निळसर, काही लालसर तर काही एकदम पांढरे शुभ्र का दिसताय. अजून बारीक नजरेने बघितलं तर असही विचाराल की एक दोन ठिकाणी खूप साऱ्या ताऱ्यांचा गुच्छ दिसतोय ते काय आहेत. ज्या प्रकारे आपण ढगांसोबत सोबत खेळ खेळतो आणि विचारतो की यात कोणता प्राणी किंवा कोणाचा चेहरा यात दिसतोय का. तसेच रात्री आकाशात काही काही ठिकाणी V, M, आयत, पंचकोन इ. अश्या आकारात तारे दिसतील. तर हे सर्व तारे आपल्या पासून एकाच distance वर आहेत का, आकाशात दिसणारे तारे एकाच speed ने कसे काय पूर्वे कडून पश्चिमेकडे सरकतात आणि त्या M, V, आयत, पंचकोन इ. अश्या आकारात दिसणारे तारे एकमेकांपासून दूर जातात का किंवा जवळ येतात का.

आपण सहज बोलून जातो की तंत्रज्ञान तर आता आले, आधी तंत्रज्ञान कुठे होते तरी आपले पूर्वज खूप मोठे शोध लावून गेलेत. तर ते असे कोणते शोध आहेत ज्यांचा आपल्याला विश्वास बसत नाही की तेव्हा त्यांनी हे सगळं कस काय केलं असेल असा विचार येतो.

चंद्राचं सूर्याचं आपल्या पासून कसं अंतर मोजलं असणार. चंद्राचं, पृथ्वीच, सूर्याचं मोजमाप कसं केलं असणार म्हणजेच यांचा व्यास कसा मोजला असणार. पृथ्वी ही गोल आहे ह्या मतावर कसे आले असणार. ग्रह-चंद्र-तारे पृथ्वीभोवती फिरतात की सूर्याभोवती याचा छडा कसा लावला असणार. आपल्या डोळ्यांना न दिसणारे दूरवरचे ग्रह आणि त्यांचे satellites केव्हा पासून आपण दुर्बिणीने बघायला लागलो. तर या दुर्बिणीचा शोध कधी लागला व कोणी लावला. दुर्बिणीचे प्रकार किती आणि त्या कशा काम करतात हे सर्व जाणून घेण्याची तुमची इच्छा झालीच असेल आता पर्यंत. या दुर्बिणीतून आपण किती दूरवरचे तारे बघू शकतो तसेच आपण या दुर्बिणीच्या मदतीने किती zoom करु शकतो असे अनेक प्रश्न सहज मनात येतात. आपल्याला या सर्व प्रश्नांचा वेध घ्यायचा आहे.

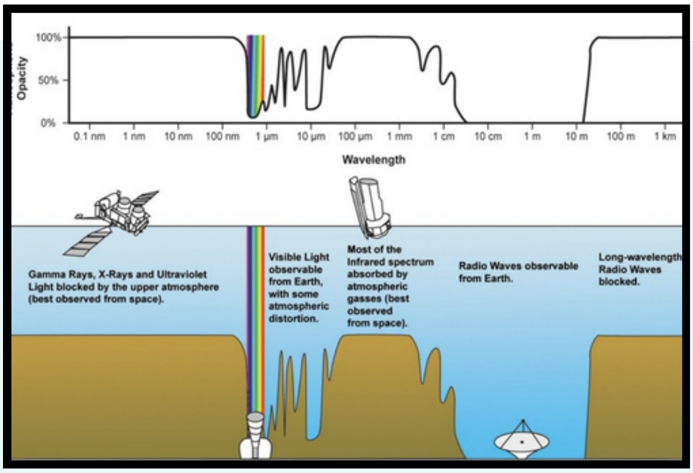

Fig-1: Atmospheric Windows

दुर्बिण नव्हती तेव्हा डोळ्यांनी जितकं शक्य होईल तितकं आकाशात दिसणाऱ्या ताऱ्यांचा अभ्यास केला गेला. त्यामुळे तो अभ्यास फक्त Optical wavlenegth पर्यंत सिमित होता. तसेच दूरवरुन येणाऱ्या सर्व wavelengths आपल्या पर्यंत पोहचू शकत नाही. काही विशिष्ट wavelengths (जसे Optical आणि radio waves) फक्त जमिनीपर्यंत पोहचू शकतात. त्यामुळे ground based telescopes हे मुख्यत्वे Optical आणि radio telescopes असतात. याला Atmospheric Window असे म्हणतात (उदा. Fig-1). त्यामुळे इतर wavelengths मध्ये बघण्यासाठी space based telescopes वापरले जातात.

सर्वात आधी दुर्बिण कशी काम करते आणि कोणकोणत्या प्रकारच्या दुर्बिणी असतात हे बघुयात.

दुर्बिणी मुख्यतः दोन प्रकारच्या असतात. दूरवरुन येणारा प्रकाश कोणत्या पद्धतीने focus केला जातोय त्या वरुन दुर्बिणी चा प्रकार ठरतो. जेव्हा येणारा प्रकाश हा lenses च्या मदतीने focus केला जातो तेव्हा त्या प्रकारच्या दुर्बिणींना refracting दुर्बिण (Refracting Telescope) म्हणतात. जेव्हा mirrors वापरुन प्रकाशाला focus केले जाते तेव्हा त्यांना reflecting दुर्बिण (Reflecting Telescope) म्हणतात (उदा. Fig-2).

Telescope दूरवरुन येणारा प्रकाश गोळा करतो आणि त्याच्या focal plane वर एक image बनवतो. येणारा प्रकाश जितका जास्त गोळा करता येईल तितकं आपण अधिक clear आणि दूरवरच बघू शकतो. यासाठी telescope च्या mirror/lenses चा व्यास (diameter) जितका जास्त तितका जास्त फायद्याचा.

खूप मोठ्या diameter चे lenses बनवण्यापेक्षा मोठे mirrors बनवणे अधिक सोपे. खूप आधी refracting telescope वापरले जायचे. पण Chromatic किंवा spherical abberations तसेच खूप मोठ्या lenses न बनवता येणं या त्यांच्या काही limitations मुळे त्यांचा वापर कमी होत गेला. त्यानंतर reflecting telescope चा वापर वाढत गेला आणि त्यांचे वेगवेगळे designs अस्तित्वात आले. Reflecting Telescopes चे वेगवेगळे design concave, convex, plane, hyperbolic, spherical mirrors यांच्या combinations मधून अस्तित्वात आलेत.

Telescope हा फक्त एक mirror वापरून तयार केला तर telescope ची लांबी ही primary mirror च्या focal length इतकी होईल. आणि ती 1-2 meter पर्यंत लांब असु शकते. Telescope compact करण्यासाठी दोन mirrors चा उपयोग केला जातो. एक मोठा primary mirrors आणि दुसरा लहान secondary mirror. Primary हा मुख्यत्वे concave mirror असतो आणि secondary mirror हा एकतर concave, convex, plane किंवा hyperbolic shape मध्ये असू शकतो. Newtonian, Cassegrane, Schmidt-Cassegrain, Ritchey-Chrétien,

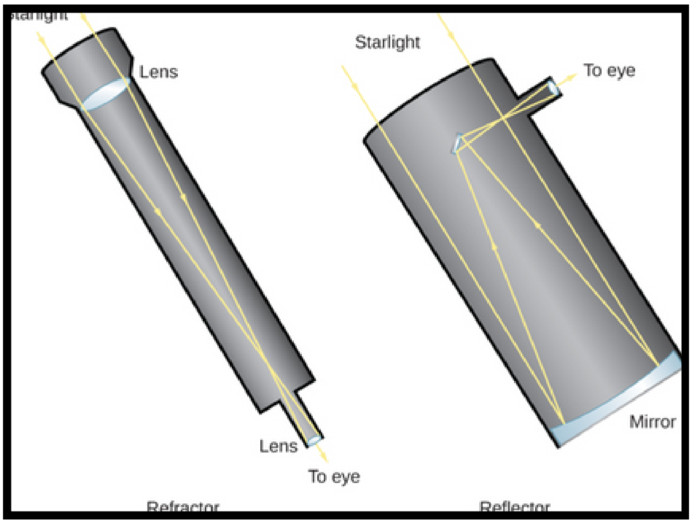

Fig-2: Refracting and Reflecting Telescope.

Grogorian हे त्यातले काही प्रकार.

Type	**Primary Mirror**	**Secondary Mirror**
Newtonian	Concave	Plane
Cassegrane	Concave	Convex
Schmidt-Cassegrain	Concave	Convex
Ritchey-Chrétien	Concave	Hyperbolic
Grogorian	Concave	Concave

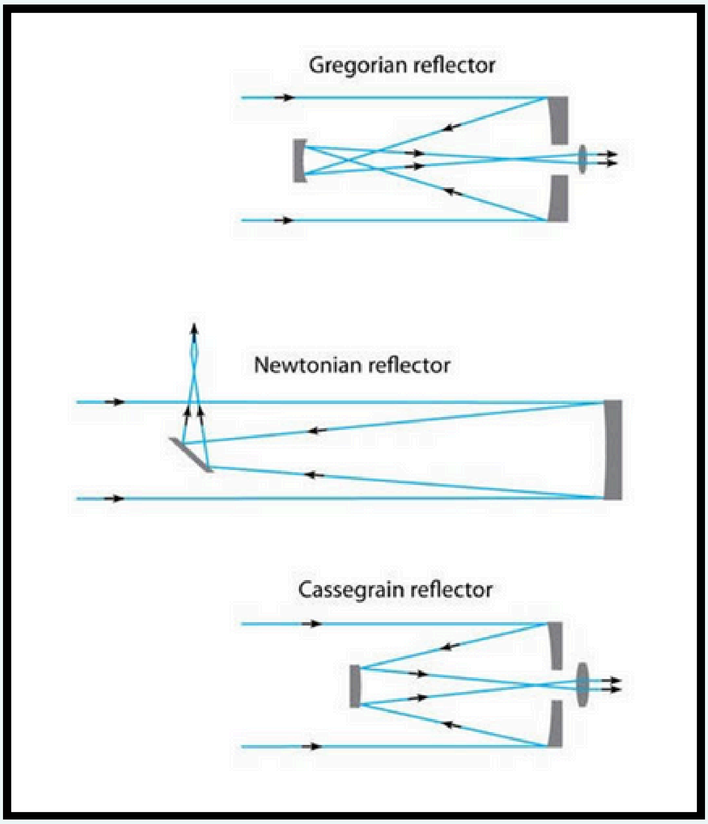

Fig-3: Different optical designs for optical telescopes.

Schmidt-Cassegrain हा मुख्यत्वे Cassegrane design आहे त्यात फक्त एक corrector plate जोडलेली असते. या corrector plate मुळे spherical abberations कमी होतात आणि Secondary mirror ला एक support ही मिळतो.

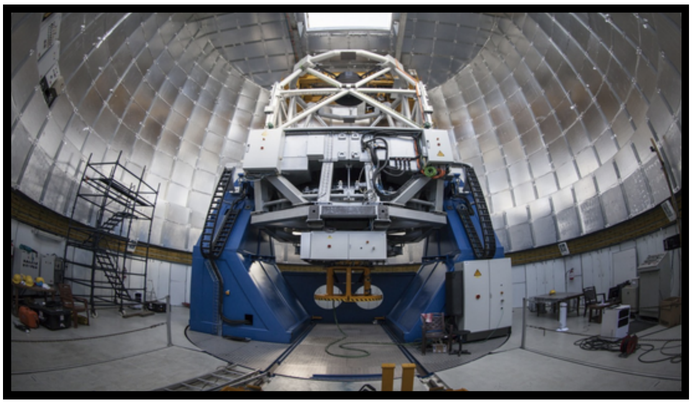

Fig-4: India's largest Devasthal Optical Telescope (DOT), Two-mirror Ritchey-Chrétien design with effective F-ratio of 9.

Telescope हा त्याच्या aperture size वरुन ओळखला जातो. जसे 1.04m Sampurnanand Telescope, 1.3m JC Bhattacharya Telescope, 2m IUCAA Girawali Telescope, 3.6m Devasthal Optical Telescope. यात 1.04 meter, 1.3 meter, 2 meter, 3.6 meter हा त्या-त्या telescope च्या primary mirror चा diameter आहे. ह्या पेक्षा ही मोठ्या aperture size चे telescope बनवण्यासाठी एका पेक्षा जास्त segmented mirrors एकत्र करून एक मोठा mirror बनवला जातो.हे सर्व आपण Optical telescope संदर्भात बोललो. इतर wavelengths मध्ये radio, X-ray, gamma-ray यांच्यासाठी वेगळ्या designs चे telescope असतात. Telescope च्या Resolution, F-ratio बद्दल तसेच इतर wavelengths च्या telescopes बद्दल पुढच्या article मध्ये सविस्तर चर्चा करुयात.

Web Links:

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- https://www.iiap.res.in/centers/vbo/
- Eyes on the Sky: The story of telescopes by Biman Nath:
- https://www.arvindGuptatoys.com/arvindGupta/vp-eyes-in-sky.pdf

Kiran completed his M.Sc. in Physics at MES's Nowrosjee Wadia College during the academic year 2016-17. He successfully cleared the MAH-SET and CSIR-NET examinations, which paved the way for his doctoral journey at the Aryabhata Research Institute of Observational Sciences (ARIES), Nainital, Uttarakhand. His doctoral thesis, titled Studies of Flux and Spectral Variability of Blazars, reflects his focus on understanding the dynamic behavior of these astronomical objects. Recently, Kiran has embarked on his post-doctoral career as a fellow at the Indian Institute of Astrophysics, located in Koramangala, Bengaluru.

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Self-supported Biomass Derived Carbon for Advanced Multifunctionality

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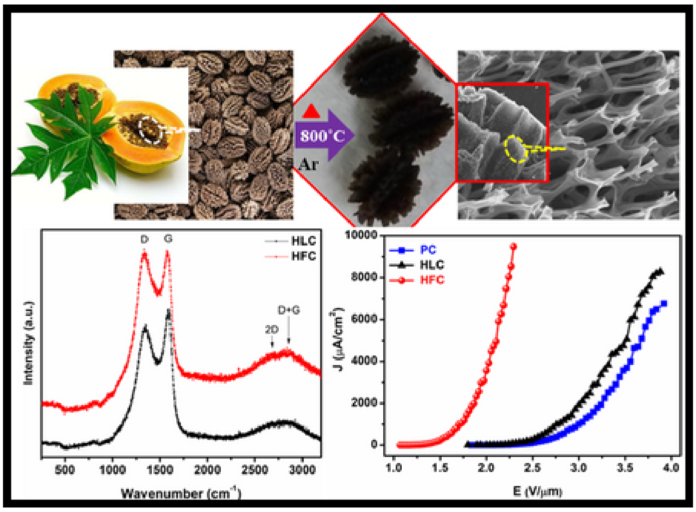

Fig-1: Self-supported biomass derived carbon for advanced multifunctionalty

Conventional porous carbon materials, typically produced through hydrothermal methods followed by controlled biomass pyrolysis, often consist of small, isolated particles. This fragmentation restricts electron and ion pathways, posing challenges to forming a self-supporting matrix. To address these limitations, the creation of a self-supported carbon network through the pyrolysis of selectively chosen biomass introduces a ground breaking and sustainable strategy for advanced material design. This technique highlights the versatility of carbon networks in energy storage and field emission applications, underlining the importance of biomass selection. The intrinsic qualities of the biomass—such as high carbon content, structural integrity, and compatibility with pyrolysis conditions—play a decisive role in determining the structure and function of the resulting carbon framework.

This study specifically employs Carica papaya seeds as a biomass precursor due to their favorable attributes. Pyrolysis conducted at 800°C under an argon atmosphere for varying durations results in the formation of interconnected, shape-preserving structures with self-supported architectures. These frameworks exhibit exceptional mechanical robustness and stability, serving as the foundation for multifunctional material applications.

Furthermore, the carbon network is subjected to selective interfacial modification through the in situ growth of calcium fluoride (CaF_2) and fluorine doping (F-doping). This approach leads to the formation of semi-ionic C–F bonds, optimal F doping levels, reduced work function, and increased interlayer spacing, culminating in enhanced field electron emission properties, greater specific capacity, and improved cycling stability compared to amorphous carbon.

Field emission studies revealed turn-on field values of approximately 2.16 V/µm and 1.21 V/µm at an emission current density of ~10 µA/cm² for the as-prepared carbon and F-doped carbon, respectively. Notably, the F-doped carbon exhibited a high emission current density of ~9.49 mA/cm² under an applied electric field of ~2.29 V/µm, indicating superior field emission performance. These heterostructures demonstrate enhanced electron transport efficiency and stability under high current densities, advancing the boundaries of vacuum electronics.

Additionally, supercapacitor studies highlight the multifunctionality of these materials. The F-doped carbon electrode exhibits a specific capacitance of

234 F/g at 0.5 A/g, underscoring its effectiveness in energy storage applications. To evaluate practical performance, a symmetric coin cell supercapacitor device (HFC//HFC) was fabricated, demonstrating the applicability of the hybrid structures for real-world energy storage solutions.

This comprehensive study integrates sustainable synthesis methods and advanced interfacial engineering, offering a forward-looking perspective for developing materials with multifunctional capabilities, particularly in the fields of field emission and energy storage.

The author serves as an Assistant Professor of Physics at Nowrosjee Wadia College, Pune. With expertise in Nanomaterials, Supercapacitors, and Energy Storage Devices, the author is actively contributing to advanced research in these fields.

Stealth Technology in Advanced Fighter Aircrafts

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Fighter aircrafts (FAs), which are one of the marvels of science and engineering, are designed primarily for air-to-air combat as well as precision ground attacks. The new generation FAs are armed with advanced avionics, superior electronics and highly developed weaponry. However, one mother-of-all-invention in the technology in 90s, has made these machining marvels the deadliest. It is the stealth technology (ST), also known as low observable technology, designed to make the advanced FAs almost invisible to even advanced detection systems such as radio detection and ranging (RADAR) and infrared detection (ID). Now imagine a FA, with deadliest arsenal of bombs and missiles, with no to little observability, coming for the attack. Quite a scary picture, isn't it!

There are quite a few countries which have stealth FAs viz. USA (B2 Spirit, F-117 Nighthawk, F-22 Raptor), Russia (Su-57), China (J-20 Chengdu). India too has started an ambitious indigenous project of stealth FAs, that is, Advanced Medium Combat Aircraft (AMCA) with Hindustan Aeronautics Limited (HAL), expected to be ready by 2035.

What is important for FAs to be stealthy?

There are two fronts for FAs to appear to be stealthy:

1. Radar Cross-Section Reduction: Also known as RCS Reduction, it is the RADAR detection value, need to be as small as possible. RCS is measured in sq-m and for FAs like F-117 it is 0.003 sq-m while for Su-57 it is 0.1 sq-m. To compare, a pigeon has RCS value of 0.01 sq-m on RADAR while an insect has 0.001 sq-m. So, FAs like F-117, though appears on the RADAR as an insect, obviously has a much more stinging capability than it!

Fig-1: Image of Su - 57

2. Infrared Signature Reduction: The minimum IRSR increases the survivability of FAs. The stealth FAs should have minimum IR radiation (heat) emission so that the IR sensors don't read them. The ultra-low IRSR is also important to avoid the IR homing1(guiding) missiles. The IR wavelength band of 3-5 µm range is minimized or blocked for the detection of heat signatures.

Fig-2: Image of F - 117

What makes the FAs stealthy? The stealthiness of the FAs depends on following factors:

1. Shape of FAs: Shapes of FAs are uniquely aerodynamic than that of their conventional counterparts. The shapes are more abrupt, angular and faceted to minimise the RADAR reflections or to increase the RADAR deflections in different directions.

2. Coatings on surfaces: Stealth FAs are coated with special Radar Absorbing Materials (RAMs) viz. light carbon-graphite composites and carbon-polymer coatings.

3. Internal weapon system: To further reduce the RCS and IR signatures, the weapons are

Fig-3: Image of B - 2

concealed inside the aircraft.

4. Specially designed engines: Special turbofan engines are used in stealth FAs high efficiency and thrust ratio. In B2 like FAs, the engines are buried in the wings. Such arrangements significantly reduce both RCS as well as IR signature.

How to detect stealthy FAs? Stealth FAs are not totally invincible in spite of their advantages.

1. Multi-RADAR networks: The FAs having stealth features can be detected in triangular RADAR network system which follows the aircraft consistently for longer period of time. Very High Frequency (VHF) RADARs and Active Electronically Scanned Array (AESA) RADARs are proving very helpful in early detection of stealth FAs.

2. Infrared Search and Track: The IRST systems with AI advancements are proving to be worthy to locate the stealth FAs.

Author is Assistant Professor in Physics at Nowrosjee Wadia College, Pune and Research Expert in thin film memristor devices. He is also the Associate NCC Officer (ANO) of Air Force Wing of NCC detailed at 3 Maharashtra Air Squadron NCC Pune.

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The Role of Density in Flying and Space Travel

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Introduction

In this article, the concept of density how it was unknowingly applied in historical times, even before the scientific principles were fully understood, and how it continues to play a major role in modern fields such as the aerospace industry.

Archimedes

We don't know exactly how scientists discovered every concept, but we do have some fascinating stories about them. The most famous and universally known is the story of Isaac Newton. Newton was sitting under a tree when an apple fell on his head. He wondered why it fell straight down and this curiosity led him to discover gravity, a force that pulls all objects toward each other. Similarly, we have an interesting story about how Archimedes discovered the concept of density.

Archimedes was a brilliant scientist and mathematician in Ancient Greece, around 287 BC. He was known for his groundbreaking work in physics, geometry, and engineering. One day, King Hiero II of Syracuse commissioned a crown and wanted to test its purity. He assigned this task to Archimedes. As the story goes, one day while stepping into his bathtub, Archimedes noticed water spilling over the sides. He realized that when he entered the tub, he displaced water and the amount displaced depended on his volume, not just his weight.

Inspired by this, Archimedes tested the crown by comparing it to a block of pure gold of the same weight. He gently lowered both into water and observed how much water was displaced.

Guess what?

The crown displaced more water than the gold block. This meant the crown was less dense, suggesting it had been mixed with a lighter metal like silver. Archimedes had solved the mystery and proved that the goldsmith had been dishonest.

From this experiment, Archimedes formulated his famous principle of buoyancy, which states:

"A body submerged in a fluid experiences an upward force equal to the weight of the fluid it displaces."

Now, some people believe these stories are true, while others think they were created to make scientific concepts easier and more interesting for children.

But one thing is certain:

The science is real. The story might be romanticized. But the impact? 100% true.

Historic

Chhatrapati Shivaji Maharaj's Naval Prowess & Shipbuilding:

Chhatrapati Shivaji Maharaj was one of the first Indian rulers to recognize the importance of a strong navy. He built forts along the Konkan coast and developed a fleet of ships that could move fast and handle rough seas.

His ships were made from carefully chosen wood like teak or sal strong, yet less dense than water making them float easily and resist decay. Artisans knew, through experience, which materials floated better, could carry cannons or soldiers, and wouldn't sink even when damaged. That's density in action!

Ships were designed with wide hulls and balanced weight, making them buoyant and stable essential for speed and combat. Even though they didn't use Archimedes' equation, their understanding of material behavior in water showed practical knowledge of buoyancy and density.

Density in Aeroplane Flight

Aeroplanes use the principle of air density to generate lift. As air flows over the curved upper surface of the wing, it moves faster and becomes less dense compared to the slower, denser air below the wing. This difference in pressure creates an upward force called lift, allowing the plane to rise. Engineers also select materials with low density like aluminum alloys to make the aircraft strong but lightweight. Jet fuel is chosen for its ideal density, providing high energy while keeping the aircraft's weight manageable.

Use of density in aerospace industry

1. Fuel Density: Power vs Lightness

NASA chose different fuels based on how dense they were.

- The first stage of the rocket used kerosene (RP-1) — a dense fuel.
- Dense fuels give more power in a smaller space — great for lifting the rocket off the ground!
- The upper stages used liquid hydrogen — a low-density fuel.
- It's very light, so it worked well in space where they didn't need as much force.

Nasa had to balance:

- How much energy they got
- How heavy the fuel was
- How far they needed to travel

2. <u>Material Density: Strong But Light</u>

The rocket had to be strong enough to survive the trip, but also light enough to fly.

- NASA used low-density materials like aluminum — light and strong
- In certain parts, they used titanium, which is denser but stronger — only where needed

They used materials with the right density to:

- Keep the rocket stable
- Carry more weight (like astronauts and moon landers)
- Save fuel

3. <u>Re-entry: Air Density Saves Lives</u>

When the Apollo capsule came back from the Moon:

- It hit Earth's atmosphere at 25,000 mph.
- The upper atmosphere is thin (low density), so it didn't slow the capsule much.
- But deeper down, the air gets denser, which helped slow it down.

More dense air = more resistance = safe landing

NASA used heat shields that burned away slowly to protect the capsule from the heat caused by the dense air.

4. <u>In Space: Tiny Density Changes Matter</u>

Even in space, there's still a little bit of air.

- NASA had to keep track of air density at high altitudes
- If it changed, it could slow satellites or affect how the rocket moved
- They adjusted the path to keep everything on track

Why Density Mattered So Much?

From liftoff to landing, NASA used density to:

- Choose the right fuel
- Pick the best building materials
- Control reentry safely
- Guide the rocket in space

Conclusion

From floating ships to space rockets, density has played a key role throughout history. It shows how a simple idea can lead to great discoveries and still guides the science of today and tomorrow.

Note: India's Mangalyaan (Mars Orbiter Mission) also used the same idea of density in smart ways. To keep the spacecraft light and affordable, ISRO chose the right kind of fuel and materials. They used fuel that gave good power without being too heavy, and built the orbiter using light but strong materials. This helped it travel all the way to Mars using less fuel just like NASA did with their rockets!

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The Unexpected Possibility of Teleportation

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Introduction

The idea of teleportation has always been fascinating, and since we've seen various scenes in movies and other animations, it has left us with enthralling thoughts on teleportation. In fictional contexts, teleportation usually refers to the transportation of a 3-dimensional object (for example, the Anywhere Door in Doraemon).

However, the reality is a lot different. In the case of Quantum Teleportation, it does not involve the transportation of any physical object.

What is Quantum Teleportation?

(The quantum state of a particle can be transmitted from one location to another without physically moving the particle.)

So lets understand this in a simple way. Well understand this from our story.

Cast: Doremon, Nobita, Shizuka

One day, Nobita wants to give his note to Shizuka, but he doesn't want to travel to her house. So he asks Doraemon for help. Doraemon agrees and gets his gadget out — his gadget uses biscuits! (*These are entangled qubits.*)

He explains that these biscuits come in pairs: if you do something to one, the other reacts, no matter the distance between them.

- Now one part of the biscuit is given to Shizuka.
- The other remains with Nobita. (*These biscuits are connected or entangled in a way.*)

Nobita holds one part in his hand along with his note. He shakes his hands twice — and **the biscuit and the note are crushed.**

Shizuka flips the part of the biscuit she holds, and **BOOM**, the note appears.

So from this we understand that

- The message didn't fly across the air to reach the destination
- The original note was actually destroyed but same appeared in front of Shizuka

This is **Quantum Teleportation**

Qubits: Qubits or Quantum Bits are basic units of information in quantum computing. Qubits can be entangled with each other. Changing one affects the other instantly, no matter the distance.

The Recent Research:

- Teleportation through internet traffic (Northwestern University): The Northwestern University engineers have successfully demonstrated the Quantum Teleportation through more than 30.2 km (around 18 miles) carrying 400GBs classical data. This experiment could lead to secure communication and networks and advance control of light. They identified optimal wavelength to minimize interference from existing internet signals, ensuring successful quantum teleportation without need for dedicated infrastructure.

- **Linking Quantum Processors (Oxford University):** This study is the first demonstration of Quantum Teleportation of logical (minimum component of an algorithm). It worked with accuracy level of 86%. The team successfully teleported data using particle of light (photons).
- **Chinese Experiment (2017):** One famous experiment was done by Chinese scientist using Micius Satellite. They teleported a photon quantum state from Earth to space over 1,400 KM.

Why these Experiments Matter?

- This experiment is a step towards creating internet, an secure communication network based on Quantum Entanglement and Teleportation.
- Instead of sending photon itself, they transferred its quantum state to another photon away in distance, its a teleportation of information.
- The potential to move quantum technologies from lab experiments to real world applications.

What are the Challenges in these Experiments?

- Keeping entangled protons linked
- Measuring without breaking
- No good signal boosters
- Still needs regular internet

Imagine 2 photons are two best friends and they are holding hands and they are riding across a road where there are obstacles (YouTube and Netflix signals) and they have to dodge the obstacles and stay stable.

"Classical signals introduce noises that can overwhelm quantum states" - Northwestern News

Guess What?
Quantum Teleportation relies on entanglement, which Einstein ones called "spooky action at a distance" - turns out, he was right.

Interesting!
So when am I getting teleported??
Uhhh....lets stick to teleporting the photons for now

What is the future of teleportation?
Well sadly we still don't have an anywhere door to just teleport from the 4 walls of our room ta a beautiful lakeside view or a beach most probably, nor do the right machine which could make this possible. Imagine trying to teleport a human? that would require copying every atom and quantum state over 10^{28} particles, damn, that's a lot of work for the scientists. But take a look on the positive side, we have achieved transfer of quantum information, isn't it fascinating too? It's more useful to have a free world tour by teleporting ourselves.

Conclusion
Well! Well!
Teleporting light by internet and linking quantum processors, that's so cool as if it works like a instant way of teleportation. Light transportation is the transfer of photons using entanglements and classical communication. These experiments are still in the early stages of developments and are potentially a lot beneficial in future. Scientist have shown quantum teleportation over increasing distance including optical fiber, free space and even satellite link an in future we would see many examples of these experiments.

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Frozen Light: The Quantum Breakthrough That Paused the Universe's Fastest Traveller

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Fig-1: Illustration of Frozen Light

As we advance in the world of technology, countless innovations continue to reshape our understanding of the universe. Yet, amidst these breakthroughs, questions persist—doubts that linger when the boundaries of research seem to reach their limits. It is precisely at these moments that physics steps in, revealing phenomena that defy our imagination.

Imagine witnessing a firework explode in the night sky, its vibrant burst frozen mid-air, suspended in time as if the universe itself had hit the pause button. Now, picture that same sensation, with light—the very essence of speed and energy. This isn't a scene from a sci-fi movie; it's the Unbelievable reality that Italian scientists achieved on March 5, 2025. They successfully "froze" light—the fastest entity in the universe—for an astonishing 60 seconds. Yes, the very light that travels across the vastness of space in mere seconds was trapped here on Earth, defying its inherent speed and nature.

Light is known for its incredible speed, traveling at an astonishing 300,000 kilometers per second (186,000 miles). But in a recent experiment, scientists led by Antonio Gianfante (CNR Nanotec) and Davide Nigro (University of Pavia) managed to slow it down to a mere 17 meters per second—a feat that defies the laws of nature as we know them. This incredible achievement was made possible inside a specially prepared medium designed to manipulate light's behavior in ways never seen before.

The key to this breakthrough was the use of a control laser. Scientists directed this laser to alter the quantum state of a material, making it appear transparent to another laser known as the Probe laser (a probe laser is a laser beam used to examine or measure the properties of a medium or system, typically without causing significant changes to those properties). This clever trick created a mirage-like effect, allowing the light to pass through the material without being absorbed. Instead of moving freely, the light's wave-like properties were forced to spread out across the entire medium.

But the real magic happened when the control laser was switched off. At that moment, the scientists effectively "trapped" the light's energy inside the medium, freezing it in time as if the light itself had been paused. Even more astonishing is that this stored energy wasn't lost. When the scientists activated it again, the light was "revived," appearing as if it had never been frozen in the first place.

"This is only the beginning," stated lead researcher Antonio Gianfante from CNR Nanotec. This experiment is more than just a scientific curiosity—it's solid proof that quantum science is real. It shows that the universe operates at the fascinating intersection of wave and particle duality, where light can behave both as a wave and a particle simultaneously. This breakthrough opens up mind-bending possibilities for the future—so mind-bending, in fact, that it might just make you scratch your head until you discover a new type of quantum energy. Could this lead to advanced quantum memory storage, next-gen optical computing, or even quantum transport? Or are we just one "Eureka!" moment away from even greater discoveries? In the end, we just have to stop believing in magic and start believing in physics—because physics is the real magic. It's like the universe's way of saying, "Surprise!"—turning the impossible into something you can't help but stare at in awe.

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Quantum Warfare: The Next Frontier

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A world where particles can be in two places at once and communicate instantly across vast distances. This isn't science fiction-it's the mind-bending reality of **quantum mechanics**, a field that's reshaping technology as we know it. Unlike everyday physics, where things exist in fixed states, quantum systems can exist in multiple states at once **(superposition)** and stay mysteriously connected no matter how far apart they are (entanglement). These strange yet powerful concepts are driving the rise of Quantum Technology, a game changer set to revolutionize warfare, communication, and national security.

What is Quantum Technology?
Imagine a world where messages are impossible to hack, computers solve puzzles faster than a million normal ones, and sensors can detect the tiniest hidden things.

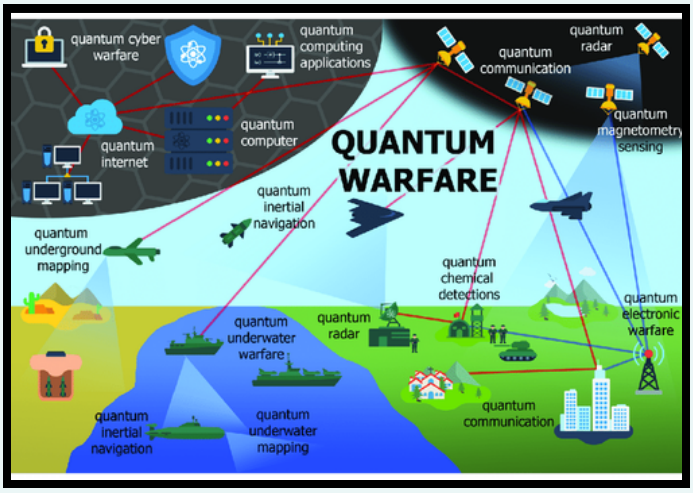


Fig-1: Image of Quantum Warfare

That's quantum technology!! It includes **quantum communication** (like secret messages that can't be copied), quantum sensing (super-precise detectors, like a superhero's x-ray vision), **quantum computing** (a brain that solves the hardest puzzles in seconds), and **quantum materials & devices** (magic-like materials that can change how we see and use technology).

1. Quantum Communication & Quantum Key Distribution (QKD)

Quantum Communication ensures secure data transmission using the principles of quantum mechanics. At the heart of this is Quantum Key Distribution (QKD), which allows two parties to share encrypted information that is impossible to intercept without detection.

How does QKD work?

QKD uses photons (particles of light) to transmit encryption keys. If an eavesdropper attempts to intercept these keys, the quantum state of the photons is altered, alerting both the sender and receiver. This ensures complete security and makes quantum communication virtually unhackable

Real-world example:

Countries like China and India are already testing QKD in satellites to establish secure communication channels for military and

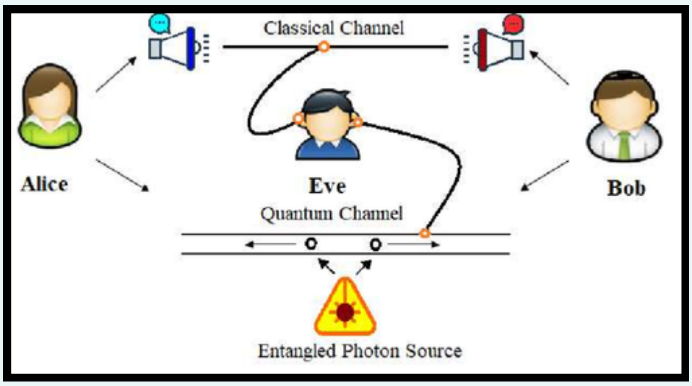


Fig-2: Image of Quantum Communication

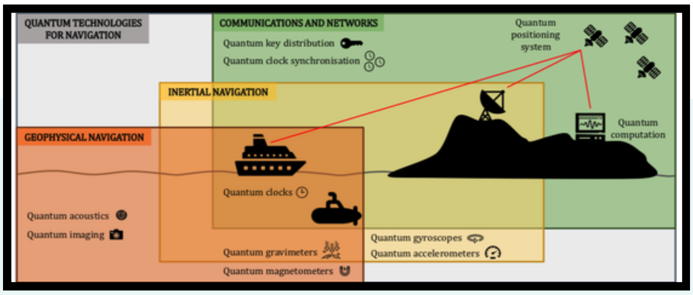
governmental use. The Indian Space Research Organisation (ISRO) successfully demonstrated QKD over 300 km, paving the way for secure military communications.

2. Quantum Sensing

Quantum Sensing leverages quantum effects to create highly sensitive detectors. These sensors are crucial in modern warfare as they can detect submarines, stealth aircraft, and underground facilities with unmatched accuracy.

Military Application:

- **<u>Submarine Detection:</u>** Quantum magnetometers can detect minute variations in the Earth's magnetic field, making it nearly impossible for enemy submarines to remain hidden.
- **<u>Radar Enhancement:</u>** Quantum radar uses entangled photons to detect stealth aircraft, rendering traditional stealth technology ineffective.



3. Quantum Computing:

Quantum Computing is set to revolutionize data processing. Unlike classical computers that rely on binary (0s and 1s), quantum computers use qubits, which can exist in multiple states at once. This allows quantum computers to solve problems exponentially faster than traditional computers.

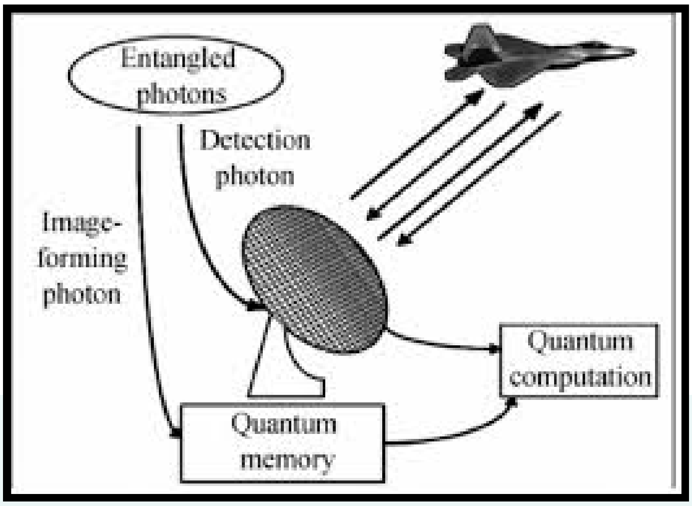
Implications for Warfare:

- **<u>Breaking Encryption:</u>** Quantum computers can crack modern encryption methods in minutes, posing a significant cyber security threat.
- **<u>Optimizing Military Strategies:</u>** AI-powered quantum computers can simulate battle scenarios in real time and suggest the best tactical approaches.

4. Quantum Materials and Devices

Advanced quantum materials are enabling the development of cutting-edge military technology, including:

- Quantum Radar for stealth detection encryption keys. If an eavesdropper attempts to intercept these keys, the quantum state of the photons is altered, alerting both the sender and receiver. This ensures complete security and makes quantum communication virtually unhackable



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2. Quantum Sensing

Quantum Sensing leverages quantum effects to create highly sensitive detectors. These sensors are crucial in modern warfare as they can detect submarines, stealth aircraft, and underground facilities with unmatched accuracy.

Military Application:

- **Submarine Detection:** Quantum magnetometers can detect minute variations in

the Earth's magnetic field, making it nearly impossible for enemy submarines to remain hidden.

- **Radar Enhancement:** Quantum radar uses entangled photons to detect stealth aircraft, rendering traditional stealth technology ineffective.
- Superconductors for faster electronics and energy-efficient weaponry
- Next-gen night-vision systems for enhanced battlefield awareness

These materials provide militaries with enhanced precision, communication, and efficiency in combat situations.

Threats of Quantum Technology & Possible Solutions

Major Threats:

- **Quantum Decryption:** Future quantum computers may break current encryption, putting global cyber security at risk.
- **Quantum Cyber Warfare:** Nation-states could use quantum-powered attacks to disrupt critical infrastructure.
- Ethical Concerns: Unchecked quantum advancements might lead to an arms race, increasing geopolitical tensions.

Solutions & Countermeasures:

- Post-Quantum Cryptography (PQC): Researchers are developing new cryptographic algorithms resistant to quantum attacks.
- Quantum-Resistant Networks: Governments and private institutions are investing in quantum-secure networks for defense purposes.
- International Regulations: Global cooperation

is necessary to regulate the ethical use of quantum technology in warfare.

India's Quantum Leap: T-Hubs Leading the Way

India is making significant strides in Quantum Technology under the **National Quantum Mission** launched in 2023. Leading research institutions such as:

- Tata Institute of Fundamental Research (TIFR)
- Indian Institute of Science (IISc)
- Raman Research Institute - ISRO & DRDO

Are spearheading innovations in quantum computing, communication, and sensing. With quantum-secure satellites and military applications in development, India is positioning itself as a global leader in quantum defense technology.

Quantum Technology: The Future of Modern Warfare

The battlefield of the future will be defined by speed, secrecy, and intelligence-all of which quantum technology can provide. Quantum-guided drones, AI-assisted military strategies, and secure quantum communication will dictate the outcome of conflicts. Nations that invest in quantum capabilities today will dominate warfare, cyber security, and intelligence in the years to come. With India making rapid progress in this field, the next decade will be crucial in shaping the global defense landscape.

Conclusion

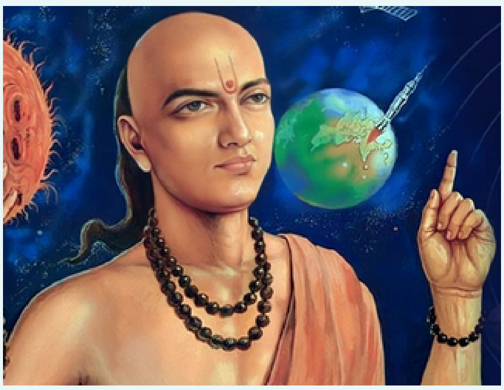
The Quantum Revolution is here, and it's not just science fiction anymore-it's rewriting the rules of security and warfare! With quantum tech evolving at lightning speed, we're looking at a future filled with both mind-blowing possibilities and head-scratching challenges. To stay ahead, we need to build hack-proof quantum networks, next-level cryptography, and smart rules **because the last thing we want is a quantum-powered cyber heist or a teleporting hacker!!**

Jai Hind

Beyond Zero

Kiran Choudhary, SYBSc Physics Major

Department of Physics, MES's Nowrosjee Wadia College, Pune 411 001



Aryabhatta one of the greatest mathematician and astronomer of India. The first Indian satellite in 1975 was named after Aryabhatta. Mostly people know him for the invention of number zero. But there is lot more than zero, his discoveries were beyond zero.

Aryabhatta was born in the 5th century during the golden ages of India 'Gupta Dynasty' in Patliputra which is Patna in present day. The most important work of Aryabhatta is Aryabhattiya which contains astronomy, astrophysics and mathematics which he had written when he was only 23 years old. There were other two books of him 'Arya Siddhanta' and 'Al nanf' which are lost but few phrases were referred by different astronomers and mathematician. Only Aryabhattiya was well preserved as it is which was written by Aryabhatta 1500 years ago. The text consists of 108 verses and 13 introductory verses and is divided into 4 padas or chapters.

1.Gitikapada-Discoveries about planetary and time computations. The very fundamentals of mathematics are described in this chapter :

- Methods of writing numbers
- Units of measurement of time
- Calculations of Earth's rotation

And many more

2.Ganitapada-Inventions about mathematics for astrophysical computations.

- Geometrical principles
- Arithmetic progression
- Indeterminate equation

And many more

3.Kalakriyapada-Discoveries about planetary positions and motion

- Measurement of time
- Determining planetary positions
- Determining days of week

And many more

4.Golapada-Inventions about geometric and trigonometric concepts.

- Trigonometric principles
- Motions of planets
- Geospatial computations

And many more

His major contributions to mathematics were:

- Aryabhatta provided an approximation of π (pi) as 3.1416, which was remarkably close to the actual value. He stated that π is an irrational number, which was later confirmed by modern mathematicians.
- He introduced trigonometric functions such as sine (called "jya" in Sanskrit). He also developed methods for solving quadratic equations and worked on arithmetic progressions.

His major contributions in astronomy were:

- Centuries before Copernicus, Aryabhatta proposed that the Earth rotates on its own axis, which explains the apparent movement of celestial bodies in the sky. Also known as heliocentric theory.
- He correctly explained that lunar eclipses occur due to the Earth's shadow falling on the Moon and solar eclipses occur when the Moon blocks the Sun's light. This was contrary to the prevailing mythological beliefs at that time.
- Aryabhatta calculated the sidereal rotation of Earth (the time it takes for Earth to complete one rotation relative to the stars) and provided a close approximation to modern values.

Aryabhatta's work had a profound impact on Indian and global mathematics. His ideas were later adopted by Persian and Arab scholars, influencing medieval European mathematics.

Aryabhatta was not just a mathematician and astronomer; he was a thinker who changed the way people understood the world. His ideas about the Earth's rotation, the value of pi, and the place-value system were far ahead of his time. His work influenced generations of scholars and laid the foundation for many scientific discoveries. Even today, his contributions remind us of the power of curiosity and the importance of questioning the unknown. Aryabhatta's legacy proves that knowledge has no boundaries, and his discoveries were much more than just zero.

Dark Energy: The Mysterious Force That's Expanding the Universe

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For a long time, scientists believed that the universe's expansion, which started with the Big Bang, would eventually slow down due to gravity. But in 1998, something shocking was discovered: the universe isn't slowing down—it's speeding up! This mysterious force that causes galaxies to move away from each other at an increasing rate is called dark energy. Scientists don't know exactly what it is, but they believe it makes up around 70% of everything in the universe.

How Did Scientists Discover Dark Energy?

To understand dark energy, scientists studied supernovae—massive exploding stars that shine brightly for a short time. By measuring their brightness, astronomers could tell how far away these stars were and how fast the universe was expanding at different points in time. What they found was unexpected. Instead of slowing down, the expansion of the universe was getting faster. This meant that something unknown was pushing galaxies apart. This discovery completely changed how we understand the universe.

What Could Dark Energy Be?

Since no one has directly seen dark energy, scientists have different theories about what it might be:

1. Einstein's Cosmological Constant (Energy of Empty Space):-

Albert Einstein once suggested that space itself has energy, even when it appears empty. This energy could naturally push things apart, just like we see in the universe today. Many scientists think this could be the answer to dark energy.

2. Quintessence (A Changing Energy Field):-

Another idea is that dark energy is not constant but changes over time. This means it could behave like an invisible energy field filling the universe and affecting its expansion in different ways.

3. A New Understanding of Gravity:-

Some researchers think that maybe our current understanding of gravity is incomplete. Instead of dark energy, what if gravity works differently on very large scales? Some theories suggest that a modified version of gravity could explain why the universe is expanding faster.

Why Is Dark Energy Important?

Dark energy isn't just a scientific curiosity—it determines the fate of the universe. There are a few possible outcomes:

The Big Freeze: If dark energy keeps pushing galaxies apart forever, they will move so far away that they won't interact anymore. Over time, the universe will become cold, dark, and empty.

The Big Rip: If dark energy gets stronger, it could eventually tear galaxies, stars, planets, and even atoms apart!

The Big Crunch (Unlikely but Possible): If dark energy weakens, gravity might take over and pull everything back together, leading to a massive collapse.

What's Next?

Scientists are working hard to unlock the secrets of dark energy. Telescopes like the Dark Energy Survey and the Euclid Space Telescope are mapping the universe to find more clues. Even though we can't see or touch dark energy, its effects shape everything around us. Understanding it could help us solve one of the biggest mysteries in science—what will happen to the universe in the end?

Bioluminescence: The Physics Behind Nature's Glow

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Imagine walking along a beach at night and seeing the waves glow with a soft blue light, or watching fireflies blink gently in the dark. This magical glow is called bioluminescence — the ability of living organisms to produce their own light. While it feels like something out of a fantasy story, bioluminescence is very real and beautifully explained by physics.

So, what exactly is happening when an organism glows? Inside their bodies, a special chemical reaction takes place between a light-producing molecule called luciferin and an enzyme named luciferase. When these two react, often in the presence of oxygen, energy is released. But instead of turning into heat like in a fire or a light bulb, this energy is released as light. That's why we call it

Fig-1: Bioluminescence Phenomenon seen in Water Body

cold light — almost no heat is produced, making it incredibly efficient. This process connects directly to the physics of light and energy. The energy from the reaction excites the molecules, raising their electrons to a higher energy level. But excited electrons can't stay up there forever. As they return to their normal state, they release the extra energy as photons — tiny packets of light.

The colour of the light depends on how much energy is released. This is explained by the simple physics formula $E = hf$, where E is the energy of the photon, h is Planck's constant, and f is the frequency of the light. Higher energy gives off blue or green light, while lower energy might produce yellow or red. That's why most marine organisms glow blue-green, which travels best through water.

Bioluminescence is not just beautiful — it's useful too. Deep-sea fish use it to attract prey, communicate, or hide from predators using tricks like counter-illumination. Fireflies flash their lights to find mates, while glowing plankton may help confuse attackers.

Even scientists are learning from this natural glow. Bioluminescence is now used in medical research,genetic studies, and ideas for energy-efficient lighting. All of this is powered by the same basic physics principles of energy transformation and light emission. in the end, bioluminescence is more than a pretty light — it's a glowing example of how life and physics work hand in hand, lighting up the darkness in the most amazing ways.

Particle Creation by Black Holes: A Review of Hawking Radiation

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Introduction

Black holes were traditionally thought to be perfect absorbers, but Stephen Hawking's groundbreaking work in 1975 showed that they emit radiation due to quantum effects. This phenomenon, known as Hawking radiation, has deep implications for black hole thermodynamics and quantum mechanics.

This review provides an overview of its theoretical foundation, key results, and implications.

Theoretical Foundations

- Black Hole Event Horizon and Quantum Fields: A black hole is described by the Schwarzschild metric, which defines the event horizon as the boundary beyond which nothing can escape. Near this horizon, quantum field fluctuations constantly produce particle-antiparticle pairs. Normally, these pairs annihilate each other, but in curved spacetime, one particle can escape while the other falls into the black hole, leading to observable radiation.

- Hawking's Quantum Analysis: Hawking used quantum field theory in curved spacetime to analyze how particles behave near a black hole. He employed the concept of Bogo Liubov transformations, which relate quantum states at different times. The result showed that an observer at infinity would detect a blackbody radiation spectrum with Hawking temperature:

$$T = \frac{\hbar C^3}{8\pi G M k_B}$$

Implications of Hawking Radiation:

Black Hole Evaporation: Since Hawking radiation leads to energy loss, black holes slowly shrink and can eventually evaporate completely. The rate of mass loss is given by:

$$\frac{dM}{dt} \sim -\frac{\hbar c^4}{G^2 M^2}$$

For stellar-mass black holes, this process is negligible, but for small black holes, it could be significant.

The Black Hole Information Paradox: Hawking radiation appears to be purely thermal, carrying no information about the black hole's original state. This raises the question of whether information is lost when a black hole evaporates, contradicting principles of quantum mechanics. Various theories, including quantum gravity and string theory, attempt to resolve this paradox.

Experimental Prospects:
While direct detection of Hawking radiation from astrophysical black holes remains infeasible, analogous effects have been demonstrated in lab systems—such as Bose-Einstein Condensates – which simulate the physics of event horizons.

Conclusion:
Hawking radiation revolutionized our understanding of black holes, linking gravity, thermodynamics, and quantum mechanics. It introduced profound questions about information loss and black hole evolution, driving ongoing research in theoretical physics.

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Shankar Abaji Bhise: The Edison of India

BHOUTIKI

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Shankar Abaji Bhise, often referred to as the "Edison of India," was a self-taught inventor whose contributions to science and technology remain a testament to ingenuity and perseverance. Born on April 29, 1867, in Bombay (now Mumbai), Bhise's journey from humble beginnings to becoming one of India's most prolific inventors is truly inspiring.

Shankar Abaji Bhise

Early Life and Education

Bhise's father, Abaji, worked in the legal profession, but Shankar's interests lay elsewhere. Despite limited formal education, he exhibited an innate curiosity for science and engineering. As a teenager, he avidly read Scientific American and conducted experiments, laying the foundation for his inventive career.

Inventions and Achievements

Around 1897, a magazine called 'Inventor Review and Scientific Record' announced a competition for designing a 'self-measuring machine.' A self-measuring machine refers to a device that could measure and dispense items like sugar, flour, etc., in the exact quantity desired by the customer. Shankarrao created a blueprint for such a machine and submitted it to the magazine. At that time, Shankarrao's design secured the first prize. This marked the beginning of Shankar Abaji Bhise's career as an inventor.

Bhise's inventive spirit led him to create over 200 devices, with 40 of them patented. His creations spanned diverse fields, including printing, transportation, agriculture, and medicine. Some notable inventions include:

- Station Indicator: A device for railways that displayed the station of halt, passed stations, and estimated time to the next station.
- Spirit Typewriter: A modification of the Ouija board that printed messages onto paper.
- Atomidine: A patented iodine-based medicine promoted in collaboration with American psychic Edgar Cayce.
- Dr. Bhise had invented automatic train doors. Dr. Bhise did not patent this invention. During an exhibition in Mumbai, he presented models of these automatic doors, which won him a prize.
- Bhise Printing Machine: This revolutionary machine in printing could print 1,200 characters per minute and was first sold in 1916. He also created another machine that could produce 2,400 typesetting letters per minute.
- Other inventions included machines for making turbans, flour mills, a device for stabilizing bicycles, and the technique for transmitting photos over telegraph wires in 1906.
- He invented a peculiar small device named 'Tingi,' which allowed buttons to be attached without disturbing the ironed folds of clothing.
- In 1918, he developed solar-powered motor cars.

- He created a lamp providing ample light at ocean depths, a machine for separating gases from the atmosphere, and a device for transmitting photographs electrically between two locations.
- Novel techniques for manufacturing ceramics and cement
- Process to extract gasoline from waste products like molasses.
- He even invented a body massager that pressed nerves to relieve headaches and created mixers for grinding chutneys and similar items.
- Vertoscope: Multiple Coloured Advertisements technology.

Bhise's contributions extended beyond inventions. He volunteered during the plague management efforts in Bombay in 1896 and was honoured for his service.

Challenges and Legacy

Despite his brilliance, Bhise faced significant challenges, including racial discrimination and financial constraints. Many of his inventions struggled to gain commercial success during his lifetime. However, his work demonstrated India's potential in science and innovation, earning him recognition as a pioneer. Bhise passed away on April 7, 1935, but his legacy continues to inspire generations of inventors and scientists.

Awards and Recognitions:

- Presidency of the 'Indian Industrial Congress' held in Madras (1900).
- Gained fame as "India's Edison" through American newspapers (from 1908 onwards).
- Awarded the Doctor of Science (D.Sc.) degree by New York University (1927).
- Honored as "India's First Scientist in America" in the presence of American scientists (April 29, 1927).
- Doctorate in Psychoanalysis from the University of Chicago.
- Conferred honorary membership by the Chamber of Commerce, Mount Vernon.
- Meeting with Thomas Alva Edison in New Jersey (December 23, 1930).

Shankar Abaji Bhise's life is a reminder that curiosity and determination can overcome adversity, leaving a lasting impact on the world. His story is not just about inventions but about the spirit of innovation that uplifts humanity.

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Indian Institute of Science: A Cradle of Research and Innovation

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Indian Institute of Science

In 1893, two great personalities of Mother India, either by a mere accident or by the divine coincidence, met on a maiden voyage from Japan to Chicago. They were namely, Shri Jamshedji Tata, a visionary industrialist and a philanthropist and the other being Shri Swami Vivekananda, the philosopher monk. What transpired between these two towering personalities over a decade, sow the seeds of a massive tree named Indian Institute of Science (IISc), that is breathing scientific and research life into the society of India since the last century. Further untiring efforts from eminent personalities such as Viceroy George Curzon, then Governor General of India, Sir William Ramsay, the Noble Laureate and Maharaja Krishnaraja Wadiyar (IV), then Maharaja of Mysore, made the dream of IISc came true in 1909 at Bengaluru, Karnataka. Since its inception and even after more than a century, IISc still serves as a beacon for the high standard scientific research, technological advancements and best educational activities in India. Currently, IISc is ranked 211 in QS (Quacquarelli-Symonds) World Ranking in the world, 62nd in Asia and 1st in India by NIRF ranking.

Education at IISc: There are eight divisions in which advanced scientific research activities of IISc are carried out. They are: Division of Biological Sciences, Division of Chemical Sciences, Division of Electrical, Electronics, and Computer Science (EECS), Division of Interdisciplinary Sciences, Division of Mechanical Sciences, Division of Physical and Mathematical Sciences. Each of these divisions further contains multiple departments which run respective curriculum befitted to the parent division and current edge science. Apart from this, IISc also runs ultra-modern courses such as GIAN (Global Initiative of Academic Networks) that targets talented international scientists and entrepreneurs with the higher education institutes in India. IISc also felicitates the Centre for Continuing Education (CCE) where wards of different universities, R&D sectors and Industries can continue in their respective research by utilising the resources of the institute. Apart from this, courses generated by IISc on MOOCs (Massive Online Open Courses) platform are well received by students and teachers all over India. Admission to IISc is possible through UG Programs of BSc (Research) and BTech (Mathematics and Computing), through PG Programs such as MSc and MTech and also through PG Research Programs (Integrated PhD).

Research programs at IISc: At high-end research, the boundaries of science are merged and entangled. With over 40 research centres, IISc carries interdisciplinary collaboration across diverse domains. The primary domain is Science & Engineering that deals with core subjects such as physical/mathematical/biological/chemical and mechanical sciences covering cutting age research frontiers such as quantum mechanics, advanced mathematics, materials chemistry, quantum electronics, neuroscience, robotics etc. While the interdisciplinary domain captures the areas of bioengineering, urban infrastructure, data science, bioinformatics, nano-scaled device engineering, IoT etc. The high research quality it produces is par with any world-class university and has a great balance for theoretical and experimental work even for the cutting age research topics. In addition, it serves as a brain behind the high-quality research for industries involved in defence and infrastructure. The setups like Centre for Nanoscience and Engineering (CeNSE) and Supercomputer Education Research Centre (SERC) have reputation as one of the best facilities in the world. Their collaborative initiatives with government, industries and institutes also targets current challenges in India such as agricultural waste reduction, water management, rural upliftment, women empowerment for skills etc. Hence, IISc is truly respected for its serious research which is not flashy, but rigorously respected and quietly powerful, thus shaping India's future through nurturing its brightest minds for generations.

Institute Images

IISC Logo

Main Building, IISC

JRD Tata Memorial Library, IISC

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Image Courtesy: Indian Institute of Science, Bengaluru

Sun Spots Observation

Gauri Kulkarni, PhD
Jyotirvidya Parisansthan, Pune 411 030

During an annual event of the department, PHYSIQUEST-25, a Sun Spot Observation event was organized in collaboration with Jyotirvidya Parisanstha (JVP). Dr. Gauri Kulkarni of JVP led participants through the observation, offering valuable insights into solar activity.

Cosmic Realm

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From quarks unseen to stars so bright,
The universe hums in the waves of light.
Gravity bends the cosmic thread,
Deforming space where time is spread.

Electrons leap, a quantum flight
Vanishing here, appearing in sight.
Uncertainty rules at nature's core,
Particles spin, yet where – unsure.

Fusion ignites the stellar glow,
Fueling worlds, we'll never know.
Dark matter hides in silent grace,
Shaping the void, unseen in space.

Yet, here we stand, on Earth so small,
Bound by forces vast and tall.
From atoms born in stellar fire,
To question, wonder, and aspire.

Physics Riddles

1. I travel in waves,
   but I'm not the sea,
   you can hear me,
   but never see me.
   What am I?

2. I am distance over time,
   With direction, I make rhyme.
   Unlike speed, I point the way-
   which physics term am I today?

3. I am push or pull,
   I change how things move.
   With mass and acceleration,
   I groove.
   What am I?

4. You walk, you run, you hit, you play,
   But I make you stop, get in your way.
   Shoes grip the floor thanks to me,
   Without me, you'll slide endlessly!
   What am I?

5. I change direction when I pass,
   from air to water or through glass.
   I'm not reflection, I'm the twin-
   What am I, where light bends in

6. I'm a tiny part of matter,
   so small I can't be seen.
   Electrons and protons are part of my team.
   What am I?

7. Push me once, I push you too,
   An equal force, straight back to you.
   I action's dance, I hold my track,
   The law's truth, I give it back.
   What am I?

8. Two tiny friends, far away,
   Still act the same everyday.
   Touching one will shake the other,
   Like magic linking one to another.
   Which phenomenon am I?

Answers are Available on Page no: 34

Physics Memes

Shubham Jadhav

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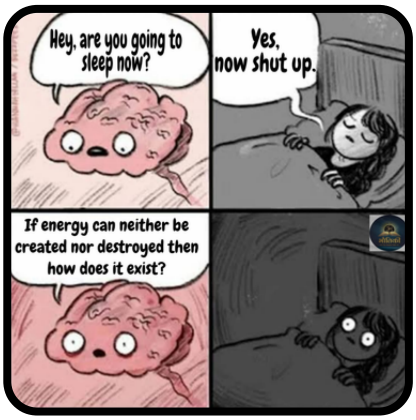

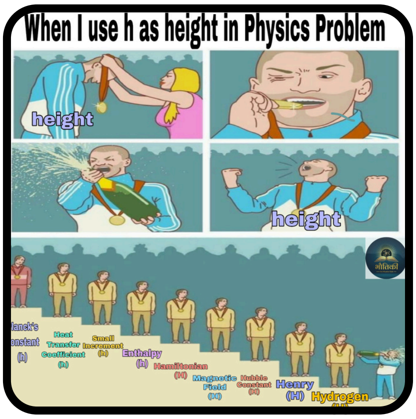

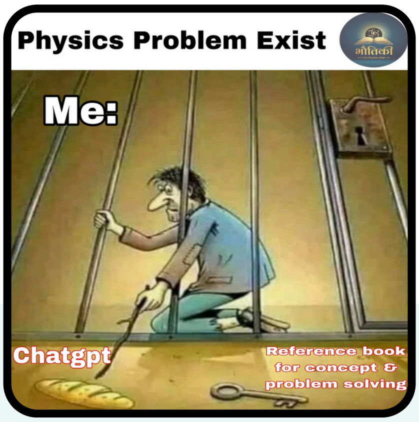

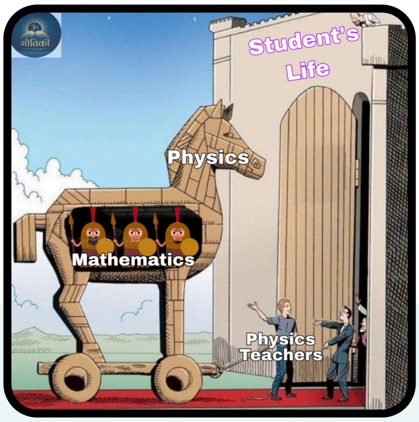

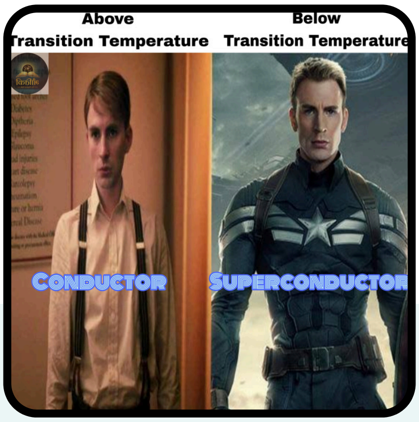

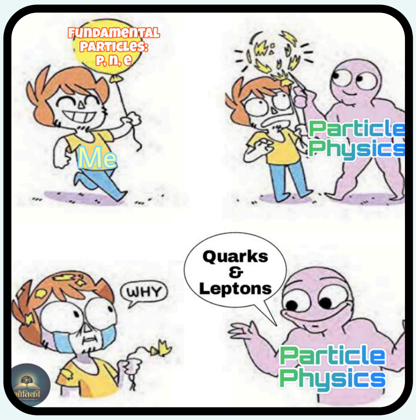

The author is an Assistant Professor in the Department of Physics at Nowrosjee Wadia College. An esteemed alumnus of our department, he specializes in Computational Physics and Theoretical Physics, while also excelling as a creative content creator.

1) Sound, 2) Velocity, 3) Force, 4) Friction, 5) Refraction, 6) Atom, 7) Newton's Third Law, 8) Quantum Entanglement


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PHYSIQUEST Winners

Exhibition Competition

Medal	UG	PG
Gold	Anurag Mehta (SYBSc) & Vidhi Baldota (SYBSc) Shivam Bitake (TYBSc) & Yash Bundile (SYBSc)	Namrata Jangam (MSc -I) Prerna Rao (MSc - I)
Silver	Kiran Choudhary (SYBSc) & Chanchal Agarwal (SYBSc) Karan Nair (TYBSc) & Sakshi Gaikwad (TYBSc)	Prithviraj Takbhate (MSc - II) Prajwal Jagtap (MSc - II)
Bronze	Atharva Randive (SYBSc) & Yashvardhan Shukla (SYBSc) Srushti Dandi (SYBSc) & Mandira (SYBSc)	

Poster Competition

Medal	UG	PG
Gold	Vidhi Baldota (SYBSc) & Anurag Mehta (SYBSc)	Prithviraj Takbhate (MSc - II)
Silver	Arnav Waghmare (TYBSc)	Pratap Lokhande (MSc - II)
Bronze	Rupali Bistchari (TYBSc) & Payal Dorle (TYBSc)	

Quiz Competition

Quiz Competition	
Gold Medal	Komal Pareek (MSc - I) Zoya Shaikh (MSc - I) Shruti Mane (MSc - I)
Silver Medal	Payal Dorle (TYBSc) Pallavi Dolas (TYBSc) Veena Aiwale (TYBSc)

Treasure Hunt

	Winners
Rank -1	Isheta Jaiswal Neelam Khandagale Namrata Pawar Tanishka Kshirsagar Kavya Jain

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