

**SIR P. T. SARVAJANIK COLLEGE OF SCIENCE
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DEPARTMENT OF PHYSICS**

SPECTRUM

2025



**INTERNATIONAL YEAR OF
Quantum Science
and Technology**

Editorial

"The 'paradox' is only a conflict between reality and your feeling of what reality 'ought to be'."

- Richard Feynman

The idea behind the SPECTRUM is to provide our readers a bunch of articles from different of Science and Technology. Especially, this magazine highlights the articles that reflects the echoes from Quantum Mechanics. We always try to include articles by which we can share knowledge, provide information about new findings or history of science, etc. This issue of the SPECTRUM contains articles about International Year of Quantum Science and Technology (IYQ) 2025: A Century of Transforming Our Understanding of Reality. The articles in this issue highlight the IYQ 2025 celebrations, a century of quantum discoveries, their technological impact and future global advancements. The magazine also contains eight another articles from students of BSc that covers the diverse areas including quantum computers, application of quantum mechanics in Lasers, LEDs, MRI machines, etc., historical aspects on the evolution of quantum physics, Quantum-Supported Safety Shoes and a Quantum-Insulated Protective Cloth, quantum communication, etc. There are articles that covers the highlights on the Nobel Prizes in Physics and Chemistry awarded in 2025. The issue also highlights the key events about Quantum Science that took place during the year 2025.

We hope you will enjoy this collection of articles. We look forward to hearing from you! We welcome your feedback and creative contribution for the magazine on specetrum@ptscience.ac.in

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1. International Year of Quantum Science and Technology (IYQ) 2025: A Century of Transforming Our Understanding of Reality

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The year 2025 marks a profound milestone in human history: the centennial celebration of quantum mechanics, a scientific revolution that reshaped our understanding of the universe at its most fundamental level. To honor this century of discovery, innovation, and technological transformation, UNESCO and the international scientific community have declared 2025 the International Year of Quantum Science and Technology (IYQ 2025). This global initiative aims to recognize the achievements of quantum pioneers, inspire the next generation of scientists, and highlight the increasing importance of quantum technologies in modern society. As we reflect on 100 years of quantum science, we not only celebrate the past but also look forward to the unprecedented possibilities of the next century.

A Year Dedicated to Quantum Science: Purpose and Global Significance

IYQ 2025 serves as a reminder of how far humanity has come in comprehending the laws that govern matter and energy at the smallest scales. One of its central purposes is to promote public understanding of quantum science—an area often perceived as abstract or inaccessible. Through global events, outreach programs, and international collaboration, IYQ 2025 seeks to bridge the gap between complex scientific ideas and the general public.

The year 2025 was chosen deliberately: it marks approximately 100 years since the pivotal developments of the 1920s, when the founding fathers of quantum mechanics formulated theories that would overturn classical physics. By dedicating this year to quantum science, the global community acknowledges the extraordinary impact quantum mechanics has had on modern technology—from lasers and transistors to MRI machines and GPS systems. In doing so, IYQ 2025 aims to foster appreciation, encourage investment, and promote scientific literacy worldwide.

The Birth of Quantum Mechanics: Breakthroughs of the 1920s

Quantum mechanics emerged at a time when classical physics could no longer explain newly observed phenomena. The journey begins with Max Planck, who, in 1900, introduced the idea of quantized energy while studying blackbody radiation. This radical proposal laid the foundation for what would become the quantum revolution.

In 1905, Albert Einstein took a daring step by explaining the photoelectric effect using the concept of light quanta—photons. This contribution earned him the Nobel Prize and signaled the beginning of a new era. However, it was the mid-1920s that truly crystallized quantum mechanics into a coherent theory.

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The Foundational Years (1924–1927)

- Niels Bohr refined the atomic model, proposing that electrons occupy discrete energy levels—a notion already radically different from classical expectations.
- Louis de Broglie introduced the revolutionary idea that particles such as electrons also possess wave-like properties, planting the seed for wave mechanics.
- Erwin Schrödinger built upon de Broglie’s insight, formulating the Schrödinger equation in 1926. This equation, the cornerstone of quantum mechanics, mathematically describes how quantum systems evolve over time.
- Werner Heisenberg created matrix mechanics, another foundational formulation of quantum theory, and soon after introduced the famous uncertainty principle, which states that certain pairs of physical properties cannot be simultaneously measured with infinite precision.
- Paul Dirac merged quantum mechanics with special relativity and predicted the existence of antimatter—later confirmed experimentally.

These pioneers, each working independently but contributing to a shared scientific revolution, laid the groundwork for a theory that not only challenged intuition but also transformed physics into a deeply probabilistic discipline. The quantum world—governed by superposition, entanglement, and uncertainty—was unlike anything imagined before.

A Century of Progress: Evolution of Quantum Science

Over the past hundred years, quantum theory has evolved from a theoretical curiosity to the backbone of modern technology. Much of today’s digital world would be inconceivable without quantum mechanics.

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Mid-20th Century Advances

The invention of the transistor in 1947, based directly on quantum principles, revolutionized electronics and paved the way for computers, smartphones, and modern communication systems. Lasers, developed in the 1960s, became essential tools in medicine, telecommunications, and manufacturing. Quantum mechanics also led to the development of nuclear magnetic resonance, enabling MRI technology that today saves millions of lives.

Late 20th Century Paradigm Shifts

In the 1980s and 1990s, scientists began exploring computation and information theory through a quantum lens. This gave birth to quantum information science, which studies how quantum systems process and transmit information. The idea of quantum entanglement—which Einstein famously derided as “spooky action at a distance”—became central to new technologies. Concepts

like quantum cryptography, quantum error correction, and quantum teleportation moved from theoretical speculation to laboratory demonstration.

The Rise of Quantum Technologies (2000–2025)

The last two decades have seen rapid advances in developing real-world quantum devices. Quantum materials, topological insulators, superconducting qubits, and trapped ions have emerged as platforms for next-generation technologies.

The maturation of quantum science over this century underscores the profound influence of the early quantum pioneers. Their abstract theories now shape industries and global policy, illustrating the enduring power of fundamental research.

Current Advances: The Frontier of Quantum Technology

The technologies driving the modern quantum revolution span several fields:

Quantum Computing

Quantum computers exploit superposition and entanglement to perform computations impossible for classical machines. Companies and research institutions worldwide—such as IBM, Google, IonQ, and major national labs—are racing to build scalable quantum processors.

Applications include:

- cryptography and cybersecurity
- drug discovery and molecular simulation
- optimization in logistics and finance
- climate modelling and material science

Although large-scale, error-corrected quantum computers are still under development, the rapid progress of recent years suggests transformative impacts ahead.

Quantum Communication

Quantum communication uses quantum states to transmit information securely. Technologies like quantum key distribution (QKD) offer theoretically unbreakable encryption, providing new tools for cybersecurity.

Countries including China, India, the United States, and the EU are building quantum communication networks, and satellite-based quantum links are becoming a reality.

Quantum Sensing and Metrology

Quantum sensors utilize phenomena such as superposition to detect minute changes in physical quantities with extraordinary precision. They have applications in medical imaging, gravitational wave detection, navigation without GPS, climate monitoring, geology and mineral exploration.

These devices promise to redefine measurement standards across scientific disciplines.

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Quantum Materials and Simulations

Quantum simulators emulate complex quantum systems, helping scientists to study high-temperature superconductors, chemical reactions, and exotic phases of matter. Such tools accelerate research in material science and energy technologies.

Societal, Economic, and Scientific Impacts

Quantum technologies are poised to become a key driver of 21st-century economic growth. Governments and industries are making massive investments, anticipating breakthroughs that could reshape global markets.

Societal Impact

Quantum technologies have the potential to:

- enhance cybersecurity and protect data privacy
- improve healthcare through precise diagnostics
- enable faster discovery of medicines
- optimize transportation systems
- accelerate scientific research

The democratization of quantum education—an important goal of IYQ 2025—ensures that societies worldwide can participate in and benefit from this technological revolution.

Economic Opportunities

According to global forecasts, the quantum technology market could reach hundreds of billions of dollars in the coming decades. Nations investing early in quantum science aim to develop high-value industries, create jobs, and secure technological leadership

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Challenges

Despite enormous promise, quantum technologies face hurdles:

- maintaining stable qubits is technically difficult
- quantum systems are prone to errors
- large-scale manufacturing remains challenging
- ethical and cybersecurity concerns must be addressed

IYQ 2025 encourages global cooperation to solve these challenges responsibly.

The Future of Quantum Science: The Next Hundred Years

Looking ahead, quantum science promises to reshape humanity's relationship with technology in ways we can barely imagine. The next century may bring:

- fault-tolerant quantum computers capable of solving humanity's grand challenges
- breakthroughs in clean energy through quantum-engineered materials
- worldwide quantum communication networks
- ultra-precise global sensing systems
- entirely new industries built around quantum devices

Beyond technological progress, the future of quantum science carries profound philosophical implications. As we deepen our understanding of the quantum world, we continue to challenge assumptions about reality, measurement, and the nature of existence itself.

IYQ 2025 reminds us that scientific curiosity is one of humanity's greatest strengths. The lessons of the last century teach us that bold ideas—however unintuitive or complex—can lead to revolutionary discoveries. The next century of quantum research may hold answers to some of the universe's deepest mysteries.

Conclusion

The International Year of Quantum Science and Technology 2025 is more than a celebration—it is a global invitation to reflect on a century of extraordinary scientific progress and to prepare for a future shaped by quantum innovation. From the pioneering discoveries of Planck, Bohr, Einstein, Schrödinger, and Heisenberg to the cutting-edge technologies of today, the quantum revolution has fundamentally transformed our world.

As nations, institutions, and individuals come together to celebrate IYQ 2025, we are reminded that science is a collective human endeavour. By embracing curiosity, supporting education, and fostering international cooperation, we can ensure that the next hundred years of quantum discovery will be just as transformative—and just as inspiring—as the first.

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2. Quantum Science 2025: The Century That Rewrote Reality

Harshit Pandey

BSc (Physics) Sem-4

In 1925, the world quietly changed. No explosions, no revolutions, no grand declarations—just a handful of equations that dared to challenge everything humanity believed about nature. A century later, as we mark the International Year of Quantum Science and Technology (IYQ 2025), we stand at the threshold of a new era built on that silent scientific rebellion. Quantum mechanics is no longer just a chapter in physics—it is the language through which the next century of innovation will speak.

Quantum theory began as a paradox: particles that behaved like waves, waves that behaved like particles, and a universe where certainty dissolved into probability. The classical world we trusted suddenly cracked open, revealing a deeper reality that was strange, beautiful, and wildly unintuitive. Yet in that strangeness, humanity found new power—the power to manipulate the fundamental building blocks of existence.

Today, quantum science is transforming from theory to technology faster than at any point in history. Quantum computers promise to solve problems that no supercomputer on Earth could ever dream of touching—designing medicines atom-by-atom, simulating climate with absolute precision, or breaking codes that were once considered unbreakable.

Today, quantum science is transforming from theory to technology faster than at any point in history. Quantum computers promise to solve problems that no supercomputer on Earth could ever dream of touching—designing medicines atom-by-atom, simulating climate with absolute precision, or breaking codes that were once considered unbreakable. Quantum networks envision communication channels where information is protected not by firewalls, but by the laws of physics themselves. Quantum sensors aim to detect the faintest signals—from gravitational waves to early-stage diseases—ushering in a world where invisibility becomes impossible.

But the real magic of quantum science lies beyond machines. It lies in the radical shift of perspective it forces upon us. Quantum mechanics teaches us that reality is not fixed but fluid, not deterministic but dynamic. A particle can exist in many states at once. An action here can influence something lightyears away. And the observer is never separate from the observed. In a time where humanity often thinks in binaries and absolutes, quantum science reminds us that the universe thrives in possibilities.

As young thinkers, creators, and learners, we inherit not only the achievements of the past hundred years but also the responsibility of shaping the next hundred. Quantum science is no longer the playground of theorists—it is the canvas on which future technologists, engineers, biologists, and philosophers will design the world.

The last century gave us the fundamental rules. The next century asks us how boldly we are willing to use them. 2025 is not just a celebration of quantum mechanics—it is a reminder that the future is built by those who dare to question reality itself.

3. IYQ 2025

Dhruvi Kevat
BSc (Chemistry) Sem-2

What is IYQ?

IYQ was established to mark the centennial (100-year) anniversary of the initial development of quantum mechanics, the fundamental theory that describes the behavior of matter and energy at the atomic and subatomic scales.

Quantum mechanics is crucial because its principles are foundational to many modern technologies used every day, including:

- Smartphones and computers
- Lasers and LEDs
- MRI machines
- GPS receivers and telecommunications equipment

Purpose of IYQ 2025

The year-long initiative is a global effort to celebrate the contributions of quantum science to technological progress and address the widening gap between the global North and South in quantum research and innovation. Key goals include:

- Increasing public understanding of quantum science and its transformative potential.
- Fostering international collaboration and building capacity in science education and research.
- Inspiring the next generation of diverse quantum pioneers, especially women, to pursue careers in STEM fields.
- Highlighting quantum technology's role in developing sustainable solutions for global challenges like climate change, energy production, and public health.

4. A Quantum Expedition: Exploring the Frontier of Reality

Archna Vora
MSc (Physics) Alumni

The development of Bohr's atomic model, while insightful, necessitated further advancements. The year 1925 witnessed the emergence of Heisenberg's matrix mechanics and Schrödinger's wave mechanics, providing powerful mathematical frameworks for describing quantum phenomena. This First Quantum Revolution led to transformative technologies like lasers, transistors, and MRI.

This essay chronicles the evolution of quantum mechanics, beginning with the challenges faced by classical physics in explaining blackbody radiation. Planck's revolutionary concept of energy quantization, followed by Einstein's explanation of the photoelectric effect, marked the initial steps towards a new understanding of the microscopic world. The development of Bohr's atomic model, while insightful, necessitated further advancements. The year 1925 witnessed the emergence of Heisenberg's matrix mechanics and Schrödinger's wave mechanics, providing powerful mathematical frameworks for describing quantum phenomena. This First Quantum Revolution led to transformative technologies like lasers, transistors, and MRI. The Second Quantum Revolution, currently underway, focuses on manipulating and controlling individual quantum particles, promising revolutionary advancements in quantum computing, communication, and sensing. This essay highlights the profound impact of quantum mechanics on our lives and the exciting potential for future breakthroughs in this field.

In 1897, the Scottish-Irish physicist William Thomson, Lord Kelvin, known for his effective contribution in the field of thermodynamics, including the invention of the international system of absolute temperature - the Kelvin scale and for his significant work in electricity, magnetism, and telecommunications that marked his age, concluded that, "There is nothing new to be discovered in physics now. All that remains is more and more precise measurement." However, in the 20th century his positivistic outlook was impugned when new fields like Quantum Mechanics and Relativity emerged.

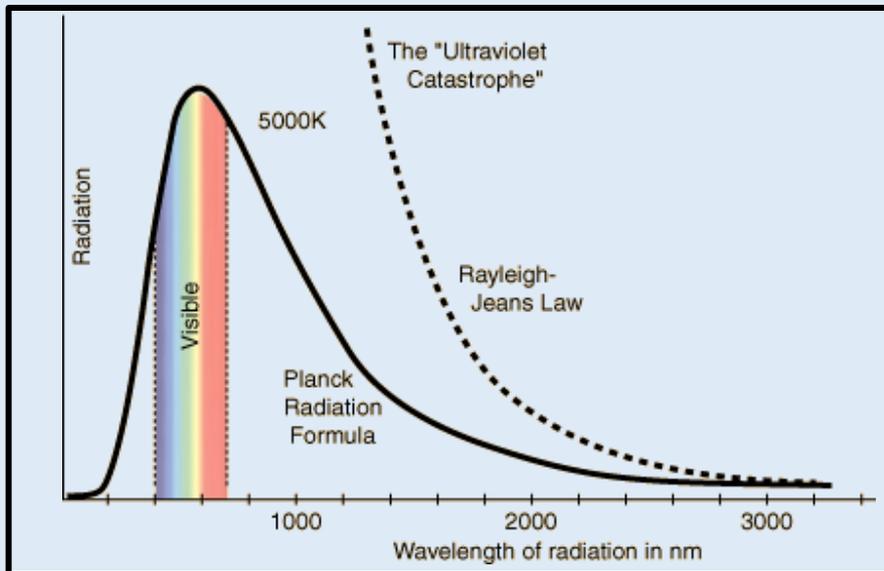
But what laid the foundation of Quantum Mechanics?

Its origin can be traced back to the date when explaining the shape of Blackbody Spectrum was elusive. This problem was examined at the end of nineteenth century by Lord Rayleigh and James Jeans. Their classical approach could provide explanation for the nature of curve only at lower frequencies.

At the ultraviolet end of the spectrum, **Rayleigh Jeans formula**

$$u(\nu)d\nu = \bar{\epsilon}G(\nu)d\nu \frac{8\pi kT}{c^3} \nu^2 d\nu$$

predicts that the energy density should increase as ν^2 . In the limit of infinitely high frequency, $u(\nu)d\nu$ should go to infinity. But in reality, the radiation rate falls to 0 as $\nu \rightarrow \infty$. This discrepancy was termed as *Ultraviolet Catastrophe* of classical physics.



Blackbody spectra

It was in 1900, The German Physicist Max Planck with his *Planck radiation formula*

$$u(\nu)d\nu = \frac{8\pi h}{c^3} \frac{\nu^3 d\nu}{e^{\frac{h\nu}{kT}} - 1}$$

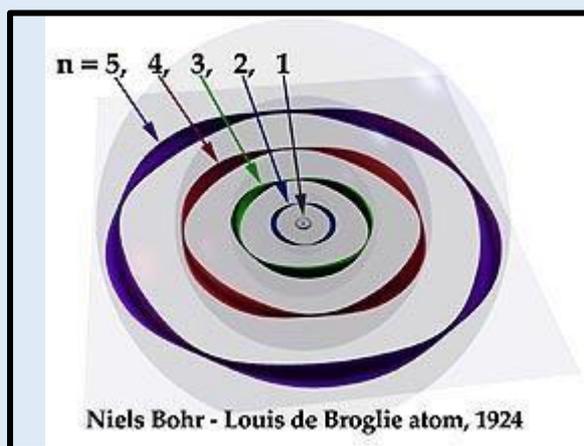
gave the correct explanation for the nature of radiation emitted by the bodies of matter. His revolutionary assumption that, “Energy is not emitted or absorbed continuously, but in discrete wave packets called *quanta*.” was a radical departure from the classical physics. He himself was sceptical for a long time of the physical reality of *quanta*.

Also, when Hertz performed an experiment on electromagnetic waves, Hertz didn’t follow up his observation on the spark that occurred in the air gap of the transmitter when UV light was directed at one end of the metal balls. It was soon discovered that those sparks were electrons which were emitted when the light of sufficiently high frequency falls on the transmitter. The famous photoelectric effect was demonstrated from the same work that proposed that light is a form of electromagnetic wave. It was Einstein who in 1905 used the radical postulate of energy quantization $E = h\nu$ proposed by Planck to explain the photoelectric effect. This quantum theory of light embarked the beginning of Quantum Mechanics.

At one end, while physicists were making significant strides in understanding the wave-particle duality of light, describing the structure of an atom proved to

“Energy is not emitted or absorbed continuously, but in discrete wave packets called *quanta*.” was a radical departure from the classical physics.

be a significant challenge. This followed the failure of Rutherford's planetary model of an atom. In 1913, the Danish physicist Niels Bohr proposed a semi classical model of an atom that combined classical and modern notions. He postulated that electrons circle around a nucleus in those orbits in which they do not emit radiation and also postulated the quantization of angular momentum. De Broglie's hypothesis of matter waves, which suggested that particles like electrons could exhibit wave-like properties, provided crucial support for Bohr's quantization of electron orbits and laid the groundwork for a more complete understanding of atomic structure.

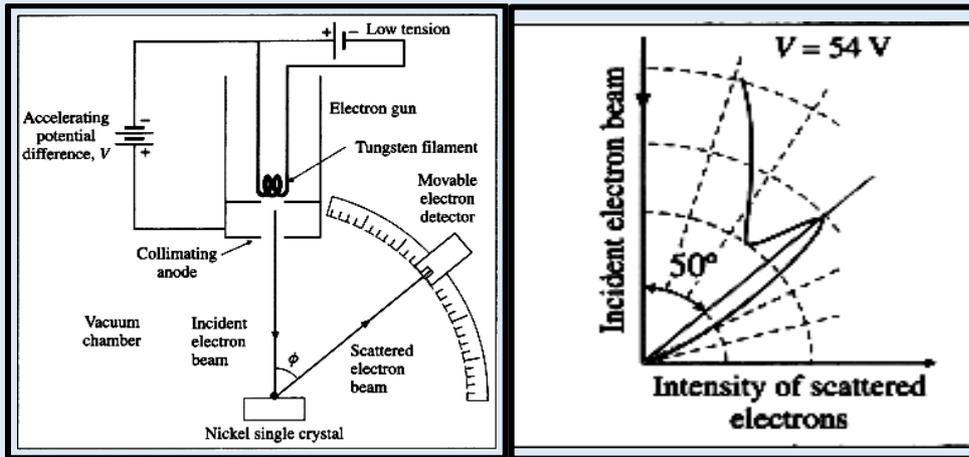


The understanding of the discrete nature of the microscopic world significantly advanced with the introduction of the concept of matter waves and the quantization of energy, supported by de Broglie's hypothesis of electron waves forming stable orbits.

De-Broglie hypothesis: a correction to the Bohr's model of an atom

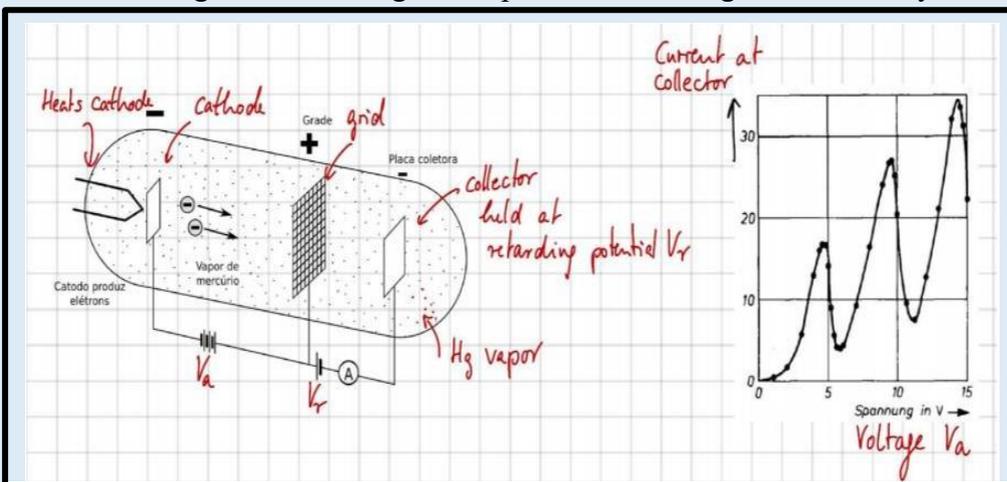
The understanding of the discrete nature of the microscopic world significantly advanced with the introduction of the concept of matter waves and the quantization of energy, supported by de Broglie's hypothesis of electron waves forming stable orbits. This quantization was experimentally verified by Davisson and Germer's demonstration of the wave nature of electrons and the Frank-Hertz experiment for studying atomic spectra. However, Bohr's model proved inadequate in fully explaining experimental observations such as the fine structure of the hydrogen atom, the Zeeman effect (splitting of energy levels in a magnetic field), and the Stark effect (splitting of energy levels in an electric field).

The Bohr-Sommerfeld model, while attempting to explain the Zeeman Effect, relied on direct postulations of selection rules of "allowable orbits" for electrons. It successfully explained the hydrogen atom spectrum and the Stark and ordinary Zeeman effects. However, it encountered difficulties with hydrogen molecule and collective effect of group of atoms with multiple electrons.



Davisson-Germer's experiment

To address the limitations of existing models, a pivotal shift occurred in 1925, marking the birth of modern Quantum Mechanics. This transformative year witnessed two ground-breaking developments that emerged concurrently.

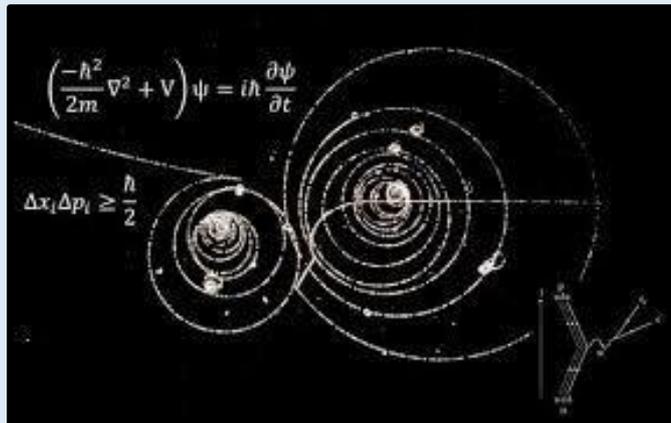


Frank-Hertz experiment

Firstly, in July 1925, a young and brilliant physicist named Werner Heisenberg, then just 23 years old, submitted a ground-breaking paper to the esteemed *Zeitschrift für Physik* journal. Titled "On quantum-theoretical reinterpretation of kinematic and mechanical relationships," this paper presented a radical new approach to understanding the behaviour of subatomic particles. Heisenberg, recognizing the limitations of classical physics in describing the atomic realm, proposed a revolutionary framework that abandoned the familiar concepts of position and momentum as precisely defined quantities. Instead, he focused on observable quantities, such as the frequencies and intensities of emitted radiation, and introduced a new mathematical formalism based on matrices to represent these observables. This bold step, though initially met with some scepticism, laid the foundation for what would become known as **matrix mechanics**, a powerful tool for describing and predicting the behaviour of quantum systems. Simultaneously, Erwin Schrödinger, inspired by the ground-breaking work of Louis de Broglie on the wave-particle duality, embarked on a parallel path

Heisenberg, recognizing the limitations of classical physics in describing the atomic realm, proposed a revolutionary framework that abandoned the familiar concepts of position and momentum as precisely defined quantities

towards understanding the quantum world. De Broglie's revolutionary hypothesis, suggesting that particles could exhibit wave-like behaviour, profoundly influenced Schrödinger's thinking. Drawing upon this profound insight, Schrödinger developed a powerful mathematical framework that elegantly described the behaviour of quantum systems in terms of wave functions. This ground-breaking work, culminating in the formulation of the *Schrödinger equation*, provided an alternative yet equally powerful approach in understanding quantum phenomena. The Schrödinger equation, with its elegant mathematical form, proved to be remarkably successful in predicting the behaviour of atoms and molecules, providing a deeper understanding of the underlying principles governing the quantum realm.



YEAR 1925

The emergence of these two distinct yet ultimately equivalent approaches – Heisenberg's matrix mechanics and Schrödinger's wave mechanics – marked a turning point in our understanding of the atomic world. This period of intense intellectual activity in 1925, fuelled by the brilliant minds of these young physicists, ushered in a new era of quantum physics, laying the groundwork for numerous technological advancements that shape our world today.

The journey from Planck's radiation law to Schrödinger's equation, often termed the *First Quantum Revolution*, signifies a profound paradigm shift in our comprehension of the microscopic realm.

The journey from Planck's radiation law to Schrödinger's equation, often termed the *First Quantum Revolution*, signifies a profound paradigm shift in our comprehension of the microscopic realm. This era witnessed a radical departure from the classical understanding of the universe, revealing that the behaviour of atoms and subatomic particles deviates significantly from the macroscopic world we experience daily. This period of intense scientific inquiry laid the foundation for ground-breaking technologies, including *lasers, transistors, semiconductors, and Magnetic Resonance Imaging (MRI)*, all born from the profound insights gleaned from this exploration of quantum mechanics.

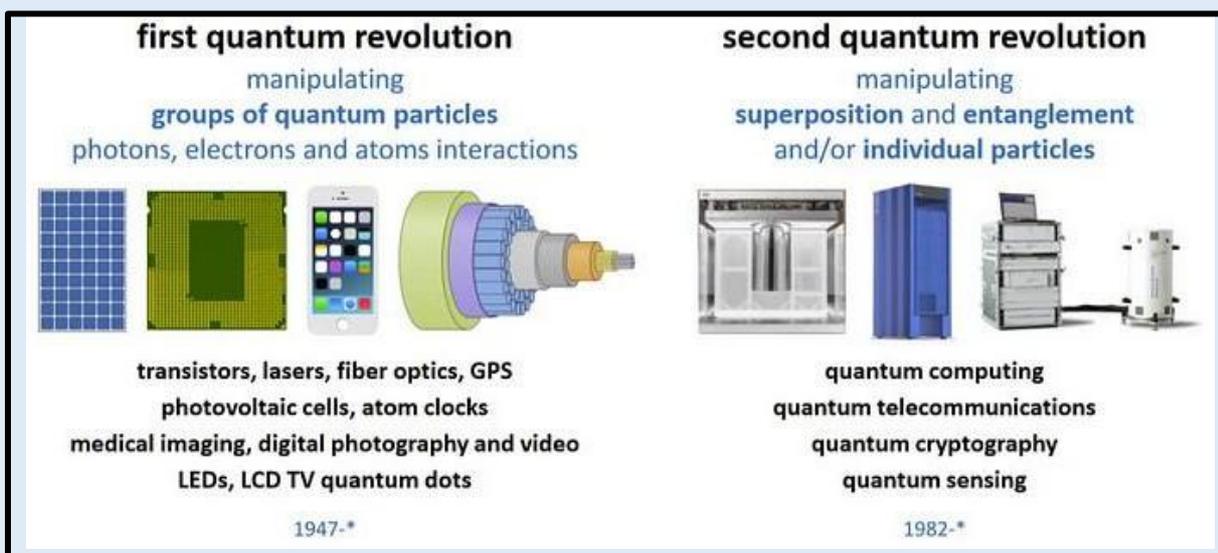
Lasers, for instance, harness quantum mechanical principles such as *stimulated emission* to generate highly coherent and intense beams of light. These beams find diverse applications across various fields, ranging from medical procedures like cancer treatment and eye surgery to revolutionizing telecommunications through fiber-optic communication. Similarly, transistors, the bedrock of

modern electronics, are deeply influenced by quantum phenomena like *tunnelling and energy quantization*, which govern the movement of electrons within these devices. This quantum influence is increasingly crucial as we push the boundaries of technology, paving the way for advancements in quantum computing and telecommunications.

Magnetic Resonance Imaging (MRI), another cornerstone of modern medical technology, relies heavily on quantum mechanical principles. *The underlying principle of MRI, nuclear magnetic resonance, exploits the quantum property of nuclear spin.* When placed in a strong magnetic field, atomic nuclei with non-zero spin align in specific orientations. By manipulating these spins using radiofrequency pulses and detecting their subsequent relaxation processes, MRI generates detailed images of internal organs and tissues. This technology has revolutionized medical diagnostics and treatment planning, providing invaluable insights for diagnosing a wide range of diseases, from brain tumours to musculoskeletal disorders.

The technologies born from the First Quantum Revolution have fundamentally transformed our lives, driving advancements in medicine, communication, computing, and countless other fields. The *Second Quantum Revolution* marks a significant turning point in our understanding and interaction with the quantum world. Built on the foundational discoveries of early 20th century physicists, this revolution moves beyond simply observing quantum phenomena. It empowers us to directly influence and guide the behaviour of individual quantum particles. This newfound control unlocks the potential for revolutionary technologies that were once confined to the realm of imagination.

Magnetic Resonance Imaging (MRI), another cornerstone of modern medical technology, relies heavily on quantum mechanical principles. *The underlying principle of MRI, nuclear magnetic resonance, exploits the quantum property of nuclear spin.*



Quantum Revolution

Quantum communication explores the possibility of ultra-fast information transmission, potentially revolutionizing how we connect and share information. Furthermore, quantum sensing enables the development of highly sensitive devices with applications in medicine, environmental monitoring, and other fields.

The Second Quantum Revolution is characterized by modern notions such as quantum computing, which leverages superposition and entanglement to solve problems beyond the reach of classical computers, finding applications in fields like drug discovery and materials science. Quantum communication explores the possibility of ultra-fast information transmission, potentially revolutionizing how we connect and share information. Furthermore, quantum sensing enables the development of highly sensitive devices with applications in medicine, environmental monitoring, and other fields. Additionally, fields like quantum metrology and quantum simulation hold immense potential to reshape our world by enabling unprecedented levels of precision in measurements and providing powerful tools for understanding complex systems.

The Second Quantum Revolution, the ongoing era of quantum technology development, is a testament to the brilliant minds that have pushed the boundaries of our understanding.

- Isaac Chuang has been instrumental in advancing quantum algorithms, error correction, and nuclear magnetic resonance quantum computing, laying the groundwork for practical quantum devices.
- David Deutsch is a visionary who proposed the first universal quantum computer and the Deutsch-Jozsa algorithm, demonstrating the computational supremacy of quantum systems.
- Peter Shor's seminal Shor's algorithm, a quantum algorithm for integer factorization, has the potential to revolutionize cryptography and cybersecurity.
- Alain Aspect conducted pioneering experiments in quantum optics, including crucial tests of Bell's inequalities, providing strong evidence for the counterintuitive phenomenon of quantum entanglement.

Serge Haroche developed innovative techniques for trapping and manipulating individual atoms, enabling precise measurements and control of quantum systems.

And let's not forget Richard Feynman, a giant of 20th century physics. While not directly associated with the term "Second Quantum Revolution", but his seminal work was foundational. *Feynman's path integral formulation of quantum mechanics and his insightful lectures on quantum computing in the 1980s* provided the theoretical framework and inspiration for many of the advancements we see today. He essentially planted the seeds for the quantum computing revolution that is now unfolding.

In conclusion, while quantum mechanics may seem like a complex and abstract concept, it's actually deeply connected to our everyday lives. From the smartphones we use constantly to the advanced medical technologies that improve our health, quantum principles are at work. Understanding the

significant impact of quantum mechanics on our world highlights the importance of continued research and exploration in this field. As we delve deeper into the mysteries of the quantum world, we have the potential to unlock even more transformative innovations that will shape the future of humanity. These may include the advancement of quantum computers that can solve problems beyond the reach of today's most powerful machines, leading to breakthroughs in fields like medicine, materials science, and artificial intelligence. The future of quantum mechanics holds immense promise, and continued research in this field will undoubtedly shape the course of human progress for generations to come.

*"The universe is not only queerer than we suppose, but queerer than we can suppose."
- J.B.S. Haldane*

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5. IYQ 2025: Inspiring the Next Generation of Quantum Thinkers

Yadav Bhargavkumar
BSc (Mathematics) Sem-2

Quantum mechanics explains the behaviour of atoms, electrons, photons, and all the fundamental building blocks of matter. Unlike classical physics, where objects behave in predictable ways, the quantum world is full of surprises.

The year 2025 has been declared the International Year of Quantum Science and Technology (IYQ 2025), marking a global celebration of one of the most fascinating and influential fields of modern science. Quantum science—which studies the behaviour of the tiniest particles of nature—has already transformed the world around us, and its future promises even greater wonders.

Quantum mechanics explains the behaviour of atoms, electrons, photons, and all the fundamental building blocks of matter. Unlike classical physics, where objects behave in predictable ways, the quantum world is full of surprises: particles can exist in many states at once (superposition), influence each other instantly across distance (entanglement), and behave as both waves and particles. These mind-bending concepts have not only revolutionized our understanding of nature but also laid the foundation for groundbreaking technologies.

Today, Quantum Technology is at the heart of a global scientific and technological revolution. Quantum computers are being developed to solve problems that are impossible for even the fastest classical supercomputers. These machines could help design new medicines, optimize complex systems like traffic and climate models, and crack codes with unprecedented efficiency. Quantum communication promises ultra-secure networks based on the unbreakable laws of physics, ensuring safe data transfer in a world increasingly threatened by cyberattacks. Quantum sensors offer extraordinary precision, enabling advances in navigation, medical imaging, and environmental monitoring.

The declaration of IYQ 2025 is more than a celebration—it is an invitation. It invites students, researchers, teachers, policymakers, and citizens worldwide to explore the possibilities of the quantum world. It encourages nations to invest in scientific education, research infrastructure, and innovation. Most importantly, it inspires young minds to pursue careers in physics, engineering, and technology, as the future will increasingly depend on quantum-literate thinkers.

As we step into this quantum century, our curiosity, creativity, and collaboration will shape how we use these powerful technologies. Whether it is decoding nature's tiniest mysteries or building machines that can outperform human imagination, quantum science stands at the frontier of progress.

6. From Sensors to Insulation: Quantum Technologies Transforming Workplace Safety

Saniya Shaikh
BSc (Chemistry) Sem-2

As we celebrate the International Year of Quantum Science and Technology (IYQ 2025), it becomes increasingly clear that quantum principles can help create safer technologies for the people who work in the most challenging conditions. In this article, I am presenting two practical and futuristic ideas: Quantum-Supported Safety Shoes and a Quantum-Insulated Protective Cloth designed to protect workers from daily life risks.

Quantum-Supported Safety Shoes for Workers

Workers who work at heights—such as electric pole workers, construction workers, and high-building maintenance staff—face a serious risk of slipping, losing balance, and falling. Even a small imbalance can lead to major injuries. These shoes are not made for fun or enjoyment, but specifically to increase workers' safety.

The concept is to design smart shoes that can slightly elevate or adjust their base level when needed, but only to improve stability. Equipped with quantum motion sensors, the shoes can detect extremely tiny shifts in body weight and balance. This allows the shoes to automatically tighten grip, increase surface friction, or adjust support instantly. Because quantum sensors are highly precise, they can significantly reduce the chances of slipping or falling. These shoes can become a life-saving technology for people working on heights or unstable surfaces.

Quantum-Insulated Protective Cloth

Workers who handle electrical equipment during rain or wet conditions are constantly at risk of electric shock. To protect them, a special quantum-insulated cloth can be created. Quantum materials control electron movement, which can stop electric current from passing through the cloth.

This cloth will also be waterproof, and it can include a micro-sensor that detects nearby high voltage and alerts the worker through a small vibration. This simple but powerful system can prevent dangerous accidents and create a safer working environment.

Conclusion

Quantum science is opening new doors for practical safety solutions. Technologies like quantum sensors and insulating materials can protect workers who risk their lives every day. By combining creativity with modern science, we can design innovations that make the world safer, smarter, and more supportive for those who build and maintain our society.

The concept is to design smart shoes that can slightly elevate or adjust their base level when needed, but only to improve stability. Equipped with quantum motion sensors, the shoes can detect extremely tiny shifts in body weight and balance.

7. Quantum Science and Technology: Shaping the Future of Human Civilization

Dubey Rohit S.
BSc (Mathematics) Sem-4

Quantum mechanics completes its hundred-year journey in 2025, marking a century of revolutionary discoveries that reshaped modern science. The declaration of International Year of Quantum Science and Technology (IYQ 2025) highlight the global importance of this field and its expanding role in shaping the future of humanity.

Quantum science introduced ideas that challenged classical physics, such as superposition, wave-particle duality, and entanglement. These concepts may seem strange, yet they form the foundation of many technologies we use daily. Devices like lasers, LEDs, MRI scanners, and atomic clocks rely on quantum principles. Without quantum mechanics, our communication systems, medical imaging, and even GPS navigation would not be possible.

In recent years, the world has entered the Second Quantum Revolution, where scientists have begun controlling quantum states instead of merely observing them. The most transformative development in this era is quantum computing. Unlike classical bits that exist as 0 or 1, qubits can exist in multiple states simultaneously. This gives quantum computers the potential to solve problems that even the world's most powerful supercomputers cannot handle. Fields like cryptography, climate prediction, drug discovery, and optimization may soon be revolutionized.

Another major area of advancement is quantum communication, which promises ultra-secure communication networks using the principles of entanglement. Quantum communication is considered un-hackable because any attempt to intercept the information disturbs the quantum state. Nations across the world, including India, are investing heavily in building quantum networks. Quantum sensing and imaging are also advancing rapidly. These sensitive devices can detect diseases at extremely early stages, measure tiny gravitational variations, and explore underground structures without physical excavation. Such advancements promise breakthroughs in medicine, environmental studies, and disaster prediction.

As we celebrate IYQ 2025, it is clear that quantum science is moving far beyond physics laboratories. It is becoming a cornerstone of modern technology and a guiding force for the future. With continuous research, quantum science is set to transform healthcare, security, computing, communication, and countless other fields—ushering in a new era of innovation for the world.

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8. Quantum Science at 100: Honouring the Past, Inspiring the Future

Shukla Sadhvi
BSc (Physics) Sem-2

The year 2025 holds a remarkable significance in the timeline of human scientific achievement. As the world celebrates the International Year of Quantum Science and Technology, we honour a century of profound discoveries that have reshaped not just the field of physics but also the foundations of modern civilization. The journey of quantum mechanics, born in the early twentieth century, continues to inspire innovation, curiosity, and futuristic possibilities.

Quantum mechanics began with an attempt to understand the behaviour of particles so small that classical physics could not explain them. The theories proposed by pioneers like Planck, Einstein, Bohr, Schrödinger, and Heisenberg ignited a scientific revolution. Their ideas revealed a universe far more mysterious and dynamic than previously imagined. Concepts such as quantization, wave-particle duality, superposition, and quantum entanglement challenged the limits of traditional logic. Although these ideas initially sounded abstract and strange, they soon became essential pillars of scientific understanding.

Over the last hundred years, quantum science has silently shaped almost every aspect of our modern world. Computers, mobile phones, MRI scanners, LEDs, lasers, satellites, GPS systems, and even the Internet depend on principles derived from quantum physics. In many ways, quantum mechanics is the invisible engine powering the digital age.

As we enter 2025, the focus extends beyond celebrating the achievements of the past. Today, the world stands at the threshold of an extraordinary new era driven by quantum technology. Unlike classical technologies, quantum technologies harness the behaviour of atoms, electrons, and photons directly—offering capabilities far beyond the reach of conventional systems.

One of the most groundbreaking developments is quantum computing, which has the potential to perform calculations that even the fastest supercomputers cannot solve. Instead of using bits that are either 0 or 1, quantum computers use qubits, which can exist in multiple states simultaneously. This allows them to process vast amounts of information at unprecedented speeds. Applications include drug discovery, climate prediction, financial modelling, cybersecurity, and advanced artificial intelligence.

Another transformative field is quantum communication, which promises ultra-secure data transfer. Using the principle of quantum entanglement, information can be transmitted in ways that cannot be intercepted or hacked. This breakthrough could redefine global communication networks and digital privacy.

The theories proposed by pioneers like Planck, Einstein, Bohr, Schrödinger, and Heisenberg ignited a scientific revolution. Their ideas revealed a universe far more mysterious and dynamic than previously imagined.

Equally revolutionary are quantum sensors, capable of detecting unimaginably small changes in physical quantities. From medical diagnostics to navigation systems and space missions, these sensors could open doors to accuracy never before achieved. They may allow doctors to detect diseases at their earliest stages and help scientists study the deepest layers of the Earth without drilling.

Beyond technological advancement, quantum science holds deep philosophical value. It teaches us that reality is not always as straightforward as it appears. At the smallest scales of existence, particles behave unpredictably, reminding us of the universe's boundless complexity. This sense of wonder fuels scientific curiosity and inspires a new generation of learners and thinkers.

The International Year of Quantum Science and Technology 2025 is not only a celebration; it is a call to engage. It urges students, researchers, and citizens to explore the exciting possibilities of quantum innovation.

The International Year of Quantum Science and Technology 2025 is not only a celebration; it is a call to engage. It urges students, researchers, and citizens to explore the exciting possibilities of quantum innovation. As the next century of quantum research begins, young minds of today will play a crucial role in shaping its future.

CONCLUSION:

Quantum science stands as a symbol of how human curiosity can unlock the secrets of the universe. The discoveries of the past hundred years have been extraordinary, yet the possibilities of the next hundred years are even more promising. As the quantum revolution accelerates, it becomes clear that the future belongs to those who are ready to imagine beyond the ordinary.

9. International Year of Quantum Science and Technology, 2025

Ankita Pal

BSc (Physics) Sem-2

The International Year of Quantum Science and Technology is a United Nations observance that aims to highlight the contributions of quantum science and practical applications of quantum technology.

Quantum science plays a central role in many technologies we rely on today, from ultra secure communication to advanced medical imaging and high-performance computing. As quantum research continues to grow rapidly worldwide, it has become essential to increase public understanding of its importance and future potential.

Why only the year 2025?

On 7 June 2024, the United Nations officially declared 2025 as the International Year of Quantum Science and Technology (IYQ). The year 2025 marks the 100th anniversary of quantum mechanics, making it a symbolic moment to reflect on a century of scientific discovery. Dozens of global scientific societies supported this proposal to highlight both the historical significance of quantum theory and its growing impact on modern technology and society.

The mission of IYQ:

The mission of the International Year of Quantum Science & Technology (IYQ) is to use the occasion of 100 years of quantum mechanics in 2025 to help raise public awareness of the importance and impact of quantum science and applications on all aspects of life.

Importance of the IYQ:

1. **Boosts global awareness:** It helps people understand how quantum science affects everyday life, from secure communication to advanced computing.
2. **Encourages scientific education:** Schools and colleges worldwide use this year to inspire students to explore physics, quantum mechanics, and emerging technologies.
3. **Promotes innovation:** Governments, industries, and research groups collaborate to push new technologies like quantum computers, sensors, and encryption.
4. **Strengthens international cooperation:** Countries work together on quantum research, ensuring that advancements are shared and developed responsibly.

The mission of the International Year of Quantum Science & Technology (IYQ) is to use the occasion of 100 years of quantum mechanics in 2025 to help raise public awareness of the importance and impact of quantum science and applications on all aspects of life.

5. Prepares the workforce of the future: With quantum technologies becoming a major career field, IYQ supports training programs that equip students and professionals with cutting-edge skills.

Key Global Events Under IYQ 2025

There are hundreds of independently organized events and activities worldwide under IYQ. Among them, a subset has been officially designated as “IYQ Global Events” with special funding / recognition.

Some of the global events are mentioned below:

1. IYQ Opening Ceremony:

Official launch of IYQ 2025: keynote addresses by leading scientists, round-table discussions, exhibitions and public outreach on quantum science & technology.

Date of Event: 4–5 February 2025

Purpose of event: To inaugurate IYQ 2025 worldwide, raise global awareness of quantum science and its societal/technological impact.

2. IYQ Launch in Geneva:

Gathering of diplomats, scientists, educators & international-community members; presentations and discussions on quantum technologies and their global importance.

Date of Event: 21 February 2025

Purpose of event: To reinforce global commitment to quantum research and development, promote international cooperation, raise awareness among policymakers and civil society.

3. ICTP Global Event on Quantum Science and Technology:

Global-scale event organized by international physics/science institutions aimed at discussing quantum science impacts, history, education, and global cooperation.

Date of Event: 26–30 May 2025

Purpose of event: To foster international collaboration, share advances, and raise awareness about quantum science’s role in research and society.

4. Quantum India Bengaluru 2025 (QIB 2025):

Event connecting academics, industry professionals, entrepreneurs to showcase latest quantum science and technologies aiming to build a quantum research ecosystem.

Date of Event: 31 July – 2 August 2025

Purpose of event: To grow quantum technology ecosystem in India, encourage collaboration and sustainable quantum development.

1. **Workshop: Quantum for Journalists 2025 World Conference of Science Journalists**

Workshop aimed at journalists explaining quantum technologies in accessible language; discussing ethics, communication and reporting challenges around quantum hype and realism.

Date of Event: 1–5 December 2025

Purpose of event: To improve science journalism related to quantum, promote responsible reporting, and increase public understanding across different regions.

2. **IUPAP–IYQ2025 Photo Contest**

International photo contest inviting images that illustrate quantum phenomena, research, or their impact on everyday life open globally and virtual.

Date of Event: Submissions: 9 June – 31 August 2025; Winners announced 24 October 2025

Purpose of event: To portray the beauty and impact of quantum science visually, and engage broader public beyond academic blending science and art for outreach.

3. **Quantum City Prize:**

A creative global competition encouraging public engagement with quantum science via artworks, posters, performances, city-space displays — making quantum ideas accessible through culture and art.

Date of Event: Application & activity period: 14 April – 14 October 2025; award events expected in November 2025.

Purpose of event: To engage the general public not only scientists with quantum science bridging art, culture, and science to increase understanding and interest across communities.

How our college celebrated the INTERNATIONAL YEAR OF QUANTUM SCIENCE

On 2 September 2025, the Department of Physics of Sir P.T. Sarvajanic College of Science organized a set of well-structured events to celebrate the International Year of Quantum Science and Technology. The programme opened with an expert talk delivered by Dr. Debesh Roy, a renowned professor from SVNIT. He explained about the fundamentals of Quantum Science and essential quantum principles and their growing influence on modern technology. This was followed by a poster making competition, in which students prepared their posters at home and later presented them before a panel of judges, describing the scientific concepts and creative ideas behind their work. The final event was a two-stage quiz competition: an initial screening quiz was conducted in classrooms, from which twelve students were selected, who then competed in the main quiz held at Taramoti Hall in front of faculty

On 2 September 2025, the Department of Physics of Sir P.T. Sarvajanic College of Science organized a set of well-structured events to celebrate the International Year of Quantum Science and Technology. The programme opened with an expert talk delivered by Dr. Debesh Roy, a renowned professor from SVNIT.

members and students of the Physics Department. The event of quiz was hosted by Dhiraj Sir. These participants were grouped into six teams of two and competed across multiple rounds. Questions for the audience were also included, with small rewards for correct responses, making the event lively and interactive. Altogether, the celebrations created an engaging academic atmosphere and encouraged students to explore quantum science with greater interest.

By promoting scientific curiosity and encouraging the next generation of learners, IYQ 2025 sets the stage for innovations that will shape technology, communication, and research in the decades ahead.

Conclusion: The International Year of Quantum Science and Technology 2025 marks 100 years of progress in quantum science and highlights its growing influence on modern life. Through global events, educational initiatives, and international collaboration, this observance aims to deepen public understanding and inspire future breakthroughs. By promoting scientific curiosity and encouraging the next generation of learners, IYQ 2025 sets the stage for innovations that will shape technology, communication, and research in the decades ahead.

10. The SQUID

Prof. Bhupeshkumar Lad
Department of Physics

The 2025 Nobel Prize in Physics was awarded jointly to John Clarke, Michel H. Devoret and John M. Martinis “for the discovery of macroscopic quantum-mechanical tunnelling and energy quantisation in an electric circuit.”

The 2025 Nobel Prize recognized that quantum mechanics — traditionally restricted to the atomic scale — can govern macroscopic, human-built circuits. The SQUID is one of the earliest and most important real-world devices showing how superconductivity + quantum interference + Josephson junctions can be harnessed. Thus, SQUIDs are not just useful instruments — they embody the same quantum-mechanical principles that the Nobel Prize celebrated.

SQUID Instrument – Superconducting Quantum Interference Device)

A Simple Introduction : - A SQUID (Superconducting Quantum Interference Device) is one of the most sensitive instruments used to detect very small magnetic fields. It works on the principles of superconductivity and quantum interference.

1. What is Superconductivity?

When some materials are cooled to extremely low temperatures (close to absolute zero), they lose all electrical resistance. These materials are called superconductors. In this state, electric current can flow without any loss, and special quantum effects appear.

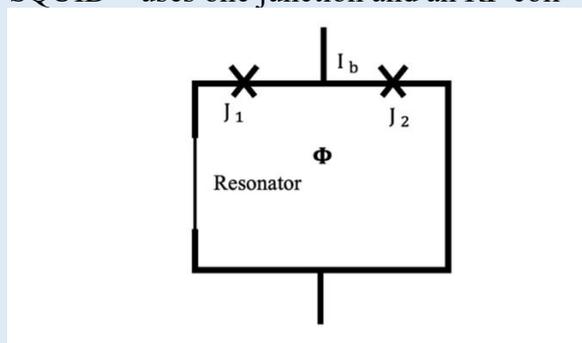
Main Parts of a SQUID

A basic SQUID consists of:

1. Superconducting Loop
2. Two Josephson Junctions (thin insulating barrier between two superconductors)
3. Input Coil / Pickup Loop (optional, for coupling magnetic signals)

Types of SQUID

1. DC SQUID – uses two Josephson junctions
2. RF (AC) SQUID – uses one junction and an RF coil



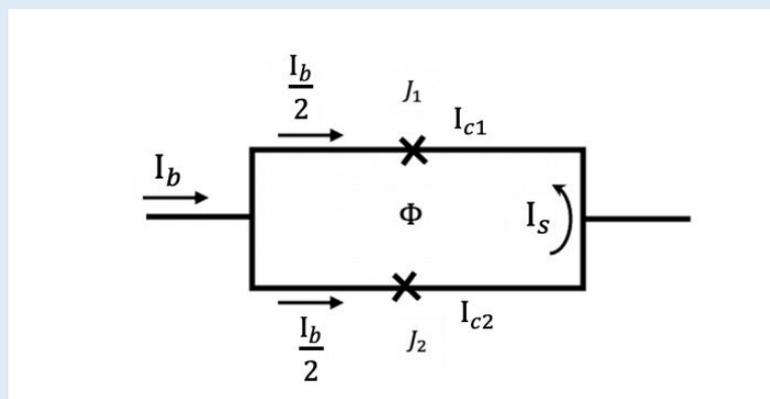
Structure of a DC SQUID

A SQUID (Superconducting Quantum Interference Device) is one of the most sensitive instruments used to detect very small magnetic fields. It works on the principles of superconductivity and quantum interference.

A DC SQUID displacement detector with two Josephson junctions J_1 and J_2 , showing the resonator. SQUID out of BNcD. This involves both investigating the superconducting properties of boron-doped nanocrystalline diamond (BNcD) and the characterization of Josephson junctions (JJs) made of the BNcD material, which are necessary for forming a SQUID.

Working Principle

Magnetic flux passing through the superconducting loop causes a change in the supercurrent flowing through the Josephson junctions. This results in a change in voltage, which can be measured.



Circuit of SQUID

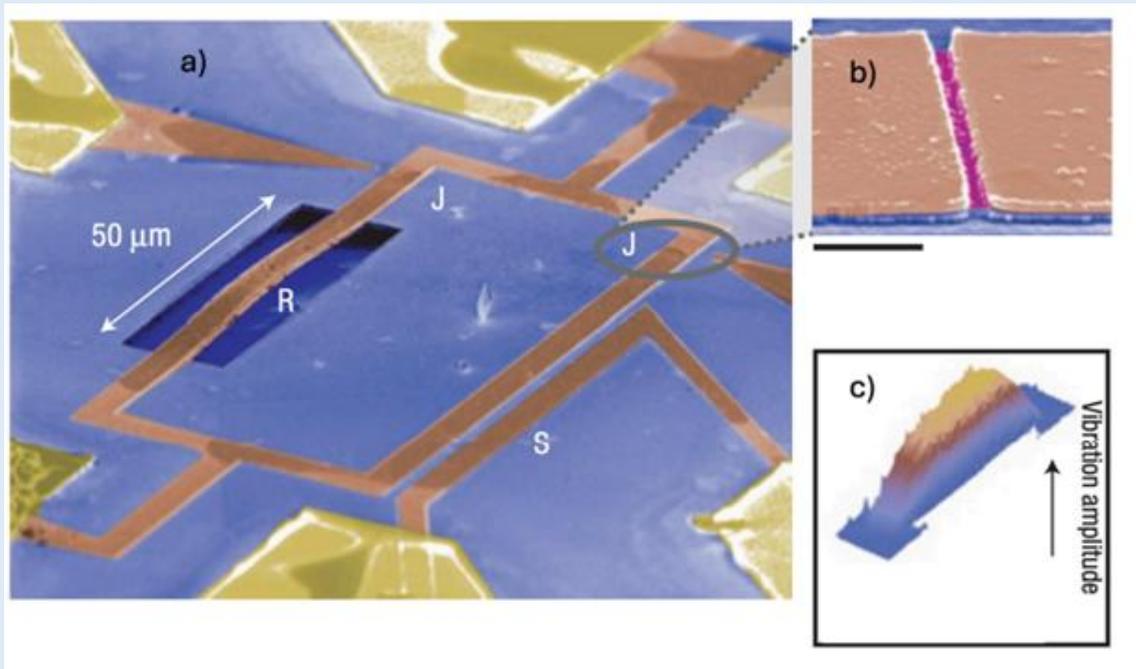
Schematic of a superconducting loop with two Josephson junctions J_1 and J_2 , each having critical currents I_{C1} and I_{C2} , respectively. The bias current I_b is split equally between the two junctions, with each junction receiving a current of $I_b/2$ the circulating current I_s flows around the loop and is influenced by the magnetic flux threading the loop, which affects the phase difference across the junctions. Because this change is extremely sensitive, SQUIDS can detect magnetic fields as small as 10^{-15} Tesla (femto-tesla). This makes SQUIDS the most sensitive magnetometers in the world.

Summary

A SQUID is a superconducting device that can detect extremely small magnetic fields using Josephson junctions and quantum interference. It is widely used in scientific and medical applications due to its unmatched sensitivity.

Applications of SQUID

- Medical: Brain imaging (MEG – Magnetoencephalography)
- Geology: Detect weak magnetic signatures in rocks
- Electronics: Study of superconducting materials
- Security: Detect hidden metals or explosives
- Research: Measure tiny magnetic moments of atoms and molecules



(a) Scanning electron microscopy (SEM) image of a micromechanical resonator integrated within a SQUID system. The labelled components include the resonator (R), SQUID (S), and Josephson junctions (J). The scale bar corresponds to 50 μm. (b) Magnified view showing one of the Josephson junctions has length 200 nm. (c) Three-dimensional visualization of the resonator's vibration amplitude

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11. From Einstein to Feynman: The Story of How Quantum Physics Was Born

Tashvi Patel
BSc (Physics) Sem-2

Introduction: The Dawn of a New Physics

At the beginning of the 20th century, physics seemed complete. Newton's laws ruled motion, Maxwell's equations explained light, and the universe appeared predictable. Yet strange experimental results - glowing hot metals, puzzling atomic spectra - hinted that something deeper was unfolding. A new physics was quietly waiting to emerge.

So how did it all start?

So well, mainly it was three people but it took efforts of many to start something that seems so unreal and breaks already existing laws.

1. Max Planck: The Accidental Revolutionary (1900)

While studying blackbody radiation, Max Planck faced a stubborn problem: classical physics simply could not explain how objects emitted light when heated. In desperation, he proposed that energy comes in tiny, indivisible packets called *quanta*. Planck treated it as a mathematical fix, unaware that he had just lit the spark of quantum theory.

2. Albert Einstein: The Rebel Who Took the Quantum Seriously

In 1905, Einstein boldly extended Planck's idea. He explained the photoelectric effect by arguing that light itself is made of particles - later called *photons*. This radical step earned him the Nobel Prize. Yet he struggled with the strange implications of quantum mechanics, famously insisting that "*God does not play dice with the universe.*"

3. Niels Bohr: Building the First Quantum Model of the Atom

Niels Bohr embraced quantum ideas to solve a puzzle even more mysterious: the structure of the atom. His 1913 model proposed that electrons move in fixed "allowed" orbits and jump between them by absorbing or emitting quanta of energy. This beautifully explained atomic spectral lines and formed the *old quantum theory*.

And it went on somewhat like this...

The 1920s: The Golden Era of Quantum Mechanics

Heisenberg introduced matrix mechanics, removing the idea of electron orbits entirely and focusing on measurable quantities. His *uncertainty principle* showed that nature places limits on what can be known.

Schrödinger followed with wave mechanics, describing electrons as waves through his famous equation.

Dirac then unified quantum mechanics with relativity and predicted antimatter—one of physics' greatest successes.

In 1905, Einstein boldly extended Planck's idea. He explained the photoelectric effect by arguing that light itself is made of particles - later called *photons*. This radical step earned him the Nobel Prize.

Richard Feynman: The Great Simplifier

Feynman transformed quantum theory from abstract mathematics into a practical tool. His *Feynman diagrams* turned complex particle interactions into simple sketches, while his “sum over all paths” idea imagined particles exploring every possible route at once. His work made modern quantum physics calculable and intuitive.

So, how would it go on?

Conclusion: A Story Still Being Written

As the world celebrates the *International Year of Quantum Science and Technology (IYQ 2025)*, we look back on a century of breakthroughs shaped by these brilliant minds. From Planck’s tiny quanta to Feynman’s elegant diagrams, their ideas power today’s quantum technologies—and the story of quantum physics continues to unfold and much more discoveries gladly await...

12. Emulsifiers: A versatile tool for emulsification

Dr. Neelam Mishra

Department of Zoology

Emulsifiers fall into the chemical class of surfactants or surfactants, especially water-soluble surfactants [1-2]. Emulsifiers that reduce interfacial tension and counteract droplet spreading are divided into ionic (mainly anionic; soaps) and non-ionic (ethoxylates) products. Soluble oils require that the water and oil emulsify rapidly to form a stable emulsion (Figure.1). The basic structure of emulsifiers consists of a hydrophobic part (usually a long-chain fatty acid) and a hydrophilic part, either charged or uncharged. The hydrophobic portion of the emulsifier dissolves in the oil phase and the hydrophilic portion dissolves in the aqueous phase, forming a dispersion of small oil droplets [3-5].

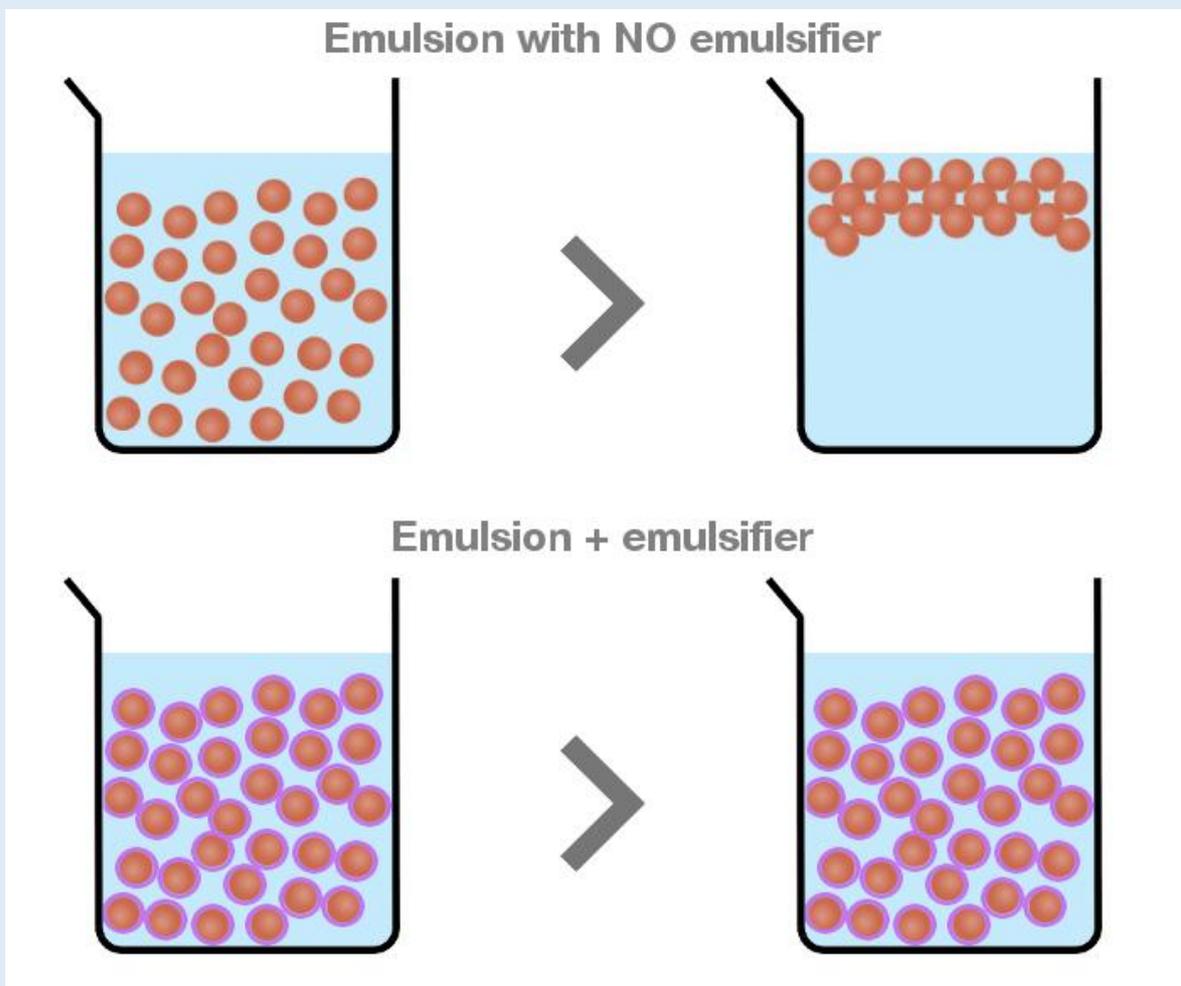


Figure 1: Role of emulsifier to form a stable emulsion

An emulsifier or emulsifier is a compound or substance that acts as an emulsion stabilizer, preventing normally immiscible liquids from separating. The word comes from Latin and means "to drink milk", and milk refers to an emulsion of water and fat. Another word for emulsifier is emulsifier. The term emulsifier can also refer to a device that shakes or agitates ingredients to form an emulsion [1-6]. Emulsifiers are used in machine shop lubricants for cutting, grinding and drilling applications [3-16]. Self-emulsifying surfactants combine lubrication and emulsification in one product. Demulsifiers promote the separation of water and oil in lubricating oils exposed to dirty water, such as; Industrial oils in circulation systems (hydraulic, gear, turbine, and compressor oils). Demulsifiers and emulsifiers use the same class of chemicals (surfactants). A special polyethylene glycol is a very effective demulsifier. Emulsifier has great use in food [6-12]. One of many chemical additives that suspend one liquid in another, such as margarine, shortening, ice cream, and oil-water mixtures in salad dressings. Many emulsifiers are derived from seaweed, such as algin, carrageenan, and agar. Lecithin, which is found in egg yolks, is also used as an emulsifier [9,11-15]. Thus, emulsifiers form and stabilize oil-in-water emulsions (such as mayonnaise), distribute oil-soluble flavour compounds uniformly in products, and prevent the formation of large ice crystals in frozen products (such as ice cream). Emulsifiers are closely related to stabilizers, i.e. substances that maintain an emulsified state[1-6]. Food consistency can also be improved by the addition of thickeners, used to add body to sauces and other liquids, and texture modifiers. These various additives serve a dual purpose. It improves the appearance and texture of food to make it more appetizing and increases shelf life (i.e., prolongs shelf life). Emulsifiers, stabilizers, and related compounds are also used in the manufacture of cosmetics, lotions, and certain pharmaceuticals, serving essentially the same purpose as food [11-16].

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13. Nobel Prize in Chemistry 2025: An award for a move towards cleaner planet

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Department of Chemistry

The 2025 Nobel Prize in Chemistry was awarded on October 8, 2025, by the Royal Swedish Academy of Sciences in Stockholm, Sweden, to Susumu Kitagawa (Japan), Richard Robson (Australia), and Omar M. Yaghi (USA) “**for the development of metal–organic frameworks (MOFs)**”, a class of porous molecular materials with vast scientific and practical significance. This research work demonstrates design, synthesis and development of metal–organic frameworks (MOFs) — crystalline materials composed of metal ions linked by organic molecules. These structures form highly porous frameworks with enormous internal surface areas and tunable cavities, often described as “rooms for chemistry”.

Key Characteristics of metal–organic frameworks (MOFs):

- **High surface area and porosity:** MOFs are known for having an extremely large internal surface area, sometimes larger than a football field per gram, due to their highly porous, 3D network structure.
- **Tunable pore size:** The size and shape of the pores can be precisely controlled by selecting different metal clusters and organic linkers during synthesis.
- **Chemical and thermal stability:** Many MOFs are robust and can tolerate a wide range of conditions, including acidic and alkaline environments, and high temperatures.
- **Crystallinity:** Most MOFs are crystalline, meaning they have a regular, repeating structure, though amorphous MOFs also exist.

Functionality: MOFs can be designed with specific functional groups on the organic linkers or metal nodes, which allows them to selectively interact with or catalyse certain molecules.

Why This Discovery Matters!

The development of MOFs represents a paradigm shift in chemistry and materials science. These materials have already shown great promise in addressing global challenges:

- **Carbon dioxide capture and climate mitigation:** Certain MOFs can selectively trap CO₂ from industrial emissions or ambient air, offering tools for reducing greenhouse gases.

MOFs can be designed with specific functional groups on the organic linkers or metal nodes, which allows them to selectively interact with or catalyse certain molecules.

By enabling precise control over molecular environments, Kitagawa, Robson, and Yaghi have provided tools that could shape the solutions to some of the 21st century's most demanding challenges — from climate change to clean energy and resource scarcity.

- **Clean energy storage:** MOFs can store hydrogen or methane at high densities, supporting future clean fuel technologies.
- **Water harvesting:** Some MOFs can absorb water vapor from arid air, potentially helping to provide potable water in drought-prone regions.
- **Pollutant removal and purification:** Their selective pores enable separation and capture of toxic substances from water and air.

Catalysis and material innovation: MOFs can act as catalysts or supports for chemical reactions, enabling greener and more efficient chemistry.

The Nobel Prize in Chemistry 2025 celebrates a discovery with far-reaching scientific and societal implications. MOFs exemplify how deep fundamental research can lead to innovations that cross the boundaries of chemistry, materials science, environmental science, and sustainable technology. By enabling precise control over molecular environments, Kitagawa, Robson, and Yaghi have provided tools that could shape the solutions to some of the 21st century's most demanding challenges — from climate change to clean energy and resource scarcity.

14. Quantum World and Nobel Prize 2025 in Physics

Dr. Pruthul Desai, Dr. Naveen Singh
Department of Physics

Quantum mechanics, based on the wave function of a particle shows its relevance and describe the nature of particle at microscopic level, where the classical laws of motion and electromagnetism no longer provide accurate descriptions. At the level of atoms, electrons, photons, and other subatomic particles, matter and energy behave in ways that differ fundamentally from the view of classical physics. Objects that appear solid and predictable at the macroscopic scale instead exhibit probabilistic and wave-like behavior when examined at extremely small dimensions.

A key aspect of quantum mechanics at microscopic scales is wave–particle duality, which shows that entities such as electrons and photons display both particle-like and wave-like characteristics depending on the experimental conditions. Rather than fitting into a single classical category, these particles can produce interference patterns while also interacting as localized packets of energy. This dual nature accounts for observable effects including electron diffraction, discrete atomic energy levels, and the processes by which light is emitted and absorbed. Additionally, physical interactions at this scale are quantized, meaning quantities such as energy can take only specific, discrete values instead of varying smoothly as they do in classical Physics.

By offering a theoretical framework for describing matter and energy at extremely small scales, quantum mechanics serves as a cornerstone of modern physics and technological development. It accounts for the internal structure of atoms and explain the behavior of devices such as semiconductors, superconductors, lasers, and magnetic materials. Through these applications, quantum mechanics continues to deepen and refine our understanding of the microscopic nature of the universe.

When many microscopic particles interact, their collective behavior gives rise to familiar macroscopic quantities. For example, electric current arises from the combined motion of many electrons, the magnetic flux through a circuit, and pressure results from countless particle collisions. Quantum mechanics explains these macroscopic variables. Under appropriate conditions, the behavior of a macroscopic variable—whether treated classically or quantum mechanically may be described by an effective state of its own, which connects to its Schrödinger wave-function. In other words, this experiment demonstrates quantum effects at macroscopic level.

The Nobel Prize in Physics 2025 was jointly awarded to *John Clarke, Michel H. Devoret, and John M. Martinis* in recognition of their groundbreaking discovery of macroscopic quantum mechanical tunnelling and energy quantisation in an electric circuit, a finding that revealed how quantum behavior can emerge in systems large enough to be observed at a macroscopic scale [1].

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A direct demonstration of quantum effects was achieved by the laureates through experiments on Josephson junctions operated at extremely low temperatures (on the order of millikelvin). Their work was based on the current-biased Josephson junction, in which the superconducting phase acts as a macroscopic variable, enabling the observation of Cooper-pair tunnelling and the quantization of discrete energy levels within an electrical circuit. The main challenge was to suppress environmental noise that could disturb the quantum wave function. Such noise increases rapidly, if not carefully controlled, would destroy the conditions necessary for observing quantum tunnelling.

Josephson Junction Effect:

Across the insulator, the cooper-pairs tunnel from one superconductor to another superconductor; known as Josephson effect [4], produces a super current. This can be understood quantum mechanically. Let Ψ_1 and Ψ_2 be the probability amplitude of electron pairs on one side and other side of the junction, respectively. Without any external potential, the time dependent Schrodinger equation for both segments can be written as [2].

$$i\hbar \frac{\partial \psi_1}{\partial t} = i\hbar T \psi_2 \quad \text{and} \quad i\hbar \frac{\partial \psi_2}{\partial t} = i\hbar T \psi_1 \quad (1)$$

respectively. The quantity T which has dimension of rate of frequency represents transfer interaction across the insulator. Redefining Ψ_1 and Ψ_2 as $\psi_1 = n_1^{\frac{1}{2}} e^{i\theta_1}$ and $\psi_2 = n_2^{\frac{1}{2}} e^{i\theta_2}$ respectively and separating the real and imaginary parts, we obtain,

$$\frac{\partial n_1}{\partial t} = 2T(n_1 n_2)^{\frac{1}{2}} \sin(\theta_2 - \theta_1) \quad \text{and} \quad \frac{\partial n_2}{\partial t} = -2T(n_1 n_2)^{\frac{1}{2}} \sin(\theta_2 - \theta_1) \quad (2)$$

with

$$\frac{\partial \theta_1}{\partial t} = -T(n_2/n_1)^{\frac{1}{2}} \cos(\theta_2 - \theta_1) \quad \text{and} \quad \frac{\partial \theta_2}{\partial t} = -T(n_1/n_2)^{\frac{1}{2}} \cos(\theta_2 - \theta_1) \quad (3)$$

More simplification is realized for $n_1 = n_2$, where we arrive to,

$$\frac{\partial \theta_1}{\partial t} = \frac{\partial \theta_2}{\partial t} \quad \text{and} \quad \frac{\partial n_2}{\partial t} = -\frac{\partial n_1}{\partial t} \quad (4)$$

Combinations of equations (2) to (4) suggests a current J across the junction, given by $J = J_0 \sin(\theta_2 - \theta_1) = \sin(\delta)$ (5)

where, J_0 is proportional to the transfer interaction T and δ is difference $\theta_2 - \theta_1$. This effect is known as dc Josephson effect. Applying external voltage V across the junction with a similar treatment leads to ac Josephson effect, where the current J is modified as

$$J = J_0 \sin\left(\delta(0) - \frac{4\pi e V t}{h}\right) \quad (6)$$

Here, $\delta(0) = (\theta_2 - \theta_1)_0$ is a value of $\theta_2 - \theta_1$ at initial time t_0 .

From the nature of solution given by Eq. (5) and (6), we can think how the quantum effects can be realized. This quantum effect can be controlled by applied voltage as Eq. (6) suggests.

Laureate used similar device with current biased Josephson junction for which phase difference across the junction δ can be written as [3]

$$C \varphi_0^2 \delta + \frac{\varphi_0^2}{R} \delta + \frac{\partial U}{\partial \delta} = 0 \quad (7)$$

With $U(\delta) = -I_0\phi_0 \left(\cos \delta + \frac{I_B}{I_0} \delta \right)$ where C is effective capacitance, R is resistor to account dissipation at non-zero frequency, I_0 is critical current and I_B is external dc bias current. The above Eq. (7) which gives the dynamics of phase difference δ is called RCSJ model. Depending the value of I_B bias current we have different solutions. Three cases arise:

Case 1: Bias current $I_B \gg I_0$:

We have an oscillatory solution for the phase difference. The phase difference oscillates [5] with plasma frequency ω_p . Therefore, the average value of phase difference δ is zero. The plasma frequency can be changed by bias current.

Case 2: Bias current $I_B \gg I_0$:

For this case, no local minima of potential exist producing δ rolls on the potential U . This leads to a non-zero value of δ when averaged over time. This gives a non-zero voltage across the junction.

Case 3: Bias current is close to critical current $I_B \leq I_0$:

Height of potential would be small for such case. It produces phase difference (or current) either by quantum tunnelling or by thermal excitations. Therefore, if one reduces the thermal effect by lowering the temperature, one can observe the quantum effect. Such a condition of low temperature and reduced noise is achieved by laureates. They used Nb-NbO₄-PbIn for Josephson junction and cooled it in a dilution refrigerator.

In the experiment done by laureates, bias current I_B swept from zero to the critical value many times and further statistical analysis is done to observe the voltage across the junction. The experiment observations agree with the theoretical prediction of RCSJ model based on quantum mechanics. Other compelling result of experiment is that it also verifies the quantization of energy. We can map phase difference as phase-particle, since it is a combination of θ_1 and θ_2 which are phase of wave functions ψ_1 and ψ_2 respectively. This phase particle when in anharmonic potential must have discrete states and discrete energies accordingly. The same is observed in the experiment. If a weak micro-field is applied across the junction, tunneling occurs at some particular frequencies demonstrating the discrete states. Therefore, the experiment demonstrates the energy quantization as well.

Conclusion:

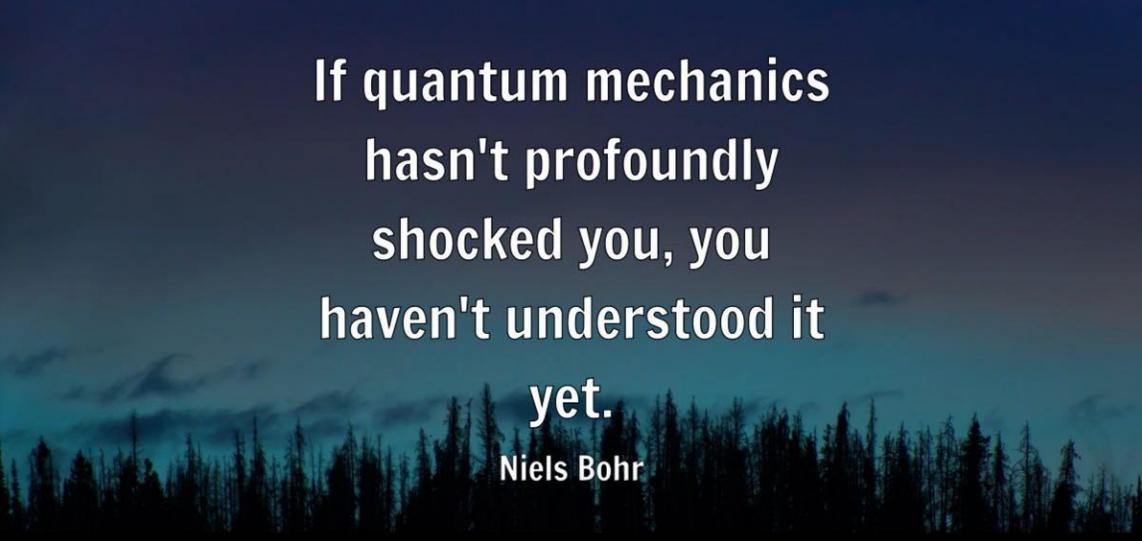
The recognition of work on the Josephson junction would underscore how profoundly the demonstration of quantum tunnelling and quantization has shaped modern physics. By revealing that macroscopic electrical currents can tunnel through an insulating barrier and remain governed by precise quantum phase relationships [6], the Josephson effect provided a clear and elegant bridge between abstract quantum theory and measurable physical reality. Its experimental verification of quantized behavior not only confirmed core principles of quantum mechanics but also enabled transformative technologies, from ultra-precise voltage standards to superconducting qubits for quantum computing. The Nobel Prize 2025 in physics would honour both a basic

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discovery about how nature works and the many important technologies that grew from learning how to control quantum effects.

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If quantum mechanics
hasn't profoundly
shocked you, you
haven't understood it
yet.

Niels Bohr

As the world celebrates the *2025 International Year of Quantum Science and Technology (IYQ)*, this magazine brings together insights, ideas, and inspirations that highlight a century of quantum discoveries and their profound impact on our lives. From the earliest breakthroughs that reshaped our understanding of nature to today's transformative innovations in communication, computing, energy, and healthcare, the quantum revolution continues to unfold with remarkable promise. This special edition captures the spirit of IYQ 2025 by showcasing visionary research, emerging applications, and the boundless curiosity that drives scientific progress. It stands as a tribute to the researchers, educators, and learners who are shaping the quantum future and empowering society through knowledge.