

Quantum: A Walk Through the Universe

← [Quantum](#)

Introduction

A Frivolous Approach to Quantum

A popular scientific overview of [quantum](#), its history, central concepts, and emerging technologies. Written in an informal style, the article covers principles such as [quantisation](#), [superposition](#), and [quantum entanglement](#), while linking them to both foundational experiments and modern applications. It covers Theory, History, Related equations, Related concepts, Applications, Interpretations and a [Quantum Cheat Sheet](#).

Theory


A quantum (plural quanta) is the smallest discrete unit of a physical property, such as energy, light, or angular momentum. For example, a [photon](#) is a quantum of light. This fundamental particle of electromagnetic radiation is the basic building block of light, which behaves as both a wave and a particle.^[1]


[Quantum physics](#) is the study of matter and energy at the most fundamental level. It aims to uncover the properties and behaviors of the very building blocks of nature. While many quantum experiments examine very small objects, such as electrons and photons, quantum phenomena are all around us, acting on every scale it is including [wave-particle duality](#) and [quantized energy levels](#).


[Quantum mechanics](#) is the mathematical framework within quantum physics that provides the rules and equations to describe and predict the behavior of [quantum systems](#). It includes principles such as the [uncertainty principle](#), [wavefunctions](#), and [superposition](#).


In summary:

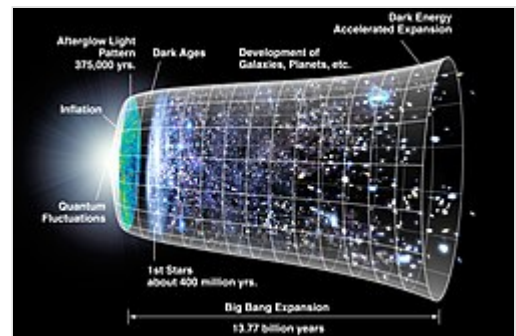
- Quantum = the smallest piece of a property.

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 **Subject classification:** this is a [physics](#) resource.

 **Type classification:** this is a [quiz](#) resource.

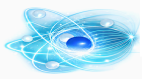
 **Type classification:** this resource is a [learning project](#).



Big Bang Explosion



Artistic impression of an atom 2c

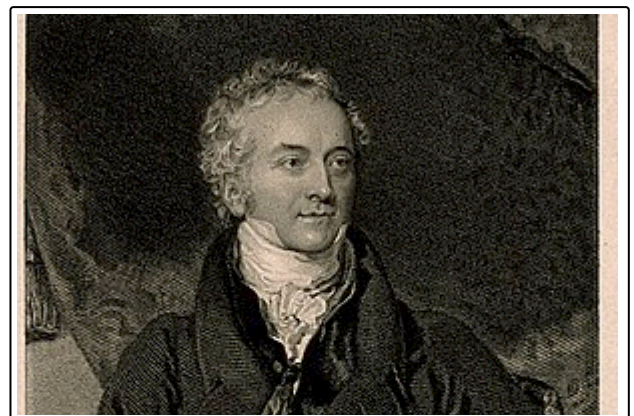


behaviour of matter and light at the atomic and subatomic scale.^[1] These phenomena underlie technologies such as semiconductors, lasers, and solar cells, and form the basis of developing fields including quantum computing and quantum sensing.^[3] Physicists have described quantum mechanics as both the most successful theory of nature and one of the most conceptually challenging, as its principles often conflict with intuitive human experience.^[4]

Historical background

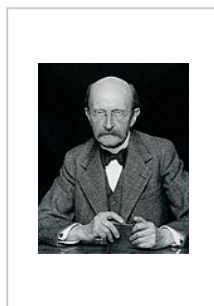
Early challenges to classical physics

In the 19th century, classical physics described motion, gravity, and electromagnetism with high precision. Experiments such as Thomas Young's 1801 double-slit experiment supported the wave theory of light.^[5] At the turn of the 20th century, several anomalies emerged. The photoelectric effect demonstrated that increasing light intensity did not increase the kinetic energy of emitted electrons as predicted by classical wave theory. In 1900, Max Planck proposed that light is emitted in discrete packets, or quanta.^[6] Albert Einstein expanded this idea in 1905, introducing the concept of the photon.^[7]

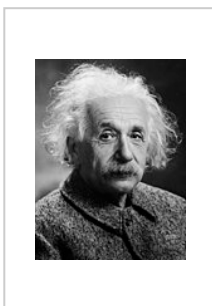


Engraved portrait of polymath Thomas Young (1769–1830) by George Adcock.

Key figures in early quantum physics



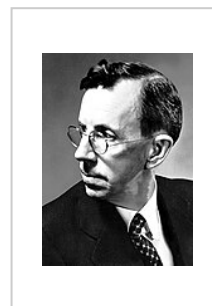
Max Planck
(1858–1947)



Albert Einstein
(1879–1955)



Niels Bohr (1885–
1962)

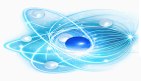


Clinton Davisson
(1881–1958)

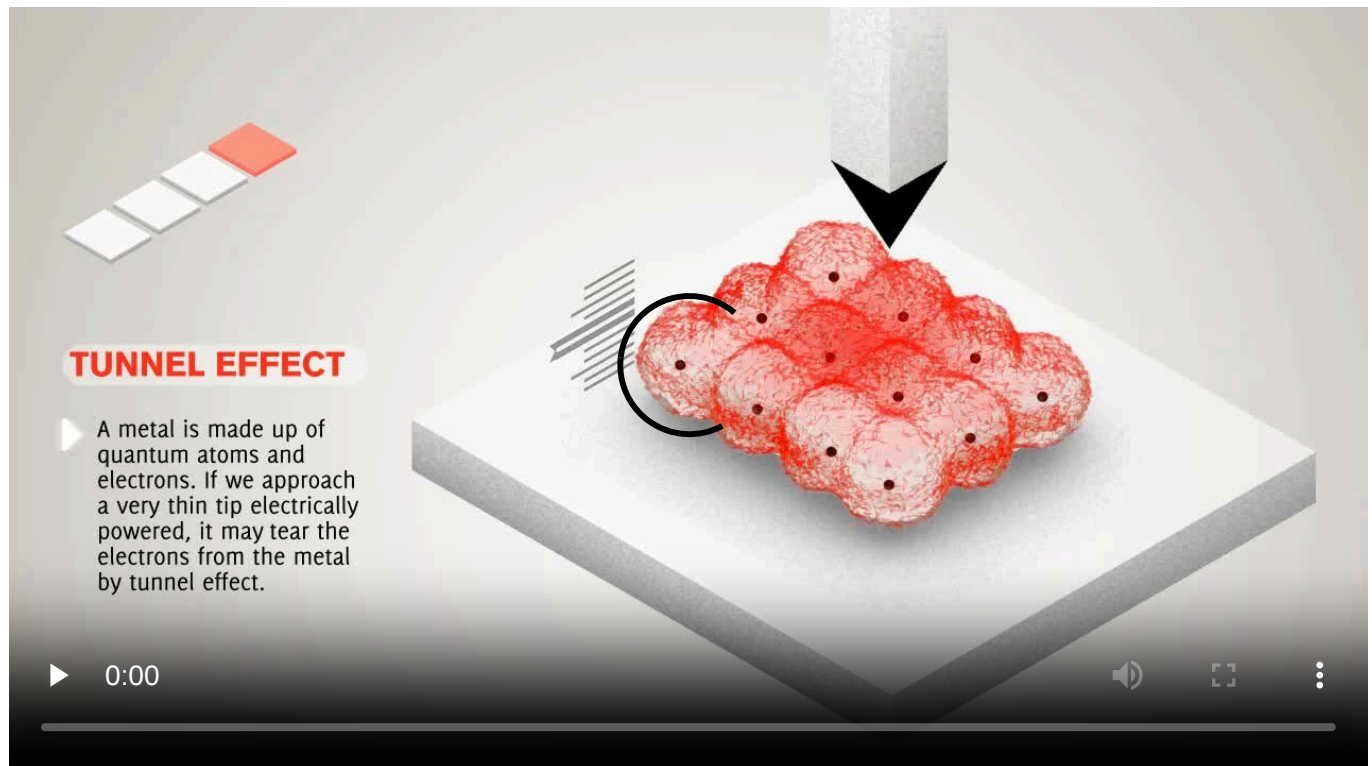


Lester Germer
(1896–1971)

Niels Bohr's 1913 atomic model explained electron behaviour in hydrogen but was limited for larger atoms and molecules. By 1927, Clinton Davisson and Lester Germer demonstrated electron diffraction, providing direct evidence of wave–particle duality.^[8]



Quantum tunneling

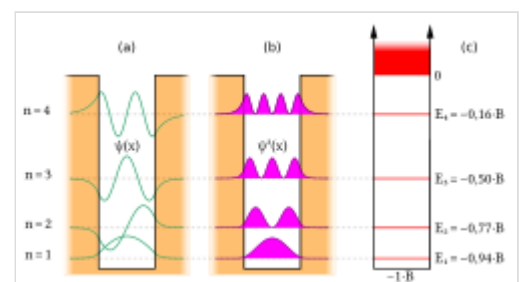


In physics, **quantum tunnelling**, **barrier penetration**, or simply **tunnelling** is a quantum mechanical phenomenon in which an object such as an electron or atom passes through a potential energy barrier that, according to classical mechanics, should not be passable due to the object not having sufficient energy to pass or surmount the barrier.

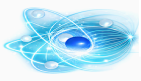
Tunnelling is a consequence of the wave nature of matter and quantum indeterminacy. The quantum wave function describes the states of a particle or other physical system and wave equations such as the Schrödinger equation describe their evolution. In a system with a short, narrow potential barrier, a small part of wavefunction can appear outside of the barrier representing a probability for tunnelling through the barrier.

Schrödinger's equation

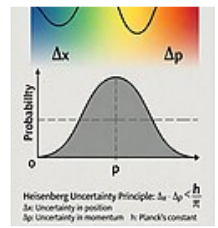
In 1925–26, Erwin Schrödinger formulated the Schrödinger equation, describing the probabilistic behaviour of quantum systems through the wavefunction (ψ). Debate persists on whether the wavefunction represents physical reality or knowledge of a system.^[9] The equation enables prediction of atomic and molecular structures and underpins semiconductor physics.



Bound-states



position and momentum, can be simultaneously known. If the position of an electron is determined with great accuracy, the uncertainty in its momentum (and therefore its energy) increases, and vice versa. This principle is a basic to quantum mechanics.^[10]

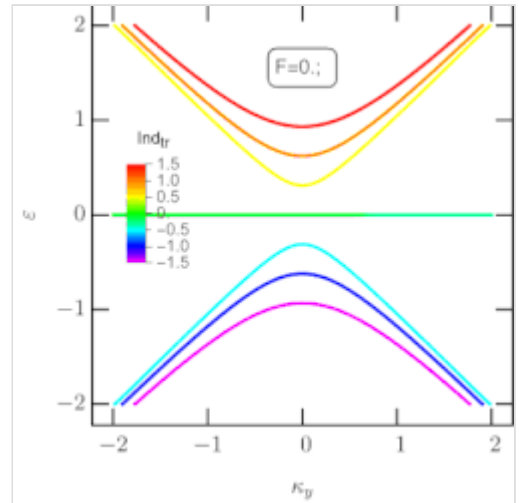
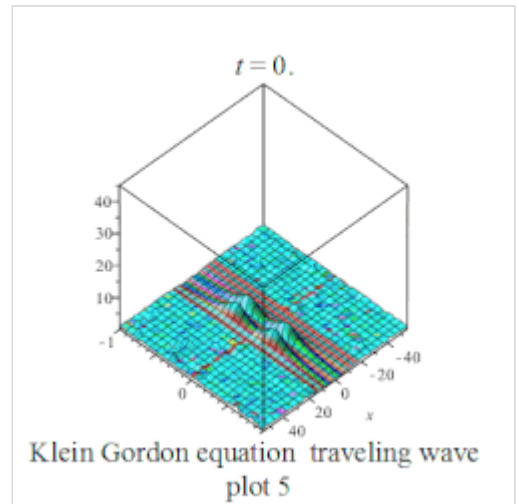


Klein–Gordon Equation

The Klein–Gordon equation is a relativistic wave equation that represented one of the earliest attempts to describe quantum particles. While it successfully incorporated the principles of special relativity, it faced difficulties with the interpretation of probability density, which made it less suitable than the Schrödinger equation for describing certain quantum systems.

Dirac Equation

The Dirac equation is a relativistic quantum mechanical wave equation formulated as a relativistic generalization of the Schrödinger equation. It combines special relativity with quantum mechanics and involves only a single derivative with respect to both space and time. In the non-relativistic limit, the Dirac equation reduces to the Schrödinger equation. It also successfully predicted the existence of antimatter. Energy bands of a half-bearded graphene nanoribbon subjected to an in-plane electric field in the continuum model based on a Dirac equation → ►



Other Related Concepts

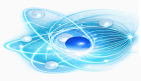
The foundational equation of quantum mechanics is the **Schrödinger equation** It appears in two primary forms:

Time-dependent Schrödinger equation:
$$i\hbar \frac{\partial}{\partial t} \Psi(\mathbf{r}, t) = \hat{H} \Psi(\mathbf{r}, t)$$

Time-independent Schrödinger equation (eigenvalue form):
$$\hat{H} \psi(\mathbf{r}) = E \psi(\mathbf{r})$$

Hamiltonian: The Hamiltonian symbol \hat{H} is a mathematical operator in quantum mechanics that corresponds to the total energy of a quantum system.^[2]

Wave function: The wave function (Ψ or ψ) is the central concept in the Schrödinger equation, representing the state of a quantum system. The squared magnitude, $|\Psi|^2$, gives the probability density of



operator acts on the wave function to yield the energy eigenvalue E .^[2]

Key concepts

Measurement and uncertainty

Werner Heisenberg's 1927 uncertainty principle formalised the limitations of measuring quantum systems, in which observation itself alters the system. This led to probabilistic rather than deterministic outcomes.^{[10] [4][11]}

Superposition

Superposition refers to the ability of quantum systems to exist in unknown states simultaneously until measurement. Schrödinger illustrated the paradox with the 1935 Schrödinger's cat thought experiment.^{[12] [2][13]}

Entanglement

Quantum entanglement occurs when two or more particles are in a shared quantum state, such that the measurement of one particle's property (e.g., spin, position, or momentum) almost instantly determines the corresponding property of the other particle(s), even at a distance between them. Einstein criticised this as "spooky action at a distance" in the EPR paradox, but later experiments confirmed the effect.^[14] Entanglement is now central to quantum cryptography and related technologies.^{[15] [16]}

Applications

Quantum mechanics underpins 20th-century technologies such as transistors, lasers, and magnetic resonance imaging. A "second quantum revolution" is under way, exploiting superposition and entanglement for new applications^{[2][3][16]}, including:

- Quantum computing: using qubits for information processing.^{[16][17][18]}
- Quantum sensing: ultraprecise sensors, including devices capable of operating without



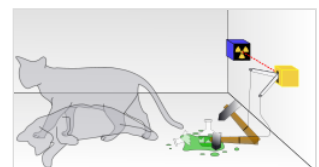
Schrodinger equation time dependent



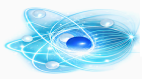
Schrodinger equation time independent



Werner Heisenberg (1901-1976)

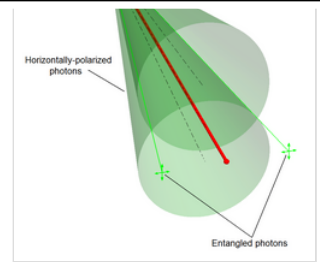


Schrödinger's cat.



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- [Optical clocks: highly precise quantum timekeeping, including devices developed at the University of Adelaide.](#)^{[24][25][26]}

Australian research institutions, including the University of Sydney, the University of Queensland, and the University of Adelaide, are noted contributors to international quantum research.^[27]



Conceptual illustration of entanglement

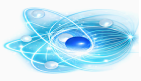
Interpretations

While quantum mechanics is experimentally well verified, its interpretation remains contested. Some physicists view the wavefunction as an element of physical reality, while others regard it as a tool for predicting measurement outcomes.^[28]

See also

- [Quantum](#)
- [Quantum A Matter Of Size](#)
- [Quantum A Spooky Action at a Distance](#)
- [Quantum: A Walk Through the Universe](#)
- [Number of independent spatial modes in a spherical volume](#)
- [Quantum Computing Algorithms in the NISQ Era](#)
- [Quantum Formulas Collection](#)
- [Quantum Matter Elements and Particles](#)
- [Quantum mechanics](#)
- [Quantum mechanics/Timeline](#)
- [Quantum mechanics measurements](#)
- [Quantum Noisy Qubits](#)
- [Quantum optics beam splitter experiments](#)
- [Quantum: The Secret of Cohesion: How Waves Hold Matter Together](#)
- [Quantum Ultra fast lasers](#)
- [Template:Quantum optics operators](#)
- [Physical Sciences](#)

- [Qubit](#)
- [History of quantum mechanics](#)
- [Wave–particle duality](#)
- [Schrödinger equation](#)
- [Quantum entanglement](#)
- [Quantum computing](#)
- [List of equations in quantum mechanics](#)



Quantum

A quantum (plural quanta) is the smallest discrete unit of a physical property, such as energy or light. For example, light comes in tiny packets called photons, each of which is a quantum of light.

Quantum Physics

Quantum physics is the branch of science that studies the behavior of matter and energy at very small scales, such as atoms and subatomic particles. It explores phenomena where classical physics does not apply.

Quantum Mechanics

Quantum mechanics is the mathematical framework and set of rules used to describe and predict the behavior of particles in the quantum world. It includes concepts such as wavefunctions, superposition, and the uncertainty principle.

Real-Life Examples

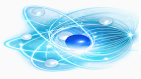
- **Smartphones and Computers:** Modern electronics rely on quantum mechanics to function. Transistors work because electrons follow quantum rules, such as tunneling and discrete energy levels.
- **Lasers:** Lasers are based on photons, which are quanta of light. Controlling how atoms release these photons creates a focused beam.
- **MRI Scanners:** MRI machines use quantum properties of particle spins to create detailed images of the body.

Weird Quantum Effects

- **Superposition:** Particles can exist in multiple states at once, like an electron spinning both "up" and "down" until measured.
- **Entanglement:** Two particles can become linked so that the state of one instantly affects the other, even at large distances.

Quantum Computers

Quantum computers use the strange rules of quantum mechanics to solve complex problems faster than classical computers.

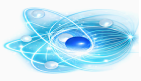


Real-World Applications

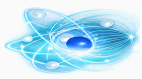
- **Drug Discovery:** Quantum computers can simulate molecules to discover new medicines faster.
- **Finance:** They can model millions of financial scenarios in parallel, helping with risk analysis.
- **Cybersecurity:** Quantum computers can break some current encryption methods or create ultra-secure quantum-based encryption.

Summary

- Quantum = smallest piece of a property.
- Quantum physics = the study of the tiny.
- Quantum mechanics = the rulebook describing how the tiny pieces behave.
- Quantum computers = devices that use these rules to solve problems classical computers cannot handle efficiently.



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