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Explanatory Secrets in the Emergence of Quantum Mechanics an Analytical Historical Study of Concepts from the Atom to Wave-Particle Duality

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Abstract

This research provides a comprehensive overview of the emergence of quantum mechanics and the fundamental experiments that shaped our understanding of the subatomic world. It begins by explaining Max Planck's discovery, which described energy as quantized rather than a continuous flow. It then discusses Einstein's work on the photoelectric effect, which confirmed the particle nature of light. The research also reviews the atomic models of Thomson and Rutherford, Millikan's oil drop experiment for measuring the electron's charge, and the double-slit experiment, which revealed the wave nature of particles.

The text discusses the philosophical challenges raised by Heisenberg (uncertainty principle), Bohr (Copenhagen interpretation), and Schrödinger (his famous cat), pointing out that many foundations of quantum mechanics originated from imprecise theoretical interpretations of practical experiments, such as the photoelectric effect and the double-slit experiment, leading to theories that appear to conflict with classical physics.

It concludes that the electron, despite numerous studies, remains an enigmatic entity because it possesses both wave and particle properties simultaneously. The modern image of the atom shows a probabilistic "electron cloud" around the nucleus, confirming the need for a deeper understanding based on scientific evidence rather than speculative models.

The research is part of a chapter in my book published on Amazon entitled:
(Physics Shock in the Clash of Geniuses)

Keywords: Quantum Mechanics, Double-Slit Experiment, Photoelectric Effect, Schrödinger's Cat, Blackbody Radiation, Electron

Introduction

Although Einstein is famous for his theory of relativity, which transformed concepts of space, time, and gravity, it was not what qualified him for the Nobel Prize in Physics, despite being revolutionary and shaking the scientific community. it remained controversial and was impossible to verify experimentally at the time. Sixteen years later, Einstein was honoured with the Nobel Prize in Physics for his explanation of the photoelectric effect. His interpretation was the first building block in establishing a new science known as quantum mechanics.

The late 19th and early 20th centuries formed a pivotal period in the history of science, as gaps in classical physics theory began to appear. While Newtonian mechanics and classical electrodynamics could describe the macroscopic world with astonishing accuracy, they failed utterly to explain a range of phenomena at the atomic and subatomic levels. Problems such as blackbody radiation, the photoelectric effect, and the stability of the atom constituted crises that revealed the limitations of prevailing theories. This failure led to an urgent need for a radically new model, announced by Werner Heisenberg, Erwin Schrödinger, Max Born, and others in the first quarter of the twentieth century, marking the birth of "quantum mechanics."

Quantum mechanics is based on a set of principles that conflict with the familiar intuition derived from our everyday experience. These principles form the theoretical framework governing the behaviour of particles at the fundamental level. Chief among them is wave-particle duality, where particles (such as electrons) can no longer be described as mere material points, nor waves (such as light) as continuous, uninterrupted phenomena. A particle can exhibit wave-like behaviour (as in the double-slit experiment), and a wave can behave like a particle (as in Einstein's photons).

Despite broad agreement on the predictive accuracy of the standard quantum model, the interpretative foundations upon which it was built have remained a subject of debate and discussion since its inception. This research aims to shed light on these "mysteries," adopting a critical approach to trace the historical development of fundamental concepts in quantum mechanics, such as the atom, electron, and photon. The research aims to examine the traditional narratives of foundational experiments, like Thomson's cathode ray experiment, the photoelectric phenomenon explained by Einstein, and the double-slit experiment, questioning the accuracy of the prevailing understanding of their strange results.

Explanatory Secrets in the Emergence of Quantum Mechanics

An Analytical Historical Study of Concepts from the Atom to Wave-Particle Duality Significance of the Research

The theoretical and experimental evolution of quantum mechanics has undeniably reshaped the modern world. It is far more than an abstract theory; it constitutes the scientific foundation for the majority of technologies we rely on today, including transistors—the heart of modern electronics—lasers, Magnetic Resonance Imaging (MRI), and solar cells, among others. Today, a deeper understanding of quantum mechanics is leading us toward new technological frontiers, most notably quantum computing, which promises to solve problems currently insurmountable for the fastest supercomputers, alongside quantum cryptography.

The significance of this study lies in providing the first practical explanation of the quantum concept, transforming it from a mathematical abstraction into a tangible physical entity. This work serves as the direct basis for analysing Hertz's experiments and the photoelectric effect presented herein, while also laying the cornerstone for the concept of wave-particle duality.

This Research Aims to:

- Trace the historical development that led to the emergence of quantum mechanics.
- Systematically explain the fundamental principles of the theory.
- Analyse revolutionary technical applications made possible through quantum understanding.
- Discuss the ongoing philosophical and experimental challenges while looking toward future prospects in this advanced field.
- Attempt to provide a more logical interpretation of scientific experiments.

The Research Problem

In his most famous book, A Briefer History of Time, Professor Stephen Hawking stated: "Today, scientists describe the universe using two basic partial theories—the general theory of relativity and quantum mechanics. Unfortunately, these two theories are known to be inconsistent with each other; they both cannot be correct. One of the major endeavours in physics today. is the search for a new theory that will incorporate them both—a quantum theory of gravity" [1].

Building upon Hawking's observation, this research proceeds from a primary hypothesis: that much of the strangeness and ambiguity surrounding quantum mechanics may stem from a flawed or incomplete interpretation of early experiments, particularly the confusion between the nature of negative electric charge and the nature of the "particle" known as the "electron." The research calls for a re-evaluation of these concepts, proposing an alternative explanatory model that emphasizes the fundamental wave nature of radiation and energy while reducing reliance on the traditional notion of the material "particle." Through this analysis, the research seeks to offer a more coherent and realistic vision of quantum phenomena, potentially dispelling some of the mystery that has long surrounded this revolutionary branch of human knowledge.

Literature Review (Previous Studies)

The theoretical and experimental developments of the early twentieth century formed the bedrock for the rise of quantum mechanics, which transformed classical physics. This section reviews the most foundational studies in the field, analysing their contributions to understanding atomic phenomena and their role in formulating core quantum principles.

Max Planck (1900) – Quantum Theory of Energy

Planck was the first to introduce the idea of energy quantization, assuming that energy is emitted or absorbed in discrete "quanta." This was the pivotal starting point for quantum mechanics, providing the theoretical basis for subsequent concepts such as the photoelectric effect and the Bohr model of the atom [2].

Planck faced the challenge of explaining blackbody radiation, which classical theories failed to fully account for. As a radical solution, he hypothesized that energy is not absorbed continuously but comes in discrete packets or quanta, where the energy of each is proportional to the radiation frequency according to the relation:

$$E = h\nu$$

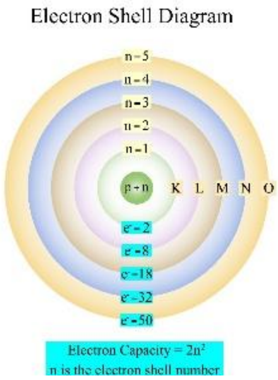
Although Planck initially viewed this assumption as a mere "mathematical trick," it opened the door to a revolution in physics. This study is vital to this research as it represents the historical launch of energy quantization, which forms the essence of all subsequent quantum interpretations discussed, such as the photoelectric effect and Bohr's model.

Albert Einstein (1905) – Interpretation of the Photoelectric Effect

Building on Planck's idea, Albert Einstein, in his revolutionary paper "On a Heuristic Viewpoint Concerning the Production and Transformation of Light," provided a bold explanation for the photoelectric effect. Einstein proposed that light itself consists of these particle-like quanta, later called "photons." This hypothesis successfully explained why the energy of electrons emitted from a metal depends on the frequency of the incident light rather than its intensity—a phenomenon classical physics could not explain [3].

Niels Bohr (1913) – The Quantum Atomic Model

Bohr presented an atomic model where electrons revolve in specific energy orbits and only radiate energy when jumping between these orbits.



Figure

In a series of papers titled "On the Constitution of Atoms and Molecules," Bohr combined the ideas of Planck and Einstein and applied them to atomic structure. He proposed that electrons orbit the nucleus in specific "allowed" orbits without radiating energy, thereby challenging Maxwellian electromagnetism. When an electron jumps between orbits, it radiates or absorbs a photon with energy equal to the difference between the two orbits. This model was remarkably successful in explaining the spectral lines of the hydrogen atom. It is intricately linked to this research as it represents the first application of quantum theory to a complex physical system whose properties remain mysterious (the atom). Furthermore, the debates sparked by this model regarding the position and velocity of the electron lead directly to the heart of the philosophical challenges and the Uncertainty Principle addressed later in this research [4].

Planck began with the abstract idea, Einstein gave it physical meaning, and Bohr applied it to the atomic model. However, these models were not without limitations. Bohr's model, for instance, succeeded with hydrogen but failed with more complex atoms, serving as a bridge between classical physics and the more complete quantum theory later developed by Heisenberg and Schrödinger. This sequence demonstrates that scientific progress is cumulative; each model resolves previous problems while raising new questions—a path this research follows in its subsequent chapters.

Theoretical Framework

The term "quantum mechanics" dates back to 1900, following the discovery of new properties of light by the German scientist Max Planck. Studies proved that photons are the smallest units of energy quanta—termed Planck energy—and that their energy depends on the frequency of the radiation rather than its quantity. This discovery was the first step toward establishing a new physics known as quantum mechanics.

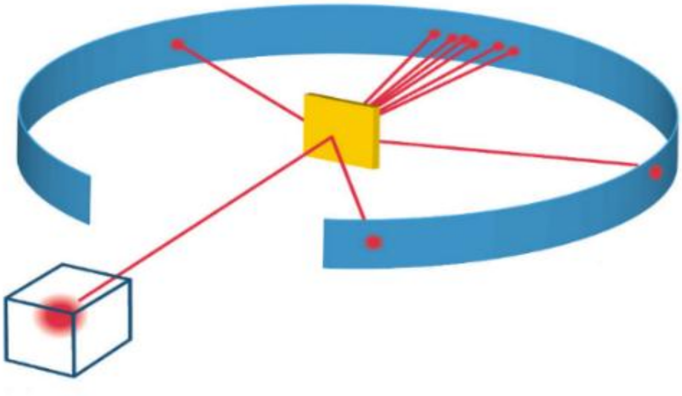
Quantum physics emerged in alignment with the mass-energy equivalence equation through the photoelectric effect. Einstein interpreted this by stating that the energy of the radiation incident on a metal arrives in quanta, displacing electrons and causing them to be released as sparks. Einstein thus discovered that energy and mass are two sides of the same coin [5].

The first indication of the structure of matter (the atom) appeared in 1827 when the scientist Robert Brown examined pollen grains under a microscope. He observed them "dancing" and moving on the water's surface as if they were living microscopic creatures. Einstein later revisited this experiment, studying it deeply and publishing a paper in 1905 explaining the phenomenon (Brownian Motion).

The Shape of the Atom

Brown's experiment was overlooked for over seventy years until Einstein realized that the movement of pollen grains was caused by the atoms composing water molecules, which are in constant motion and collide with the pollen. Through mathematical equations, Einstein determined the infinitesimal size of the atom and concluded that atoms are in a state of perpetual motion, driven by the movement of electrons surrounding the nucleus.

In 1897, the British scientist J.J. Thomson proposed an atomic model shaped like a positively charged sphere containing embedded negatively charged electrons (the Plum Pudding Model). However, in 1907, the New Zealand physicist Ernest Rutherford proved Thomson's model incorrect through his famous Gold Foil Experiment. By firing alpha particles at a thin gold sheet, he proposed a new atomic model based on empirical experimental results [6].



Rutherford Experiant

Figure

The atom was not the ultimate fundamental constituent of matter; scientists discovered that it comprises a positively charged nucleus, which determines the element's type and serves as its distinct atomic identity, surrounded by negatively charged electrons that bind nuclei together to form matter.

A vacuum exists within the smallest components of matter, as the vast majority of an atom is empty space, with physical matter occupying only a minuscule fraction of the atom's total volume. For comparison, if a hydrogen atom were the size of a football stadium, the nucleus would be the size of a table tennis ball at the center, while the electron—resembling a grain of sand—would exist as a small cloud orbiting outside the stadium stands, a phenomenon scientists termed the "electron cloud." The remainder of the stadium would be a complete vacuum through which light travels freely.

Our primary interest among atomic components, which warrants deep investigation, is the electrons orbiting the nucleus. Will we find electrons to be precisely as scientists have described them?

Atomic Constituents

In 1803, the British chemist John Dalton, the most renowned scientist of his era, articulated the atomic theory. Dalton demonstrated that matter consists of atoms that cannot be divided into smaller parts. While Dalton established the fundamental rules of modern chemistry, the atoms he described lacked electrical charge.

Scientists conducted numerous experiments to uncover the properties of the atom and its fundamental components. Among the most significant were those performed by the English scientist William Crookes in 1869 using a vacuum tube. By applying a high-voltage electric current, he discovered cathode rays, which represent a stream of electrons. However, he could not fully characterize these rays originating from the cathode in straight lines, which produced intense heat upon contact with matter. He termed this "radiant matter," considering it the fourth state of matter and a primary constituent of the atom [7].

Many scientists replicated these experiments; notable among them was Philipp Lenard in 1894, who discovered that cathode rays must be electromagnetic waves rather than matter with mass. This conclusion was drawn from the high evacuation of the discharge tube and the increased current intensity of the cathode rays.

In 1895, the German scientist Wilhelm Röntgen accidentally discovered that rays emitted from an aluminium plate struck by cathode rays were electromagnetic waves capable of penetrating human flesh but not bone. To his amazement, he asked his wife to place her hand in the path of the rays. Terrified upon seeing the skeletal image of her hand, she exclaimed: "I have seen my death." Since the rays were of an unknown nature, Röntgen named them "X-rays," though in Germany they are known as "Röntgen rays" [8].

Below is the famous X-ray image of the hand of Röntgen's wife.

Figure

However, Rutherford sought to conduct an "inverse" experiment to that of Röntgen. He directed X-rays between the terminals of a disconnected wire within a circuit equipped with a voltmeter. He observed that the meter indicated the presence of an electric current, demonstrating that X-rays generate electrons upon colliding with the air atoms located between the terminals.

Simultaneously, Henri Becquerel discovered that uranium exhibited an effect similar to that of X-rays. Remarkably, uranium salts emitted this energy without being subjected to any external electric potential; furthermore, they possessed greater energy than that produced by X-rays.

In 1897, Marie Curie replicated this experiment and succeeded in quantifying the radiation emitted from uranium salts by measuring the resulting electric current [9].

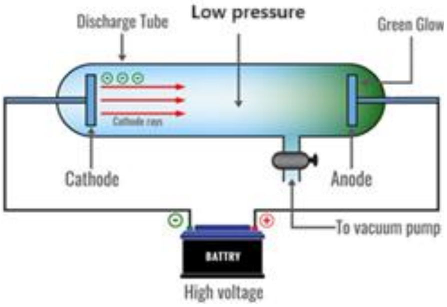
Scientists eventually discovered that radioactive elements emit not only X-rays but also two other distinct types of radiation: alpha and gamma rays. For the purposes of this research, our focus is on X-rays, which we identify as beta radiation resulting from the disintegration of negatively charged electrons. This leads to the fundamental question: What is an electron, and has anyone ever truly observed it or definitively determined its properties?

Results, Analysis, and Discussion

Who Has Seen the Electron?

We inherited the property of the particle electron in 1838 from the British scientist Richard Lamming. This concept helped him reach accurate knowledge of chemical reactions and predict them. Based on this concept, the belief continued that the electron is a particle with mass, as it is one of the parts of the atom that makes up matter.

In 1897, British physicist J.J. Thomson conducted cathode ray experiments using a Crookes tube while testing Dalton's atomic model. Thomson succeeded in providing an interpretation for phenomena that Crookes himself could not explain. By increasing the electric potential and achieving a higher level of vacuum within the tube, Thomson uncovered the core properties of the electron. He observed that the invisible rays emitted from the cathode produced thermal effects and caused the walls of the discharge tube to glow. Furthermore, Thomson discovered that these rays possessed mass, as they were capable of physically rotating a light paddle wheel upon impact. He also confirmed their negative charge, noting their interaction with magnetic fields and their attraction toward a positive pole. The figure below illustrates the configuration of the Crookes tube [10].



Figure

Following these observations, Thomson published his research indicating that matter, composed of atoms, is not the most fundamental entity. Instead, he proposed that atoms consist of negatively charged particles—which he identified as electrons—while the remainder of the atom must consist of positively charged matter. Thomson was also able to measure the velocity of electrons by balancing the magnetic field force against the centripetal force acting on the cathode rays as they were deflected by the positive pole of a magnet.

By comparing the charge-to-mass ratio (E/m) of cathode rays to that of a hydrogen ion (a proton), the mass of a single electron was determined. Thomson found this mass to be approximately 1/1836 of the mass of a hydrogen atom. The established value was recorded as:

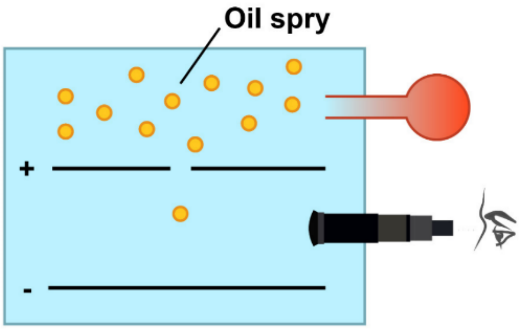
9.10938356×10^{-31} Kg

This leads us to the most famous experiment for determining the electron's properties: Millikan's experiment. Was he able to determine the mass directly from a specific physical mass?

The Oil Drop Experiment

In 1909, Robert Millikan conducted his renowned Oil Drop Experiment [11]. In this experiment, he generated an electric field to observe the behaviour of oil droplets that had been previously given a negative charge. By measuring the specific positive charge required to suspend a droplet in mechanical equilibrium within the electric field, Millikan succeeded in determining the value of the elementary electric charge. From this charge, the mass of the electron was subsequently derived [12]. He found the value of the charge to be:

$1{,}602176487\times10^{-19}$ Coulomb



Millikan oil-drop experiment

Figure

Radioactivity

In studying the radiations emitted by the radioactive element radium, Niels Bohr observed that radium emits three types of radiation: positively charged alpha rays, neutral gamma rays, and negatively charged beta rays. Bohr assumed that these negative rays are particles with mass, and by applying the law of increasing mass, Bohr deduced the rest mass of beta ray particles, by applying the equation of mass and energy equivalence, and from that study from that day on, beta rays were known, as they are nothing but electrons.(13)

What we seek to conclude here is that the mass of the electron, as shown, was not physically measured from a tangible "mass" called an electron. Rather, it was inferred from the charge-to-mass ratio of cathode rays relative to the proton, derived from the mass-energy equivalence of the energy carried by beta particles, or calculated from the charge values of oil droplets in Millikan's experiment. Consequently, scientists began to regard every negative charge as an electron. For comparison, the measured mass of a proton (the nucleus of a hydrogen atom) is:

$1{,}672621637\times10^{-27}$ Kg

While the derived mass of the electron is:

9.10938356×10^{-31} Kg

Experiments have demonstrated that the measured charge is quantized—meaning it exists in discrete, indivisible units. This unit represents the charge of a single electron, the smallest possible quantity of electric charge.

Just as the scientific community began to reconcile with the ideas of energy quantization, the French physicist Louis de Broglie introduced an even more radical concept that further challenged classical intuition. In his published research, he stated:

"Every particle in existence possesses a wave nature, and the wavelength of these particles is inversely proportional to their momentum (velocity)."

This implies that light can behave as a particle with mass, while the electron can behave as a wave—suggesting that everything we see and touch possesses an underlying wave nature. This description necessitates a precise re-examination and interpretation of the photoelectric effect in light of De Broglie's hypothesis. Undeniably, this path will lead us to a truth that has remained hidden until now.

The Photoelectric Effect

In 1900, the German physicist Philipp Lenard officially announced the phenomenon known as the Photoelectric Effect. Earlier, in 1894, the Irish physicist George Stoney had coined the term "electrons" to describe the sparks generated from a metal surface when struck by light—an experiment pioneered by Heinrich Hertz, which serves as the fundamental building block of the photoelectric effect [14].

Scientists observed that the intensity of light directed at a disconnected wire did not increase the electrical energy produced; rather, it was the colour (frequency) of the light that altered the energy's intensity. As the wavelength of the electromagnetic radiation decreased, the resulting electrical energy became more intense. This implies that each colour of light possesses a distinct quantity of energy quanta based on its wavelength. It can be stated that the intensity of the resulting electrical energy is inversely proportional to the wavelength, or directly proportional to the frequency of the incident light, while the total quantity depends on the radiation's intensity. Scientists interpreted this by suggesting that electrons on the metal surface absorb photon energy, becoming highly energized, which allows them to break free from the surface and travel to the opposite terminal, thereby generating an electric current.

However, how accurate is this description?

The photoelectric effect occurs when electromagnetic waves strike a metal surface; as the energy of the incident wave increases, so does the energy of the emitted sparks. When comparing the properties of these sparks with cathode rays, X-rays, and the charges in the oil-drop experiment, we find fundamental differences. X-rays (Beta radiation) possess extremely high energy and are electromagnetic in nature, yet they cannot move a small mechanical wheel. Similarly, the sparks emitted from the metal lack the mass required to produce such mechanical work, unlike cathode rays. Furthermore, the charge in the oil-drop experiment is an electrostatic charge, whereas the other charges are dynamic and cannot exist in a stationary state. In J.J. Thomson's cathode ray experiment, the rotation of the wheel was actually a result of thermal effects heating the paddles, creating a thermal current that drove the rotation. Meanwhile, his son, George Paget Thomson, discovered that electrons possess wave-like properties. Despite these varied findings, all experiments shared one common feature: the negative charge. Einstein later discovered that the sparks emitted from metal surfaces exhibit wave-particle duality. At this point, it is necessary to go back eighty years to observe an experiment conducted by William Crookes.

In 1870, Sir William Crookes discovered the vigorous movement of a vane (radiometer) in a vacuum using "Crookes radiation." He observed that as light intensity increased, the mill rotated faster. Scientists attributed this to the colour of the vanes; the black surfaces absorbed heat from the light, creating sufficient momentum for rotation. The black surface was attempting to "push away" from the light—a phenomenon that only occurs in a vacuum where thermal energy is converted into mechanical energy. This experiment supports the correct interpretation of J.J. Thomson's wheel movement experiment [15].

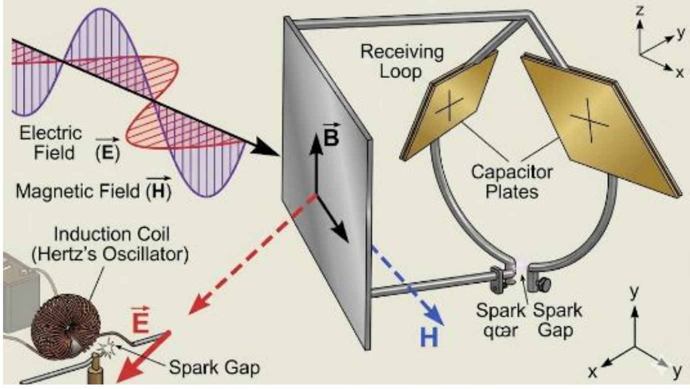
All the evidence suggests that what is emitted from the metal surface is a negative charge whose energy matches that of the incident radiation. We can explain the photoelectric effect in a simplified scientific manner by re-interpreting Hertz's experiment with the scientific rigor it deserves.

Highlighting Hertz's Experiment

The photoelectric effect is defined as the emission of sparks from a metal surface due to incident light. Heinrich Hertz first observed this in 1877 when he found that metal surfaces generate electrical sparks easily when exposed to ultraviolet (UV) radiation, unlike white light [16].

In his experiment, Hertz used a metal plate connected to two thin metal leaves (an electroscope). When he charged the plate negatively, the leaves diverged due to repulsion. Upon directing UV light at the plate, he observed the emission of sparks and the collapse of the repulsion between the leaves. When he repeated the experiment by charging the plate positively, the leaves again diverged; however, directing UV light caused the emission of sparks and increased the repulsion between the leaves. Hertz did not provide a definitive interpretation for these results, nor did he fully grasp why the sparks were emitted.

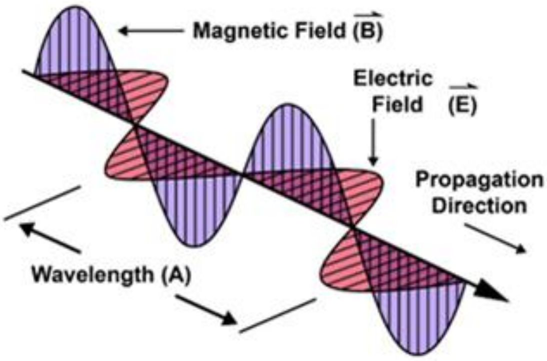
The illustration shows the experiment:



Figure

In 1905, Einstein studied the photoelectric effect deeply. Drawing on Thomson's atomic findings, he proposed that the metal surface absorbs the radiation's energy, which in turn displaces electrons near the surface, causing them to be emitted as "photoelectrons" [17].

Is it truly possible for an atom to allow its electrons to drift away from the nucleus, given that electrons are responsible for maintaining atomic cohesion? Why and how would electrons absorb radiation energy when their energy levels are quantized and fixed? And how would electrons "transform" into light, considering light is an electromagnetic wave? These questions require logical and scientific answers. (The figure below illustrates the components of a light wave, consisting of oscillating magnetic and electric fields).



Electromagnetics Wave

Figure

The sparks rebounding from the metal surface possess varying energies depending on the frequency of the incident radiation, while their intensity depends on the radiation's flux. The liberation of an electron from an atom would imply atomic decay or disintegration—a process known as high-energy beta particle emission—which is not the negative charge observed in the photoelectric effect. It is inaccurate to claim that an electron absorbs incident photon energy to escape the metal surface. Electrons do not "absorb" energy in this manner because their energy is fixed; furthermore, an electron cannot easily distance itself from the nucleus as it is an integral component held by the Strong Nuclear Force. It is physically impossible for a photon with zero rest mass to displace an electron if the electron possesses mass.

The correct interpretation of Hertz's experiment is as follows: Since the incident radiation is an electromagnetic wave composed of magnetic and electric components, the magnetic component (always positively charged) interacts with the metal. The electric component, which is negatively charged, rebounds as if it were being emitted from the surface. This phenomenon is observed only with high-energy radiation, resulting in high-energy electric waves that appear as sparks. These electric waves are what generate electricity, leading to the invention of solar cells. With this sound interpretation, Lenard's work on the photoelectric cell becomes scientifically acceptable, accurate, and realistic.

It is well-established that light exhibits all wave properties: frequency, polarization, refraction, reflection, diffraction, and scattering. However, light has been assigned a new property—particle behaviour—due to the misinterpretation of the photoelectric effect. Consequently, the photon is defined as having zero rest mass. But does a moving photon possess a mathematical mass value?

The Double-Slit Experiment confirms that light is a wave. What results will we find when we fire electrons instead of light through the double slits?

The Wonders of the Double-Slit Experiment

The French doctoral student Louis de Broglie closely followed Einstein's interpretation of the photoelectric effect, which revealed that light—previously understood as a wave—also possessed particle-like properties. De Broglie became convinced that the electron must exhibit the same behaviour, possessing wave properties in addition to its nature as a particle. For his 1924 thesis and subsequent research, De Broglie was awarded the Nobel Prize in Physics, as his work laid the foundation for a new era in quantum mechanics.

In 1924, De Broglie hypothesized the "wave-particle duality" of the electron. To empirically evaluate this wave nature, scientists replicated the Double-Slit Experiment, originally conducted by the British polymath Thomas Young in 1801. Young's experiment was simple in design but profound in its implications; it decisively refuted Newton's corpuscular (particle) theory of light by demonstrating an interference pattern, thus confirming the wave nature of light.

When scientists conducted Young's experiment using electrons, they discovered that the electron behaves as a wave rather than a solid particle with a fixed mass. Intrigued by this wave behaviour in an entity traditionally defined as a particle, scientists decided to place a monitoring device (an observer) to detect which slit the electron passed through. To their astonishment, the electrons ceased their wave-like behaviour and acted instead as particles, appearing as two distinct bands on the screen behind the slits. While puzzling, this was only the beginning of the mystery [18].

The experiment was further refined by firing a single electron at a time. Remarkably, even as a single entity, the electron appeared to pass through both slits simultaneously, interfering with itself to create a wave interference pattern. However, the moment a measurement or observation was introduced, it reverted to particle behaviour. These results were profoundly counterintuitive. Some interpretations even suggested a form of "retro causality," where the electron appears to "alter its past" based on whether it encounters an observer in its future path. The conclusion was radical: in the absence of observation, the electron exists as a massless wave; upon observation, it collapses into a particle with mass. Thus, the scientific community agreed that electrons, like light, possess a dual wave-particle nature, as proposed by De Broglie and Einstein.

Scientists have traditionally classified the universe into two categories: Matter, which constitutes objects with mass, and Energy, which moves those objects. While we know that a proton is matter that occupies a specific volume—composed of fundamental particles called quarks—the electron does not seem to occupy space in the same way. It possesses no known internal structure, and its exact location is never certain. Instead, its existence is described as a state of probabilities (the electron cloud) surrounding the nucleus. Its presence is an assumption of probability rather than a localized reality. Consequently, the double-slit experiment led to the realization that matter and energy are two sides of the same coin.

Spindle Winding and Quantum Entanglement

Further experiments regarding the spin of electrons revealed even stranger phenomena. When a beam is split into two, the spin of the second electron is always found to be the exact opposite of the first. Scientists interpreted this as the first electron instantaneously "communicating" its state to the second, regardless of the distance between them. Einstein famously referred to this phenomenon as "Spooky Action at a Distance".

This did not sit well with Einstein, as it contradicted the limits of his Theory of Relativity (which forbids faster-than-light communication). He famously critiqued the quantum mechanical interpretation with a simple analogy:
"If there is a pair of gloves, and each glove is placed in a separate box, if I open one box and find the right-hand glove, I immediately know the other box contains the left-hand glove, even if that box is at the other end of the universe."

Does the Electron Really Spin?

It is impossible to see an electron even with best microscope. The story began with an attempt to understand atomic spectra. Scientists noticed strange divisions in the spectral lines, and Bohr's model could not explain them. It was as if electrons had additional energy that was not considered, and this matter puzzled scientists. In 1922, the response came from an interpretation of the experiment of scientists Otto Stern and Walter Gerlach.

The idea is that if an electron is rotating around itself, it is acting like a magnet. To measure this, silver atoms were heated and vapor was passed through an irregular magnetic field. The electrons were then supposed to spread out randomly. Instead, the electrons split into only two groups, one of which went up and the other went down. In this scenario, scientists explained that electrons have momentum.

In 1925, scientists Olin Beck and Judd Smith proposed that the electron possesses intrinsic angular momentum, which they called (spindle rotation), imagining that the electron is in the form of a sphere rotating around its axis.

Although the scientist Paul Dirac, in 1928, combined quantum mechanics with Einstein's relativity and formulated a mathematical equation for it, describing the quantum value of the electron, today we know for sure that the electron does not revolve around itself.

The Survival of Schrödinger's Cat

The results of the double-slit experiment left even the greatest geniuses in a state of bewilderment, leading to a race to explain the electron's bizarre behaviour. Among them was the Austrian physicist Erwin Schrödinger, who formulated wave mechanics and addressed the role of probability through his famous thought experiment, "Schrödinger's Cat." Although complex, it can be understood through the following simplified explanation:

Figure

Schrödinger hypothesized the existence of an iron box containing a single radioactive atom that decays randomly at any point within an hour. The exact moment of decay is unknown. The box also contains a Geiger counter to measure radiation; upon detection, it triggers a hammer that breaks a glass flask containing a lethal poison [19]. If a cat is placed inside this closed box, we cannot know when the atom decays. Consequently, at any given moment, there is a probability that the cat is either alive or dead. However, according to Schrödinger's quantum logic, as long as the cat is not observed, it exists in a superposition of being both dead and alive simultaneously until the hour ends and the state is collapsed by observation. This is a philosophical conceptualization detached from objective reality, where the cat is physically either dead or alive at any specific moment regardless of observation. It is logically inconsistent to compare a cat to a subatomic electron, especially since there is no empirical evidence that the electron is a three-dimensional particle, whereas its wave nature is certain. Einstein famously critiqued this line of reasoning, stating: "I like to think that the moon is there even if I am not looking at it."

In 1926, Schrödinger formulated his Wave Equation—a partial differential equation describing the probability density and the evolution of a quantum system over time. However, in this thought experiment, the only thing that could "save" the cat is the Quantum Zeno Effect. But what exactly is this effect?

The Quantum Zeno Effect

The Greek philosopher Zeno of Elea famously contemplated the paradox of motion. He proposed that if one divides the distance between a house and a park into infinite halves, one will technically never reach the destination. Does observation itself affect motion?

Physicist David Wineland conducted experiments on Beryllium atoms to study the effect of observation on electronic transitions. Theoretically, when radio waves (30 Hz - 300 GHz) are applied to a Beryllium atom, its electrons transition to a higher energy orbit. However, Wineland discovered that by frequently "observing" the electrons using pulses of ultraviolet (UV) light, the transition was suppressed. The electrons remained in their original state as long as they were being monitored. This phenomenon is known as the Quantum Zeno Effect. If we could "observe" the radioactive atom continuously in this manner, we could effectively prevent its decay, thereby protecting Schrödinger's cat from death even after the hour expires [20].

The Electron Between Probability, Uncertainty, and the "Ghost"

Schrödinger's wave equation was a monumental achievement, attempting to explain the dual nature of the electron. Paradoxically, it was not derived from a confirmed physical law but emerged as a brilliant, albeit ungrounded, conceptual leap. Most subsequent "bizarre" theories were attempts to interpret this equation, which became an indisputable cornerstone of the newly established field. To justify the paradoxes like Schrödinger's cat, the Uncertainty Principle was introduced by Heisenberg, utilizing matrix mechanics rather than scalar quantities. Max Born followed with the statistical interpretation of the wave function, and Paul Dirac further developed the principle of uncertainty based on the noncommutativity of operators. Dirac's guiding philosophy was that "it is more important to have beauty in one's equations than to have them fit experiment."

The misinterpretation of the photoelectric phenomenon led to a flaw in the interpretation of the double-slit experiment, which in turn led to sterile equations that scientists formulated in vain to find the location and speed of the electron. Theoretically, it is easy to write the equations, but in practice it is impossible to find the location and speed of the electron or to find its mass, as confirmed by the best recent observations in the best atomic microscope.

The strange nature of these theories arises from the fact that scientists in the double-slit experiment were firing a negatively charged wave rather than solid particles with mass. Waves behave differently than particles; a wave in a vacuum is only affected by another wave. When a "single electron" is fired, we are actually launching a negatively charged wave carrying a single unit of quantized energy. This wave passes through both slits, but the charge—being indivisible—only passes through one. Behind the slits, the empty wave and the charged wave interfere. When an observer (a measuring device) is introduced, it acts as an intercepting wave that disrupts the incoming electron wave. This interference cancels the wave pattern, leaving only two lines of energy impact, which misleadingly suggests particle behaviour. The absence of energy in certain areas of the screen is simply where the peak of one wave meets the trough of another, resulting in destructive interference.

The cathode rays described by J.J. Thomson as having mass and traveling slower than light are distinct from Beta rays (which are electromagnetic) and the sparks of the Photoelectric Effect (which are pure negative charges). Each scientist interpreted these phenomena based on different energy levels and vacuum pressures within their tubes.

If the electron were interpreted as a wave and not a substance with mass, we would understand how to describe the spin, since the energy of the wave settles only at the top and bottom, then the interpretation of the Stern-Gerlach experiment would be simple and does not need strangeness. Bohr's model is unrealistic because the atom does not have orbits in which electrons move at various levels. Rather, the electron wave exists around the nucleus at a single level, but their energies vary depending on the nucleus that makes up the type of matter, The amount of energy depends on the number of neutrons.

Nobel Prize

While Nobel Prizes have been awarded to many for their conceptualizations of the electron, the entity itself remains hidden. Recent studies suggest the electron may be aspherical—egg-shaped—orbiting the nucleus in an obscure manner. The latest atomic imagery shows the nucleus surrounded by a "foggy halo" known as the Electron Cloud. If doubts remain regarding this description, they can be dispelled by re-examining the mechanism of the Edison Lamp.

The Edison Bulb

The operation of the Edison bulb is based on the principle that when a metal is supplied with electrical energy, it heats up and emits electromagnetic radiation in the form of light. In 1879, Thomas Edison invented the incandescent light bulb, consisting of a metal filament enclosed in a vacuum glass bulb. When electricity passes through the filament, it heats up and glows, initially emitting a red light. As the electrical energy increases, the temperature of the filament rises, and its glow intensifies, shifting from red to white. Beyond a certain temperature, the filament maintains its white colour regardless of further energy increases [21].

The Edison bulb left three perplexing questions seeking answers:

- Why does the filament glow when heated?
- Why does the colour of the filament shift from red to white as the temperature increases?
- Why does the light remain white despite further increases in temperature?

Max Planck was able to address these three questions using Bohr's model. Planck described energy as arriving in discrete quantities (quanta). When electrical energy heats the filament, electrons absorb this energy and are excited to higher energy levels. Upon returning to their original lower energy levels, they release the absorbed energy as light. A slight heating raises electrons by one level, emitting low-energy red light. Higher temperatures excite electrons to multiple higher orbits, producing assorted colours of the spectrum (including yellow), which eventually combine to appear as white light. Planck also posited that electrons cannot exist between energy levels; they absorb only the specific amount of energy required for a transition, which is why the light remains white at high energies rather than shifting further.

While these answers were convincing to the scientific community at the time, they represented Planck's theoretical perspective without empirical proof. This context introduces new questions that require rigorous scientific answers regarding the actual movement of the electron, based on evidence rather than conceptual speculation. In order to be able to answer everything that is going on in the mind of the questioner, we need to study the energy of the black body.

Blackbody Radiation

In 1900, Max Planck reached an understanding of the relationship between the energy emitted by a blackbody and its temperature. A blackbody is a theoretical ideal that absorbs all incident radiation and reflects none yet emits electromagnetic waves proportional to its temperature. Planck formulated his law by considering the distribution of energy within each atom, confined to specific units of energy. Initially, Planck viewed the quantization of energy merely as a mathematical tool to align theoretical equations with experimental measurements across all wavelengths [22].

The description of blackbody radiation is a description of anybody in the universe, regardless of its temperature. This means, in an Addison bulb, the metal does not necessarily need to be heated to emit radiation, because the metal emits electromagnetic radiation, the wavelength of which is greater than the wavelength of visible radiation, and that heat is emitted from the movement of the components of the atom. Planck utilized Wien's Displacement Law, formulated by Wilhelm Wien, which describes the relationship between a blackbody's temperature and the peak wavelength of its emission.

Based on the studies of Wien, Boltzmann, and Planck, this research concludes that the electron, in addition to its orbital motion, exhibits wave-like movement within energy levels—a distance equal to one electronic wavelength between the peak and the trough. This movement generates electromagnetic radiation. Thus, electrons are in a state of perpetual motion within a single energy level, even without added thermal energy, emitting low-energy radiation as heat. In the Edison bulb, increasing the temperature increases the frequency of this electronic wave. When the frequency matches the visible red spectrum, the filament glows.

Contrary to Planck's interpretation, this research proposes that electrons do not jump to new levels but rather increase their oscillation frequency within their existing level. As the temperature rises, the frequency encompasses all visible colours, resulting in white light. At extreme temperatures, such as in electric arc welding, the motion becomes so rapid that the metal emits high-energy invisible ultraviolet radiation, often appearing blue and causing ocular damage. In a standard Edison bulb, the Tungsten filament cannot withstand such extreme energy; it reaches its melting point It is 3422 degrees Celsius, and breaks before it can emit high-energy blue waves.

Wineland's experiment remains significant here: it suggests that electrons do not jump between levels instantaneously—a "bizarre" interpretation where an electron disappears from one orbit and reappears in another without traversing the space between. Instead, they oscillate as waves within a single level.

Conclusion and Recommendations

Quantum mechanics emerged from an unexamined assumption of the electron's particle nature, rooted in 18th-century descriptions. This led to illogical interpretations of the photoelectric effect. This study concludes that despite extensive research, the electron remains a mysterious entity, exhibiting both wave and particle properties. The modern atomic model, showing a probabilistic "electron cloud" around the nucleus, underscores the need for a deeper understanding based on scientific evidence rather than speculative models.

All evidence, including the double-slit experiment, confirms the wave nature of what we call the electron, though the act of observation introduced doubts regarding its nature. This research recommends a re-evaluation of the electron's confirmed properties, noting that quantum laws governing subatomic particles do not apply to macroscopic objects, such as Schrödinger's cat. We must correct the interpretation of scientific experiments to align with subsequent empirical evidence.

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