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On the Physical Process and Essence of the Photoelectric Effect

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Abstract

A hundred years ago, Planck and Einstein and others created quantum theories or quantum mechanics while they explained the photoelectric effect. Planck and Einstein empirically obtained a statistical relationship between the energy of light quantum and the frequency of light but have not studied the physical process and essence of the photoelectric effect, so some photoelectric phenomena are difficult to be explained by existing quantum mechanics currently. In this paper, a dynamical process of orthogonal interaction between a photon and an electron to form a new state of matter in photoelectric effect experiments is studied so finding that the Planck constant is a product value of the mass, length, and velocity of a high-energy particle. The dynamics of the orthogonal collision of matter (particles) can not only give the physical process and essence of the photoelectric effect, but also have great significance for the further development of quantum mechanics. It can physically explain phenomena such as wave-particle duality and quantum entanglement in the motion of high-energy particles. Its prospects can be widely used in cosmic physics, macro physics, and micro physics.

Keywords

Photoelectric Effect, Planck Constant, Physical Essence, Orthogonal Collision

1. Introduction

The photoelectric effect is the emission of electrons when electromagnetic radiation, such as light or high-energy particles, hits a material. Electrons emitted in this manner are called photoelectrons [1] [2]. This phenomenon has been studied in condensed matter physics, solid states, and quantum chemistry to infer the properties of atoms, molecules, and solids.

The phenomenon of the photoelectric effect has been discovered and studied for a long time. Before the mid-19th century, it was noted that the effect produced by light on electrified bodies and developed the first practical photoelectric cells that could be used to measure the intensity of light [3] [4]. One found that different metals with respect to their power of discharging negative electricity were different so that it was the first sign of the photoelectric effect. In 1887, Hertz observed the photoelectric effect and reported on the production and reception of electromagnetic waves such as ultraviolet radiation [5] [6]. Since then, people have paid more attention to many metals that discharge negative electricity under the action of ultraviolet light, including the effect of ultraviolet light on gas ionization.

In 1900, while studying black-body radiation, German physicist Planck proposed the relation between energy element and the common frequency of resonators. His paper "*On the law of distribution of energy in the normal spectrum*" published in 1901 [7] showed that the energy carried by electromagnetic waves could only be released in packets of energy. In 1902, Lenard [8] found that the maximum electron kinetic energy is determined by the frequency of light. In 1905, Einstein [9] published a paper advancing the hypothesis that light energy is carried in discrete quantized packets to explain experimental data from the photoelectric effect. Einstein theorized that the energy in each quantum of light was equal to the frequency of light multiplied by a set of constants which was similarly called by Planck as a universal constant in 1901. He noted that a photon above a threshold frequency has the required energy to eject a single electron, creating the observed effect. This theory was a key step for the development of quantum mechanics.

In 1914, Millikan's highly accurate measurements of the Planck constant from the photoelectric effect supported Einstein's model and theory, even though a corpuscular theory of light was for him, at the time, "quite unthinkable" [10] [11]. Einstein was awarded the 1921 Nobel Prize in Physics for "his discovery of the law of the photoelectric effect", and Millikan was awarded the Nobel Prize in 1923 for "his work on the elementary charge of electricity and on the photoelectric effect". Planck's law was the first quantum theory in physics, so he won the Nobel Prize in 1918 "in recognition of his contribution to the advancement of physics through the discovery of energy quanta". At the time, however, Planck's view was that the introduction of energy quanta was a purely formal assumption [12] or a heuristic mathematical construct, rather than a fundamental change in our understanding of the micro world.

Above we have briefly summarized the observation, understanding and interpretation of the photoelectric effect by physicists in the early 20th century. After Einstein proposed the classical theory (law) of the photoelectric effect in 1905, the theory of wave dynamics was proposed in the early 20th century [13] [14], and the quantum mechanics was also developed in the 1920s [15] [16]. Their aim was to try to give a theoretical explanation for the Planck constant and the photoelectric effect. However, they still use statistical mathematical methods of probability and matrix mathematical concepts so that the physical explanation is still difficulty. The wave behavior equation uses a mathematical description of the wave function with wave energy. Those properties that are not known with precision must be described by probabilities.

Although the photoelectric effect has been widely studied and applied, there are still some problems to be solved, such as photoelectric conversion efficiency. In terms of theoretical explanation, despite the classical photoelectric effect equation and the theory of wave dynamics can describe the relationship between photons and electrons [13] [14], but there are still some photoelectric phenomena that cannot be explained. Isaacson [17] described the quantum mechanics controversy about uncertainties and probabilities in his book "*Einstein: His Life and Universe*". Although Einstein was the creator of quantum mechanics, however, he believed that underlying quantum mechanics must be a theory that explicitly forbids action at a distance, because he did not recognize the quantum entanglement. He argued that quantum mechanics was incomplete, a theory that was valid but not fundamental, analogous to how thermodynamics is valid, but the fundamental theory behind it is statistical mechanics. Also, Planck was not interested in producing an empirically correct law, but in establishing a rigorous derivation of it [12].

Existing quantum theories, such as quantum mechanics, offer some statistical explanations for the behavior of micro particles such as the photoelectric effect and other phenomena. However, these theories still have limitations when it comes to certain phenomena. We can summarize the limitations in following five aspects.

1) The theories of physics have not yet been fully unified. Quantum mechanics and general relativity are two fundamental theories of physics. They have all been incredibly successful in their respective fields. However, there is currently no complete theory, such as the "theory of everything" or quantum gravity, that can successfully unify the two frameworks. This limitation prevents us from fully understanding phenomena that occur under extreme conditions, such as near black holes or during the early moments in the universe.

2) Measurement is an open question. Quantum mechanics introduces the concept of wave-particle duality, in which particles can exist in a superposition of states. However, the theory does not explicitly explain what constitutes a measurement or why the measurement behavior causes the wave function to collapse to a definite state. This measurement problem has been the subject of debate and an unsolved puzzle in quantum theory.

3) Particle information is non-localized and entangled. Quantum mechanics allows for a phenomenon called entanglement, in which two or more particles become so related that their properties are so closely connected, regardless of the distance between them. This correlation seems to go against the classical concept of locality. Although entanglement has been experimentally confirmed, its un-

derlying mechanisms and the informational relationships between them are still not fully understood.

4) Probability and wave functions diverge from the determinism. In contrast to the determinism of classical physics, quantum mechanics introduces inherent randomness into the micro world, as described by probability and wave functions. This departure from the determinism raises philosophical questions about the nature of reality and the role of consciousness in observing behavior.

5) Quantum mechanics lacks an intuitive explanation of how the world works. While the mathematical framework of quantum mechanics can make accurate predictions, it lacks a complete intuitive understanding of concepts like wave-particle duality, quantum entanglement, superposition, and tunneling.

The photoelectric effect is a start-up experiment for the creation of quantum mechanics. Therefore, the problems encountered in quantum mechanics still require an understanding of the fundamental mechanism of the photoelectric effect. The process of how photons and electrons interact to achieve the optimal efficiency of photoelectrons is not only necessary to understand the photoelectric effect, but also the content that needs to be studied for the in-depth development of quantum mechanics. This article attempts to find the fundamental theory of quantum mechanics that Planck and Einstein expected. From Section 2, we will find that Plank and Einstein's photoelectric effect relations are both in the form of statistical physical laws so that their relations are difficult to express the essence of photoelectric effect. Thus, we give a dynamical result of the photoelectric effect without statistical constants in Section 3. The dynamical result use to explain phenomena proposed in current quantum mechanics is described in Section 4. Section 5 gives the conclusions and discussion of this article.

2. Traditional Explanation on the Photoelectric Effect

The photoelectric effect gives the phenomenon of photons hitting the surface of a substance (solid metal) to excite electrons. The first to give a description of the photoelectric effect was Planck. In his 1901 article published in Annalen der Physik, he used the calculation of resonator entropy as a function of energy [7]. For the system of N resonators, he gives a definite total entropy,

$$S_N = NS. \tag{1p}$$

where S represents the average entropy of a single resonator, and the total entropy S_N depends on the disorder with which the total energy UN is distributed among the individual resonators.

The entropy S of a resonator as a function of its single energy U is given by,

$$S = \kappa\left[\left(1+U/\varepsilon\right)\log\left(1+U/\varepsilon\right)-\left(U/\varepsilon\right)\log\left(U/\varepsilon\right)\right]. \tag{2p}$$

where κ is a universal constant, ε is as a discrete quantity as a part of the energy element. From here the discrete energy has been mentioned by Planck in his paper.

He applied Wien's displacement law to Equation (2p) for the single entropy S. He then found that the energy element ε must be proportional to the frequency ν, thus,

$$\varepsilon = h\nu \quad (3p)$$

where, *h* is another universal constant called in his paper.

In 1905, Einstein's article "*On a heuristic point of view about the creation and conversion of light*" published in the same journal was divided into 9 parts [9]. In Part 8, "*On the generation of cathode rays by illumination of solid bodies,*" a similar expression to Planck appears, but his description of quantum is clearer. The following italics are English translations based on his German article.

The usual understanding, that the energy of light is distributed over the space through which it travels in a continuous way encounters extraordinarily large difficulties in attempts to explain photo-electric phenomena, as has been presented in the groundbreaking article by Mr. Lenard [8].

According to the understanding that the exciting light consists of energy quanta of energy (R/N)βν the generation of cathode rays by light can be conceived as follows. Quanta of energy penetrate the surface layer of the solid, and their energy is transformed, at least partially, in kinetic energy of electrons. The simplest picture is one where the light quantum gives its entire energy to a single electron; we assume that this will occur. However, it must not be excluded that electrons accept the energy of light quanta only partially. An electron that has been loaded with kinetic energy will have lost some of its energy when it arrives at the surface. Other than that we must assume that on leaving the solid every electron must do an amount of work P (characteristic of that solid). Electrons residing right at the surface, excited at right angles to it, will leave the solid with the largest normal velocity.

In this paragraph, Einstein explicitly gave academic terms for quantum concepts such as "energy quanta of energy", "quanta of energy" and "light quantum". His energy quanta can be written as,

$$\varepsilon = \left(R/N\right)\beta \cdot \nu \quad (4e)$$

where R is the absolute gas constant, N is the number of "real molecules" in a gram equivalent ($N = 6.17 \times 10^{23}$), ν is the frequency, and $\beta = 4.866 \times 10^{-11}$.

As Einstein published in the same year as his article on the mass-energy equivalence relationship [18], he did not directly give a relation as Equation (4e). But from his articles, it is easy for people to understand or write his expressions. So, we can use the same symbolic ε for energy quanta in Equation (4e) as used by Planck in Equation (3p). In comparation of Equation (3p) and Equation (4e), it can be found that the universal constant h used by Planck is equivalent to Einstein's three synthetic constants, *i.e.*,

$$h = \left(R/N\right)\beta \quad (5)$$

We will not concern the respective estimates of Planck constant with Einstein constant. Both from their respective derivations and estimates of the Planck constant and from the experimental data of others, they all agree that the energy of photoelectrons is proportional to the frequency of photoelectrons.

Planck's research on this problem began with blackbody radiation, Einstein began with the photoelectric effect, and they both got the relationship between energy and frequency. Quantum mechanics textbooks and encyclopedias now refer to the relationship between photon energy E and photon frequency f as the Planck-Einstein relation [19],

$$E = hf . \tag{6}$$

In honor of Planck, where h is called the Planck constant.

The statistical relationships confirmed by observations are called laws, such as Newton's law of universal gravitation and Coulomb's law in electromagnetism. People can conveniently use these laws of physics in their daily lives and work. But there are two problems in the laws of physics: one is not precise enough because constants that exist are statistical and another is not known their physical mechanism. Therefore, the physical discipline developed with the laws of statistical relationship is not precise enough, and the physical attribution is not clear.

3. The Dynamical Process of the Photoelectric Effect

The photoelectric effect is a representation of a physical phenomenon. Planck and Einstein gave statistical mathematical expressions of the photoelectric effect, respectively. The fundamental description of the photoelectric effect requires a dynamical method that combines from mathematics and physics. Based on the description in Einstein's 1905 article [9], we drew **Figure 1**. There are many electrons within and on a metal plate. A photon or particle p radiates into a solid metal plate in a path of micro fluctuations. This particle p collides with an electron e on the metal plate and causes a photoelectron to escape out the metal plate.

We examine the collision between a particle and an electron from the subatomic scale. The propagation of energetic particles has the property of wave-particle duality. In **Figure 2**, an electron e is moving at a high speed around its nucleus. A particle p along a wave-like path collides with an electron at point H. The collision angle between them is θ. Instead of focusing on whether the photons

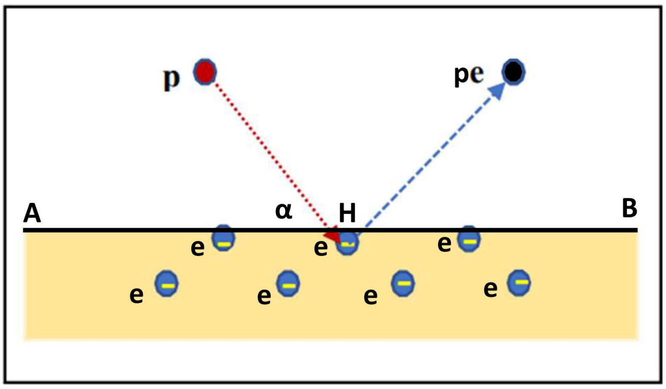

Figure 1. The emission of a photoelectron pe (black point) from a metal plate (yellow shading area) caused by a light quantum—a photon or particle p (red point). The letter α is an angle of a photon radiating to the plate and interacting with an electron e (blue point) at the point H on the surface between A to B.

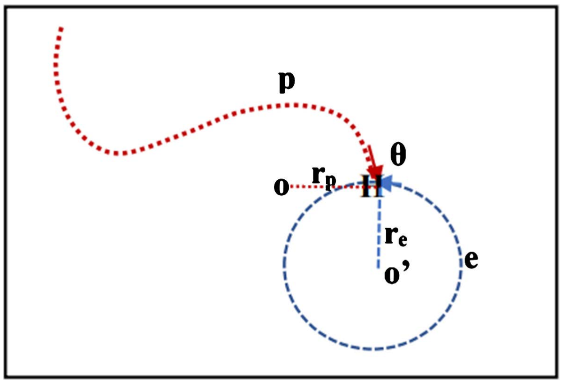

Figure 2. A photon or particle p and an electron e collide at point H with a collision angle θ between them. The letter o' indicates the center of the electron e circled by the blue-dashed line around its atomic nucleus and the letter o is the curvature center of the photon or particle p moving along a wave-like path indicated by the red-dotted line, the letters r_p *and* r_e are their moving radiuses.

entering the surface of the metal plate have mass, we first confirm that there is a high-energy particle p with its mass m_p. There may be multiple electrons orbiting around an atomic nucleus. Different substances have different atoms. Different atoms carry different numbers of electrons.

In Figure 2, the mass of a particle is m_p and the mass of an electron is m_e. They all have their own centripetal forces $\boldsymbol{F}_p$ and $\boldsymbol{F}_e$ when they collide at point H. Two forces are,

$$\boldsymbol{F}_p = \frac{m_p}{r_p} v_p^2 \boldsymbol{n}_p , \tag{7}$$

$$\boldsymbol{F}_e = \frac{m_e}{r_e} v_e^2 \boldsymbol{n}_e . \tag{8}$$

where the term $\frac{m}{r} v^2 \boldsymbol{n}$ is a centripetal force with mass m and velocity v at the $\boldsymbol{n}$ direction, r_p and r_e are the moving radiuses of particle and electron respectively.

The centripetal force is an inertial force. Considering that they collide with each other under the action of centripetal forces,

$$\boldsymbol{\tau} =|| \left(\frac{m_p}{r_p} v_p^2 \right) \cdot \left(\frac{m_e}{r_e} v_e^2 \right) \cdot \left(\boldsymbol{n}_p \times \boldsymbol{n}_e \right) . \tag{9}$$

The direction of shear stress $\boldsymbol{\tau}$ is perpendicular to the plane formed by two-unit vectors $\boldsymbol{n}_p \times \boldsymbol{n}_e$. The symbol "$=||$" in Equation (9) indicates that the quantities (vector and scalar) on both sides represent events separated in the two different worlds (or two different universes). The magnitude on both sides is equal, but the information on both sides cannot be communicated. From the new world (new universe) $\boldsymbol{\tau}$, people cannot find any information even appeared in the old world (old universe), $\left(\frac{m_p}{r_p} v_p^2 \right)$ and $\left(\frac{m_e}{r_e} v_e^2 \right)$. Similarly, no information of the new world (new universe) existed in the old world (old universe). The symbol has a philosophical meaning. After a collision and taking $r_p = r_e = r$, the shear stress modulus is,

$$\tau = \| \left(m_p v_p^2\right) \cdot \left(m_e v_e^2\right) \sin\theta / \sigma . \quad (10)$$

where $\sigma = r^2$ and θ is the angle between two directions $\boldsymbol{n}_p$ and $\boldsymbol{n}_e$. The shear stress modulus can be seen as the density of mass-energy product (or mass-energy density for simply) formed by the collision of the particle and the electron, which is distributed in a new area σ.

In Equations (9) and (10), the collision of two energetic particles causes a revolution between the old and new worlds, namely the birth of the new universe like a "big bang" and the demise of the old universe like a "black hole". In Equation (9), the shear stress $\boldsymbol{\tau}$ as a new universe has two moving directions of new material (photoelectrons) perpendicular to the plane of the photon and electron involved in the collision in the old universe. The directional shift between the old and new worlds can explain many phenomena observed and discovered in micro world of quantum mechanics, such as the opposite spin of new matter, the opposite polar jet directions of black holes, the opposite charge, and so on.

In Equation (10), the information of the old and new worlds (universes) has changed qualitatively. The two high-energy particles involved in the collision will leave different traces (inertia) to the new world (new universe) depending on the angle of collision. When the collision angle is 0 degrees, it corresponds to a head-on collision between two high-energy particles, leaving the shear stress modulus to the new world (universe) as $\tau = 0$. When the collision angle is 180 degrees, it corresponds to a rear-end collision between two high-energy particles, so that the shear stress modulus left to the new world (new universe) is also as $\tau = 0$. For these two collisions, no new world (universe) or no new materials can be generated. This description shows that if a collider we build in the form of particle collision is a head-on collision or a rear-end collision, then a concentration of energy can be formed, but not a mass-energy conversion from the old world to the new worlds. The purpose of an artificial collider is to form new states of matter such as plasma or photoelectrons through the collision of high-energy particles. Only orthogonal collision is the best mechanism for the conversion from the old state of matter to the new state of matter, meaning that the conversion from the mass of matter to energy can occur [20]. Orthogonal collisions are the best choice for building high-efficiency and low-consumption colliders [21].

How can we best obtain new states of matter or produce sudden changes in mass and energy from an old world to a new world (universes)? At an angle of 0 < θ < 180, the shear stress modulus in Equation (10) is positive. At an angle of 180 < θ < 360, the shear stress modulus is negative. To achieve the maximum mass-energy density, the collision angle should be 90 degrees when $\sin\theta = \sin\left(\frac{\pi}{2}\right) = 1$. The maximum mass-energy density when two energetic particles collide orthogonally is,

$$\tau =\| \left(m_p v_p^2\right)\cdot\left(m_e v_e^2\right)/\sigma . \quad (11)$$

In 1986, the famous Chinese painter Li Keran created a Chinese painting for Lee Tsung-Dao, winner of the 1957 Nobel Prize in Physics, entitled "Nucleons are as heavy as ox, and collisions generate new states". The sculpture is now placed in the center of the Tsinghua University Science Park Square in Beijing, China. Nucleons refer to high-speed photons and electrons. The collision of two oxen on the sculpture shows the traditional head-on collision of high-energy particles, not the orthogonal collision that can generate a new state of matter in Equation (11).

Under the mass-energy density generated by the orthogonal collision of two old high-speed particles, lots of new high-energy particles (plasma or photoelectrons) are formed there. Half of these new particles are concentrated in the area *σ*, and the other half radiate outward. Half of the energy from the mass-energy density produced by two old particles and radiated outward is,

$$E_h = \left(m_p v_p^2\right)\cdot\left(m_e v_e^2\right)/2 . \quad (12)$$

On the other hand, half of the *N* new particles are radiated outward. The mass of each new particle radiating outward is *m* and its velocity is *c*. Thus, the total energy radiated outward by half new particles is,

$$E_h = Nmc^2 . \quad (13)$$

The energy of each new particle or photoelectron is,

$$E = mc^2 =\| \left(m_p v_p^2\right)\cdot\left(m_e v_e^2\right)/N . \quad (14)$$

The left side of Equation (14) represents the energy *E* of a new particle or photoelectron, and the middle side indicates the mass *m*, velocity *c*, momentum *mc*, and energy mc^2 of the new particle or photoelectron. The meaning of relation between mass and energy $E = mc^2$ in Equation (14) is entirely different from the Einstein's mass-energy equivalence in his 1905 paper [18]. His mass-energy equivalence was speculated from the mathematical derivation of special relativity based on the Lorentz transformation of two coordinate systems [20].

The right side represents the mass m_p (m_e), velocity v_p (v_e), momentum $m_p v_p$ ($m_e v_e$), and energy $m_p v_p^2$ ($m_e v_e^2$) of an old photon or particle (electron), respectively. Although there is no exchange of information between the two worlds (universes), the mass-energy relationship between them is certain. These quantities are all fundamental quantities in traditional physics but reflected in two different worlds (universes). It means that conventional physical quantities can be used equally in both the old and new worlds (universes). However, there is no correspondence in physical quantities between old and new worlds (universes). This notation, "$=\|$", which is not an equal sign, indicates that there is a conversion of mass to energy in the collision process from the old world (universe) to the new world (universe). The collision during the conversion produces a new particle number *N*, which needs to be determined. In the old and new worlds (universes), each of these physical quantities is individually countable, which means quantum. But the N number can vary from 0 to N, depending on factors such as different collision angles between photons and electrons and collision environments. Thus, Equation (14) physically reveals a dynamical model of the photoelectric effect process.

Based on Figure 1 and the above theory, we can give an experimental setup and procedures for the orthogonal interaction between photons and electrons. Step 1 is to choose a clean and flat metal plate that knows the atomic composition of the substance. Step 2 is to make an arc-shaped light hood using the length from point H to position pe in Figure 1 as the radius. We only detect the energy of photoelectrons because the position, mass, and momentum of photoelectrons are difficult to measure. A simple experiment is to have photons hit point H in Figure 1 at different angles and measures the maximum energy position of photoelectrons on the arc-shaped light hood for each α angle. Theoretically, this position is determined and its angle (the angle between the A-H and H-pe lines) is α+90 degrees.

4. The Physical Essence of the Photoelectric Effect

Through the mathematical description of the dynamic process of the photoelectric effect, we understand that there are many particle collision possibilities and different particle collision effects. We start by considering an environment of optimal particle collision. In Equation (14), the energy E of a new particle or a photoelectron can be measured, but the measurement of mass m and momentum mc is difficult. For two original particles, their energies of photon and electron are known, but their mass and momentum are also difficult to measure. In the theory of quantum mechanics, there is an uncertainty principle, but there is no mention and distinction between the measurement of particle mass, velocity, and momentum in the old and new worlds. Energy is a measurable large number which is multiplied by mass and velocity squared. If the energy of old and new particles can be measured, then the best effect of photon and electron collisions should be a large number of new particles N. The number of new particles, N, can be estimated, and the key is to know the environment in which the collision occurs. As the angle of collision between photon and electron changes and is uncertain, there is also uncertainty in the estimation of the number N for the new particles produced.

In Figure 1, the flatness and cleanliness of the metal surface, the material composition of the plate, the angle of incidence of photons, and the environment in which photons are incident are all surface (macro) factors that affect the photoelectric effect. In the theoretical descriptions of Planck and Einstein, in experimental detections, and in many textbooks of physics, the description of the photoelectric effect does not consider the number N of new particles or photoelectrons that appear in Equation (14). In theoretical research, one can consider as a most ideal or best surface situation. If the velocity of the new particle is,

$$c = fL. \tag{15}$$

where L is the wavelength of the new particle. From the new particle velocity in Equation (15), the Planck-Einstein relation in Equation (6) and the new particle energy $E = mc^2$ in Equation (14), the Planck constant can be obtained as,

$$h = mL^2 f = mLc. \tag{16}$$

This result shows that the Planck constant is not a universal constant, nor is it Einstein's composite constant. It is the product of the mass m, length L, and velocity c of the particle. It reflects the three basic features of matter in physics: mass, scale, and motion. For energetic particles, all three quantities are difficult to be measured. Therefore, the Planck constant, which has a physical meaning, is also difficulty to be determined. It is no wonder that Planck and Einstein gave different constants. Since the first measurement to determine the Planck constant is based on the photoelectric effect, however, the values obtained so far have exhibited a large uncertainty [22].

In **Figure 2**, the motion of two particles before the collision is wave-like form, but the collision is in the form of two particles. In Equation (16): particle mass m is the physical object; particle frequency f is in wavering form, not matter, and is an equivalent to energy. Therefore, at the micro scale of particles, **Figure 2** and Equation (16) fully reflect the characteristics of wave-particle duality during particle collision.

In **Figure 1** and **Figure 2**, what elements (atoms) are the metal composition of the plate? Is it a pure metal, or a synthesis of different metals? Are metals or other materials contaminated (e.g., oxidized)? What is the speed (vector) of electrons in metal atoms rotating around the nucleus and what is the collision angle between photon and electron? These aspects affect the total number N of new particles or photoelectrons generated, and whether measurable new particles escaping out after a collision can be formed, or whether it becomes a thermal phenomenon of the metal plate after the collision, that is, the relaxation process.

For the theoretical research, a collision of the above two high-speed (high-energy) particles occurs on the metal surface or in a shallow layer, forming the photoelectric effect. The actual photoelectric effect can be observed from the interaction of lots of photons with lots of electrons. If an interaction of high-velocity particles occurs in a vacuum, it can form lots of micro synthetic cosmological phenomena, such as black hole events. At the cosmic and macro levels, black holes to those that appear in the central part of the Milky Way are structurally like super typhoons (hurricanes), although they differ in scale [23]. The four spiral nebula belts around the center of the Milky Way and the four-spiral cloudy-rain belts around the super typhoon converge to the center, forming an orthogonal collision (or convergence) of the four material belts. The shear stress of their orthogonal collision not only forms a high-density concentration of mass and energy, but also a spiral ejection of new material in the two directions of poles perpendicular to the material convergence plane. These polar jets perpendicular to the accretion disk form outside the black hole's event horizon. The event horizon of a super typhoon is the wall of cloud and rain around the eye of the typhoon. Typhoon vertical jets are the sinking air flows in the eye area and the updraft air flows along the ring cloudy-rain wall. They form vertical convection inside the super typhoon.

In the Earth's atmosphere, typhoons belong to large-scale weather systems, while tornadoes belong to small-scale weather systems. Tornadoes also develop under the orthogonal collision of the surrounding environment disturbance air flows [24]. The vertical ascending and sinking air flows in the center of the tornado is perpendicular to the directions of the environmental disturbance air flows. A large object, such as a house and a tree, enters a tornado "black hole" and is smashed and thrown high into the upper air. Our universe structure spans from micro scales such as the Planck-scale black hole to cosmic scales such as astronomical black holes. Einstein initially proposed the idea of electron black hole which is a micro universe. The electron black hole considered has a Planck length horizon and spin electromagnetic jets [25].

In astronomy, many cosmic and macro phenomena are also the aggregation products or results of orthographic collisions of micro energetic particles. The auroras observed over the polar regions of planets and moons in the solar system are optical phenomena formed by the orthogonal collision between energetic particles ejected by solar storms and ionospheric ions in the planet's (satellite) atmosphere during sunspot activity [26]. During a total solar eclipse, the observed gravitational lensing effect is an orthogonal collision between solar particles and alien star particles, resulting in an optical phenomenon [27].

The phenomenon of particles colliding to form new states of matter can be found in daily life and in nature. An example is the triboelectric effect. Triboelectric is when two particles interact to produce new particles with unlike charges. New particles are divided into positive and negative charges which can be explained by both directions of shear stress. Continuous collision of particle beams with multiple angles, especially orthogonal collision, will accumulate heterogeneous charges on two adjacent carriers. In this way, an electric potential, *i.e.*, an energy difference, is formed between the two carriers. Lightning in an atmospheric storm is a discharge phenomenon caused by the electric potential difference between two adjacent cloud bodies. The two forms of motion of matter in nature are inertia and collision. The inertial motion (potential energy) is changed only during a collision (change in momentum). Force is needed to change the inertial motion.

The theory of orthogonal collision can be used to explain not only the photoelectric effect but also many natural phenomena occurred in cosmic, macro, and micro aspects. This theory can also promote the development and application of quantum mechanics. Quantum entanglement and nonlocality are a peculiar phenomenon in quantum mechanics. When two or more particles are entangled, their states are closely related, no matter how far apart they are. For example, in new particles formed after the orthographic collision of old particles, their spin direction and polar jet direction, as well as charge of particles, are completely different from those of old particles, but the new particles (new particle swarms) have statistical similarities between them, no matter how far apart. People call this phenomenon as quantum entanglement.

The current state of motion of planets and moons in the solar system is traces (products) left after an orthogonal collision. The pre-collision material information is all gone. In the Earth-Moon system motion relationship, one side of the Moon rotation always faces the Earth, like other moons orbited and faced to their planets. Different planetary systems that are more distant away are also entangled because their similar characteristics. Multiple tornadoes that form in a hurricane (typhoon) or a cyclone can also become statistically entangled, although they are far apart. The new state of matter after the orthogonal collision and the two original particles are no longer an event happened in the same world, but the physical features of new particles have many similarities. Such similarities appear to be quantum entanglement or disappear through other influences. Some phenomena in quantum mechanics occur with statistical probability, such as quantum entanglement and quantum decoherence. These phenomena in quantum mechanics are not found in classical mechanics. Similarly, the phenomena that occur in the result of orthogonal collisions do also not occur in conventional mechanics.

The origination of quantum mechanics is mainly based on the statistical mathematics, which was limited by understanding the essence of the photoelectric effect and applying the method of combination of physics and mathematics. Philosophically, Einstein long believed that things in the universe could be determined and predicted. Therefore, quantum mechanics should also be physically based on deterministic mathematics from a micro perspective, except it is limited by detection technology. Cosmographically, the transformation between the two worlds is long, such as the formation of the solar system. Synoptically, the transformation of the two worlds is visible, such as the formation of a weather storm. Microscopically, the transformation between the two worlds is rapid, such as the photoelectric effect and Planck-scale black holes. For all three space scales, their transformation (collision) is faster than their inertial motion. The development of quantum mechanics requires mastering the worldview and methodology of the transformation of material worlds.

5. Conclusions and Discussion

The main conclusion of this article can be boiled down to the phrase "material orthogonal collision generates new physical states". Its philosophical significance is that there is no exchange of information between the two worlds before and after the orthogonal collision. It reflects the shift from a gravitational worldview of Newtonian two-body world and Einstein many-body world to a matter inertial worldview. The shear stress of orthogonal collisions reflects the methodological formulation under the inertial worldview. The mass of an old particle can be converted into the energy of lots of new particles on one-way direction through orthogonal collisions.

The photoelectric effect is a well-known phenomenon and a field widely used in daily life by modern people. This paper theoretically explains that the photoelectric effect can produce photoelectrons escaping from the process of orthogonal collision between photons and electrons outside the nucleus. What escapes is many particles. The energy of the escaped particles has quantum properties and can be measured. The theory of orthogonal collisions between particles can be used to explain phenomena such as radioactive decay, scanning tunneling microscopy, and semiconductor devices.

The new theory provides a definitive explanation for the uncertainty of particle statistics and wave functions in quantum mechanics. The statistical relationship between Planck and Einstein's constants in the photoelectric effect is physically meaningful in nature, as it is the product of a particle's mass, length, and velocity. It can explain experimentally observed wave-particle duality, as well as special quantum behaviors such as quantum entanglement, quantum superposition, and quantum tunneling. It can predict various extreme events in the cosmic, macro, and micro worlds, such as "black holes" at their respective time-space scales.

Some special and non-intuitive behaviors such as wave-particle duality, quantum entanglement, quantum superposition, and quantum tunneling are exhibited in the motion of energetic particles. The motion of photons and electrons is undoubtedly characterized by the properties of particles. At the same time, they in turn appear in the form of energy units. The alternation between kinetic energy and potential energy (magnetic energy) of mass particles during the propagation of inertial motion shows the basic wave-particle characteristics. The phenomenon of quantum entanglement is not only manifested in the micro particle world, but also in the cosmic and macro worlds. They manifest themselves as similarities to the overall motion characteristics (collective states) of a subsystem composed of multiple particles. Quantum entanglement is the intrinsic relationship formed between particles after orthogonal collisions. Only orthogonal collisions can produce new mass-energy densities and form the conversion from the mass of original particles to new mass-energy density. So, such a huge amount of new particle energy can pass through the energy barrier. Lots of new particles are formed so that they can exist in multiple superposition states at the same time. The spin up and spin down, as well as the positive and negative charges of new particles, are the result of orthogonal collision shear stresses, without considering the wave function. These unique phenomena of the quantum world do not go against people's intuition and can correctly allow people to understand the principles of quantum mechanics.

The photoelectric effect as an optical phenomenon has undergone a long-term process of understanding and a rapid process of experience summary. The exploration of the photoelectric effect began two centuries before the beginning of the 20^{th} century, since the notably famous double-slit experiment in 1803. At the beginning of the 20^{th} century, Planck and Einstein quickly used statistical methods to establish a mathematical relationship between particle energy and particle frequency. This statistical-mathematical relationship does reflect the intrinsic linkage between two physical quantities existed in the photoelectric effect. Although the statistical relationship between energy and frequency is established, the phenomenon of wave-particle duality in light propagation has not been physically explained. For a long time, neither wave dynamics nor quantum mechanics in quantum physics fully explain wave-particle duality. So, different theories and schools of thought have emerged and argued.

For more than a hundred years, the true value of Planck constant that people have been searching for is limited by the difficulty of measuring these three physical quantities which is referred as the uncertainty principle. The energy and direction of motion of a new particle are completely different from an old particle. Depending on the angle of collisions, new particles can appear in different rotational states with opposite (left and right) spins. The two directions of motion of new particles are perpendicular to the plane of collision of old particles and can form opposite charges. The six basic quantities in physics: mass, position, momentum, energy, spin, and charge, all appear in the dynamics of orthogonal collision for explaining the photoelectric effect in this paper. The orthogonal collision of two energetic particles yields the largest mass-energy density, while the mass-energy density of head-on collisions and rear-end collisions is zero.

The dynamics of the orthogonal collision of two particles can be used to explain many phenomena that occur in cosmic, macro, and micro interactions of matter motion. On cosmos scale, it can explain the black hole phenomenon and internal structure of cosmic celestial bodies, can explain the aurora phenomenon at the poles of the Earth, and can explain the gravitational lensing effect around the Sun during a total solar eclipse. At the macro scale, it can explain the dynamics of superstorms such as typhoons (hurricanes) and tornadoes in the internal structure and formation of meteorological disasters. At the micro scale, it can explain the phenomenon of Planck-scale black holes, the entanglement phenomenon between newborn particles, and the wave-particle duality of the movement of high-energy particles. The dynamic explanation of these particle collision phenomena does not distinguish between the relativistic high-speed motion of particles and the low particle speed of Newtonian mechanics.

Just as the statistical relationship between particle energy and particle frequency in the photoelectric effect was established, the research at that time led to the birth of quantum mechanics. Quantum mechanics should develop from its original statistical manner to current dynamical manner. The dynamics of generating new states of orthogonal interactions of matter (new particles) can not only fully explain the photoelectric effect but can also contribute to the development of theoretical quantum mechanics with mathematical and physical significance. In terms of application, it will accelerate the development of new detection instruments, optoelectronic equipment, including quantum computers. Orthogonal collisions can produce new things and can also cause the most serious disasters. After correctly grasping the dynamical principle of orthogonal collision, it can benefit and avoid disadvantages for human development.

Planck and Einstein and others derived the concept of quantum when studying the photoelectric effect and developed quantum mechanics. Later, Einstein developed the general theory of relativity. As a result, general relativity and quantum mechanics became the two basic theories of physics, each of which could explain and predict many phenomena in the cosmic and micro worlds. But unifying these two theories has become a theme and a problem in contemporary physics. The basic assumptions and mathematical frameworks of the two theories are different. Space-time and mass-energy in general relativity are continuous, while micro particle states in quantum mechanics are discrete. For the world description, the former used the complex geometric mathematics instead of Newtonian simple statistical gravity, and the latter used statistical relations and wave functions to mask the physical nature of the photoelectric effect.

This paper argues that a unified theory of physics requires a new worldview and methodology. This new worldview is that the motion of matter (particles) in the universe follows inertia. The methodology is that orthogonal collisions of matter (particles) from the old world can produce the mass-energy density of the new world. Matter (particle) information in the old and new worlds is not exchanged. The motion of matter (particles) in the new world has new inertia, satisfying the relationship of all members relative to their subject object as described by the general relativity equation. The unified theory can exhibit special quantum behaviors such as wave-particle duality, quantum entanglement, quantum superposition and quantum tunneling. This new theory can unify general relativity and quantum mechanics. At the same time, this new theoretical framework can predict various extreme events in the cosmic, macro, and micros worlds, such as "black holes" at their respective scales.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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