A New Perspective of Quantum Mechanics and Particle Physics

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ABSTRACT

We would introduce here a further intrinsic quantum property, pin, like a tiny string, borrowed from the Clifford algebra as back word of spin, other than the intrinsic quantum property, spin, in quantum electrodynamics. In the Clifford algebra, it would be found that spinors are essential in describing spin with the general nature of an intrinsic angular momentum and pinors may be essential in describing pin with the general nature of an intrinsic linear momentum of subatomic particles. The physical consequences of spin and pin in quantum electrodynamics may be obtained in the phenomenon of uniform circular motion of a point object, as such, spin and pin, by acting at right angle to each other in any reference frame, being quantized, would represent the observable quantum states such as subatomic particles. It would also be found that a spin is associated together with an intrinsic magnetic moment, which is the permanent attribute to spin at antiparallel relation and a pin may be associated together with an intrinsic electric moment, which is the permanent attribute to pin at antiparallel relation in quantum electrodynamics and particle physics.

The presence of the four intrinsic properties spin, pin, magnetic moment and electric moment of subatomic particles in quantum electrodynamics may thus open a new perspective of quantum mechanics and particle physics, which may support to find out the isolated quantized electric monopoles, as well as, the isolated quantized magnetic monopoles as free positive and negative electric and magnetic charges carried by specific particles.

Keywords: Clifford algebra, Quantum field theory, Quantum electrodynamics, Quantum mechanics, Properties of particles, Induced magnetic field, Induced electric field, Stark effect, Zeeman effect, Stern-Gerlach experiment

1. INTRODUCTION

Introducing a further intrinsic quantum property, pin, borrowed from the Clifford algebra as back word of spin (Page 3, line 17 of Clifford Modulas, Atiyah, Bott& Shapiro, 1964), other than the intrinsic quantum property, spin, in quantum electrodynamics [1]. In the Clifford algebra, it would be found that spinors or spin group (Sec. History of Spinors, Wikipedia, 2024) and (Sec. Description of Theory of Spinors, Moshe Carmeli and Shimon Malin, 2000), are essential in describing spin with the general nature of an intrinsic angular momentum and pinors or pin group (Pin group, Sec. Name of Pin group, Wikipedia, 2024) and (The Pin Groups in Physics: C, P, and T ,Marcus Berg, C´ecile DeWitt-Morette, Shangjr Gwo and Eric Kramer, 2000), may be essential in describing pin with the general nature of an intrinsic linear momentum of subatomic particles in Quantum Electrodynamics (QED). Thus, the pin and the spin may have some physical consequences in QED [2-7].

The physical consequences of spin and pin may be obtained in the phenomenon of uniform circular motion of a rotating point object about its axis of rotation. Now, if spin is considered as an intrinsic quantum property with the general nature of an intrinsic angular momentum of a subatomic particle in QED, then pin, like a tiny string, would also be considered as a further intrinsic quantum property with the general nature of an intrinsic linear momentum of that subatomic particle in QED, where we may find that the spin along a specified axis of rotation to the plane of rotation and the pin about the same specified axis of rotation on the plane of rotation would be perpendicular to each other. As such, spin and pin, by acting at right angle to each other in any reference frame, being quantized, would represent the observable quantum states such as subatomic particles in QED.

We would also obtain in literature that electromagnetic fields carry linear momentum and angular momentum. As such, photon, subatomic particles, composite particles and atomic nuclei as observable quantum states also carry linear momentum and angular momentum in Quantum Field Theory (QFT). With regards to angular momentum, we would get the spin angular momentum along a specified axis of rotation perpendicular to the plane of rotation associated together with an Intrinsic Magnetic Moment (IMM), which is the permanent attribute to spin at antiparallel relation of an observable quantum state of the field; analogously, with regards to linear momentum, we may find the pin linear momentum about the same specified axis of rotation on the plane of rotation associated together with an Intrinsic Electric Moment (IEM), which is the permanent attribute to pin at antiparallel relation of the same observable quantum state of the field.

We organize this paper as follows: Section 2 contains method and procedure as deduction the definite discrete values of pin and spin of photon and electron in Quantum Electro Dynamics (QED); the relations between pin and associated electric moment and spin and associated magnetic moment; the definitions of pin and spin ; the relation between intrinsic magnetic moment and electric moment of photon and electron in QED; the units and definite discrete values of magnetic moment and electric moment of subatomic particles; the representative observable quantum states with spin and pin; the steady state solutions for an observable quantum state represented by spin and pin in the time dependent Schrödinger equation in quantum statistical mechanics. Section 3 contains the discussions and results to prove the existence of pin together with associated electric moment along with the existence of spin together with associated magnetic moment of subatomic particles theoretically through the review and interpretation of some phenomena in Quantum Mechanics (QM) and particle physics, and the four degree of freedom of an electron. Section 4 contains conclusion expecting the isolated quantized electric and magnetic monopoles as free positive and negative charges carried by specific particles.

Signs and Symbols

We would use in this paper some special symbols as μ to mean the moment, magnetic and electric, such that μ_M and μ_E would mean the magnetic and electric moments of an electron respectively, and s and ρ to mean spin and pin of subatomic particles, such that, μ_s and μ_ρ would mean the intrinsic magnetic moment related to spin and the intrinsic electric moment related to pin of subatomic particles, other than the usual Signs and Symbols.

2. METHOD AND PROCEDURE

In QM and particle physics, we would find that photon and other subatomic particles follow almost the same formalism in finding the definite discrete values of spin, pin, IMM and IEM.

2.1. Pin and spin of photon and electron in QED

According to QED, the photon moves at c, the speed of light in vacuum, where energy (E) and momentum (p) of a photon depend only on its frequency (v) or inversely on its wavelength (λ) (Sec. Relativistic energy and momentum in article Photon, Wikipedia, 2024) such that

$$E = \hbar\omega = hv = hc / \lambda \tag{2.1.1}$$

and

$$p = \hbar k = \hbar(2\pi / \lambda) = h(v / c) = h / \lambda \tag{2.1.2}$$

where $\omega = 2\pi v$ is the angular frequency, $k = |k| = 2\pi / \lambda$ is the wave number and $\hbar = h / 2\pi$ is reduced Planck constant respectively [8].

Since p points in the direction of propagation of photon, then the magnitude of its momentum may be written as:

$$p = |p| = \hbar k \tag{2.1.3}$$

Now considering $\hbar = |\rho|$, where ρ is the pin, like a minute string, a further intrinsic quantum property of photon in QM with the general nature of an intrinsic linear momentum, wherefrom we may obtain the definite discrete value of pin of a photon as:

$$|\rho| = 1\hbar \tag{2.1.4}$$

We would obtain in particle physics that the definite discrete value of spin of a photon is $|s| = 1\hbar$, so, we may get a relation between spin and pin of a photon as:

$$|s| = |\rho| = 1\hbar \tag{2.1.5}$$

Where 1 is the eigenvalues of spin and pin of a photon with $\hbar$ as their units, though they are different consequences with different properties.

Therefore, the relation (2.1.5) may be written as the general expression as:

$$|s| = |p| \tag{2.1.6}$$

Probably, in particle physics, all subatomic particles follow the analogous formalism as photon with their respective definite discrete values of spin and pin, so that the definite discrete values of spin and pin are equivalent with the same eigenvalues and units.

And if the definite discrete value of spin of an electron is $|s| = 1/2\hbar$ in particle physics, then with respect to relation between the definite discrete values of spin and pin of an electron may be written as:

$$|s| = |p| = \tfrac{1}{2}h \tag{2.1.7}$$

where $\tfrac{1}{2}$ is the eigenvalues of spin and pin of an electron with $\hbar$ as their units, though they are different consequences with different properties.

2.2. Representative observable quantum states with spin and pin

In the phenomenon of uniform circular motion of a rotating point object about its axis of rotation, if spin is considered as an intrinsic quantum property of subatomic particles in quantum electrodynamics, then pin would also be considered as a further intrinsic quantum property of subatomic particles in quantum electrodynamics, as such, we would find that the spin along a specified axis of rotation to the plane of rotation and the pin about the same specified axis of rotation on the plane of rotation would be perpendicular to each other.

Now, considering the fact that any observable quantum state in any phase-space at an instant of time would be represented by its own two intrinsic properties, viz., only one of the spin observables (s_x, s_y, s_z) in the Cartesian coordinates having a definite discrete value along a specified axis of rotation to the plane of rotation and only one of the pin observables (ρ_x, ρ_y, ρ_z) in the Cartesian coordinates having a definite discrete value about the same axis of rotation on the plane of rotation. As such, these two intrinsic quantum properties, spin and pin, by acting at right angle to each other with respect to a specified axis, being quantized, would exhibit an observable quantum state in any phase-space at an instant of time in any reference frame.

The wave number k in the relation may be written as:

$$|k| = 2\pi / \lambda = (2/d) \tag{2.2.1}$$

where $\lambda / \pi = d$, d is the diameter of the helical motion of photon (Confirmation of Helical Travel of Light through

Microwave Waveguide Analyse, R. A. Ashworth, 1998), which may be signified that the pin is about the specified axis of rotation on the rotational plane. If it would be considered that spin s of an observable state is along the z-axis perpendicular to the $x-y$ plane in the upward or downward direction in the Cartesian coordinates, then pin ρ would be expected about the z-axis on the $x-y$ plane in the Counter Clock Wise (CCW) or Clock Wise (CW) direction in the Cartesian coordinates [9].

2.3. The definitions of pin and spin

The pin may be defined as the intrinsic quantum property of an observable quantum state in any phase space at an instant of time with the general nature of an intrinsic linear momentum about a specified axis of rotation on the plane of rotation in the counter clockwise or clockwise direction. Whereas, the spin may be defined as the intrinsic quantum property of an observable quantum state in any phase space at an instant of time with the general nature of an intrinsic angular momentum along a specified axis of rotation to the plane of rotation in the upward or downward direction.

Thus, a pin is such a characteristic intrinsic property of an observable quantum state, which is about a specified axis of rotation on the plane of rotation in any phase-space at an instant of time, whereas a spin is such a characteristic intrinsic property of an observable quantum state, which is along the same specified axis of rotation in any phase-space at that instant of time, such that, spin and pin of an observable quantum state would remain perpendicular to each other in phase-space at an instant of time in any reference frame.

2.4. Quantum statistical mechanics

Introducing probability amplitudes in the spirit of quantum mechanics as:

$$\psi(x,y,z,s,\rho;t_0)=u(x,y,z,s,\rho)=u(q,s,p) \tag{2.4.1}$$

For specifying the states of system in the x,y,z,ρ language at any selected time t_0. These amplitudes would be functions of the continuous variables of position x,y,z and of two eigenvalues of spin $s=\pm a$ and two eigenvalues of pin $\rho=\pm b$, which may be possible [10]. For the actual probability of finding observable quantum states in a specified range $dxdydz$ with specified eigenvalues of s and ρ we may obtain as:

$$W(x,y,z,s,\rho)d_xd_yd_z=u^*(q,s,\rho)u(q,s,p)d_xd_yd_z \tag{2.4.2}$$

We would find the definite discrete values of spin and pin of an electron as observable quantum state in relation as:

$$|s|=|\rho|=\tfrac{1}{2}\hbar,$$

where $\frac{1}{2}$ is the eigenvalues of spin and pin of an electron with $\hbar$ as their units, though they are different consequences with different properties? We may also find that the spin and pin of subatomic particles as observable quantum states are vector quantities, so they must have their respective directions other than their definite discrete values. Regarding spin, there are two possible directions, viz. the upward and downward directions and regarding pin, there are again two directions, viz. the Counter Clockwise(CCW) or right handed and clock wise or left handed directions.

Therefore, conveniently making choice of the spin eigenvalues as $s = \pm a$ having up and down directions and the pin eigenvalues as $\rho=\pm b$ with CCW and CW directions of subatomic particles as observable quantum state with the same units $\hbar$ in respect to a specified axis in phase-space at an instant of time in any reference frame, where a and b be any numbers fractional or integral, we may obtain the steady state solutions for an observable quantum state represented by spin and pin in the time dependent Schrödinger's equation as the four times steady state solutions in the time dependent Schrödinger's equations for the four observable quantum states.

And for the total probability of finding the observable quantum states somewhere and with one or other of two possible values of spin and two possible values of pin, the summation would be obtained as:

$$\sum_{-a}^{+a}\sum_{-b}^{+b} \iiint u^*(q,s,\rho)u(q,s,\rho)d_x d_y d_z = 1 \qquad (2.4.3)$$

Now for the consideration of the statistical mechanics, the most important consequence of the existence of the spin and the pin of observable quantum states is that there would be four times as many solutions of Schrödinger's equation for an observable quantum state with these properties as for a simple observable quantum state without these.

Therefore, we may obtain four steady state solutions for an observable state with $s = \pm a$ and $\rho = \pm b$ in the forms, taking $h/2\pi = \hbar$, as:

$$\Psi_1(x,y,z,+a,+b;t) = u_1(x,y,z,+a,+b)\exp[-(i/\hbar)E_1 t] \qquad (2.4.4i)$$

$$\Psi_2(x,y,z,+a,-b;t) = u_2(x,y,z,+a,-b)\exp[-(i/\hbar)E_2 t] \qquad (2.4.4ii)$$

$$\Psi_3(x,y,z,-a,-b;t) = u_3(x,y,z,-a,-b)\exp[-(i/\hbar)E_3 t] \qquad (2.4.4iii)$$

$$\Psi_4(x,y,z,-a,+b;t) = u_4(x,y,z,-a,+b)\exp[-(i/\hbar)E_4 t] \qquad (2.4.4iv)$$

where E_1, E_2, E_3, E_4 be the same energy E of the observable quantum state, and indeed in most cases we may even expect u_1, u_2, u_3, u_4 to have the same dependence on the coordinates x, y, z and on the energy E to be equal since the interaction of intrinsic magnetic moment and intrinsic electric moment of the observable quantum state with the surrounding electromagnetic field will either be absent, negligible or at least on the average independent of s and ρ.

Since only one of the spin observables, let s_z, with a definite discrete value together with only one of the pin observables, let ρ_z, with a definite discrete value, acting at right angle to each other, being quantized, would exhibit an observable quantum state in phase-space with reference to a specified axis, we would find the steady state solutions of the time dependent Schrödinger's equation of an observable quantum state as four times steady state solutions in the time dependent Schrödinger's equations for the four observable quantum states.

Thus, we would find just four distinguishable observable quantum states in the time dependent Schrödinger's equations represented by two spins having up and down directions and two pins having CCW and CW directions with the same units as $\hbar$ in respect to a specified axis in phase-space at an instant of time in any reference frame.

2.5. The relation between pin and associated intrinsic electric moment of an electron

We may get a relation between the electric moment of an electron and the linear momentum by considering the classical motion of an electron moving in a closed loop under the influence of a central field as per Ampere's model.

Therefore, the electric moment of the small current loop may be written as:

$$\boldsymbol{\mu}_E = i\,\boldsymbol{D} \qquad (2.5.1)$$

where D is a vector parallel to the plane of the loop and equal to the average r from the centre of the loop, i is the current and $\boldsymbol{\mu}_E$ is the electric moment of electron respectively. The positive direction of D is such that the current circulates through the loop in an anticlockwise direction when looking along the area A.

If we consider q is the charge and T is the time period, the

$$i = q / T = e / T$$

i.e., $$i = e / T \tag{2.5.2}$$

where e is the unit electric charge.

An element of radial distance may be obtained as dr , and the magnitude of the distance vector D of the closed current loop is then

$$D = \int_0^r dr = \int_0^{T/2} (dr / dt).dt \tag{2.5.3}$$

where the integration is taken over 0 to $T / 2$

The linear momentum p may be written as:

$$p = m(dr / dt)$$

i.e. $$dr / dt = p / m \tag{2.5.4}$$

therefore, the relation (2.5.3) becomes as:

$$D = \int_0^{T/2} (p / m).dt = pT / 2m$$

i.e., $$D = pT / 2m \tag{2.5.5}$$

Now comparing the relations (2.5.1), (2.5.2) and (2.5.5), the electric moment of an electron may be obtained as:

$$\mu_E = -(e/2m_e)\, p \tag{2.5.6}$$

where m_e is the mass and μ_E is the electric moment of an electron respectively and p is the general linear momentum, and the minus sign of the relation arises due to negative charge of an electron.

Analogously, we may obtain the relation between the magnetic moment of an electron and the angular momentum as:

$$\mu_M = -(e / 2m_e)L \tag{2.5.7}$$

where m_e is the mass and μ_M is the magnetic moment of an electron respectively, and L is the general angular momentum.

As the spin is an intrinsic quantum property of subatomic particles with the general nature of an intrinsic angular momentum and pin is supposed to be the intrinsic quantum property of subatomic particles with the general nature of an intrinsic linear momentum, therefore, replacing the general angular momentum L by the spin s or spin angular momentum and the general linear momentum p by the pin ρ or pin linear momentum, consequently, replacing the magnetic moment of an electron μ_M by the spin related IMM μ_s and the electric moment of an electron μ_E by the pin related IEM μ_ρ of an electron, the relations (2.5.6) and (2.5.7) may be written as:

$$\mu_s = -(e / 2m_e)s \tag{2.5.8}$$

and $$\mu_\rho = -(e/2m_e)\rho \tag{2.5.9}$$

where $(e/2m_e)$ in both the relations is a common constant.

Thus, the relation (2.5.8) is the relation between spin and associated IMM of an electron, where IMM is antiparallel to spin and the relation (2.5.9) is the relation between pin and associated IEM of an electron, where IEM is antiparallel to pin.

2.6. The intrinsic magnetic and electric moments of a photon

Electromagnetic (EM) energy is radiant energy that travels as EM waves in the free space at the speed of light c. EM energy consists of changing magnetic and electric fields caused by their energies. In the EM waves the carriers containing radiation particles, photons, can travel at the speed of light [11, 12].

A dipole moment is an infinitesimal distance of action of two opposite charges. If we would consider that there exist no real or virtual positive and negative charges in free space or within a photon, then we may find that there would not be any electric dipole moment or magnetic dipole moment in EM wave other than there may possibly exist the electric monopole moment or simply the electric moment which produces electric field *E* and there may possibly exist the magnetic monopole moment or simply the magnetic moment which produces magnetic field *B*.

A changing magnetic field can cause a changing electric field, which can cause a changing magnetic field, and so on, and together these fields oscillating at perpendicular to each other create transverse EM waves in any reference frame. Thus, electromagnetic waves bring energy into a system by virtue of their electric and magnetic fields.

Therefore, a photon consists of a magnetic moment together with a spin and an electric moment together with a pin, which may be considered as the intrinsic properties of a photon. As EM waves or photons carry energy as well as angular and linear momentums, so we may find that an Intrinsic Magnetic Moment(IMM) μ_s of a photon is associated together with an intrinsic angular momentum, spin s; and an Intrinsic Electric Moment (IEM) μ_ρ of a photon may be associated together with an intrinsic linear momentum, pin ρ.

As such, the magnitude of magnetic potential energy u_B relating to magnetic field B and IMM μ_s of a photon may be written as

$$u_B = \mu_s B\cos\theta \tag{2.6.1}$$

and the magnitude of electric potential energy u_E relating to electric field E and IEM μ_ρ of a photon may be written as:

$$u_E = \mu_\rho E\cos\theta \tag{2.6.2}$$

We have an expression from Maxwell equations in vacuum in classical electrodynamics as:

$$E = B/\sqrt{(\varepsilon_0\mu_0)} = cB \tag{2.6.3}$$

where ε_0 is the permittivity and μ_0 is the permeability of vacuum respectively, and c is the speed of light in vacuum.

Now considering $\varepsilon_0 = \mu_0 = c = 1$ in natural units, the relation (2.6.3) may be written as:

$$E = B \tag{2.6.4}$$

i.e., $$E/B = 1 \tag{2.6.5}$$

therefore, the magnitudes of magnetic potential energy u_B and electric potential energy u_E become as:

$$\mu_s B = \mu_\rho E$$

i.e., $$\mu_s / \mu_\rho = E / B = 1$$

i.e., $$|\mu_s| = |\mu_\rho| \qquad (2.6.6)$$

which would mean that the definite discrete values of IMM and IEM of a photon are equivalent with the same eigenvalues and units, though they are different consequences with different properties.

2.7. The discrete values and units of magnetic and electric moments of electron and photon

We would further write here the relations in (2.5.8) and (2.5.9) as:

$$\mu_s = -(e / 2m_e)s$$

and $$\mu_\rho = -(e / 2m_e)\rho$$

such that above two relations may be written as:

$$\mu_s = -(e\hbar / 2m_e)s / \hbar \qquad (2.7.1)$$

and $$\mu_\rho = -(e\hbar / 2m_e)\rho / \hbar \qquad (2.7.2)$$

where $(e\hbar / 2m_e)$ is a common constant in both the relations, which may be reasonably named as the Bohr constant μ_B and safely used in both the relations as the units of IMM and IEM analogous to the reduced Plank constant $\hbar$ be safely used as the units of spin and pin of subatomic particles in QM and particle physics.

Therefore, considering the relation with respect to electron (2.1.7) as $|s| = |\rho| = \frac{1}{2}\hbar$, the definite discrete values of IMM and IMM of electron may be obtained as:

$$\mu_s = -\frac{1}{2}\mu_B \qquad (2.7.3)$$

and $$\mu_\rho = -\frac{1}{2}\mu_B \qquad (2.7.4)$$

so the relation between the IMM and IEM of an electron may be written as:

$$\mu_s| = |\mu_\rho| = \frac{1}{2}\mu_B \qquad (2.7.5)$$

where $\frac{1}{2}$ is the eigenvalues of the IMM and IEM of an electron with μ_B, the Bohr constant, as their units, though they are different consequences with different properties.

And if the definite discrete value of IMM of a photon be $|\mu_s| = 1\mu_B$ in particle physics, then the relation (2.6.6) between the definite discrete values of IMM and IEM of a photon may be written as:

$$|\mu_s| = |\mu_\rho| = 1\mu_B \qquad (2.7.6)$$

where 1 is the eigenvalues of IMM and IEM of a photon with μ_B, the Bohr constant, as their units, though they are different consequences with different properties.

Quantum mechanics teaches us that the spin angular momentum inherent to subatomic particles does not correspond to any macroscopic notion of spinning in Quantum Mechanics (QM) (Article: Quantum Particles Aren't Spinning. So where does their spin come from? Adam Becker, 2011), therefore, if spin of subatomic particles does not correspond to spinning of any macroscopic notion of spinning in QM, then there would not be possible to generate any magnetic moment of an electron other than to consider the magnetic moment of an electron as an intrinsic property like spin of an electron such that an Intrinsic Magnetic Moment (IMM) is associated together with the spin [13].

Analogously, as a spin and a pin with reference to a specified axis acting at right angle to each other, being quantized, would represent an observable quantum state at an instant of time in any reference frame, then the pin linear momentum inherent to subatomic particles would not correspond to any macroscopic notion of displacement or translation in QM, then there would not be possible to generate any electric moment of an electron other than to consider the electric moment of an electron as an intrinsic property like pin of an electron such that an Intrinsic Electric Moment (IEM) is associated together with the pin.

The same formalism as electron would also be applicable for all the fermions in quantum mechanics and particle physics.

Since the spin as an intrinsic quantum property of observable quantum states of the field along a specified axis of rotation to the plane of rotation is associated together with an IMM as permanent attribute to spin at antiparallel relation and the pin as a further intrinsic quantum property of observable quantum states of the field about the same specified axis of rotation on the plane of rotation supposed to be associated together with an IEM as permanent attribute to pin at antiparallel relation, therefore, only one of the spin associated IMM observables and only one of the pin associated IMM observables with respect to a specified axis, by acting at right angle to each other in any phase-space, being quantized, would exhibit an observable quantum state at an instant of time in any reference frame, like the magnetic field and electric field, by acting at right angle to each other in any reference frame, being quantized, would exhibit the electromagnetic wave or photon.

Thus, an electron as an observable quantum state contains the four intrinsic quantum properties of its own – spin, pin, magnetic moment and electric moment other than its mass and momentum like other subatomic particles.

3. RESULTS AND DISCUSSION

The discussions and results of this paper would rely upon the theoretical proof of the existence of pin together with an associated IEM along with the existence of spin together with an associated IMM through the review and interpretation of some phenomena in quantum mechanics and particle physics.

3.1. Subatomic particles as distinguishable observable quantum states

We have stated in this paper that we would find just four distinguishable observable quantum states in the time dependent Schrödinger's equations represented by two spins having up and down directions and two pins having CCW and CW directions with the same units ħ in respect to a specified axis in phase-space at an instant of time in any reference frame. As such, we would find just the four distinguishable subatomic particles in each generation of leptons, baryons and mesons represented by spin and pin. We would present here the first generation of subatomic particles of leptons, baryons and mesons as:

- Electrons, first generation of leptons have the four distinguishable particles as e^-, e^+, υ_e , $\bar{\upsilon}_e$,
- Nucleons, first generation of baryons have the four distinguishable particles as p, $\bar{p}$, n, $\bar{n}$, and

- Pions, first generation of mesons have the four distinguishable particles as π^+, π^-, π^0, $\pi^{\not{0}}$.

  Extending our findings to other generations of leptons, baryons and mesons, we would find the same four distinguishable particles in each generation, where neither the spin nor the pin alone could signify the four distinguishable subatomic particles in each generation of leptons, baryons and mesons in particle physics.

Thus, the existence of pin along with the existence of spin is proved in particles physics.

3.2. The mechanism of induced electric and magnetic fields

We may remember that spin and pin of an observable quantum state are remained at perpendicular to each other in any reference frame, as such, the spin associated IMM and the pin associated IEM are also remained at perpendicular to each other in any reference frame.

We may remember that spin and pin of an observable quantum state are remained at perpendicular to each other in any reference frame, as such, the spin associated IMM and the pin associated IEM are also remained at perpendicular to each other in any reference frame.

Therefore, due to the fact that the IMM and IEM are being remained at perpendicular to each other in any reference frame, we may find that whenever the IMMs of electrons in any medium are aligned in parallel or antiparallel by the influential magnetic fields with respect to time, then the arbitrary IEMs of electrons in the medium would be aligned accordingly at perpendicular to the influential magnetic field resulting to the Induced Electric Fields (i.e., emf). And whenever the IEMs of electrons in any medium are aligned in parallel or antiparallel by the flow of steady electric current with respect to time, then the arbitrary IMMs of electrons in the medium would be aligned accordingly at perpendicular to the influential steady electric current resulting to the induced magnetic fields [14–23].

As IMM and IEM of electrons are remained at perpendicular to each other in any reference frame, then the mechanisms of the induced magnetic and electric fields are realized.

Maxwell's equations in classical electrodynamics in magnetic and electric fields indicate that the change of B-field with time would be the induced electric field (Faraday's law of induction) and the change of E-field with time would be the induced magnetic field (Ampere's circuital law) respectively.

Thus, as pin is associated together with electric moment and spin is associated together with magnetic moment of an electron, therefore, the existence of pin together with electric moment along with the existence of spin together with magnetic moment of an electron has been proved [24-26].

3.3. Atoms in magnetic and electric fields

Since, any observable quantum state in any phase-space at an instant of time in any reference frame would be represented by its own two intrinsic properties, viz., only one of the spin observables, let s_z, along a specified axis of rotation to the plane of rotation together with an associated antiparallel related Intrinsic Magnetic Moment (IMM) and only one of the pin observables, let ρ_z, about the same axis of rotation on the plane of rotation together with an associated antiparallel related Intrinsic Electric Moment (IEM). As such, these two intrinsic quantum properties spin and pin, by acting at right angle to each other with respect to a specified axis, being quantized, would exhibit an observable quantum state in any phase-space at an instant of time in any reference frame, we may then find that an electron as an observable quantum state contains four intrinsic quantum properties of its own – spin, pin, magnetic moment and electric moment other than its mass and momentum.

We would also be considered here that all electrons are identical in all their properties. It may be obvious that pin or intrinsic linear momentum of an electron is related to linear motion, therefore, pin would not be activated in electric field other than its associated intrinsic electric moment. As such, the orientation, flipping or swapping of the electric moments of electrons in electric field in any phenomenon would signify the orientation, flipping or swapping of pin of electrons. Analogously, it may also be obvious that spin or intrinsic angular momentum of an electron is related to angular motion, therefore, spin would not be activated in magnetic field other than its associated intrinsic magnetic moment. As such, the orientation, flipping or swapping of the magnetic moments of electrons in magnetic field in any phenomenon would also signify the orientation, flipping or swapping of spin of electrons.

3.3.1. The splitting of spectral lines in the static homogeneous electric and magnetic fields

We would have in literature the Stark Effect, a phenomenon in which spectral lines splitting occur in the presence of a homogeneous external strong electric field due to the interaction of electric field with the electric moment of outmost electron(s) of the atoms; analogously, the Zeeman Effect, a phenomenon in which spectral lines splitting occur in the presence of a homogeneous external strong magnetic field due to the interaction of magnetic field with the magnetic moment of outmost electron(s) of the atoms [27-32].

Thus, as pin is associated together with electric moment and spin is associated together with magnetic moment of an electron, therefore, the existence of pin together with electric moment along with the existence of spin together with magnetic moment of an electron has been proved.

2.3.2. The splitting of a beam of atoms through the inhomogeneous electric and magnetic fields

We would have a phenomenon in which one polarized beam of atoms having single outermost electron splits into two beams through the external static inhomogeneous electric field due to the interaction of electric field with the electric moment of single outermost electron of the atoms analogous to the Stern-Gerlach Experiment (SGE), a phenomenon in which one polarized beam of atoms having single outermost electron of atoms splits into two beams through the external static inhomogeneous magnetic field due to the interaction of magnetic field with the magnetic moment of single outermost electron of the atoms [33-40].

Thus, as pin is associated together with an electric moment and spin is associated together with a magnetic moment of an electron, therefore, the existence of pin together with electric moment along with the existence of spin together with magnetic moment of an electron has been proved [41-43].

3.3.3 Sequential experiment consecutively in the inhomogeneous magnetic and electric fields

We may obtain an evidence of the presence of magnetic moment and spin and electric moment and pin of electron of atoms, if it would be possible to perform the sequential experiment consecutively in a static external inhomogeneous magnetic field and in a static external inhomogeneous electric field, where we may find that one polarized beam of atoms having single outermost electron of atoms would split into two beams at equal proportion with respect to a specified axis by sending through a static external inhomogeneous magnetic field, consequently, we may find that when one of the two spitted beams in magnetic field would again split into two beams at equal proportion with respect to the same specified axis by sending through a static external inhomogeneous electric field.

Thus, the result of the performance of the sequential experiment may be the strong evidence to prove that an electron as an observable quantum state contains the four intrinsic quantum properties of its own – spin, pin, magnetic moment and electric moment other than its mass and momentum, as well as, it would support the same for all the subatomic particles.

3.3.4. The degree of freedom of an electron in quantum mechanics

Spin was discovered in the Stern-Gerlach Experiment (SGE) with a polarized beam of atoms through a static inhomogeneous magnetic field as interpreted that the two states quantum degree of freedom associated with a magnetic moment suggesting that the magnetic moment had only two observable orientations. But Wolfgang Pauli came up with a matrix representation of spin, which had been taken the two orientation quantum degrees of freedom of spin instead of two magnetic moment orientations of an electron; probably, due to the fact that a magnetic moment is associated together with a spin at antiparallel along the same specified axis as spin. So, the two observable orientations or flippings of the magnetic moments would be signified as the two observable orientations or flippings of the spin in the SGE. Thus spin of an electron with two spin states having up and down directions would be taken into consideration as quantum degree of freedom of an electron in QM and particle physics.

Analogously, the two observable orientations or flippings of the electric moment may be signified as the two observable orientations or flippings of the pin in the experiment with a polarized beam of atoms spitted into two equal proportion beams through the static inhomogeneous electric field. Thus, as per norms, pin of an electron with two pin states having CCW and CW directions may be taken into consideration as quantum degree of freedom of an electron in QM and particle physics.

However, we may obtain the four quantum degree of freedom of an electron in QM and particle physics by considering the two states quantum degree of freedom of spin and the two states quantum degree of freedom of pin, which may be changed by swapping or flipping. Thus, we would somehow obtain the four quantum degree of freedom of an electron in QM and particle physics.

This approach may be applicable to all the other fermions in QM and particle physics.

1. CONCLUSION

The introduction of pin other than spin in quantum electrodynamics and the existence of pin together with an intrinsic electric moment along with the existence of spin together with an intrinsic magnetic moment through the review and interpretation of some phenomena in quantum mechanics and particle physics would infer the presence of the four intrinsic properties, viz., spin, pin, magnetic moment and electric moment, of subatomic particles in quantum electrodynamics, which may open a new perspective of quantum mechanics and particle physics and support to find out the isolated quantized electric monopoles as free positive and negative electric charges carried by specific particles, as well as, the isolated quantized magnetic monopoles as free positive and negative magnetic charges carried by specific particles, which remains unsolved so long in spite of all efforts since the introduction of the idea of the existence of magnetic monopoles by Paul Dirac in1931.

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REFERENCES

1. Atiyah, Michael F., et al., "Clifford modules."*Topology*, **1964.**3: p. 3-38. [Google Scholar]
2. "Spinor". *Wikipedia scholar*, **2024**.
3. Carmeli, Moshe, and Shimon Malin. "Theory of spinors: An introduction". *World Scientific Publishing Company*, **2000**. [Google Scholar]
4. "Pin group". *Wikipedia scholar*,**2024**.
5. Berg, Marcus, et al., "The pin groups in physics: C, P and T." *Reviews in Mathematical Physics*, **2001**.13(8): p.953-1034. [Google Scholar] [Crossref]
6. Mansuripur, Masud., "Angular momentum exchange between light and material media deduced from the Doppler shift." *Optical Trapping and Optical Micromanipulation*. *SPIE*, **2012**.9: p. 8458. [Google Scholar] [Crossref]
7. Gawhary., et al., "Role of radial charges on the angular momentum of electromagnetic fields: spin-3/2 light." *Physical Review Letters*,**2018**.121(12): p.123202. [Google Scholar] [Crossref]
8. "Photon". *Wikipedia scholar*,**2024**.
9. Ashworth, R. A., "Confirmation of helical travel of light through microwave waveguide analyses." *Physics Essays*, **1998**.11: p. 343-352. [Google Scholar]
10. Tolman, Richard Chace. "The principles of statistical mechanics". *Courier Corporation*, **1979**. [Google Scholar]
11. Chew, Weng Cho., "Quantum mechanics made simple: Lecture notes." **2012**: p. 11-12. [Google Scholar]
12. Alsaleh, Salwa. "Lecture Notes in Quantum Mechanics."[Google Scholar]
13. Adam Becker., "Quantum Particles Aren't Spinning. So Where Does Their Spin Come from?".*Scientific American*, **2022**.
14. Lucas, Jim. "Live Science Article: What Is Faraday's Law of Induction? "*Live Science contributor Ashley Hamer*, **2022**. [Google Scholar]
15. "Faraday's law of induction".*Wikipedia scholar*, **2024**.
16. Giuliani, Giuseppe. "Electromagnetic induction: physics, historical breakthroughs, epistemological issues and textbooks." *arXiv preprint*, **2021**. [Google Scholar]
17. "Lenz's law".*Encyclopaedia Britannica.*
18. "Lenz's law". *Wikipedia scholar*, **2024**.
19. Martins, Roberto De Andrade. "Resistance to the Discovery of Electromagnetism: Ørsted and the Symmetry of the Magnetic Field." *Volta and the History of Electricity*, **2003**: p. 245-266. [Google Scholar]
20. "Ampere's Law", Illinois Institute of Technology.
21. "Biot-Savart law".*Encyclopaedia Britannica*.
22. "Biot-Savart Law".*Wikipedia scholar*.**2024**.
23. Biot-Savart Law"."*Janathan Dowling*.
24. "Maxwell's equations". *Wikipedia scholar*.**2024**.
25. Song, Jun S. "Theory of magnetic monopoles and electric-magnetic duality: a prelude to S-duality." *J. Undergrad. Sci***1996**.3: p. 47-55. [Google Scholar]
26. Rajantie, Arttu., "The search for magnetic monopoles." *Physics Today*,**2016**. 69(10): p. 40-46. [Google Scholar] [Crossref]
27. "Stark Effect",*Encyclopaedia Britannica*.
28. "Stark effect",*Wikipedia scholar*, **2023**.
29. "Stark Effect",*University of Illinois Urbana-Champaign*.
30. "Zeeman Effect",*Encyclopaedia Britannica*.
31. "Zeeman effect", *Wikipedia scholar*, **2024**.
32. "The Zeeman Effect",*University of California San Diego*.
33. deHeer, et al. "Electric and magnetic dipole moments of free nanoclusters." *arXiv preprint*, **2009**. [Google Scholar]
34. Palmer, J., and S. D. Hogan. "Experimental demonstration of a Rydberg-atom beam splitter." *Physical Review A*, **2017**.95(5): p. 053413. [Google Scholar] [Crossref]

35. Palmer, J. E., and S. D. Hogan. "Electric rydberg-atom interferometry." *Physical Review Letters* ,**2019.**122(25): p. 250404. [Google Scholar] [Crossref]
36. Schmidt-Böcking, Horst, et al. "The stern-gerlach experiment revisited." *The European Physical Journal H*,**2016**.41: p.327-364. [Google Scholar] [Crossref]
37. Rodríguez, E. et al. "A full quantum analysis of the Stern–Gerlach experiment using the evolution operator method: Analyzing current issues in teaching quantum mechanics." *European Journal of Physics*, **2017.**38(2): p. 025403. [Google Scholar] [Crossref]
38. Marinsek, Johann. "Contradicting results of Stern-Gerlach and." **2017**. [Google Scholar]
39. Daghigh, Ramin G., et al "A modified Stern-Gerlach experiment using a quantum two-state magnetic field." *Results in Physics*,**2018**.9: p. 740-744. [Google Scholar] [Crossref]
40. Wennerström, Håkan, and Per-OlofWestlund. "The Stern–Gerlach experiment and the effects of spin relaxation." *Physical Chemistry Chemical Physics*, **2012**.14(5): p.1677-1684. [Google Scholar] [Crossref]
41. D. Acosta, "Magnetic Dipoles", Lecture Notes, PHY2061-Enriched Physics 2, University of Florida, Department of Physics,**2006**.
42. "The Stern-Gerlach Experiment",*Caltech Scholar, Experiment 33*, **2009**.
43. Henkel, Carsten, et al. "Stern–Gerlach splitting of low-energy ion beams." *New Journal of Physics*, **2019**.21(8): p.083022. [Google Scholar] [Crossref]