Some Thoughts on Spin

Prof. K.V.K. Nehru, Ph. D.

Detailed study of the characteristics of the so-called nucleus of the atom has not been carried out by Larson. Therefore we have undertaken this much needed investigation and been reporting our results.[1,2,3]

It has been our experience that such investigation hardly ever proceeds in a strictly serial manner. Rather, it is more akin to the process of fitting the pieces of a jigsaw puzzle together. Nascent understanding gradually builds up and evolves from various seemingly diverse starting points, the concepts on each line of thinking modifying the ones on other lines, and in turn themselves getting modified by the latter. Eventually a nexus of coherent structure ensues. The thoughts presented in this article, too, constitute such a preliminary group of ideas that might serve to crystallize some of the earlier concepts enunciated on the topic of the so-called atomic nucleus.

1 Spin-1 and Spin-½

The one-dimensional rotational space (angle) as well as the two-dimensional rotational space (solid angle), both are customarily regarded as dimensionless in the context of the conventional three-dimensional spatial reference system (the time-space region). This practice, therefore, does not distinguish between one-dimensional spin (angular momentum) and two-dimensional spin (angular momentum). We end up measuring both in units of erg-sec. In order to clarify the issue let us first note that the dimensions of momentum are energy/speed. In the present case these are Planck's constant, h, divided by space unit. If the motion is translational, the space unit concerned is taken as the *centimeter*. If the motion is rotational, the space unit concerned is taken as *radians*. The basic unit (quantum) of one-dimensional angular momentum is taken as h erg-sec (spin-1), which is the same thing as (h ergs)/(2π radians/sec). The denominator, 2π radians/sec, can be seen to be one-dimensional rotational speed. On this basis, the quantum of two-dimensional angular momentum is to be taken as (h ergs)/(4π steradians/sec), which is the same thing as ½h erg-sec (spin-½). We can immediately see that particles like photons (the bosons), which have integral spin, are based on one-dimensional rotation, whereas those like proton and electron (the fermions), which have half-odd integral spin, are based on two-dimensional rotation.

In the conventional theory it is recognized that the quantum state of the integer-spin particles cycles at 2π radians and that of the half-odd-integer-spin particles cycles at 4π radians. What is needed to clarify the physical fundamentals is to recognize that in the latter case the value is 4π steradians rather than 4π radians—and hence it really pertains to two-dimensional rotation.

1 Nehru K.V.K., “Wave Mechanics in the Light of the Reciprocal System,” *Reciprocity*, Vol. XXII, No. 2, Autumn 1993, pp. 8-13

2 Nehru K.V.K., “Quantum Mechanics as the Mechanics of the Time Region,” *Reciprocity*, Vol. XXIV, No. 1, Spring 1995, pp. 1-9. (See especially Section 5.1)

3 Nehru K.V.K., “Non-locality in the Reciprocal System,” *Reciprocity*, Vol. XXVI, No. 1, Spring 1997, pp. 7-14

2 Unbounded Phase

There is yet another unforeseen feature of rotation in the Time Region. In the conventional time-space region, after rotating through an angle of 2π radians one comes back to the starting point. An angle of θ radians cannot be distinguished from an angle of $\theta + 2n\pi$ radians. In the Time Region, however, this need not be true. Speaking of spin-½ particles, Bhandari states: "…studies… bring out the additional fact that phase changes of $2n\pi$ are real, physical and measurable, something that is often ignored. For example, our experiments make it obvious that the difference between $+\pi$ and $-\pi$ or the difference between π and 3π is measurable and that it is unnatural to restrict the value of the phase that is being continuously monitored to be between 0 and 2π . The need to incorporate this unbounded nature of the phase variable presents a promising program for the future."[4]

3 Non-degenerate Spin

A one-dimensional spin is represented by a single spin coordinate, say σ_1, and could be either {+} or {-}. The two-dimensional spin requires two spin coordinates, σ_1 and σ_2, and is categorized into four domains: {+ +}, {- +}, {- -} and {+ -}. From the point of view of the time-space region there is a degeneracy: {+ +} and {- -} are effectively identical, and {- +} and {+ -} are effectively identical. However, these four domains remain distinct in the three-dimensional zone of the Time Region itself, necessitating a quaternion representation rather than one of an ordinary complex number.

4 Helicity

Unlike in the case of the one-dimensional rotation, there is an internal chirality or handedness arising in the case of the two-dimensional rotation out of the multiplication of the two constituent one-dimensional rotations. Thus the combinations {+ +} and {- -} both result in the positive sign and may be treated as Right-handed. In similar manner, the combinations {- +} and {+ -} both result in the negative sign and may be treated as Left-handed. The Quantum theorists recognize the existence of this internal chirality when they posit the characteristic of Helicity. They do not, of course, have the benefit of the insight given by the Reciprocal System regarding its origin.

5 Photon Wave

According to the Reciprocal System the photon is situated permanently in the space unit (of its origin) of the background space-time progression. As these space units are ever moving scalarly outward, away from one another, no two photons can ever contact each other. However, both may be able to contact a gravitating particle since the latter is moving scalarly inward, and can enter the space unit in which a photon is situated. That bosons, the class of particles of which photon is a member, do not interact with each other is an observed fact. If this is so, one may ask, how do we explain the phenomena like interference and diffraction, wherein the waves associated with the photons are apparently interacting! The answer from the Reciprocal System has already been explained in detail elsewhere,[3] where we have shown that the photon interacts with itself by virtue of the nonlocality feature of the Time Region. The wave associated with the photon is actually in the Time Region and is to be represented by *complex* vibration rather than a real vibration. The projection on the real axis appears sinusoidal.

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4 Bhandari R., "Geometric Phase in Interference Experiments," *Current Science*, Vol. 67, No. 4, 25 August 1994, p. 230

6 Point Particles

The reason why photons and electrons appear to measurement as point particles is this: they are units of rotational space—not of linear space.

7 Complex Wave

The wave function φ of a particle in the one-dimensional zone (that is, the zone of one-dimensional rotation) of the Time Region is to be represented by a complex wave. This follows from the fact that the equivalent speeds pertaining to this zone that correspond to the one-dimensional speeds of the conventional spatial reference frame (the time-space region) are two-dimensional.[2] Thus

$$\varphi = \{ \varphi_1, i\varphi_2 \}$$

where φ_1 and φ_2 are real and the symbol i represents the operation of orthogonal rotation, from the real to the imaginary axis, such that $i^2 = -1$. It must be noted that φ denotes a one-dimensional rotation. The probability density, as applicable in the time-space region is, of course, given by the square of the modulus, $|\varphi|^2$ (or $\varphi^* \varphi$ where φ^* is the complex conjugate of φ).

8 Quaternion Wave

What we have called the three-dimensional zone of the Time Region is the zone of two-dimensional rotation of the atom. We have shown[2] that the equivalent speeds pertaining to this zone that correspond to one-dimensional speeds of the time-space region are *four-dimensional*. Consequently, the wave function germane to this zone needs to be represented by a four-component mathematical object. Since we have represented the one-dimensional rotation pertaining to the Time Region by a complex quantity $\{ \varphi_1, i\varphi_2 \}$, we recognize that to represent two-dimensional rotation (pertaining to the Time Region) we need to introduce an additional imaginary dimension j. Thus, replacing φ_1 and φ_2 respectively by ψ_1 ($=\{\psi_a\, j\psi_b\}$) and ψ_2 ($=\{\psi_c\, j\psi_d\}$) which are complex, we have for the wave function of this zone

$$\psi = \{\psi_1\; i\psi_2\} = \{\{\psi_a\, j\psi_b\}\; i\{\psi_c\, j\psi_d\}\} = \{ \psi_a\; i\psi_c\; j\psi_b\; ij\psi_d \}$$
$$= \{ \psi_a\; i\psi_c\; j\psi_b\; k\psi_d \},$$

where we define $k = ij$, and ψ_a, ψ_b, ψ_c and ψ_d are all scalar.

As can be seen this is a quaternion, with the following basal elements: the identity operator 1 (which keeps a quantity unchanged) and the three orthogonal rotation operators i, j, and k. The properties of the operators are:

$$1^2 = 1;\ 1i = i1 = i;\ 1j = j1 = j;\ 1k = k1 = k;$$
$$i^2 = j^2 = k^2 = -1;$$
$$ij = -ji = k;\ jk = -kj = i;\ ki = -ik = j.$$

The probability density, once again, is given by

$$\psi^*\, \psi = \psi_a^2 + \psi_c^2 + \psi_b^2 + \psi_d^2.$$

In the conventional theory the theorists find that the speeds of the nucleons approach the light speed because of the large "nuclear" interaction energies (on the order of tens of MeV) concerned. In view of these large speeds they find it necessary to resort to the Relativistic Quantum Mechanics. Some of the celebrated theoreticians who worked on the relativization of the wave equation, like Paul Dirac, were led by mathematical necessity to adopt wave functions with four components like we have been talking of.

9 Dimensionality of Space

In a closed group of operators, like [1 *i j k*], the result of the combination of any number of the basal elements is also a member of the same group. The result of any such combination can be known only if all the possible binary combinations of the elements are first defined in terms of the basal elements *i*, *j* and *k* themselves (besides, of course, the identity operator, 1). Let there be *n* basal elements (excluding the unit operator 1) in a group. Then the number of unique binary combinations of these elements, in which no element occurs twice,[5] is $n(n-1)/2$. We can readily see that a group becomes self-sufficient (finite) only if the number of binary combinations of the basal elements is equal to the number of those basal elements themselves, that is

$$\frac{n(n-1)}{2}=n \quad .$$

The only definite solution for *n* is 3. (Zero and infinity are other solutions.) Therefore if we regard space (time) as a group of orthogonal rotations, its dimensionality has to be three in order to make it self-sufficient dimensionally. Otherwise the number of dimensions either has to shrink to zero, or proliferate to infinity.

5 The equation is a common statistical formula for *interconnectivity*.