Proposing the Existence of a New Symmetry Called the Wick Symmetry-Representation of a Particle as a Primary Gas -VI

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Abstract

The author discusses the similarity between the expression for the state function of the primary gas representing a particle and that of the wave function. It is observed that the only difference between these two expressions is that in the former time appears as a real function while in the latter it appears as an imaginary function. He shows that the primary gas approach which treats time as a real and the quantum mechanical approach which treats time as imaginary are two ways of representing the same reality and points to a new symmetry called the Wick symmetry. He shows that the probability postulate of quantum mechanics can be understood in a very simple and natural manner based on the primary gas representation of the particle. It is shown that the zero point energy of the quantum mechanics is nothing but the energy of the thermal bath formed by the vacuum fluctuations in the Higgs field. He shows that the quantum mechanics is nothing but the thermodynamics of the primary gas where time has not lost its directional symmetry.

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1 Introduction

It was earlier shown that a particle could be represented by a standing half wave called "staphon" which is formed by the confinement of a single circularly polarized wave called "photino". The standing wave could be identified with the electromagnetic wave in the case of electron. It is observed that such a standing wave structure not only acquires rest mass and the electric charge but also the half spin of the particle and it takes on the form of a plane wave when given a translational velocity [1],[2][3],[4]. We know that the plane wave representing a particle with energy E' is given by

$$\phi' \quad = \quad B(E') \, e^{-i\hbar^{-1}(E't - \text{p}'\text{x})]}$$ (1)

In the case of the free particle, the energy states lie in a narrow region (E-ΔE) < E' < (E+ΔE) where ΔE could be taken as quite small and the action function possesses a sharp minimum. In other words, action could be taken as a constant in the narrow region and we may express it using the average values of energy and momentum of the particle as

$$\phi' \quad = \quad B(E') \, e^{-i\hbar^{-1}(Et - \text{p}x)]}$$ (1A)

The variation in the value of E′ is accounted for by the random translational motion of the particle keeping the rest mass as an invariant. In the rest frame of reference (1A) would transform into

$$\phi_o^{'} \quad = \quad B(E_o^{'}) \, e^{-i\hbar^{-1}\mathrm{E}_o t_o} \tag{1B}$$

Note that this represents an eigen state, and not a localized particle state. In the rest frame of reference, the standing wave will have no preferred direction of orientation and therefore it is possible to assume that the standing wave is directed in all possible directions symmetrically. Although the amplitude of the plane wave (it will have infinite wave length) in one direction would be zero, the square of the amplitude the linear combination of all plane waves occupied in all possible directions could be taken as unity.

We shall now show that the staphon structure of a particle makes it possible to approach the issue in a completely different way which would provide us with a deep insight into the nature of quantum reality. Since the staphon is assumed to be formed by the interactions with the vacuum fluctuations in the Higgs field, it will be occupying different energy-momentum states successively in these interactions [5]. It was observed that these states could be treated as a primary gas, which is an ideal gas where the microstates are occupied successively in time. This allows us to treat a particle as a primary gas which in turn makes it possible to interpret its dynamics in terms of the thermodynamics of the primary gas. In this approach the probability for the primary gas to occupy a state with intensive energy E` is given by [5]

$$W' \quad = \quad g(E') \, e^{-h^{-1}(E't-\text{þ}'x)]} \tag{2}$$

In the rest frame of reference, the above equation would transform into

$$W_o^{'} \quad = \quad g_o^{'} \, e^{-E_o/K\theta_o} \quad = \quad g_o^{'} \, e^{-E_o t_o/h} \quad , \tag{2A}$$

The above equation has the same form as (1B) except for the absence of the factor '$2\pi i$' in the exponential term. This is quite startling. What does this similarity of the plane wave with the expression for the primary gas mean? Let us go back to the basis of deriving the equation for the plane wave and compare it with the derivation of the state function for the primary gas in order to explain the similarity between the two functions.

We shall show that when we examine the concept of a particle from two different approaches, we obtain the same function but with one difference. In the case of the primary gas approach, time appears as real while in the wave function approach, it appears as imaginary. Prima facie one may feel that since both functions represent the same system, they should be equivalent. However we observe that there are major differences between the two functions. The function $\phi_o^{'}$ in (1B) is a periodic function representing a wave and its value oscillates as time progresses while $W_o^{'}$ in (2) is a probability function and the exponential factor on the right hand side keeps on decreasing as time progresses. Thus prima facie these two functions seem to represent two different realities which are fundamentally irreconcilable. But we shall shortly show that these differences could be reconciled.

We shall now try out various options to explain the appearance of the imaginary nature of time in the wave function approach. The idea that comes first to one's mind is Minkowski's four-dimensional formalism of the relativistic mechanics where time is treated as the fourth coordinate [6]. In this formalism, if time is taken as an imaginary quantity represented by $\tau = ict$, then the four dimensional interval between two events with coordinates (x_1,y_1,z_1,t_1) and (x_2,y_2,z_2,t_2) will be Euclidian given by

$$S_{12}^2 \quad = \quad (x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2 + (\tau_1 - \tau_2)^2 \qquad (3)$$

But the problem with this approach is that it treats energy as imaginary while momentum is taken as real with the result that the action function which has the dimension of the product of energy and time remains real. That is to say, the Boltzmann factor, B_f in (2) which appear in the rest frame as
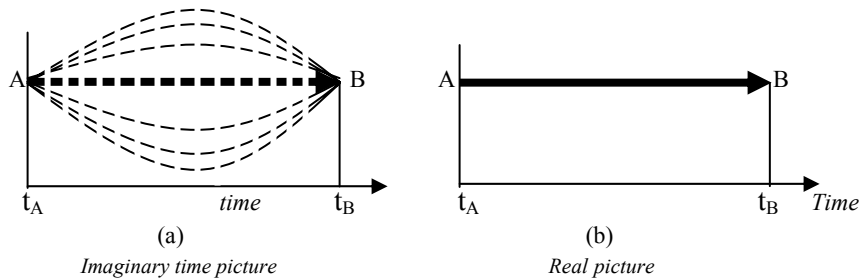
$$B_{fo} \quad = \quad e^{-E_o t_o / h} \qquad (4)$$

would continue to remain real since both time and energy are treated as imaginary. Therefore, treating time as an imaginary forth coordinate does not help in resolving the problem.

2 More About Real Time and Imaginary Time

On detailed scrutiny of equations (1) and (2) we observe that the two approaches differ in one fundamental aspect. In the case of the plane wave approach, each of the energy momentum states is assumed to exist at the same instant. In other words, the wave function represents a system where the simultaneous occupation of all energy-momentum states is possible. However, the system evolves without collapsing into any one state. On the other hand, in the primary gas approach the situation is quite different. Here we had assumed that at every instant the system occupies a particular energy-momentum state. This is quite different from the approach based on the wave nature of the particle. In the primary gas approach, since we took it for granted that the system could occupy only a single energy-momentum state in one instant, it is equivalent to assuming that the system crystallizes into reality at every instant and therefore the primary gas we have been dealing with is a real gas. The path which has the maximum probability is the path along which system would progress for all practical purposes. The other paths which the system could occupy remain just as the probable ones.

Let us examine the issue taking a specific example. Let us take the case of a micro-system progressing from point A to point B (see figure 1). In the wave picture, the particle would evolve along different paths. We know that action along the classical path (shown in thick dotted lines) would be the minimum and it would vary only by second order along paths

| (a) | (b) |
| Imaginary time picture | Real picture |

(a) shows the evolution of the system in the imaginary time. Here all the paths exist simultaneously. (b) shows the corresponding picture in the real time. Here only one path out of many possible ones gets occupied.

Figure.1

close to it. But, for paths which are slightly more removed from the classical path, the action changes substantially even for a slight change in the path. Therefore, except along the paths close to the classical paths, the amplitude of all other waves become zero due to the destructive interference. But close to the classical path, the waves interfere constructively making the

amplitude of the waves maximum. Note that here the system does not collapse into a particular energy-momentum eigen state.

In the primary gas approach, the situation is different. Here we had assumed that at every instant the system occupies a particular energy-momentum state. This is quite different from the approach based on the wave nature of the particle. In the primary gas approach, since we took it for granted that the system could occupy only a single energy-momentum state in one instant, it is equivalent to assuming that the system crystallizes into reality at every instant and therefore the primary gas we have been dealing with is a real gas. Needless to say, we could as well treat the primary gas as representing the potential paths it could occupy and not necessarily the path it actually occupies. Note that the probability along the classical path will have a delta function like peak along the bold line (figure.1-b) because the degeneracy $g_{(E')}$ increases with extensive energy of the broglieon gas while the Boltzmann's factor decreases with it and the sharp peak is obtained along the classical path. The probability for the occupation of the other paths would be practically zero. This means that when we take the linear sum of the primary gas states to arrive at B, we end up with the classical path which is represented by the thick line in figure 1 b. Note that here the particle would progress along a single path that has maximum probability. Thus the difference between the two approaches could be traced to the state of crystallization of reality. This leads us to conclude that the imaginary time could be associated with the evolution when we treat the system as occupying a large number of states simultaneously while the real time could be associated with the situation where we treat the system as occupying only one state at a time. This would mean that the wave function is nothing but the state function of the primary gas where real time is replaced by the imaginary time. This gives us a completely new insight into the nature of wave itself. We shall later see that there is a further twist to this argument.

In the light of the above discussion, it is clear that the primary gas follows a single path in a given time interval compared to the large number of paths taken in the wave representation. In figure 1 for the sake of convenience, we have shown only 7 paths out of infinite ones which are possible in the evolution of the system from the instant t_A to the instant t_B. As the system is in equilibrium (uniform motion), it is assumed to occupy states with energy close to a well defined average value. Here all paths are occupied in an unmanifested manner. But the path with the thick line is assumed to have the maximum amplitude. This would mean that the phase difference of this path with any neighboring ones is negligibly small resulting in constructive interference. Therefore, if we catch the system at point B, we have to assume that the particle has evolved along all possible paths. This is similar to the path followed by a wave front. We can only say that the amplitude of all other paths except the most probable path becomes zero due to the destructive interference.
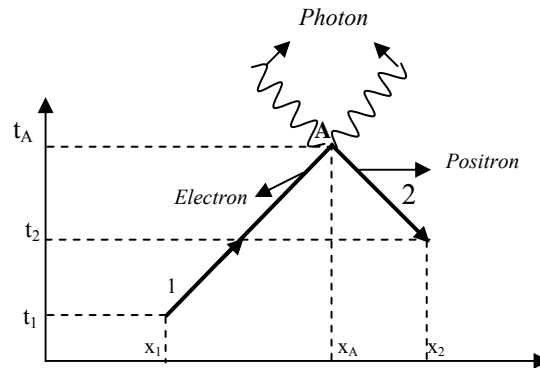
In the wave representation, all states that could be occupied are occupied simultaneously. This raises a very serious problem. How can a particle occupy so many paths at the same time? Quantum mechanics tries to resolve the issue by assuming that the particle gets disembodied into a wave front and occupy all possible paths. But at the point of observation, the particle is assumed to discard the disguise of the disembodied wave front and appears as a localized entity. There is no explanation how the particle takes up the disguise of a wave when not observed off stage and how it takes on the particulate appearance when on stage. But this is the best quantum mechanics could offer. But a deeper scrutiny in the light of the discussion in the previous paragraphs allows us to interpret the situation differently. Since the same particle occupies a large number of paths at the same time, we have to conclude that

the states occupied cannot be real. The most logical choice is to treat these states along the paths as imaginary. We shall shortly show that this is equivalent to treating time as imaginary.

Let us now see what happens in the case of the primary gas. Here while the particle has the choice to occupy all these paths, as shown in figure 1(b), it occupies only one particular path. All the others remain as potential paths. This is what we expect in real time which we identify with the macroscopic time experienced in our daily life. In short, the fundamental difference between the real time and the imaginary time is this. In the case of the real time, when the system could evolve along a large number of paths, it chooses one particular path. All other paths remain as potential ones which are not occupied. In the case of the imaginary time, the system evolves along all possible paths simultaneously. The more probable a path is, more often that path is occupied compared to the others.

It may seem that the primary gas picture is unworkable as it is impossible to observe each microstate at every instant of the evolution of the system so that it remains always crystallized in reality. In actual situation, the observation would be done at very long intervals only, and in between the system may be free to evolve without the intervention by an external observer. In that sense, the imaginary time picture which treats the system of a particle as a wave would appear to be better suited for the job. However, the equivalence of the imaginary time picture and the real time picture in terms of the equations (1) and (2) appears to be too good to be discarded outright.

Actually there is a simple way we could redeem the primary gas approach and put it on the same pedestal as the imaginary time picture (wave picture). The explanation for this has been around us thanks to the genius of Feynman. It is based on the picture of a particle jumping into future and jumping back in time [7]. Feynman found that a positron could be taken as an electron traveling backward in time. Let us take the world lines for the electron-positron annihilation that results in the creation of photons as shown in figure.2. Feynman showed that

The solid line is the world line of the electron as it goes from (x_1,t_1) to (x_A,t_A).
At $A(x_A,t_A)$ it collides with the positron coming from (x_2,t_2) resulting in the
annihilation of both, and emission of two photons. This also can be seen as
the electron from 1 going backward in time after interacting with photons at A

Figure.2

taking a positron as an electron traveling backward in time simplifies the picture substantially. He developed this idea further and came up with his path integral formalism which revolutionized the approach to quantum electrodynamics. It is really surprising why he did not extent this idea to explain the wave particle duality. Of course, such an explanation calls for a thorough reinterpretation of quantum mechanics right from its foundations.

We shall now use this basic concept to explain the numerous paths followed by the system of a particle in the primary gas picture in its evolution from t_A to t_B (figure 1). We know that in the plane wave representation, the evolution of the system takes place simultaneously along all possible paths. But in the primary gas picture the system is more localized and could be thought of as jumping forward from A to B along a particular path. The particle could, then, move back from B to A in a reverse time-travel. The particle could take another path similarly and then travel back in time again. In this manner, we can imagine that the particle could exhaust all possible paths. More probable the path is, more number of times it could be traversed compared to others. Note that in this picture we are able to treat evolution along each path just as in the case of real time. The system is allowed to occupy only one state at a time. It has to jump back to the starting instant (in the reverse real time) to initiate a new path of evolution. Therefore, when we deal with each path, we are able to treat it just like we treat it in real time. We may actually call the time in which the primary gas is defined as the reversible real time or just the "reversible time" because the system is able to travel back in time here. We should keep in mind that this is not the real time which we experience in our daily life because there we cannot go back in time. We shall examine the difference between these different concepts of time later in a separate section.

A detailed study would reveal that even the wave picture also has to take into account the reverse time travel by the particle. This is represented by Ψ^*. But here, the particle traveling in the reverse direction (the anti-particle) is assumed to exist as a shadow of the real particle everywhere. Therefore, the need to treat the particle traveling in the reverse direction in isolation never arises. However when the probability of observing the particle is to be calculated, then Ψ^* becomes an essential part of the computation. Therefore, we may say that the wave picture and the primary gas picture are two ways of looking at the same process. In the wave picture, the system of the particle is assumed to evolve simultaneously along all probable paths while the corresponding reverse motion in time is accounted in terms of the anti-particle that exist as a shadow particle. On the other hand, in the primary gas approach, the particle is assumed to evolve along one path at a time and then travel backward to the starting point in time and then again travel forward along another path and back and so on. This means that the physical content of both approaches would be the same. The difference would be only in the interpretation of the process involved. Before we make the equivalence between the two approaches to be total there are many other issues which will have to be resolved. For example, the property of the interference cannot be explained without invoking the wave nature which is an imaginary time property. We shall explain these aspects as we go on.

We shall now modify the definition of the extensive time given in the earlier paper [5] and relate it to the temperature using the relation

$$t_e \quad = \quad n_e N T_e \quad = \quad n_e N h \, / K \theta \tag{5}$$

Here N stands for the number of microstates states forming a primary gas while n_e stands for the number of broglieon states. Note that N is fixed. From (5) it is clear that when we take N to be imaginary, it means that we are treating t_e to be imaginary. We are justified in taking N to be imaginary as the microstate has not crystallized into reality. In the primary gas approach, the microstate is assumed to be real which means that N can be taken as a real. This makes time real. Thus treating time imaginary is another way of conveying the idea that the system is evolving by occupying a number of micro-states simultaneously in an uncrystallized state of reality. The better way to qualify this state may be to call it the unmanifested state. This is the basis behind the quantum superposition. Note that since the system occupies a large number of

micro-states simultaneously, the only way this could be accounted would be by assuming that these states exist in imaginary time. This means that the quantum superposition which emerges from the wave nature is a direct consequence of the imaginary nature of time. This explains the similarity between equations (1) and (2).

In the light of this interpretation of imaginary time, we may have a better understanding of the staphon structure of the particle. We saw in the earlier paper [2] that a moving particle is represented by a staphon oriented in the direction of motion of the particle. When the particle becomes stationary, it should gain its directional symmetry and the staphon could be taken to be aligned along all possible directions simultaneously. As we already know, this could be attributed to the quantum superposition. We now understand that the quantum superposition is essential part of the existence in imaginary time. When the particle gains velocity, only the waves representing the staphons in the direction of motion acquire non-zero amplitude. In this manner, with the concept of imaginary time we are able to retrieve the spatial symmetry in the rest frame of reference of the particle.

We now notice that along with time, spatial coordinate also has to be treated as imaginary. This is because the spatial coordinate is defined by the relation [5]

$$x_e \quad = \quad n_e NvT_e \quad = \quad n_e Nvh \;/ K\theta \tag{5A}$$

Therefore, when N is taken as imaginary, x_e also has to be taken as imaginary. Compare this treatment with the four-dimensional (Euclidian) formalism of the special theory of relativity where only the time coordinate is taken as imaginary while the space coordinate is treated as real. In the present approach since N is imaginary all extensive quantities become imaginary. Needless to say, action and Langrangean also would have to be treated as imaginary.

3 The Wick Symmetry

The concept of Wick rotation where real time is converted into imaginary time was introduced as an adhoc procedure to facilitate easy manipulation of certain functions in quantum field theory [8]. No body knows why such an adhoc procedure works, but all the same it became an established procedure. We shall now show that this is actually a new symmetry and points to the equivalence of the wave and the primary gas representations of a particle. Let us now examine the issue of the action-entropy equivalence proposed in the earlier paper [5]. Actually, when we study the issue in depth, we observe that there is one major difference between action and entropy which is not discussed in that paper. The difference is while action is defined in the imaginary time, entropy is defined in the real time. This means that the equivalence between action and entropy is restricted to that extent. But this problem can be reconciled. Let us now introduce an operator called Wick's operator denoted by $\breve{R}$ which operates on a function of N such that

$$\breve{R} \; f(iN) \quad = \quad f(N). \tag{6}$$

This means that operator $\breve{R}$ is defined in such a way that wherever iN appears, it is replaced by N. Since $t_e = NT_e$, we have

ie; $$\breve{R} \; f(it) \quad = \quad f(t). \tag{6A}$$

Let us now take the wave packet given in (1) which is formed by a group of plane waves that represent the individual states of the system. On operating with $\breve{R}$ on (1B) we obtain

$$\breve{R}\,[\,B_o'\,e^{\,i\hbar^{-1}E_o\,t_o}\,] \qquad = \qquad B_o'\,e^{\,-\hbar^{-1}E_o t_o} \tag{7}$$

Here B_o' is taken to be independent of N. This is because if B_o' were to be dependent on N, then the amplitude of the plane wave would become time dependent and this would have gone against its basic property. Note that $E_o t_o/h = S/K\ = nN\check{s}/K$ where $\check{s}$ is the intrinsic entropy.

The function on the right hand side of (7) has the basic form of the state function of the primary gas as given by (2A) provided we take $B_o' = g_o'$ However, when we try to identify (7) with the state function of a primary gas given by (2A), we are faced with two problems. The first one is that $\hbar$ in the exponential term in (7) has to be replaced by h. The second problem is that that B_o' which is the amplitude of the wave packet, is independent of n while g_o' which represents the degeneracy, increases exponentially with nN. Therefore, there is no logical way by which B_o' could be equated to g_o' and this comes in the way in identifying the right hand side of (7) as the state function of the primary gas. Note that for the state function to have a well defined average value, the degeneracy should increase exponentially with nN while the Boltzmann factor decreases with nN so that we obtain a sharp maximum at the average values as discussed in the earlier paper [5].

At first glance this requirement may appear irreconcilable. Surprisingly, the solution to the problems including that that of $\hbar$ appearing in the place of h on the right hand side of (7) could be found in a simple modification of the Wick's operator $\breve{R}$. We have to just modify the definition of the operator given in (6) slightly as given below.

$$\breve{R}\;f\,(2\pi inN\;) \qquad = \qquad f\,(nN\,) \tag{8}$$

In terms of the time and space coordinates, we may express this relation as

$$\breve{R}\;f\,(2\pi\;it\,) \qquad = \qquad f\,(t\,)\quad and\quad \breve{R}\;F\,(2\pi ix\,) \qquad = \qquad F\,(x\,) \tag{9}$$

Note that in the quantum field theory, the Wick rotation operates only on t and converts the function "$\exp(-i\hbar^{-1}E_o t_o)$" to "$\exp(-\hbar^{-1}E_o t_o)$" and leaves the space coordinates unchanged. On the other hand, the Wick's operator defined here operates on N, the number of microstates with the result that it rotates time and spatial coordinates at the same time. This difference does not affect the computational aspects as one can always transform the system to the proper frame of reference where the action function is free of the spatial coordinates. Possibly, that may provide the theoretical justification why Wick rotation works.

Let us write the amplitude of the plane wave in a more general form without altering its basic properties as

$$B_o' \qquad = \qquad B_o'\,e^{\,2\pi\;inN} \tag{10}$$

Note that the exponential factor in this equation will always be unity as N and n can take only integral values. Therefore, replacing B_o with $B_o\,e^{2\pi inN}$ does not alter the wave function in any way. In the light of these modifications, let us re-express **(7)** to obtain

$$\breve{R}\left(B_o'\,e^{\,-i\hbar^{-1}E_o\,t_o}\right) \qquad = \qquad \breve{R}\left(B_o'\,e^{\,2\pi\,inN}\,e^{\,-i\hbar^{-1}E_o\,t_o}\right)$$

$$= \qquad B_o'\,e^{\,nN}\,e^{\,-i\hbar^{-1}E_o\,t_o} \qquad = \qquad B_o'\,e^{\,nN}\,e^{\,-nN\,\bar{s}/K} \tag{11}$$

Here while the first exponential function increases with nN, the second one decreases with nN with the result that we obtain a sharp maximum for the probability function. Thus, for large values of nN, all possible primary gas states crowd around the average value of the internal energy. Since we know that $t_o = nNh/K\theta_o$, taking $B'_o e^{nN} = g'_o$, the right hand side of (11) may be expressed as

$$W'_o \quad = \quad g'_o \ e^{-nN \ E_o/K\theta_o} \tag{12}$$

This shows that the plane wave state on undergoing Wick operation becomes the state function of the primary gas. When viewed from a moving frame of reference, (12) would become

$$W' \quad = \quad g' \ e^{-nN \ (E - \mathfrak{p} \cdot \mathbf{v})/K\theta} \tag{12A}$$

Here one doubt may be raised regarding the meaning of the function obtained by the action of the Wick's operator $\breve{R}$ on ϕ^*. We saw that when $\breve{R}$ operates on ϕ, we obtain the probability function for the forward evolution. On the same logic, when $\breve{R}$ operates on ϕ^*, we should obtain the probability function for the reverse evolution (reverse jump) in time.

ie; $\quad \breve{R}\phi_o^* \quad = \quad \breve{R}\left(B_o * e^{-2\pi \ inN} \ e^{i\hbar^{-1}E_o t_o}\right) \quad = \quad B_o \ e^{-nN} \ e^{E_o t_o/h}$

$$\quad = \quad g_o^c \ e^{nN \ E_o/K\theta_o} \quad = \quad g_o^c \ e^{nN \ \bar{s}/K} \quad = \quad W_o^c. \tag{13}$$

Here $B_o \exp(-nN) = g_o^c$, is the degeneracy of the state and W_o^c represents the probability density function when nN takes negative values. Note that we have assumed B_o is a real function so that $B_o^* = B_o$. On first scrutiny, the function on the right hand side of (13) appears unsuitable to represent a probability function as $\exp[nNE_o/K\theta_o]$ is a divergent function and would keep on increasing as nN increases. Note that this function represents the reverse time evolution of the system. Therefore, although the Boltzmann's factor keeps on increasing, the exponential factor constituting the degeneracy denoted by "$B_o \ e^{-nN}$" keeps on decreasing. Now the net result is similar to what we obtained when time evolved in the positive direction. There the Boltzmann's function given by "$e^{-nN\bar{s}}$" was decreasing with nN while the degeneracy factor "e^{nN}" was increasing correspondingly. In the case of the reverse time evolution, only the roles of the Boltzmann's factor and the degeneracy factor are interchanged. The net result remains unchanged. In fact, the situation described here is similar to a system having negative temperature.

The concept of the negative temperature is quite well understood in thermodynamics [9]. The best example of the negative temperature is obtained when the external field acting on a paramagnetic material is reversed. In this situation, the system exists in a state of maximum energy. Suppose initially all the molecules in the paramagnetic material were aligned in the direction of the external magnetic field. Now on reversal of the magnetic field, the state of the maximum energy of the material possesses only one way of arranging the molecules among themselves, treating them as indistinguishable. But for slightly lower energy, the number of ways the molecules could be arranged increases. In other words, the degeneracy increases as energy decreases. In the case of an ideal gas, we know that

$$d\xi \quad = \quad \theta \ dS + P \ dV \qquad or \qquad \partial \xi/\partial S \quad = \quad \theta$$

But in the case of a system under negative temperature

$$\partial \xi / \partial S \quad = \quad - \theta$$

We know that the entropy S depends on the level of randomness of the system. In the case of the system under negative temperature, the degree of randomness decreases as temperature increases. When we take n to be negative as is the case in (13), we end up getting a system having negative temperature. Therefore, the function on the right hand side of (13) is a well defined function and is well suited as a probability density function.

Now we can afford a guess that the quantum mechanical systems could be understood in terms of the thermodynamics of the primary gas. This would mean that when we replace $2\pi it$ in the quantum theory by t, then for each law in quantum mechanics we may have an equivalent law in thermodynamics so that the physical reality remains unchanged. In other words, for every law, which determines the dynamics of a particle in the imaginary time, there should be an equivalent law in the real time. We shall first of all take the case of action in the imaginary time. Action is the most important function because we can derive the entire dynamical equations of classical and relativistic mechanics using the least action principle. We are already familiar with the equivalence of action to entropy from the earlier paper [5] . We see that the least action principle can be directly related to the second law of thermodynamics which is based on the maximization of entropy. In other words, Fermat's principle of least action is nothing but a restatement of the second law of thermodynamics. We shall establish this equivalence of quantum mechanics to thermodynamics of the primary gas in more detail in the following sections. Before that, we should have a clear concept of the various aspects of time as we know it.

Here it has to be stated that the localization of a particle which is easily understood in the wave picture in terms of the superposition of a group of waves is not easily explained in the primary gas approach. This is because, in the primary gas approach, the system will be spread in space over N broglino states occupied successively which will have a spread of $N\lambda$, where λ is the wave length of the broglino or the plane wave. We shall resolve this issue once the probability postulate is explained in terms of the primary gas.

4 The Imaginary Time, Reversible time and the Progressive Time

Before we proceed further with our investigation it is necessary to have a clear understanding of what is meant by the imaginary time, reversible time and the progressive time which we experience by our senses. We already saw that when a particle occupies microstates simultaneously, then, these states have to be treated as imaginary. This results in time and space acquiring imaginary nature. In this approach, a particle would be represented by a plane wave. When we transformed the wave function of a particle by the Wick's operator, $\breve{R}$ we obtained a probability function. In this picture, various paths of progression of a particle (each path is represented by the primary gas states) are occupied successively. Note that in the imaginary time, various paths may appear to be occupied simultaneously, but in the primary gas approach this picture gets altered and each path is occupied one at a time. But, since the system is able to jump back in time, ultimately all paths get occupied. In fact, by the process of the reverse jump in time, ultimately, all the paths get occupied simultaneously. In other words, the end result of using the wave picture and the primary gas picture is the same. But in the primary gas approach only one path is assumed to be occupied in one channel of progression and therefore it can be treated as a real time process. The probability function gives only the

density of occupation of the paths. The picture that emerges may be called reversible time picture.

In our everyday experience, a reverse jump in time is not possible. For example, when we throw dice, we obtain only one outcome at a time. Other outcomes will occur when the experiment is repeated. In other words, the other outcomes cannot occur simultaneously. They could occur successively. Therefore, the reversible time obtained by the operation of $\breve{R}$ on the imaginary time is not the time with which we are familiar in our experiences with our senses. It pertains to a different category altogether. Actually reversible time is so named because the system can occupy all possible paths successively only if it can jump back in time and again start the forward jump again. This is the only way the system could occupy all possible paths. Such a picture is quite familiar to us thanks to Feynman who created a whole new formalism based on it. This is a very important property which will help us to differentiate the reversible time from the progressive time.

Time as we experience in our daily life is the progressive time. Time progression and the increase in entropy are two sides of the same coin. For example, if we play backwards a very short video recording of the collision of the billiard balls on a billiards table, then their motion will appear as natural. To put it differently, the laws of mechanics are invariant to time reversal. Actually, this invariance is an idealization. In actual experiments, the progressive nature of time will leave its imprint to some extent, even if the time duration involved is small. For example, in the experiment with the billiard balls, if we play back the video recordings for slightly longer duration, we would observe that balls which were standing stationary start moving by themselves and gain momentum. Balls may even pop up from the pockets and come into play on the board. This may appear quite absurd and against the laws of mechanics. This is the reason why we have to segregate time into two categories. The time in which the mechanical laws operate and the time which we perceive in our day to day experience. The time which we experience in our day today experience may be called the progressive time. In this time, entropy keeps on increasing. In fact, we may use the increase in entropy as a marker to measure the progression of time.

We should keep in mind that all those states which remain as probable for occupation in the progressive time actually get occupied in the reversible time and the imaginary time. The probability function only gives the frequency of occupation, or to be more specific, the density of occupation of a certain states. Here we may compare the picture that emerges from the imaginary time with that of the reversible time. We saw that in the imaginary time, the particle has to be described in terms of a group of waves progressing in time along all paths. Or in other words, we have to use the wave picture to describe the particle. On the other hand, when we use the reversible time, we describe the particle in terms of the primary gas which occupy states successively by traveling forward and backward in time along all possible pathways. In the wave picture, there is no need to imagine the forward and backward jumps. The square of the amplitude of the wave represents its energy density and therefore it is identified with the particle density or the probability density for observing the particle. In the case of the reversible time and the progressive time which are both defined in the real time, the common feature is that the primary gas states are occupied successively. This means that only one state is occupied at one instant. It is a different issue that in the case of the reversible time, by the process of reverse jump in time the system is able to occupy all possible states at the same instant.

In the progressive time, time gains the directional property and because of that it is no more possible to jump back in time. In that sense, the progressive time picture is identical with

the primary gas picture provided the reverse jumps in time are disallowed. Note that in the imaginary time picture, the particle disembodies into a large number of waves and they get back the particulate nature only at the instant of observation. This sudden change has been one of the most discussed topics in quantum mechanics and known as the collapse of wave function. It is also one of the least understood. One advantage of the reversible time picture over the imaginary time picture is that we do not have to disembody the particle and therefore, there is no sudden change to the structure of the particle at the time of observation. But then we have to pay a price by way of allowing the reversible jumps in time. Actually, the concept of the reverse jump exists in the wave picture also. In fact, when we take the complex conjugate of the wave function, Ψ^*, we are dealing with a wave which is travelling backwards in time. But in the wave picture, Ψ^* represent the anti-particle which is assumed to exist as a shadow of the real particle everywhere. This shows that the Wick's operation has not created anything new. It only changed the method of accounting the states. In the wave picture, the forward and the reverse waves are taken together, the reverse wave being treated as a shadow of the forward wave. Therefore, when the system evolves, it evolves along all possible paths simultaneously. In the primary gas approach, the forward jumps and the reverse jumps are segregated and accounted taking each path separately.

The problem we face in taking the increase in the entropy as a marker for the progressive time is that we do not have a process which can be taken as a norm for this purpose. If we take the case of a billiard ball rolling over the surface and coming to a standstill, then we know that the kinetic energy of the ball is converted into heat energy due to friction. If we denote the increase in the heat energy by dq and the temperature of the board as θ, then the increase in entropy in the slow down of the billiards ball will be dq/θ. But this creation of heat depends on so many factors that it becomes virtually impossible to use it as a norm to measure the progression of time. But we know that the rest mass can be taken as a measure of the internal heat of the particle [5]. Therefore, the progressive time should be in some way related to the most basic process which results in the creation of the rest mass of a particle.

In the previous section we have taken $W_{(E)}$ as the probability density function for the occupation of the energy states by the system. But actually $W_{(E)}$ cannot be taken to represent the probability to observe the system in that state. We know that the probability to observe the system in a state with energy E is given by $P = \Psi^*\Psi$ and not by $W_{(E)} = \breve{R}\Psi$. We shall shortly discuss the basis for the probability postulate of quantum mechanics using the path integral formalism introduced by Feynman.

The Wick symmetry shows that it is possible to study the evolution of a micro-system either in the imaginary time in which case quantum mechanical laws would apply or in reversible time in which case the laws of thermodynamics would apply. This means that apart from the canonical approach and the path integral approach we have a third option in the primary gas approach to study the quantum behavior. It is well known that the path integral formalism is eminently suited to solve the problems of quantum electrodynamics while the canonical approach has its own high points. In a similar manner, the primary gas approach may be ideally suited to resolve some of the conceptual problems of quantum mechanics and quantum field theory. We shall examine these aspects as we go on.

Here it is interesting to note that Feynman had used the basic idea of replacing t by $-i\hbar/K\theta$ to interpret the path integral formalism on the basis of statistical mechanics [10]. He obtained the value of the density matrix ρ which is the sum of all contributions from each motion, considering all possible paths, or motions, by which the system can travel between the initial configuration in time "$\hbar/K\theta$" as

$$\rho \quad = \quad \int\limits_0^{h/K\theta} \left\{ \exp \left[-\hbar^{-1} \int [\tfrac{1}{2} m x^2 (u) + V(x)] \; du \right] \right\} Dx(u) \tag{14}$$

Here u is a parameter having the dimension of time and *Dx(u)* relates to the individual path taken. He comments about the above result in following words. " This is very amusing result, because it gives the complete statistical behavior of a quantum-mechanical system as a path integral without the appearance of the ubiquitous *i* so characteristic of quantum mechanics. This path integral (in reversible time) is much easier to work with and visualize than the complex integrals which we have studied previously. Here it is easy to see why some paths contribute very little to the integral; for there are paths for which the exponential is very large and thus the integrand is negligibly small. Further more, it is not necessary to think about whether or not nearby paths cancel each other's contributions, since in the present case all contributions add together with some being large and others small."

We can understand the mathematics behind the equation given in (14) as follows. The number of paths that can be taken by a system *Dx(u)* to move from a point A to another point B in a certain time interval will increase as the energy of the system increases. Note that the particle could take all circuitous paths and still make it to point B from A in the given time if it travels faster in the intervening period. But these paths would belong to states of higher energy and momentum. But for the higher energy states, the exponential term within the bracket on the right hand side in (14) will have a lower value. Thus we observe that while *Dx(u)* increases with energy, the exponential term would decrease with the increase in energy. In fact, the integral will have a maximum along the classical path. We know this is exactly what happens in the primary gas approach provided we take *Dx(u)* as representing the degeneracy g.

It is interesting to note that this concept of the Wick symmetry cannot be taken to the internal coordinates of the particle where the spin of the system is defined. At the level of the internal coordinates if we transform the imaginary time to the real time, the amplitude wave ϕ_A which defines the spin of the particle would no more be in a position to represent spin [5]. This means that the Wick symmetry operates only at the level of the broglino. It cannot be applied to the level of its internal structure. The reason for this is quite simple. The most basic state in the reversible real time is a single microstate or the broglino state when $N = 1$. Therefore, it is not possible to apply the concept of the Wick symmetry to the internal structure of a broglino. To put differently, we cannot destroy the spin of the system by the action of the Wick's operator $\breve{R}$.

5 Feynman's Pathintegral Formalism

Before attempting to understand the basis of the probability postulate, it is necessary to go through Feynman's path integral formalism briefly. The path integral formalism is a completely new way of looking at the quantum phenomena. In Feynman's approach, a particle evolves from one point in space-time to another along various paths and each path may be associated with certain probability amplitude [11]. According to Feynman if $\phi[x(t)]$ is the probability amplitude for a particle to reach a point (x_b, t_b) from point (x_a, t_a) along a particular path defined by x(t), then

$$K(b, a) \quad = \quad \sum \phi[x(t)] \tag{15}$$

where $K_{(b,a)}$ is the probability amplitude for the particle to move from (x_a,t_a) to (x_b,t_b). The summation means that all paths from (x_a,t_a) to (x_b,t_b) contributes to the probability amplitude. On the other hand the probability for the same movement is given by

$$P(b,a) \quad = \quad |K(b.a)|^2 \tag{16}$$

The interesting aspect of these paths is that the adjacent ones vary substantially in phase because a change as low as h can alter the phase by 2π. So ultimately all amplitudes cancel each other out except those, which lie very close to the path having least action. Here, a small change in the path creates changes in the phase only in the second order. So the classical path gets maximum amplitude and becomes the observable path. Therefore, in the classical limit

$$K(b.a) \quad = \quad \text{" smooth function ".} \; e^{i\hbar^{-1}A_{cl.}} \tag{17}$$

Based on this simple line of reasoning, Feynman shows that

$$K(b.a) \quad = \quad \int K(b,c)\,K(c,a)\,dx_c \tag{18}$$

where (x_c,t_c) is a point lying between (x_a,t_a) and (x_b,t_b). Equation (18) represents a basic property of the probability amplitude.

A wave function by definition represents the total amplitude arriving at the point (x,t). It does not specify the previous state from which it is coming. In other words, a wave function does not give any information about the past history of the particle or system. If a system is in the initial state with coordinates (x_a,t_a) which is not fixed the wave function for the state (x_b,t_b) will be given by

$$\psi(x_b.t_b) \quad = \quad \int K(x_b,t_b;x_a,t_a)\,\psi(x_a,t_a)\,dx_a \tag{19}$$

In other words, the wave function $\psi(x_b,t_b)$ which is the total amplitude to arrive at (x_b,t_b) is the sum of or integral over all amplitudes from all possible points (x_a,t_a) which are prior to (x_b,t_b). Note that $t_a < t_b$. If $t_a > t_b$, then it would be tantamount to assuming that future events are affecting the present which is not acceptable.

Now we shall try to express the amplitude $K(x_b,t_b; x_a t_a)$ in terms of the state functions at b and a. We know from equation (19) that $\psi^*(x_b,t_b)$ can be expressed as

$$\psi^*(x_b.t_b) \quad = \quad \int K^*(x_b,t_b;x_a',t_a)\,\psi^*(x_a',t_a)\,dx_a' \tag{20}$$

It is implicit here that the integral sign represents integration over the region from $-\infty$ to $+\infty$. Now post multiplying both sides of (20) by $\psi(x_b,t_b)\,dx_b$ and integrating, we have

$$\int \psi^*(x_b,t_b)\psi(x_b,t_b)dx_b \quad = \quad \iiint K^*(x_b,t_b;x_a',t_a)\,K(x_b,t_b;x_a,t_a)\psi^*(x_a',t_a)\psi(x_a,t_a)\,dx_a\,dx_a'\,dx_b$$

$$= \quad \int \psi^*(x_a',t_a)\,\psi(x_a,t_a)\,dx_a \tag{21}$$

This represents the conservation of the probability. For this relation to hold good for arbitrary Ψ, we must have

$$\iint K*(x_b,t_b;x'_a,t_a)\,K(x_b,t_b;x_a,t_a)\,dx'_a dx_b \quad = \quad \delta(x'_a - x_a) \quad (22)$$

That is, in order to interpret ψ as probability amplitude, the kernel must satisfy equation (22). To know what $K*(x_b,t_b; x_a',t_a)$ stands for let us multiply (22) by $K(x_a,t_a; x_c,t_c)$ and integrate over x_a, to obtain

$$\iiint K*(x_b,t_b;x'_a,t_a)\,K(x_b,t_b;x_a,t_a)\,K(x_a,t_a;x_c,t_c)dx_a\,dx'_a dx_b \quad = \quad \int \delta(x'_a - x_a)\,K(x_a,t_a;x_c,t_c)\,dx_a$$

ie; $$\int K*(x_b,t_b;x_a,t_a)K(x_b,t_b;x_c,t_c)\,dx_b \quad = \quad K(x_a,t_a;x_c,t_c). \quad (23)$$

This holds good only if $t_b > t_a > t_c$. Compare this to the relation to the following equation based on the property given by (22)

$$\int K(x_a,t_a;x_b,t_b)\,K(x_b,t_b;x_c,t_c)\,dx_b \quad = \quad K(x_a,t_a;x_c,t_c) \quad (24)$$

where $t_a > t_b > t_c$. The process behind the second relation could be explained as follows. Starting from at t_c, $K(x_b,t_b; x_c,t_c)$ gives us the amplitude at a later time t_b. If we still want to go to a later time t_a, we could do so using the kernel $K(x_a,t_a; x_b,t_b)$. On the other hand, if having the amplitude at t_b, we want to work back to find it at an earlier time $t_a < t_b$, we can do this using the function $K*(x_b,t_b; x_a,t_a)$. In other words, $K*(x_b,t_b;x_a,t_a)$ is undoing the work of $K(x_a,t_a; x_b,t_b)$. Another way of looking at this is that while $K(x_a,t_a; x_b,t_b)$ stands for movement of amplitude in the direction of the time evolution which is from t_b to t_a where $t_a > t_b$, $K*(x_b,t_b; x_a,t_a)$ represents movement of amplitude going back in time from t_b to t_a where $t_b > t_a$. This means that $\psi*(x_b,t_b)$ given by

$$\psi*(x_b,t_b) \quad = \quad \int K*(x_b,t_b;x_a,t_a)\,\psi*(x_a,t_a)\,dx_a \quad (25)$$

represents the total amplitude going back from the states (x_b,t_b) to (x_a,t_a). To put things in proper perspective, while $\psi(x_b,t_b)$ represents the probability to arrive at the state (x_b,t_b) from all past states, $\psi*(x_b,t_b)$ represents the probability to go back from (x_b,t_b) to all past states. Thus we may state that *while $\Psi(x_b,t_b)$ represents the probability amplitude for evolving from the past states to the state (x_b,t_b), $\Psi*(x_b,t_b)$ represents the probability amplitude to go back in time to the past states from the state (x_b,t_b).* We shall see that this interpretation is ideally suited for the proposed idea of the Wick symmetry.

If ϕ_n represents a set of eigen functions which are orthogonal to each other, and E_n the set of eigen values of energy, then we know tha the state function can be expanded as

$$\psi(x,t) \quad = \quad \sum_{\alpha=1}^{\infty} c_n\,e^{-i\hbar^{-1}E_n t}\,\phi_n(x) \quad (26)$$

If we now take two points in space time (y,t_1) and (x,t_2) where $t_2 > t_1$, then it can be easily shown that

$$K(x,t_2;y,t_1) \quad = \quad \sum_{\alpha=1}^{\infty} \phi_n(x)\,\phi_n^*(y)\,e^{-i\hbar^{-1}E_n(t_2-t_1)} \quad (27)$$

$\phi_n(y)$ represents the nth energy-momentum eigen states of the wave function at the point (y,t_1). It is possible to express the eigen functions as

$$\phi_n(x) \quad = \quad e^{i\hbar^{-1}p_n(x-y)}\,\phi_n(y) \quad (28)$$

With this expression for $\phi_n(x)$, we may write (27) as

$$K(x,t_2;y,t_1) \quad = \quad \sum_{n=1}^{n=\infty} \phi_n(y)\,\phi_n^*(y)\,e^{-i\hbar^{-1}[E_n(t_2-t_1)-\mathrm{p}_n(x-y)]} \qquad (29)$$

for $t_2 > t_1$. Let us suppose that the states denoted by E_n and p_n are lying very close so that we may take the distribution as a continuous one. Let us now denote by x and y the four vector space-time coordinates and by **þ** the four vector energy momentum coordinates. Now for notational convenience we may switch over to the natural units where $\hbar = 1$ and $c = 1$. In that case (29) becomes

$$K(x,y) \quad = \quad (\tfrac{1}{2\pi})^4 \int |\phi_n(y)|^2\ e^{i\mathbf{p\cdot(x\text{-}y)}} d^4\mathrm{þ} \qquad (30)$$

The constant $(1/2\pi)^4$ has been introduced for normalizing purpose. It is quite obvious that in a field free situation K(x,y) should be equal to $\delta(x\text{-}y)$ because that is the only way that $\psi(x)$ will retain the same form as $\psi(y)$ as the system moves from y to x. This is possible only if $|\phi(y)|$ does not dependent on **þ**.

In quantum field theory K*(x,y)* is called the propagator and is denoted by G*(y-y')*. It is worthwhile to note that the propagator depends only on the interval in the coordinates, which is (y-y′) and the notation brings this out explicitly. In the general case, equation (30) may be written as

$$G(y-y') \quad = \quad (\tfrac{1}{2\pi})^4 \int G(\mathrm{þ})\ e^{-i\mathbf{p\cdot(y\text{-}y')}} d^4\mathrm{þ} \qquad (31)$$

Note that G*(þ)* will change according to the field acting on the system. The wave function is nothing but the sum total of all such eigen states weighted with their amplitudes. We see from (31) that the weightage factor G(þ) remains unity if the field acting is zero. But when a field acts on the system, in the journey from y to y′, the weightage factor for each eigen state of þ undergoes a change due to the action of G*(þ)* and thus the wave function gets altered.

In Feynman's approach $\Psi(x_b,t_b)$ represents the sum of the probability amplitude reaching the state (x_b,t_b) from the past, while $\psi^*(x_b,t_b)$ represents the sum of all amplitudes starting from the state (x_b,t_b) and going back to the past. This sort of an interpretation is in-built in the Feynman's picture. But such an interpretation would mean that evolution of a system backward in time is equally possible. In other words, such an interpretation would treat forward and backward evolution of time symmetrically. But in real world, time progresses only in one direction. This may be the reason why Feynman never attempted to seek an alternate interpretation for the probability postulate based on his path integral formalism.

6 The Probability Postulate and the Wick Symmetry

In the light of the above discussion, we may interpret the probability postulate in terms of the forward and reverse evolution in time. To understand the meaning of the probability postulate we shall take up the special case of the evolution of a system from the initially observed eigen state (x_a,t_a) to the state (x_b,t_b) where $t_b > t_a$. Note that the eigen state represented by a plane wave in the wave picture would become the broglieon state in the primary gas approach. Since the wave function $\Psi(x_b,t_b)$ by definition represents the total amplitude arriving at the point (x_b,t_b), in the case on hand it would represent only the amplitude arriving at (x_b,t_b) from just (x_a,t_a). In other words,
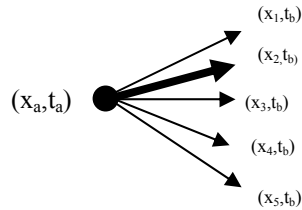
$$\psi(x_b, t_b) \quad = \quad K(x_b, t_b; x_a, t_a) \quad .$$ (32)

Similarly, taking the complex conjugate, we obtain

$$\psi^*(x_b, t_b) \quad = \quad K^*(x_b, t_b; x_a, t_a)$$ (33)

Here Ψ^* represents the probability amplitude for the system to devolve from the state (x_b, t_b) to the earlier state (x_a, t_a). Thus the function $\Psi^*\Psi$ represents the probability amplitude for evolving from the state (x_a, t_a) to the state (x_b, t_b) and then back to the state (x_a, t_a). Note that we have taken only (x_a, t_a) as fixed while (x_b, t_b) stands for a large number of states as shown in figure.3. Therefore, when the system evolves from (x_a, t_a) to the states denoted by (x_b, t_b), then this takes place along a number of paths. We may say that in any observation at the instant t_B, the system may be caught in any one of the (say) five paths as shown in figure 3. Since the system would be in any one of the five paths at the instant t_b, we may take the probability for the system to be in the first path to be

$$P(x_b, t_b) \quad = \quad \psi^*(x_b, t_b)\,\psi(x_b, t_b)$$ (34)

provided we take Ψ as normalized such that $\sum \Psi^*(x_b, t_b)\,\Psi(x_b, t_b) = 1$. Here we have taken the initial state (x_a, t_a) to be the eigen state which is given. Actually, the entire chain of reasoning

The figure shows the evolution of the system from a single initial state at instant t_A to a large number of states at a subsequent instant t_B and back.

Figure.3

would hold good even if the initial state (x_a, t_a) is not a single eigen state but a large number of eigen states. This means that the system is not observed in any particular eigen state at the instant t_A but retains its potential to occupy a large number of eigen states.

The evolution of the quantum mechanical system into future and back may appear quite absurd, but then we should keep in mind that in the microcosm, time has not lost its directional symmetry unlike in the case the macroscopic world. As a result, the system may evolve into future and back to the present and again into future and so on. In other words, in the imaginary time or reversible time, a particle could be in many places simultaneously. However, when the system comes into contact by way of an observation with the macroscopic time which may be called the progressive time, it will be caught in one of the possible locations. This is because in the progressive time, a particle could be only in one place at an instant. One may say that the observation is a process by which a micro-system shifts from the imaginary time to the progressive time. Note that if the micro-system were to evolve in progressive time, then it has to be under continuous observation. Therefore, the probability to occupy the state (x_2, t_b) will be given by the probability to jump from (x_a, t_a) to (x_2, t_b) only. There is no possibility of a reverse jump here. On the other hand, in the imaginary time, we have to take both forward and the reverse jumps to arrive at the probability to occupy the state (x_2, t_b). Thus the basis of the probability postulate could be traced to the fact that a micro-system exists in a time with its reversibility or directional symmetry intact.

We shall now try to find out what is the quantity which is conserved in the Wick symmetry. We know that if the Wick symmetry is a universal symmetry, then there should be an invariant property of the system associated with this symmetry. It appears that the probability density is the quantity which remains invariant in the Wick's rotation. Let us apply the Wick's operator on the wave function to yield

$$\breve{R} P_i \quad = \quad \breve{R}[\psi_i * \psi_i] \quad = \quad W_i^{\,c} W_i \quad = \quad B_i^{\,2} . \tag{35}$$

Here $W_i^{\,c} = B_i\, e^{-nN}\, e^{nN\bar{s}/K}$ and $W_i = B_i\, e^{nN}\, e^{-nN\bar{s}/K}$ where B_i is taken as a real quantity. Note that W_i denote the probability of the primary gas which progresses in time while W_i^c denote the probability for regression in time. From the above analysis it is obvious that the probability density P_i is conserved in the Wick rotation provided B_i is taken as real. In other words, we could take the conserved quantity connected with the Wick symmetry to be the probability density.

7 Localizing the broglieon

Now that we have understood the true meaning of the probability postulate, we may now proceed to solve the problem of the localization of the broglieon. Since the broglieon is a primary gas, its micro-states will be stretched in time over a duration of NT_e and in space over a length $N\lambda$ where N is a large number. This means that in the primary gas formalism, the system cannot be localized within a reasonably small region. In the case of the wave representation of the particle, we do not face such a problem. Here when we take a group of waves, they will interfere with each other destructively everywhere except in the small region where the amplitude will have a sharp maximum and the particle could be assumed to be located there.

We should remember that when we localize a particle, we are not carrying out an observation. Here we have to keep in mind that in any interaction with the particle at an instant, the microstates involved need not belong to the same primary gas. In fact, since we are confining to the interactions at one spatial point, the micro states involved would belong to various primary gas states. In other words, the N microstates belonging to separate primary gas states could represent the particle which is localized in a small region. Such a group of microstates would form a real gas stat as they all exist at the same instant. In fact, as the primary gas states close to the classical path are occupied maximum, the N states involved in the localization could belong to these primary gas states along the classical path. Note that the uncertainty principle would still hold good if viewed in terms of what is stated in section 8 of the last paper [5]. In the wave picture, the sharpness of the localization is brought about at the cost of the spread in the energy momentum states. So we should have a similar situation here also. In other words, if the localization is sharp, the momentum states cannot be restricted to a narrow band. Here we should keep in mind that the wave picture is the space-time picture while the primary gas picture is the energy momentum picture.

8 Zero Point energy as the thermal energy of vacuum fluctuations

We shall now investigate the concept of the zero point energy of quantum mechanics and look out for the equivalent law in the reversible time. According to Quantum Mechanics, vacuum is taken as zero energy state or the ground state. This does not disallow the existence of fluctuations in the energy and momentum of the vacuum state. We know that the staphon

(standing half wave) is created by its interactions with the vacuum fluctuations in the Higgs field [4]. Note that the photino, which represents a single composite wave (electromagnetic wave in the simplest case) is in thermal equilibrium with the fluctuations in the Higgs field. In other words, the fluctuations in the Higgs field act like a thermal bath and the energy of the particle is equal to the energy of the vacuum fluctuations confining it. Here we should keep in mind that a staphon has two degrees of freedom just as the photino constituting it has got two directions of polarizations. Therefore, for one polarization we have

$$E \quad = \quad \tfrac{1}{2} h \, v \qquad\qquad (36)$$

And if we take the both polarizations we obtain

$$E \quad = \quad h \, v \qquad\qquad (36A)$$

This is the energy of the fluctuations in the Higgs field which confines the photino forming the particle.

Actually, in the above calculations we have not taken into account the confinement of the photino in the transverse direction. Here we should presume that the electromagnetic wave is not confined in the transverse direction. The fact that the electromagnetic field oscillations are transmitted along the transverse direction means that there is no confinement of the electromagnetic energy in the transverse direction. We already know that the ratio of the electromagnetic field energy of the electron to its total energy is a universal constant called the fine structure constant [3].

We should keep in mind that if the vacuum fluctuations interacting with the photino did not have this much energy, then the photino would have lost out its energy to the vacuum and faded away. But since the confined photino is in equilibrium with the fluctuations in the energy of the Higgs field, we should assume that the rest energy of the particle and the energy of the Higgs field fluctuations are perfectly matched. But we have $v = 1/T$, where T is the period of oscillation of the confined photino. Therefore, we have

$$E \quad = \quad h / T_e \qquad\qquad (37)$$

But T_e, which is the intrinsic time of the particle is related to the temperature of the primary gas by $T_e = h/K\theta$ [5]. Therefore, we have

$$E \quad = \quad K \, \theta \qquad\qquad (38)$$

But we know that $\tfrac{1}{2}K\theta$ represents the thermal energy for unit degree of freedom. But since vacuum fluctuations have two degrees of freedom in two possible directions of polarizations, we have $K\theta$ instead of $\tfrac{1}{2}K\theta$ in (38) In other words the zero point energy is nothing but the energy of the vacuum fluctuations acting as a thermal bath.

In the light of equation (37) let us examine the action function of a free particle given by

$$- (Et - þx) \quad = \quad - E_o t_o \qquad\qquad (39)$$

We know that we can always replace the external coordinates of space and time with the intrinsic coordinates of the primary gas [5]. Accordingly, replacing the external coordinates in the above equation with the intrinsic coordinates, we obtain

$$- (ET_e - \text{þ}X_e) \qquad = \qquad - E_o T_{eo} \tag{40}$$

But we know that $T_{eo} = h/K\theta_o$. At the same time, from (38) we have $E_o = K\theta_o$. Therefore (40) can be written as

$$(ET_e - \text{þ}X_e) \qquad = \qquad E_o T_{eo} \qquad = \qquad h \tag{40A}$$

Note that h is the intrinsic action of the particle. This shows that whatever be the nature of particle, the intrinsic action is a universal constant denoted by h. Therefore

$$A/h \quad = \quad - Et_o/h \quad = \quad - nNE_o T_{eo}/h$$

$$= \quad - nNh \, \nu_o T_{eo}/h \quad = \quad - nN \tag{41}$$

But since $\quad A/h \quad = \quad - S^{\#}/K$, we have $S^{\#}/K \quad = \quad nN$. $\tag{41B}$

Here we should keep in mind that entropy $S^{\#}$ appearing in the above equations is not the actual entropy of the system, but the adjusted entropy. The actual entropy $= S^{\#} - \phi/\theta$, where ϕ is the thermodynamic potential given by [5].

$$- \phi/\theta \quad = \quad \ln\{\Sigma \, g_k \, e^{-(\xi_k/K\theta - \rho G_k/K)}\}$$
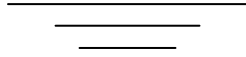
9 Conclusion

In view of what is discussed above it is quite obvious that quantum mechanics is nothing but the thermodynamics of the primary gas that exists in the reversible time. In the next paper, we shall examine each of the postulates of quantum mechanics and show how it conforms to the primary gas approach. We shall also show how the results of Young's double slit experiment could be explained in the primary gas approach. We already saw here how the probability postulate has its origin in the reversibility of time. The idea that an elementary particle is in thermodynamic equilibrium with the fluctuations in the Higgs field provides us with a simple picture of the inner structure of the elementary particle and in a sense takes us to the concept that all elementary particles can be interpreted in the layman's language as some sort of vortices created by electromagnetic and other composite waves. But we are still far from understanding why only certain rest energies are allowed for the particles. Could it be understood in terms of the relative strengths of the basic fields?

When we examine Feynman's path integral formalism, it is quite surprising to note that how close he came to the real time approach. He even arrived at the similarity between the imaginary time approach and the real time approach as discussed in section 4. He had already introduced the concept of the forward jump in time and the reverse jump in time. The only reason why he couldn't arrive at the Wick symmetry could be traced to the fact that he couldn't think up the concept of the primary gas. His mind was busy solving the problems of quantum electrodynamics using the newly discovered path integral formalism.

It is interesting to examine the emergence of the space-time from the interactions of the particles with the fluctuations in the Higgs field. Remember that these interactions are undergone by all particles and the universal nature of these interactions is the basis behind the perception of a universal background of time and space. By the same reasoning, we may attribute space-time for other short range interactions. But the only problem is that such a

space-time would not form a continuum. Besides, since these interactions are of different nature, this space-time would not form a part of the universal space-time which is created by the Higgs field interactions. In other words, we have to introduce new dimensions to accommodate these localized space-times. Note that in the language of the string theory, they would represent warped higher dimensional spaces. Needless to say these warped spaces would apply to only quarks and the composite particles created out of them. In a way we come to the conclusion that the space and time are essentially outer manifestation of the various types of interactions undergone by particles having mass.

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