# A Physical Theory of Quantum Mechanics based on a wave controlled flow of localized Particles

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ABSTRACT. A deterministic theory of quantum mechanics is presented which is based on real guiding waves interacting with and controlling the motions of localized particles. The guiding waves are assumed to obey a plasma-type wave equation, which is equivalent to the Klein-Gordon equation (a relativistic Schrodinger equation) with an assumption that the plasma frequency for the wave is equal to $mc^2/\hbar$. The waves entrain a phase space of particles and are responsible for the wave-like distribution of particles during interference and tunneling,. . . .

*RESUME. On présente une théorie déterministe de la mécanique quantique basée sur l'idée de véritables ondes de guidage qui interagissent avec des particules localisées en dirigeant leurs mouvements. On présume que les ondes de guidage obéissent à une équation ondulatoire du type plasma, qui est équivalente à l'équation de Klein-Gordon (une équation relativiste de Schrödinger) et en supposant que la fréquence de plasma de l'onde soit égale à* $mc^2/\hbar$. *Les ondes entraînent une espace de phase de particules et sont responsables de la distribution à caractère ondulatoire des particules sous l'effet d'interférence et pendant les effets tunnel, etc.*

## 1. Introduction

Quantum mechanics is an amazingly successful centerpiece of modern physics. Starting with a few basic ideas at the turn of this century, it has been expanded to explain virtually all observed microscopic phenomena and has given birth to the technology of solid state electronics. While many people have found its non-determinism unsettling [1], attempts to provide a more classical foundation have so far been unsuccessful [2].

Recently however, there have been a number of beautiful experiments [3,4] in which classical electromagnetic fields have created long range order and wave-like and crystal-like ordering of entrained particles, suggestive of quantum mechanical phenomena. This paper tries to build on these new, particle-capture concepts from experimental physics to model quantum mechanics as a complex, but classical wave-particle interaction, involving classical particles interacting with classical wave fields [5]. The model presented here is similar to de Broglie's double solution [6].

This model assumes that the de Broglie or guiding wave fields obey the plasma equation [7]:

$$\nabla^2\psi - \frac{1}{c^2}\frac{\partial^2\psi}{\partial t^2} - \frac{{\omega_o}^2}{c^2}\psi = 0 \; , \tag{1}$$

where $\psi$ is some unspecified potential, $c$ is the free space velocity of light, and $\omega_o$ is the plasma resonance frequency. The ${\omega_o}^2/c^2$ term is an addition to the regular wave equation due to the plasma resonance. The plasma equation is a very general equation which governs wave propagation through any medium having a resonance at each point in the medium of frequency $\omega_o$. Examples of such media are plasmas, waveguides, and even mechanical systems (with a different $c$ value) if they have the required resonance in each unit cell or lattice point. We assume that there is a special wave propagation mode in space corresponding to each elementary particle type, each mode with its own distinct "plasma" or resonant frequency $\omega_o$ given by

$$\omega_o = \frac{mc^2}{\hbar} \; , \tag{2}$$

where $m$ is the rest mass of the particle and $\hbar$ is Plank's constant. Equation (1) is the same assumption used by de Broglie many years ago [6]. It might also be pointed out that (2) predicts such very high frequencies for the waves (roughly $10^{20}$ Hz for an electron, and higher for heavier particles), that technologically we could not be expected to have directly observed these waves, even though perhaps we have witnessed them indirectly in the quantum mechanical effects they bestow on particles.

One might think that (2) is a rather arbitrary assumption, wishfully relating two independently fundamental parameters. However we will see that in the model presented in this paper, the particles are entrapped by the guiding wave field of (1) and it is this wave field which determines particle dynamics (much as in the conventional interpretation of quantum mechanics) instead of any local particle property, such as mass. That is to say that a particle has an *apparent* mass $m = \hbar\omega_o/c^2$ because it is trapped in a guiding wave field of plasma frequency $\omega_o$.

It is further assumed that each wave mode is selective and will interact mostly with its associated particle type. This selectivity is based on two factors. First, particles will respond most strongly to frequencies near their "plasma" frequencies. Thus, for example, because the masses of electrons and protons are so different, the corresponding frequencies of these wave fields, as per (2), will differ by more than three orders of magnitude, making it unlikely that the two wave fields will interact much. Secondly, each particle type will be associated with a wave type having many of the attributes normally associated with that particle and will interact with its wave field via these attributes. For example, a particle with spin will have associated waves which have a spin nature to them, similar to the spin waves [8] in a ferromagnetic material, and will interact with the waves via the spin interaction. A neutral particle will have a very different type of wave field (perhaps with a large quadrupole component) than will a charged particle. While it may seem artificial to hypothesize space with so many types of waves, we should remember that solids also have many types of waves. For example, a ferromagnetic solid has many modes and polarizations for each of the following types of waves: compressional, shear, surface, spin, plasma, etc. Each of these wave types and each wave mode has a very special way of interacting with its sources and scatterers and all can coexist simultaneously, often with very little interaction.

Substituting (2) into (1), our defining wave equation becomes the relativistic Schrodinger equation, the Klein-Gordon equation [9]:

$$-\hbar^2 \frac{\partial^2 \psi}{\partial t^2} = -\hbar^2 c^2 \nabla^2 \psi + m^2 c^4 \psi \ . \tag{3}$$

Because this is the Klein Gordon equation, it means that these classical wave fields will faithfully model the guiding waves of quantum mechanics. So far as the waves are concerned, the classical wave fields of this model will have the same wavelengths and same interference patterns as predicted by standard quantum mechanics.

In the case of a bound state such as an electron bound to an atom, the wave field would be "bent" to form a circular standing wave or resonant configuration by the electrostatic field of the nucleus as per the normal Klein-Gordon equation with the electromagnetic fields addition [10]. The electric fields of the nucleus perturb the local phase velocity or "metric" of the guiding waves of the electron and so cause the bending. This interaction is also the non-linear basis of most scattering as will be discussed later.

## 2. Wave controlled flow of an ensemble of particles.

As discussed above, each wave field will interact mainly with its own type of particles. Quantum mechanics, however usually considers the interaction of a wave with an *ensemble* of particles, where "ensemble" means the superposition of all possible particles and trajectories for a given physical setup. In this way of viewing the interaction, each wave will interact with an ensemble of its particle type. This ensemble may conveniently be viewed as a type of flowing fluid. Quantum mechanics requires that a wave field coax the particle density in its ensemble to be proportional to the wave amplitude squared, i.e. to the wave intensity:

$$\rho \propto \psi^2 \tag{4}$$

For modeling a simple particle source, this proportionality is easy to achieve. One simply requires that a source emitting particles also emits waves of an intensity proportional to the average flux of particles. Both the particles and waves will spread out with the inverse square law and so stay in proportion.

Interference situations are more complex. Next, we will examine the fields in a standing wave situation, and see that the interactions of high frequency oscillating forces (of frequencies near $\omega_o$) and motions cause much slower varying forces and motions (the normally observed forces and motions), similar to the dynamics of particles in an electromagnetic Paul trap [11]. These slower particle motions can be conveniently viewed in their phase space orbits (which turn out to obey (4)). For simplicity we will consider one-dimensional, steady-state, standing wave patterns, where the particles are moving in the z direction. These calculations are very simplistic to illustrate the general principle here.

First, as in fluid mechanics (Euler's Equation [12]), particles in the ensemble flow will obey:

$$\begin{aligned} F_{av} &= \frac{dp}{dt} = \frac{\partial p}{\partial t} + \frac{\partial p}{\partial z}\frac{\partial z}{\partial t} = \frac{\partial p}{\partial z} v \\ &= \frac{p}{m_r}\frac{\partial p}{\partial z} = \frac{1}{2m_r}\frac{\partial p^2}{\partial z} \quad , \end{aligned} \tag{5}$$

where $F_{av}$, $v$, and $p$ are the $z$ directed force, particle velocity, and particle momentum averaged over a wave cycle, and $m_r$ is the effective mass (to be discussed below) for these slow or average motions. Also for simplicity, we assume a steady-state ensemble flow field for which $\partial p/\partial t = 0$.

Secondly, a particle and its waves will interact so that the waves force the particle to oscillate with a time varying displacement of $\tilde{\xi}$, which we will take to be the $z$ direction. One might think that such an oscillating force would average to zero. However if $\partial \tilde{F}/\partial z$ is non-zero and the force is therefore greater during the part of the cycle when $\xi$ is positive than when it is negative, then the average force will not be zero. This effect is the basis for currently used traps for electromagnetic particles. The average $z$ directed force can be calculated as:

$$F = \tfrac{1}{2}\,\mathrm{Re}\left(\frac{\partial \tilde{F}}{\partial z}\,\tilde{\xi}^*\right), \tag{6}$$

where $\tilde{F} = a\psi$ is the oscillating force on the particle (which is proportional to the wave amplitude and $a$ is the constant of proportionality), and the tilde over the $F$ and other variables is to remind us that these are oscillating quantities. $\psi$ is also oscillating; however, in keeping with conventional quantum mechanics, we will not use a tilde over it. The "Re" in (6) stands for "the real part of". Considering the particle as a classical entity with effective mass $m_1$ in responding to the oscillating force, we can write $\tilde{\xi}$ as:

$$\tilde{\xi} = \frac{\tilde{v}}{i\omega} = \frac{-\tilde{F}}{m_1\omega^2}\,, \tag{7}$$

where $\tilde{F}$ is the oscillating force on the particle, and $\tilde{v}$ is its time varying, oscillating velocity. The mass $m_1$ would consist of the mass of the naked particle plus that of the fields close enough to the particle to follow it at these high frequencies. Making this substitution yields:

$$F_{av} = \frac{-1}{2\omega^2 m_1}\frac{\partial\left|\tilde{F}\right|}{\partial z}\left|\tilde{F}\right| = \frac{-a}{2\omega^2 m_1}\frac{\partial\left|\psi\right|}{\partial z}\left|\psi\right|. \tag{8}$$

The third consideration involves the resonant nature of the plasma type wave equation (1) for frequencies near $\omega_o$. This resonant nature, coupled with low group velocity of the waves means that the particles, oscillating at frequencies near $\omega_o$, will excite local resonances in the fields (governed by (1)) around themselves. It is reasonable to assume that this local resonance has an energy $U$ and an inertial mass $m_r = U/c^2$ which are proportional to the external wave amplitude (i.e. the driving force) squared:

$$\begin{aligned} U &= m_r c^2 = a_1 \psi^2 \\ \Rightarrow m_r &= \frac{a_1}{c^2}\psi^2 \quad , \end{aligned} \tag{9}$$

where $a_1$ is a constant. In order to insure that the waves totally dominate the particle dynamics, we assume that the inertial mass $m_r$ of these local resonances dominates over any other masses the particles may have for the motions which are slow compared to a wave cycle. A second effect of the local resonance is to shield the particle from the external field on average, effectively inverting the sign of the average force in (8).

Putting together (5), (8), and (9), we get:

$$\begin{aligned} \frac{\partial(p^2)}{\partial z} &= 2m_r \\ &= 2\frac{a_1}{c^2}\psi^2 \left( \frac{-a^2}{2\omega^2 m_1} \frac{\partial\,|\psi|}{\partial z}\,|\psi| \right) \\ &= {a_2}^2 \frac{\partial \psi^4}{\partial z} \quad , \end{aligned} \tag{10}$$

where $a_2$ is a constant. Integration yields:

$$\begin{aligned} p^2 &= {a_2}^2(\psi^4 - {\psi_o}^4). \\ \Rightarrow p &= \pm a_2 \sqrt{\psi^4 - {\psi_o}^4} \\ &= \pm a_1 v_g \sqrt{\psi^4 - {\psi_o}^4} \quad . \end{aligned} \tag{11}$$

This defines the phase space orbits of the entrained particles having various integration constants $\psi_o$ which are constant for each orbit and equal the $\psi$ potential amplitude at which point the orbit has zero $z$-momentum. Also, ${\psi_o}^2$ is a binding potential of a particle to its orbit. In (11) we also used the relationship $a_2 = a_1/{v_g}^2$, as required to make the momentum of a pure traveling wave $p_{tw} = m_r v_g = a_1\psi^2 v_g$ with zero binding potential or ${\psi_o}^2 = 0$.

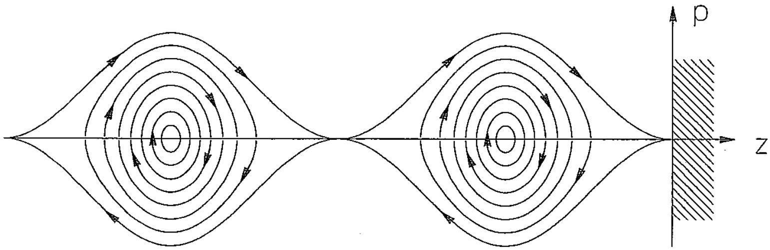


**Figure 1.** Phase space orbits in the presence of a pure standing wave field. Momentum is plotted versus particle position. The shaded region on the right is a totally reflecting barrier.

For a situation where $\psi = \psi_1 \sin\omega t \cos\kappa z$, i.e. a pure wave, we get the phase space orbits as shown in Fig. 1, where the particles are orbiting around regions of maximum $|\psi|$ values. Assuming that the phase space is filled to the maximum "bound" orbits, i.e. to the $\psi_o = 0$ orbit for which:

$$p = \pm a_1 v_g \psi^2, \tag{12}$$

then the width in the $p$ direction of the entrained phase space is equal to $2a_1 v_g \sqrt{\psi^4 - {\psi_o}^4} = 2a_1 v_g \psi^2$, i.e. it is proportional to $\psi^2$. Since the number of particles is proportional to the occupied phase space area, we expect the density of particles at any one position $z$ to be proportional to the orbital width and therefore to $\psi^2$:

$$\textit{ensemble density}(z) \propto \psi^2. \tag{13}$$

Looking at Fig. 1, it is easy for us to understand the reason there are more particles around the peak $\psi^2$ regions: these regions represent potential wells around which the particles orbit and as a consequence have the greatest concentration of orbits and therefore particles.

The phase space for the case of a mixed wave having standing and traveling waves together, as in front of a partially reflective barrier, is shown in Fig. 2.

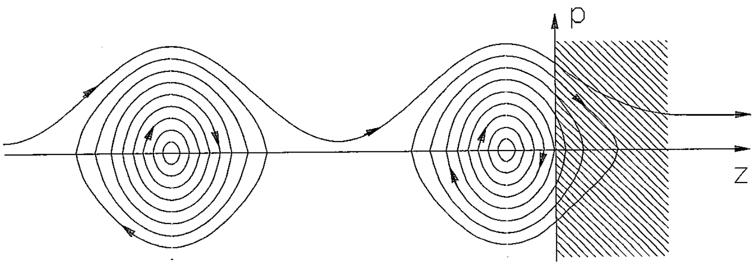


**Figure 2.** Phase space orbits in a mixture of standing and traveling waves. The shaded region on the right is a partially reflecting barrier.

We might note that there are two distinct regions. First, there is the lower region of closed orbits whose particles are bound to the interference region. This region is populated when the interference is first set up and has half the density of particles as the second region. The second or upper region has open orbits that travel through the barrier. We might have also drawn a lower open region, the mirror image of the upper region below the axis, however there is no means to populate these orbits.

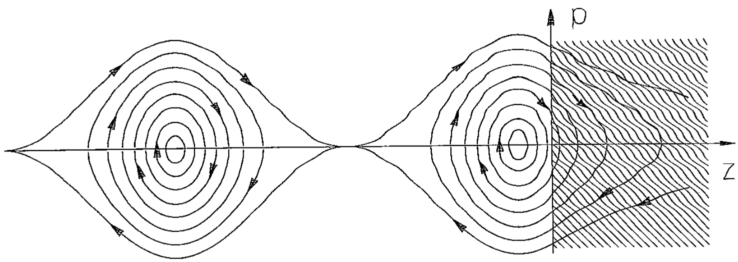


**Figure 3.** Phase space orbits in the evanescent wave region inside a barrier. The shaded region on the right is a very thick barrier whose potential is slightly greater than the particles' kinetic energy.

Fig. 3 shows the phase space created by a finite height potential barrier illustrating total reflection of the particles and evanescent penetration of that barrier. Notice that the orbits near the barrier carry the particles some distance into the barrier before they turn around. Fig. 4 shows a similar, but finite length, barrier through which the waves can "tunnel". Here, the closed orbits are practically the same as in Fig. 3, however there are also open orbits which allow a net flow of particles through the barrier. The number of particles in these orbits that penetrate the barrier is proportional to the energy (or $\psi^2$) of the penetrating waves, since by (12) the height of the orbitals in phase space (i.e. $p$ for $\psi_o = 0$) is proportional to $\psi^2$.

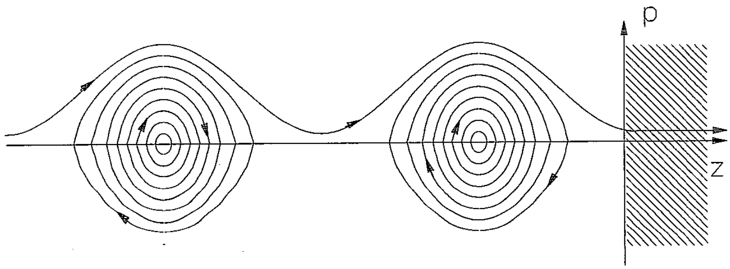


**Figure 4.** Phase space orbits in a tunneling situation.

## 3. Measurement and scattering.

Just how do the waves and particles interact with other particles, the walls of an experiment, and detectors? The scattering relationships which govern such interactions are outlined next.

The waves are basically linear processes and can pass through other waves without scattering. However, as discussed before, the fields of one particle can perturb the local phase velocity or metric of waves of other particles, and, for instance, can cause the waves of the electrons to bend around the proton in the case of the hydrogen atom, or in the case of an oscillating particle, this process will result in a non-linear mixing of the perturbing particle's field with other wave fields passing through. In the latter case, the two frequencies create a third product frequency:

$$\psi(t) \propto \exp i\omega_1 t \cdot \exp i\omega_2 t = \exp i(\omega_1 + \omega_2)t \ . \tag{14}$$

In order to make this equation valid for various points $\mathbf{r}_p$ in space along the perturbing particle's trajectory, we need to add the position dependence of the product wave into the equation:

$$\begin{aligned} \psi(\mathbf{r}_p, t) &\propto \exp i(\ \kappa_1 \cdot \mathbf{r}_p - \omega_1 t) \cdot \exp i(\ \kappa_2 \cdot \mathbf{r}_p - \omega_2 t) \\ &= \exp i[(\ \kappa_1 + \ \kappa_2) \cdot \mathbf{r}_p - (\omega_1 + \omega_2)t] \quad , \end{aligned} \tag{15}$$

where the $\kappa$'s are the wave numbers of the respective waves. For this product signal to produce a reasonably intense product wave of frequency $\omega_3$:

$$\psi_3(\mathbf{r}_p, t) \ \propto \ \exp i(\kappa_3 \cdot \mathbf{r}_p - \omega_3 t) \quad , \tag{16}$$

i.e. the phase of the incident product must equal that of the final wave fields at each point in space and time over which the mixing occurs, so that the components of the scattered wave add up constructively. This approach is similar to that used in the classical derivation of Bragg scattering and in the scattering of waves by diffraction gratings [13]. That is, the exponent in (15) must equal the exponent in (16) over a range of $r_p$'s and $t$'s:

$$\begin{aligned}[(\kappa_1 + \kappa_2) \cdot \mathbf{r}_p - (\omega_1 + \omega_2)t] &= \kappa_3 \cdot \mathbf{r}_p - \omega_3 t \\ \Rightarrow \kappa_1 + \kappa_2 = \kappa_3 \ \text{ and } \ \omega_1 + \omega_2 &= \omega_3.\end{aligned} \tag{17}$$

This can be extended to a more general case involving any number of particles, stationary or moving, to show *in a general scattering process, a classical wave-particle system will conserve frequency and wave number totals.* Note that similar to the case in Feynman diagrams, the processes of emission, absorption and detection are simply special cases of general scattering where one of the particles is initially or finally at rest, or in a bound state.

## 4. Microscopic versus macroscopic parameters.

We have seen that this model allows for a varying dynamic mass $m_r$ and, in a standing wave situation, varying particle velocities, whereas conventional physics uses constant mass particles and a constant magnitude of momentum in the same standing wave situations. Thus this model diverges from the conventional interpretation of physics. In measured (or "observed") results, on the other hand, we will hopefully get agreement of the model with conventional quantum mechanics, which has been well verified experimentally. Let's think out what the model would predict, for example, for a time-of-flight measurement. In this model, a packet of waves is released with every burst of particles. Because these wave packets move at the group velocity of the wave field, in a reference frame moving at the group velocity, they appear to be stationary wave packets with local, stationary field maxima similar to those in simple standing waves. We would expect the particles to execute orbits, similar to those shown in Fig. 1 around each of these local maxima. In this sense, the particles are trapped by the local maxima and carried along with them at the group velocity, in agreement with conventional quantum mechanics which has particles moving at the wave field's group velocity. At the same time, the particles will also be orbiting inside the wave packet and as such will have instantaneous velocities which vary somewhat from the average. Experimentally, we do see this variation and usually attribute it to quantum mechanical uncertainty. Thus, in time-of-flight measurements, there does seem to be agreement between this model and conventional physics, even though the dynamic details of the two are fairly different. Note that the group velocity of the waves, and not the instantaneous particle dynamics, is most important in determining the outcome of the time-of-flight experiment. The particles' chief role is to provide catalytic mixing sites for emission and detection of the waves.

Other classical measurements such as measurement of particle mass, momentum, and energy are made by similarly analyzing particle trajectories, or by analyzing scatterings off other particles. (These would be classified, along with the above time-of-flight measurement, as an indirect measurement by Lochak [14].) In the model here, average or ensemble particle trajectories will be determined by the wave fields. In scatterings also, we have seen that the wave properties, the wave numbers and wave frequencies in this case, determine the outcome. Thus the model presented here mirrors conventional quantum mechanics in having measurements of the propagation of particles be determined by the wave fields. It should be pointed out that in all cases, because the classical waves of (1) agree with those in the standard quantum mechanical picture and the ensemble particle density flows with these waves, all ensemble averaged properties of this model and conventional quantum mechanics will be the same.

Classically calculated momentums and energies are linked with normal quantum mechanics using the energy and momentum operators on the wave functions. For simple waves, these result in the following:

$$\mathbf{p} \equiv m_{rel}\mathbf{v}_g = \hbar\kappa, \tag{18}$$

and:

$$U \equiv m_{rel}c^2 = \hbar\omega, \tag{19}$$

where $m_{rel}$ is the relativistic mass. (We use the relativistic forms to allow easy comparison with our model which uses the relativistic forms.) Conventional quantum mechanics effectively replaces the particle momentum and energy with the wave number and frequency of the guiding wave field. In the model, we can also use (18) and (19) which can be derived for the model from (3) and classical properties of the wave fields: Using $v_g = d\omega/d\kappa$ with (3) we get $mv_g = \hbar\kappa$ , i.e. the right most relation of (18), where the left relation of (18) $\mathbf{p} \equiv m_{rel}\mathbf{v}_g$ is the definition of classical momentum. Making a Lorentz transformation on (2) results in the right relationship of (19) with the left relationship being the definition of regular relativistic energy. Making these links, (18) and (19), between our model and classical physics allows us to see that it is wave number and frequency conservation in scattering, (16) and (17) that are the foundations of the classically calculated, or macroscopic, momentum and energy conservation.

Equation (2) links a particle's conventional rest mass with the "plasma resonance" of the wave fields associated with that species of particles. Even though this model has particles of varying microscopic masses $m_r$ instead of the fixed mass $m$, this link (2) will insure that the wave field has the proper group velocity to force the ensemble of particles to move with the same average trajectories and other same observable parameters as would a conventional quantum mechanical particle ensemble. In a sense, the classical particle mass, momentum, and energy have been replaced, at the microscopic level, with the guiding wave field's plasma frequency, wave number, and frequency, respectively. We might say that the waves carry the (macroscopic) particle mass, momentum, and energy in the somewhat altered forms of plasma frequency, wave number, and wave frequency. The *microscopic* or actual particle mass, momentum, and energy are less important and certainly different from their macroscopic or classical counterparts.

What happens to the *microscopic* wave energy in the model after a wave spreads out? First of all, this energy would be usually hidden in most experiments and would not play the central role in scattering that *macroscopic* energy or the wave frequency do. Besides, the wave field energy is diffuse and not as easy to account for as the energy of a classical particle. On the other hand, it would power the waves and particle dynamics and so is of interest. Most likely, the nearby particles would scatter and rescatter this remnant wave energy. However, because the particles and their local resonances are resonant structures (or scatterers), their scattering cross sections are much larger for scatterings involving their resonant frequencies. Thus, most scatterings would involve the resonant frequencies of the particles, perhaps similar to a gambling house being involved in all gambling on the premises. As a consequence, the populated resonance modes or states would have, on average, a very enriched share of the remnant wave energy, while the unpopulated states would have little. The average share of the populated states would be proportional to their population densities, and, because of special relativity, to their frequencies.

## 5. Relation to Bell's Theorem and hidden variable theories.

Particle spin plays a very important role in quantum theory. As mentioned earlier, particles with spin would need to involve spin in their guiding waves, analogous to the spin waves in magnetic materials. Then experiments that polarized beams would polarize the spin of the waves which guide the particles. Experimentally, detection of spin usually involves a non-spin sensitive detector behind a polarizer and really only indicates the fraction of particles that traverse the polarizer and not their microscopic spins (analogous to microscopic momentum). In the model presented here, the spin waves would be split by the polarizer, in the same way as quantum mechanics predicts, and a fraction of particles would be carried along with each wave in proportion to the energy in each. Thus the detected spin is analogous to the detected energy or momentum we discussed before: while the particle is an essential, nonlinear catalyst in the detection process, the spin of the waves determines the fraction of particles penetrating the polarizer and thus the average "spin" actually detected. Analogously, in a spin related transition, we would expect the spins of the waves to be carefully conserved, with certain selection rules applying. Along these lines, Bell's Theorem [15] does not constrain the model presented in this paper, but instead constrains theories having the observed spin determined by the spin of the actual particles.

We might also examine the old criticism of hidden variable theories [16], which are similar to the model proposed here in that both theories postulate particle dynamics that are as yet unobserved. The old hidden variable theories would allow new degrees of freedom and so create additional contributions to specific heat, in conflict with experiments [17]. In a classical monatomic gas, for example, the degrees of freedom are the three directions of particle motion in which the particles can move. In quantum theory, the wave numbers take over this role as the degrees of freedom, since particle motions are embodied in the wave dynamics. In the theory presented here, the waves are also the dominant factor and assume the role of the "degrees of freedom": a wave field with the appropriate wave number (for the particle velocity) exists for each particle, with the average energy in this wave field being proportional to the number of particles it entrains times their frequency. Wave field modes or states which entrain no particles (i.e. are empty) will have most of the energy removed from them by the particles via the resonant scattering process discussed above. The particles are bound to the entraining waves and have negligible energy compared with the wave fields. This differs from the classical case of independent particle energy and independent field energy: in the present theory there is only field energy.

## 6. Summary of the wave-entrained particle model.

[ 1.] Particles have real physical associated guiding waves obeying the plasma equation, having some of the properties of the particles they are associated with, and having a "plasma" resonant frequency of $mc^2/\hbar$ where $m$ is the classical particle mass.

[ 2.] Particle sources create the guiding waves with energy densities in proportion to the average density of particles times the wave frequency.

[ 3.] The particles are entrained by the waves and move in phase space orbits. Details of the orbital processes make their density proportional to the wave amplitude squared.

[ 4.] A process that splits the wave will also split the captured phase space of particles in proportion to the energies of the two emerging waves.

[ 5.] Scattering processes will conserve the vectorial wave number sums and the frequency sums.

[ 6.] Resonant scattering will statistically put most of the remnant microscopic wave energy into resonant modes or states that are populated by particles in proportion to the particle densities and frequencies.

[ 7.] The microscopic wave energy and momentum is hidden from conventional, macroscopic experiments which detect particles. Instead, the frequency and wave number of the guiding waves determine the statistical outcome of scattering, absorption, and detection experiments.

The de Broglie double solution model similarly involves a wave field interacting with localized singularities, which act as oscillators, much the same as do the localized resonances of the present model. The model presented in this paper gives a more physical interpretation of these singularities and also assumes the wave field to have a physical reality. The question immediately arises as to the meaning of multiparticle wave functions; however that is topic for future work and will not be addressed here. Also, the present model considers scattering, detection, etc. to be wave mixing phenomena.

In conclusion, we see that it may be feasible to model quantum mechanics as a complex, classical wave-particle interaction with deterministic, phase space orbits for particles, providing we are willing to change our mental picture of a particle from a classical body to that of an essentially massless entity surrounded by a local resonance, whose oscillator strength and microscopic mass depends on the intensity of the local guiding wave fields. In this model, most of the "observables", i.e. the observed "particle rest mass", "particle momentum", "particle energy", etc., are carried (or determined) by the guiding wave fields in somewhat altered forms, i.e. plasma frequency, wave number, frequency, etc., respectively.

This model is similar to the conventional interpretation of quantum mechanics in that both exchange the classical picture of particles for a wave-particle interaction and both replace particle momentum with wave number and energy with frequency, etc. In both, emission and absorption processes occur locally around particular particles, while propagation is determined by the more spread out wave fields. The model presented in this paper has the added attraction of providing a physical picture of the intriguing wave-particle process.

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*(Manuscrit reçu le 21 janvier 1992, révisé le 2 juin 1992)*