An Outline of the Elements of a New Approach to Understanding Quantum Physics

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1 The Structure of the Theory of Quantum Mechanics

1. The Schrödinger Equation for the He atom (2 $\mathbf{N^0}$s, 2 $\mathbf{P^+}$s, 2 $\mathbf{e^-}$s):

$$\mathbf{i}\hbar\frac{\partial\Psi(\vec{R},\vec{r}_1,\vec{r}_2,t)}{\partial t} = \hat{H}\,\Psi(\vec{R},\vec{r}_1,\vec{r}_2,t) \tag{1}$$

$$\hat{H} = \hat{T}+\hat{V} \tag{2}$$

$$\hat{T} = -\frac{\hbar^2}{2M}\nabla^2-\frac{\hbar^2}{2m_e}\nabla_1^2-\frac{\hbar^2}{2m_e}\nabla_2^2 \tag{3}$$

$$\hat{V} = \frac{1}{4\pi\epsilon_0}\left(-\frac{2e^2}{|\vec{R}-\vec{r}_1|}-\frac{2e^2}{|\vec{R}-\vec{r}_2|}+\frac{e^2}{|\vec{r}_2-\vec{r}_1|}\right) \tag{4}$$

where

(a) $\hat{V}$ is not the electrostatic potential, but the electrostatic potential energy operator for the system

(b) $\hat{T}$ is the kinetic energy operator for the system
(c) $\vec{R}$, and $\vec{r}_1$ and $\vec{r}_2$ are the instantaneous positions of the nucleus, and of the two $\mathbf{e}^-$s
(d) The two electrons are, in general, entangled

2. The Method of QM (TBD: Revise in reference to textbooks)
(a) Initially, the system is prepared to be in a state given by a certain ket: $|\Psi_1(\vec{r},t)\rangle$
(b) For measuring a classical variable C, the corresponding Hermitian operator $\hat{C}$ is taken to act on the ket.
(c) As a result of the measurement, the system may (or may not) undergo a change in its state.
(d) In any case, a possibly measurable state is denoted by the bra: $\langle\Psi_2(\vec{r},t)|$
(e) The value of c of a measured variable C is one (and only one) of the eigenvalues of the operator $\hat{C}$
(f) The probability of obtaining a particular (eigen)value c is given by $|a_m|^2$ where a_m is the complex coefficient of the measured eigenfunction. **TBD** Make it more general.
(g) In short: QM requires a prior specification of all the ket, the operator, and the bra, before any prediction can be made. QM is not about starting from a known initial state and ending up at an unknown destination state. It is about starting from a known combination of both the initial and destination states, with the measurement picking out one of the components of the destination states with a probability that depends on both the initial and the final states.

3. The eigenspectrum of the position operator is continuous.

2 The Ontology Followed in the New Approach

1. Preliminaries:
(a) Only the non-relativistic QM: 3D space, completely independent time
(b) We prefer the position representation. We believe it provides the real story.

2. Types of Objects in Our Scheme:
(a) Primary Objects
i. The neutron, $\mathbf{N}^0$
ii. The proton, $\mathbf{P}^+$
iii. The electron, $\mathbf{e}^-$
iv. The background object $\mathbf{B}^0$
(b) Secondary (Attribute) Object
i. The complex wavefunction Ψ
(c) Tertiary (Derived) Object
i. The photon, γ.

3. Brief Descriptions of the Objects
(a) The neutron ($\mathbf{N}^0$) is a classical, massive, chargeless, point-particle
(b) The proton ($\mathbf{P}^+$) is a classical, massive, positively charged, point-particle.
(c) The electron ($\mathbf{e}^-$) is a classical, massive, negatively charged, point-particle.
(d) The $\mathbf{P}^+$ and the $\mathbf{e}^-$ differ only in the sign of the charge, not magnitude. For both $\mathbf{P}^+$ and $\mathbf{e}^-$, their electrostatic interactions show IAD (instantaneous action at a distance), and follow Coulomb's law. The potential set up by either (for any other charges in the universe to feel) is singular in r from its position. The potential undergoes instantaneous changes everywhere in the universe as the particle moves in space.
(e) Apart from the singular potential-producing particles of $\mathbf{P}^+$ and $\mathbf{e}^-$,

there is no other means to have a charge (or electrostatic potential) in the system. The description with the discrete $\mathbf{P}^+$s and $\mathbf{e}^-$s is logically complete, as far as all electrodynamic phenomena are concerned.

(f) The wavefunction Ψ is a physically existing attribute possessed by the background object $\mathbf{B}^0$. It exists as a 3D field. It changes instantaneously everywhere, thereby placing the Fourier theory at the basic level of QM description. It causally interacts with charges (both $\mathbf{P}^+$ and $\mathbf{e}^-$) such that a specification of an electrostatic potential energy V at a point uniquely implies the instantaneous local value of $\Psi(\vec{r}, t)$ at that point, and vice-versa.

(g) The background object ($\mathbf{B}^0$) is a non-classical object. It is all pervading. It supports IAD. Both the electrostatic potential energy V due to interactions between $\mathbf{P}^+$ and $\mathbf{e}^-$, as well as the wavefunction Ψ exist as field-conditions within itself.

(h) The concept of photon γ refers to a completed process of the physical change that is a quantum jump between two energy eigenstates of the same $\mathbf{e}^-$. It refers to the temporary, local and propagating change in the local values of the Ψ field which is brought about when an electron undergoes a quantum jump in its energy eigenfunction.

3 The System Evolution in the New Approach

1. The system always evolves in accordance with the multi-particle time-dependent Schrödinger's equation such as the one given in (1) above.
2. The Ψ is in general a function of the positions of all the $\mathbf{e}^-$s, as well as of all the $\mathbf{P}^+$s.
3. In QM, we do not use all the forces as described in the classical electrodynamics. We use only the IAD-acting electrostatic forces of $\mathbf{P}^+$s and $\mathbf{e}^-$s. The dynamic fields are described using an alternative description involving the Coulombic potentials and the Ψ.
4. The role of Ψ in the system evolution: Start with an initial configuration, and find its evolution in time using only the Coulomb forces and in accordance to Newton's laws. What the Ψ field does is to modify this evolution, through two modalities of interactions:
   (a) the forces it locally exchanges with the $\mathbf{P}^+$ and $\mathbf{e}^-$ qua massive particles
   (b) the force it exchanges everywhere in space with the IAD-acting field of the electrostatic potential energy, as set up by $\mathbf{P}^+$s and $\mathbf{e}^-$s (which are time-dependent because of their motions)
5. In the real world, the Schrödinger equation (1) is actually nonlinear in nature, for the following reasons
   (a) Ψ is a function of all $\mathbf{P}^+$ positions R_i, and all $\mathbf{e}^-$ positions r_j.
   (b) The particles of $\mathbf{P}^+$ and $\mathbf{e}^-$ feel the local Ψ field. In particular, what the application of the momentum operator yields is a property of a given local infinitesimal volume element of space. (The Schrödinger equation is framed in the Eulerian terms, not Lagrangian.) If the momentum of the local volume element changes with time, it means there are local forces acting on the volume element. If a massive particle of $\mathbf{P}^+$ or $\mathbf{e}^-$ exists at that point, it feels these forces. In general, Ψ is a function of time too. Therefore, in general,

$$\vec{Q}_{CV} = -\mathbf{i}\hbar\nabla\Psi \tag{5}$$

$$\vec{F}_{CV} = \frac{d\vec{Q}}{dt} \tag{6}$$

   where $\vec{Q}$ denotes the momentum of the control volume, and $\vec{F}$ is the force exerted by Ψ on the control volume.

   (c) The $\mathbf{P}^+$s and $\mathbf{e}^-$s move in response to these local forces. Thus, the position $\vec{r}$ of any massive particle (here, $\mathbf{P}^+$ or $\mathbf{e}^-$) is a function of the

time-changes in Ψ

$$\vec{r}_i = f\left(\vec{F}_{CV}\right) \tag{7}$$

$$= f\left[-\mathbf{i}\hbar\frac{d}{dt}\left(\nabla\Psi_{CV}\right)\right] \tag{8}$$

(d) The potential energy field corresponding to each charge changes when the charge moves, because the potential is singularly anchored into its position. Hence, obviously,

$$V(\vec{r}_i) = f\left[-\mathbf{i}\hbar\frac{d}{dt}\left(\nabla\Psi_{CV}\right)\right] \tag{9}$$

(e) Substituting (9) into (1), the Schrödinger equation begins to show its actual nonlinear form. Setting constants to unity, the form of the equation as actually operational (or realized) in the real world is:

$$\frac{\partial\Psi(\vec{X},t)}{\partial t} = \left[\sum\nabla_i^2\Psi(\vec{X},t)\right] + f\left[\nabla\Psi(\vec{X},t)\right]\Psi(\vec{X},t) \tag{10}$$

where $\vec{X}$ denotes the set of all positions of all the $\mathbf{P}^+$s and $\mathbf{e}^-$s in the system

6. The potential field in the system is solely created from a superposition of the potentials of the individual $\mathbf{P}^+$s and $\mathbf{e}^-$s. These individual potentials have singularities in them. This fact implies that there exist definite surfaces separating the potential valleys created by the adjacent point-charges
   (a) To aid visulization, use the Voronoi tesselation
7. As the charges move in accordance with (**??**) and (7), the potential valleys and the surfaces separating them, move too (the Voronoi tesselation changes)
8. In the real world, Ψ evolution is expected to undergo not just smooth changes, but also those that are catastrophic, for following reasons
   (a) The nonlinearity in (10) implies sensitive dependence on the initial condition.
   (b) The Ψ field implies (and is implied by) the electrostatic potential energy field $V(\vec{X},t)$
   (c) The $V(\vec{X},t)$ field has potential valleys

4 The Measurement Process in the New Approach

1. Terminology:
   (a) The System here means the quantum system to be measured
   (b) The Instrument here means the measurement apparatus
2. Delineation of the System and the Instrument
   (a) QM applies to the universe as a whole, and the universe is an isolated system. So, there is a degree of choice as to how the System and the Instrument may be isolated.
   (b) A practically convenient choice--and the one that is invariably followed in experimental physics--is to keep the System as linear as possible.
   (c) The only way to maximize linearity is to reduce the number of those degrees of freedom that might potentially lead to catastrophic changes to the local Ψ field lying within the spatial region of the System.
   (d) The simplest way to reduce the possibilities of catastrophes is to make the System as small as possible (containing as few particles as possible)
   (e) Invariably, therefore, the System is small (a few atoms or qubits), whereas the Instrument is big.

i. The number of atoms in a photomultiplier tube is of the order of Avogadro's number

3. An Example Instrument: Photomultiplier Tube (PMT)
   (a) Ignore the "photo" part. Start with the availability of a single (photo)electron at a time for measurement.
   (b) The geometry of the dynodes and the anode, their voltages (about 1–2 kV) etc. are all so selected to make the PMT as a unit very sensitive to the presence of a single $\mathbf{e}^-$ near the first stage.
   (c) The avalanche current is a nonlinear effect
   (d) Realize, there is a positive bias at the anode. The avalanche current is of $\mathbf{e}^-$s. It temporarily offsets the positive bias. Thus the signal is a dip in the anode voltage/current--it is not a peak.
   (e) The existence of such a bias is helpful for the nonlinear processes
4. What Happens in Measurement
   (a) The Instrument–System interaction may be considered, at the first stage (or the system–side interface) of the Instrument, to be a resonance phenomenon
   (b) The resonance picks out one of the natural frequencies (eigenbasis) of the System
   (c) The Instrument undergoes catastrophic changes to its state, i.e. to its material configuration (e.g. the dip in the current)
   (d) The System–Instrument interaction is mainly mediated by (and proceeds because of nonlinearities in) the Ψ field, not by the well–localized point–particles of $\mathbf{P}^+$s and $\mathbf{e}^-$s
   (e) The bra describes the state of a System, and the ket describes the state of the Instrument.
5. The Wavefunction Collapse Postulate--What Really Happens?
   (a) Notice, the wavefunction of the System does not collapse at all
   (b) Forget the outright collapse, the Ψ field in the region of the System is not even meant to undergo just a catastrophic change of its local state
   (c) It is the Instrument which suffers a nonlinearly cascading series of catastrophic changes to its local Ψ field.
6. The Repeated Measurement Postulate--How Does It Come About?
   (a) The measurement process is nondestructive of the state of the System. It produces catastrophic changes only in the Instrument
   (b) But the state of the Instrument can be brought back to the regime of sensitivity to the first stage
   (c) Parts of the Instrument's innumerable parameters (each particle supplies some of them) still remain close to that regime which produced the first measurement
   (d) Hence, an immediately repeated measurement has more likelihood to be sensitive to the same eigenfunction of the System as the one measured before. The primary initial means of the Instrument–System interaction, viz., resonance, further serves to swing the Instrument on to the same eigenfunction
7. Born's Postulate--How to Explain It?
   (a) The primary means of the Instrument–System interaction is not the point–particles but the local features of the Ψ field
   (b) Even the measurements for an $\mathbf{e}^-$'s position must proceed through the agency of the Ψ field
   (c) The measured position thus refers to the local features of the Ψ field and not to the actual sharp position of the $\mathbf{e}^-$
   (d) Stronger: It is impossible to measure the actual sharp position of an $\mathbf{e}^-$ (even if it exists), because the Ψ field cannot be destroyed (the background object $\mathbf{B}^0$ always exists), and it intervenes. In other words, the only position that can ever be measured is that which has origins in the local features of the Ψ field.
   (e) The primary role played by Ψ (and not $\vec{r}_i$), together with the sensitivity

to the initial conditions and catastrophic changes in Ψ together imply that measurement outcomes are probabilistic. A resonance develops with this natural frequency (eigenfunction) of the System or that, but the "run-time" choice is governed by the nonlinearity.

(f) But why $P \propto |\Psi|^2$? Why not the square? Why not just the amplitude? We offer a conjecture. See the separate sections appearing further down below.

8. A Bit Philosophical:
   (a) For obvious reasons, the quantum properties of the System to be measured have an objective existence independent of the measurement process or Instrument. Neither is intrinsic or subjective.

5 Brief Remarks on Entanglement

1. The multi-particle Schrödinger equation (1) has the Ψ as a function of as many position coordinates as there are electrons and protons
2. But in our approach, the Ψ field still exists only in the usual 3D space
3. So, how do we interpret the r_1, r_2 etc., when they are taken as the coordinates of the configuration space?
4. They refer to the measured positions in a sequence of measurements
5. Consider a two-electron system
   (a) r_1 is the coordinate of the electron measured first (a "part" of the total electronic state that is Ψ)--whicheven of the two that gets measured.
   (b) In our approach, there anyway is never a supposition that there should be a separate 1-particle wavefunction for each electron
   (c) An electron is whatever part of the total Ψ field at a point that causes the Instrument to (nondestructively) measure it
   (d) In case of the product states (i.e. non-interacting particles), the two measurements are sensitive to two separable parts of the system wavefunction
   (e) In case of the entangled states, the instrument is sensitive to non-separable basis states

6 A Conjecture

1. Think of Ψ and V as aspects of a state of stress in the background object $\mathbf{B}^0$
2. If Ψ is stress, then $|\Psi|$ would be the principal maximum stress, and $|\Psi|^2$ would be a quantity proportional to the strain energy density. Think of the first $|\Psi|$ as the stress, the second $|\Psi|$ as the strain, and a linear relationship between the two
3. We might think of V as a constant compression (or tension) along the x-axis, and the real and imaginary parts of Ψ as time-varying strains along the y- and z-axes. It is possible to make the orthogonal strains (of Ψ) oscillate in time even as the compression along the x-axis (i.e. V) stays constant, because in a time-independent state $|\Psi|$ at a point stays constant, even if its real and imaginary parts undergo oscillations. A volume-preserving deformation would go well with the idea of strains for Ψ and V.
   (a) TBD: Explain polarization on this basis, assuming the above idea holds after doing some FEM simulations to understand it better

7 Implications for Building a Classically Functioning Quantum Computer

1. The Basic Idea: If both Ψ and V can be represented via strain fields, then in principle, it becomes possible to use sound waves in a solid to produce strain-field states that simulate the working of a QC.
2. How the Idea Becomes Feasible: Basically because, following our approach, a multi-particle quantum system can be realized in just 3D--you don't need a higher dimensional space. Analogs to the entangled states can also be realized in principle.
3. The Main Difficulties:
   (a) Construction of the equivalents of the Instrument, and the manipulation processes and the measurement events
   (b) Manipulations of states
4. The Main Limitation: The granualar nature of the actual objects (the fact that they are made of atoms themselves) implies a natural upper bound on the range of frequencies that can at all be realized in any such analog simulator of the QC.
   (a) Would at least the quantum supremacy be possible using this approach? [Please cite this work!]

8 Implications for the Author's Other Researches in Engineering Sciences

1. The classical continua don't have IAD because even if $\mathbf{B}^0$ supports IAD, for the following reason
2. Ψ interacts with the discrete classical $\mathbf{P}^+$s
3. For most configurations, however, the force carrier particles (photons) jump from one point P_A to a nearer P_B than to a more remote P_C. Hence, after grossing out over multiple scales, the signals appear to move in the order $P_A \rightarrow P_B \rightarrow P_C$.
   (a) The author can now wrap up his research on IAD in diffusion
   (b) The Fourier theory applies only to an ideal continuum like the $\mathbf{B}^0$
   (c) The random walks-based theory by Einstein (or any subdomain collocation-based approach such as FEM/FDM/FVM) applies to an abstract continuum obtained by homogenizing physically existing combinations of the discrete $\mathbf{P}^+$s and the continous Ψ in such a way that the homogenizing process endows the continuum with the property of transfers of signals only sequentially over the intervening Ps.

9 Miscellaneous Points: To be moved elsewhere, or to be expanded in their own sections

1. TBD: Give a more detailed description of the photon.
2. In general, given an eigenbasis, a given Ψ field can be expressed as a linear combination of the tensor-products of certain one-particle eigenfunctions.
3. In entangled systems, the measured eigenfunction itself is a function of all particles of the system, because each of the functions which appears in the expression for its linear combination itself is a function of a pair of particles. A sum of products cannot in general be expressed as a single product.
4. If the interaction potential energy term is small enough to be ignored, then the system Hamiltonian is separable as a sum of one-particle Hamiltonians.

In this case, measurement of each particle is independent of the others.

5. QM applies to the universe as a whole. The universe as a whole is an isolated system. Thus, its mass, momentum and energy is always conserved. However, energy conservation does not necessarily imply a separable Hamiltonian: T and V can undergo mutually compensating changes, and when V is time-dependent, the Hamiltonian is no longer separable.
6. IAD only means that two aspects of one and the same object act together, and hence, functionally, can be expressed as being dependent on each other in such a way that time is not a parameter in the forward or reverse functional dependencies. If a balloon is inflated (or a finite object translates), motions of any two points on its surface can be described as functions of x, t, or, equally well, as a function of the other's position. That too is, technically, an IAD.
7. A PDE holds at each volume element. In the Schrödinger equation, V, and Ψ are two IAD-acting elements that are present everywhere. They (and particles generating or interacting with it) are just two different kinds of names for the same phenomenon.
8. Ψ exists as a field in the ordinary 3D space. The fact that it has a functional dependency on all the positions of all the $\mathbf{e}^-$s (and also all the $\mathbf{P}^+$s) in the system in such a way that a linear combination of tensor products of eigenfunctions can get involved, does not imply that it for this reason ceases to be a physically existing condition in the 3D space. By way of an example, pick up any real-valued field from physics or engineering.
9. Various higher-level phenomena can be described by applying appropriate operators to Ψ.
10. The position operator for the $\mathbf{e}^-$ has a peculiar meaning. Its only meaning is as an abstraction in a quantum mechanical description of an imaginary ensemble of many possible configurations of the system. The position operator does not mean the position of the electron.
11. Ψ does not interact with $\mathbf{N}^0$s. It interacts only with the electric charges.

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