# A Natural Philosophical Critique of Quantum Mechanics

© H. J. Spencer *

VIIa


## *ABSTRACT*

This paper re-opens the debate on the **failure** of quantum mechanics to provide an understandable view of micro-reality. A critique is offered of the commonly accepted '**Copenhagen Interpretation**' of a theory that is **only** a **mathematical** approach to the level of reality characterized by atoms and electrons. This critique is based on the oldest approach to thinking about nature for over 2500 years, known as Natural Philosophy.

Quantum mechanics (QM) was developed over the first quarter of the 20th Century, when scientists were enthralled by a new philosophy known as **Positivism**, whose foundations were based on the assumption that **material objects exist** only when measured by humans – this central assumption conflates epistemology (knowledge) with ontology (existence). The present critique rejects this human-centered view of reality by assuming material reality has existed long before (and will persist long after) human beings ("**Realism**"). The defensive view that the micro-world is too different to understand using regular thinking (and only a mathematical approach is possible) is rejected totally. At least 12 earlier QM interpretations are critically analyzed, indicating the broad interest in "what does QM mean?"

The standard theory of quantum mechanics is thus constructed on only how the micro-world **appears** to macro measurements - as such, it cannot offer any view of how the foundations of the world are acting when humans are **not** observing it - this has generated almost 100 years of confusion and contradiction at the very heart of physics. Significantly, we live in a world that is **not** being measured by scientists but is interacting with itself and with us.

QM has failed to provide **explanations**: only recipes (meaningless equations), not insights. Physics has returned to the pre-Newtonian world of Ptolemaic phenomenology: only verifiable **numbers without real understanding**. The focus needs to be on an **explicit** linkage between the micro-world, when left to itself, and our mental models of this sphere of material reality, via the mechanism of measurement. This limits the role of measurement to confirming our mental **models** of reality but never confusing these with a direct image of 'the thing in itself'. This implies a deep divide between reality and appearances. This paper proposes that it is the attempt to preserve continuum mathematics (especially **calculus**), which drives much of the mystery and confusion behind all attempts to understand quantum mechanics. The introduction of **discrete mathematics** is proposed to help analyze the discrete interactions between the quintessential quantum objects: the electrons and their novel properties. Additionally, several hidden major **assumptions** have been present in Classical Mechanics (represented by continuum mathematics) since its inception by Newton that are blocking progress and understanding of quantum mechanics.

A related paper demonstrates that it is possible to create a point-particle theory of electrons that explains all their peculiar (and 'paradoxical') behavior **without** introducing the **continuum** mathematical ideas of **fields** or **waves**.


* Surrey, B.C. Canada (604) 542-2299 spsi99@telus.net

Version 1.195 10-07-2016 Begun 23-06-2008 {pp. 80, 70.4 Kw; 800 KB}

# 1. INTRODUCTION & OVERVIEW

## 1.1 INTRODUCTION

This paper was born originally as the introduction to another paper that presented a new theory of electron interactions at the atomic scale of reality, called Quantum Electron Mechanics (**QEM**). Although intended to set the scene for a new theory of quantum mechanics (QM) it became obvious that there was too much material to be included in a single paper. Since this paper emphasizes both the historical and philosophical roots of QM, it was relatively easy to separate the parts at birth. Here a critique is presented to show that there are deep philosophical problems in the existing theory of quantum mechanics, which is a **mathematical theory** that has captured the interest of many educated people today who have insufficient mathematical knowledge to read the original texts and professional papers, where this foundational subject was developed. As a result, the word 'quantum' has acquired **magical** significance in our modern culture, where it is applied to many areas, such as health and technology. The widespread perception is that our civilization has uncovered the real foundations of reality.

The purpose of this paper is to demonstrate that theoretical physicists have "built on sand" and that the applicability of QM is much narrower than is generally believed. This is the reason why a new theory of the quantum, based on well-established foundations, such as the **electron**, has been developed by the author as part of a wider investigation into the foundations of **electromagnetism**, the core science underpinning the technology of our modern civilization. This paper has retained a little mathematics (only in section III) to illustrate how mathematics has been used to develop QM, while the power of natural language is emphasized overall, as it has played a much larger role throughout our western culture's interest in philosophy. Physics needs to return to its Natural Philosophy roots.

### 1.1.1 RESEARCH PROGRAMME

The QEM paper is major milestone in the author's independent research programme into the nature of electricity. It is part of a multi year theoretical physics research investigation into those many areas of physics known as **electromagnetism**. This paper now reaches one of the primary goals of this research programme: a theory of how **electrons** behave when unobserved and what happens when humans attempt to measure them, as they interact at the atomic scale of reality. The electron has always been at the center of this research programme [1] and first appeared explicitly in the second paper [2] where its unexpected discovery was shown to threaten the dominant paradigm of **Maxwell**'s theory of the electromagnetic (EM) **field** that is today presented, as if electricity exists in the form of a continuous fluid ("**charge density**"). The next paper [3] also included a summary of the first attempts to understand this new discrete form of electricity, which was referred to as *Classical Electron Theory*. A theory of large numbers of electrons interacting locally and remotely was also presented in this paper (*Mesoscopic Electrodynamics*) that reproduced the macroscopic results of Maxwell's mathematics without using any **continuum** concepts and only needing the hypothesis of two-electron interactions. Later papers in this programme continually exposed the attempts throughout the 20th Century to accommodate the discrete facts of the electron with the foundational continuum concepts underpinning Maxell's field theory (perhaps, attempting to salvage 300 years of mathematics).

The fourth paper [4] focused on the finite temporal separations that are a primary feature of remote electron interactions. This enabled the theory to be extended to all distances and relative velocities. The result was a fundamental critique of Einstein's Special **Relativity** Theory (SRT), exposing it to be a consequence of viewing light: without including its sources. The new theory demonstrated the importance of synchronizing remote interactions (on the 'Light-Cone') at **two** different interaction times. This also showed that the (in)famous Lorentz transformations were a necessary constraint on the mathematics of instantaneous (local) field theories and did not require a massive revision in the commonsense views of the reality of space and time, which are usually offered to the non-mathematical members of the public. The fifth paper [5] replaced the venerable instantaneous Coulomb (electrostatic) interaction with a pair-wise, ray-like form of the dynamic EM **impulse**, whose magnitude diminished linearly with increases in temporal separation. Quantizing both the dynamical and kinematical activity between two electrons introduced **light-quanta** in a physical (rather than mathematical) manner. This also led to the natural emergence of positive electrons that become a complementary fundamental particle to the usual negatively charged electron. These two entities become the **only** natural material objects needed in this fundamental theory of nature. It is important to always remember that a light-quantum is **not** an energy packet but the **quantum** of inter**action**.

The previous paper [6] extended the quantization requirement to 'far' interactions, which resulted in an invariant transverse impulse between 'static' pairs of electrons at macroscopic distances. This model was shown to be sufficient to explain **both** the wave characteristics of '**light**' and its discrete, low intensity interactions. It abolished the ideas of light as a **photon** or as a **wave** of (electric and magnetic) 'force density'. The companion paper [7] extends this perspective to the "pulsating possibilities" of electrons as they interact together presenting the observer with phenomena that are easiest to describe with the mathematics of waves; it is demonstrated that this does **NOT** mean that electrons **are** waves – they remain **particulate** in their localized motion forever.

## 1.2 OBJECTIVES

One of the principal objectives of this research programme is to refute the modern view that the **goal** of theoretical physics is to produce a set of **equations** that can be used to make predictions that numerically agree with the numbers obtained from the corresponding experiments. While this is a worthy goal, it is not seen here as sufficient. Most people in the last 300 years have expected physics to provide a comprehensible model of the material world, which it did with *Classical Physics* until 1900. After that year, physics continued to produce mathematical theories but these became increasingly difficult to **interpret**. Worse, professional physicists accepted this difficulty with the defeatist view that the atomic world is too remote from normal experience, so that it operates in mysterious ways that can only be represented by mathematics. This approach was so deficient that even when conceptual contradictions arose between alternate mathematical schemas (such as waves and particles), these problems were swept away with the rhetorical flourish of simply naming them "**paradoxes**". This programme refuses to go along with this professional consensus and has attempted to create a single ontological model of the **electron** that can not only explain its apparent "weird" behavior but is readily visualizable by most non-mathematicians. This programme is committed to the view that physics is 'Natural Philosophy' and explicitly includes metaphysics. The value of physics to the broader intellectual community is to provide a comprehensive and coherent **worldview**.

A new revisionist view of the history of QM has developed since 1945, whereby all the quantum issues were considered to have been resolved in the Fifth Solvay Conference of 1927, when Heisenberg and the 'Copenhagen School' defeated Einstein and the 'Old School'. The opposite view has been documented recently in a new book [8] by science historian Sheilla Jones. She concludes that: '*the subsequent confusion and uncertainty that has bedeviled quantum physics undermine the idea that it was all figured out a long time ago*'. In her introduction, she dares to write that: '*If after such a long time all the smart men and women who work in physics have not been able to reconcile the two sets of rules for the universe {classical and quantum}, it's natural to wonder if one – or both – of the sets might just be wrong. … This suggestion is tantamount to goring a sacred cow, as much as questioning relativity or quantum physics.*' The present paper will directly pick up this challenge even though this new view will inevitably generate a huge resistance by professionals, who are heavily invested in the widely accepted orthodoxy, which accepts logical contradictions when they are covered by Bohr's blanket called **Complementarity**.

## 1.3 OVERVIEW

In this overview, the contents of this paper are summarized by including a brief description of each section plus the major reasons the particular material has been included. The paper ends with a 'Summary and Conclusions' that focuses on the implications of the material covered, along with brief previews of future papers in this series.

### 1.3.1 APPROACH

This research programme is founded on the dual pillars of history and philosophy, believing that both are required to make fundamental progress in understanding nature. Contrary to the modern view, knowledge of the **history** of science is needed to understand how contemporary science has reached its present situation, especially when it finds itself in an impasse. It is also believed here that **metaphysics** is a necessary component of any theory of reality. What is rejected throughout this research programme is the orthodoxy that mathematical equations form a sufficient explanation of the world. Worse, the mathematical perspective has now come to dominate theoretical physics and it is assumed that this approach is creating an asymptotic view of the truth. Such arrogance (and its come-uppance) has arisen several times in the history of science. Harvard historian of science, Thomas Kuhn in his famous book [9] describes several examples, including more than a few from physics, to illustrate the deep beliefs (theories) of scientists about the nature of the world that were subsequently discarded as '*more than wrong*'. There is nothing to suggest that the evolution of science has already ended.

The idea of simply doing theoretical physics as an exercise in applied mathematics has been a demonstrated failure with no new concepts arising or even reaching the level of a useful technology, as happened to much of earlier physics that provided visualizable models for both professional physicists, engineers and non-scientists. Bohr and Heisenberg, the originators of the so-called '**Copenhagen Interpretation**', believed that they could use natural languages while forcing everyone to accept contradictory concepts (particles and waves) as a new 'mysterious' property of the micro-world by simply invoking a new 'scientific' principle, which Bohr called '**Complementarity**'. Heisenberg expected the rest of the humanity to give up the "illusion of the world" that we experience on a daily basis when we come to think of atomic systems but still insists that the descriptions of atomic experiments can continue with the rest of our standard vocabulary and concepts. A related paper [7] provides an explanation of all these atomic scale experiments using natural language and a model of particle physics that extends Newton's original views with a few, reasonable hypotheses of electron interactions at this tiny scale of reality. The ongoing reliance on Scientific **Principles** is a deeply held approach, which should have been abandoned after their medieval heyday.

### *1.3.1.1 History*

Historically, curious intellectuals have looked for patterns in nature. In the western tradition, this started to become formalized with the Ancient Greek philosophers. Over time, those who specialized in this aspect of investigating **reality** were referred to [10] as "**Natural Philosophers**". Much of this activity was purely verbal speculation, which resulted in endless argumentation. The rise of modern science began when many of the Natural Philosophers agreed that Nature must resolve these disagreements. This was the vital **empirical** step were actual manipulations of material reality, also better known as **experiments**, began to play an increasing role in resolving speculations. Until the end of the Nineteenth Century, the study of matter was dominated by astute experimenters, who used new technologies (such as the vacuum pump) or even invented new technologies, like electromagnetism, to discover new phenomena and new properties of matter in its various forms. This style of manipulating the world was contrasted with abstract investigations that had begun with Pythagoras and actively promoted by **Plato** [11] as the only true form of knowledge: these investigations of **timeless** relationships became known as pure mathematics. Since mathematics could be readily taught (and examined), this style of human activity soon dominated the education of the social elites across western societies. It was not long before this academic approach began to encroach on the realistic model of what soon became known as science. The great pioneer here was the polymath, Isaac **Newton**, who combined admirable, experimental skills with a rare, imaginative talent for mathematical innovation. His most dramatic contribution was his explanation of planetary motion using his conceptual model of inertial motion and his radical proposal for action-at-a-distance, attractive forces between masses (given the name ***gravity***) and a mathematical summarization as a continuous reciprocal **force**, whose strength varied inversely with the square of their spatial separation. This was the foundation of the science of **classical mechanics** and the subsequent introduction of **calculus** as the preferred mathematical description of nature. This introduced the new model of science, where mathematics calculated numbers to be compared with measurements to confirm the 'truthfulness' of the associated theory.

### *1.3.1.2 Philosophy*

Central to this programme's efforts to create a sensible alternative to QM is the view that physics has made a major error in retreating from its close historical association with philosophy: especially the Philosophy of Nature. Chapter IV is included to redress this massive mistake. If physics is to be grounded in material reality, then it is not sufficient that it simply conduct experiments on nature; it is important that theoretical physics represent reality as accurately as possible; otherwise, it simply degenerates into a branch of applied mathematics. This means theoretical physics must explicitly address the core issues of **metaphysics**. The common practice today is to dismiss all metaphysics from physics – this dismissal is actually an implied philosophical position that is intellectually lazy, as it cannot be justified. The position taken here is that many of the problems of QM tie directly back to the two principal areas of metaphysics: ontology (existence) and epistemology (knowledge). The study of ancient natural philosophy demonstrates that intellectuals have long tried to eliminate **time** from the heart of reality; this was quite acceptable to the **Platonists**, who venerated timeless **geometry** as the perfect intellectual creation. We recover the centrality of time with the researches and theories of Galileo and Newton. Newton needed the concept of continuously evolving universal time; this brought in to mathematical physics the most powerful parameter in classical physics. This step required **Kant** (an ex-Newtonian) to formalize the core ideas of space and time as universal intuitions in our human language models of reality. This started a tradition in English philosophy of the role of **language** in our evolving models of reality – a tradition that went off the rails with the rise of **Positivism** around 1900 that strongly influenced most of the theorists who created quantum theory. In summary, it would be unscientific today to deny the reality of the atomic world but it would be equally foolish to focus only on atomic scale phenomena and ignore the human scale; both scales of reality are given equal weight in the present theory. Intellectual progress becomes possible again, when the full power of the human **visual** imagination (developed in the macro world) can be brought to bear in developing models of the microcosm; reliance on linear rules of symbol imagination alone has proved a crippling limitation. Since many intellectuals in the western tradition have raised mathematics to its role as "*the Queen of the Sciences*", they see no need for any conceptual explanations beyond the symbology in their equations. In effect, they have **hijacked** physics, pushing empirical science into the background, doing no more than generating numbers that can validate their theories. In many cases today, it is deemed sufficient to conduct experiments in their own heads: so-called "thought experiments". This mind-before-matter approach is rejected here, where conceptual innovations are considered to be much more fruitful than inventing new equations. Recently, world-class specialists in mathematical physics, frustrated that their latest theories (e.g. "Strings") cannot expect to be examined experimentally have suggested that rationalism alone can be relied on to advance knowledge of nature. This would remove science from the grounded world of physics before 1900, where new experiments dictated the new directions of physics and mathematics was viewed only as a **tool** to produce numbers, not explanations. In her immensely readable book, [8] historian Jones retells the quantum tale very well, showing how a handful of men '*fired by ambition, philosophical conflicts and personal agendas*' created the quantum revolution. She clearly shows that there was never a consensus, so that by the Fifth Solvay Conference '*there was such ill will that most were barely on speaking terms*' as they presented their three competing versions of QM. The quantum revolution failed to produce a **single** philosophical worldview, which many leading academics demanded. The immediate result of this impasse was for physicists to abandon the need for a philosophical theory of quantum physics. Indeed, by 1940, philosophers of science were expelled from their long-time home (the Temple of Natural Philosophy). Ironically, the three competing versions were soon shown to mathematically equivalent but the interpretation puzzle (as we will see) was still left unresolved.

### *1.3.1.3 Ontology of Matter*

This programme is proudly positioned in the ancient tradition of the atomic model of material reality. This view originated with Leucippus and his pupil, Democritus. This was extended in Roman times by Epicurus and documented in the infamous poem *The Nature of Things* by Titus Lucretius. Almost all of these ancient texts were lost until a much-copied codex of the last one was rediscovered in 1417, as described in the bestseller *The Swerve* by Stephen Greenblatt. [12]. This eventually influenced Isaac Newton, the father of modern science. Although all these thinkers perceived the world in terms of localized particles, they had no idea of how this idea might manifest in the real world. It was not until the discovery of the electron, at the end of the nineteenth century, was realizing this dream made possible. In contrast to most of the standard efforts in so-called "particle physics", the present theory only requires one particle, the **electron** to define all the other fermions. This new theory does **not** keep inventing new particles to explain the embarrassing plethora of the *Standard Theory*: instead, it posits new properties of the electron. It requires new modes of interaction between electrons but does **not** view these styles of interactions as new particles ("*bosons*"). Rather, it is the microscopic manifestation of the universal electromagnetic interaction, which defines the very nature of the foundational quantum of matter in the universe by adopting the view that objects are defined by their dynamic set of interactions (i.e. relationships), not their static qualities.

## 1.3.2 FAILURE OF CLASSICAL PHYSICS

Section II is included to remind readers of the areas where classical physics started to break down after 1900. It shows how the continuous assumptions underlying Maxwell's electromagnetic theory could not account for the discrete behavior of EM interactions, especially when the oscillations moved into very high frequency ranges, such as X-rays. This review follows the historical sequence of major **experimental** observations, such as the energy spectrum of heated matter, the way in which crystals reacted anomalously to heat (specific heats), the bizarre results now referred to as the photoelectric effect, and the problems of explaining the stability of atoms and nuclei, particularly the mystery of discrete atomic spectra. More problems arose when the continuous wave picture could not explain the discrete results found in several scattering experiments, again involving X-rays, such as Bragg scattering and Compton's scattering off electrons. Further mysteries arose in the case of low-speed electrons, after de Broglie's hypothesis prompted searches for evidence of electron diffraction and interference effects. This section also makes explicit several of the well-known assumptions underlying the development of both classical mechanics and Maxwell's EM theory. Additional assumptions that are rarely discussed are also examined because it is the firm belief of the present theory that it is in the area of **false assumptions** that answers are most likely to be found.

## 1.3.3 QUANTUM MECHANICS

The bitterest battles in physics [6] have always occurred over the interpretations of the various theories (perhaps, this is why modern physicists are loathe to re-admit philosophers into their professional deliberations). $19^{th}$ century science was riven between the proponents of the corpuscular theory of light and the academic mathematicians, who promoted their 'elegant' wave theory of light. A similar battle arose in the last quarter of that same century centered on the reality of atoms when the **Positivists**, following Ernst **Mach**, decided that only evidence available to human senses could define reality; this was vigorously opposed by '**Realists**' such as Einstein, who believed there was a world **beyond** humans. The Austrian, Ludwig **Boltzmann** (1844-1906) was the first physicist to challenge the idea of the classical continuum with his statistical theory of thermodynamics to estimate the degree of chaos (entropy) at the molecular level. These molecules were far too small to be seen, never mind tracked, but this did not prevent him calculating macroscopic averages that could be compared with experiments. This assumption of atomic scale entities seriously offended Mach, who was massively influential at that time. Worse, Boltzmann's approach relied on **probabilities** – or the 'mathematics of gambling', as it was often called by its opponents. Ironically, both features eventually contributed to the development of QM. Even Max **Planck** eventually used some of Boltzmann's techniques when he tried to fit the energy-frequency curves of so-called 'blackbody' radiation: the first step in launching the quantum revolution. Poor old Boltzmann soon committed suicide because he could not handle the constant antagonism from his more powerful and prestigious Viennese academic colleague (Mach). This section reviews the major developments that are now called quantum theory; again, a historical approach is followed to see how the various ideas stimulated later evolution of more sophisticated theories. This approach shows how much of the final versions of QM owed so much to **Bohr**'s earliest '**planetary**' model, even though this was later severely criticized by most of the second generation quantum physicists. Both versions of QM ('Old' and 'New') focused on the atomic equivalence of the planetary model of the **hydrogen** atom, as this was the one and only example, which was solvable.

Important differences between these two diverse scales of nature are summarized in a useful table to illustrate why this model should never have been expected to work at the atomic level. The tragedy of QM is that the electron is the smallest level of reality that human beings deal with on a regular basis but physics has failed to develop its full implications and has moved on too quickly to even more remote problems, such as nuclear physics and deep space cosmology. It is also shown here how central and mistaken is the original Newtonian definition of instantaneous momentum to all formulations of QM: a foundational concept embedded in CM and QM.

## 1.3.4 PROBLEMS WITH QM

Section IV is included to deliberately counter the widespread impression that QM is "*one of the best theories in physics*". The review of the various formulations of QM showed how the mathematical ideas representing particle **and** wave concepts were merged in creating the second generation (mathematical) version of QM, so it is not surprising that the physical ideas associated with these two **contradictory** concepts lie at the heart of QM. This duality has been promoted to the status of a principle of nature (Bohr's **Complementarity**) and has become now accepted as the standard ('Copenhagen') interpretation. The wave/particle duality is related to the false wave model of light created by Maxwell around 1865 and later 'particulated' by Einstein in 1905 when he invented his photons.

One of the 'triumphs' claimed by QM is the detailed explanation of the structure of the **Periodic Table** of elements; this key claim is critically examined in section 4.1.5. Since both explanations **ignore** the powerful intra-electron interactions within all multi-electron atoms then they are viewed here as simply more 'just-so' stories to enhance the image of these theories. Section 4.2 introduces the central idea of **measurement** in QM because this is eventually shown to be a theory of human knowledge (epistemology), not reality (ontology). This area is where QM's "**Superposition** principle" is smuggled in. As described in section 4.2.2, the quantum 'wave function' does not carry energy (like sound waves) but is a wave of probability, as Born proposed. This reduces QM to a 'calculational device' but most humans will rarely accept this abstract viewpoint; it returns physics to its pre-Newtonian role when the Ptolemaic calculational rules ("circles on circles") could provide very accurate predictions of planetary activity when viewed from Earth but no way implied that these convolutions represented the actual motions of the planets through space. The Copernican Revolution occurred because it offered a richer model of reality, even though, for a long time, its predictions were **not** as accurate as the Ptolemaic results. Nonetheless, the most powerful intellectuals of 1600 (including academics and theological intellectuals) strongly resisted these threats to the Status Quo of ideas; a process that one can again see being repeated today. 'Old Ideas' have many committed supporters.

The deep philosophical problems of QM ('*What does QM mean?*') are brought to ahead in section 4.3, where over a dozen different **interpretations** of all this mathematical theorizing are compared. Calling these questions *pseudo-problems* is an unworthy 'copout'. Section 4.3.1 raises the fundamental challenge to theoretical physics that equations are **not** explanations; at best, they are condensed symbolic summaries when **each** symbol can be unambiguously interpreted back to reality. As no realist model of the atomic world has yet to be accepted; the **Positivists** soon retreated to their mathematics and the contradictory iconic explanations of our day-to-day language when used to "describe" the microscopic world. This process was begun in the 1920s when Heisenberg encouraged his friends in the Vienna Circle to leave the mathematics to the physicists, while the philosophers should restrict themselves to the verbal definitions of science itself.

### 1.3.5 NATURAL PHILOSOPHY

Central to this programme's efforts to create a sensible alternative to QM is the view that physics has made a major error in retreating from its close historical association with philosophy: especially the Philosophy of Nature. Chapter V is included to redress this massive mistake. If physics is to be grounded in material reality, then it is not sufficient that it simply conduct experiments on nature; it is important that theoretical physics **represent** reality as accurately as possible; otherwise, it simply degenerates into a branch of applied mathematics. Its theories will mysteriously generate numbers, as the symbols will deliberately **not** represent aspects of reality, by design. Some of these theoretical numbers will then be compared with numbers produced from experiments. If these agree, then we will have a formula ('recipe') for calculating numbers; but this is only an esoteric scheme for physicists – it will have no meaning or significance for the rest of the world: physics will have set the clock back 500 years (before Copernicus) with a new Ptolemaic scheme. This means theoretical physics must explicitly address the core issues of metaphysics. The common practice today is to dismiss all metaphysics from physics – this dismissal is actually an implied metaphysical position that is intellectually **lazy**, as it cannot be justified. The position taken here is that many of the problems of QM tie directly back to the two principal areas of metaphysics: ontology (existence) and epistemology (knowledge). The study of ancient natural philosophy demonstrates that intellectuals have long tried to eliminate **time** from the heart of reality; this was quite acceptable to the Platonists, who venerated timeless **geometry** as the perfect intellectual creation. Science recovered the centrality of time with the researches and theories of Galileo and Newton. Newton needed the concept of continuously evolving universal time; this brought in to mathematical physics the most powerful parameter in classical physics. This step required Kant (an ex-Newtonian) to formalize the core ideas of space and time as universal intuitions in our human language models of reality. This started a tradition in western philosophy of the role of language in our evolving models of reality – a tradition that went off the rails with the rise of **Positivism** around 1900 that strongly influenced most of the theorists who created quantum theory. In summary, it would be unscientific today to deny the reality of the atomic world but it would be equally foolish to focus only on atomic scale phenomena and ignore the human scale; both scales of reality are given **equal** weight in the present theory. Intellectual progress becomes possible again, when the full power of the human visual imagination (developed in the macro world) can be brought to bear in developing models of the microcosm; reliance on linear rules of symbol imagination alone has proved a crippling limitation.

# 2. THE FAILURE OF CLASSICAL PHYSICS

Classical physics is now considered to cover all of the physics developed between 1600 and 1900. It includes ***Classical Mechanics*** (the study of the motion of massive objects) and ***Electromagnetism*** (the study of macroscopic electrical bodies and magnets.) Classical Mechanics began with Isaac Newton; LaGrange and Hamilton subsequently elaborated Newton's new physics and mathematics. Classical Electromagnetism (EM) covers the early investigations by giants like Ampere and Faraday. Clerk Maxwell gave EM its final mathematical formulation in his eponymous Equations, though their modern form is actually due to his 'disciple', Oliver Heaviside.

This review will return to the foundational ideas of both Newtonian mechanics and Maxwell's electromagnetism to unravel the mysteries of QM as both these theories planted bad seeds, whose failures have only become apparent as experimenters investigated the world of the micro-cosmos (i.e. atoms). Around 1900, it was the development of new technologies, which exposed new phenomena of nature. These led to the invention of modern quantum theory, when these new experiments could **not** be explained by the theories of classical physics. We will show that the contradictions of QM were already buried deep in foundational ideas of classical physics.

This paper will not review the triumphs of classical physics. It does review the major anomalies that forced a realization that the concepts and techniques that had worked so well for 300 years could no longer work for certain phenomena that had begun to emerge by 1900 and continued to appear as experimentalists tested more of the new predictions of these new theories. The approach taken here will again be historical and this section focuses on experiments, as these experiential facts cannot be denied and form the solid foundation of physics as an empirical science; the same cannot be said for its theories.

In classical mechanics, it was always assumed that a given property (e.g. the speed or mass of a particle; temperature of a gas) could be measured, **in principle**, to any degree of accuracy desired, particularly as technologies continued to improve. However, the study of the problem of measurement in quantum mechanics has shown that our measurement of any object involves interactions between the measuring apparatus and the object that inevitably affect it, in some way; at the scale of atomic particles, this effect is necessarily large. On the everyday macroscopic scale, the effect can be made small. Furthermore, the classical idealization of a property simply being "measured" ignores the fact that the measurement of such a property - temperature of a gas by thermometer, say - involves a pre-existing account of the behavior of the measuring device. When effort was devoted to working out the operational definitions involved in precisely determining position and momentum of micro-scale entities, physicists were required perforce to provide such an account for measuring devices to be used at that scale. The key 'thought-experiment' in this regard, as we shall see, is known as the "**Heisenberg Microscope**".

The problem for any individual is how to properly characterize a part of reality of which one has no direct sense experience. The conventional interpretations of the atomic world are based on the **Positivist** philosophy popular in the first half of the $20^{th}$ Century. This philosophy dismissed as meaningless everything that could not be measured scientifically. Our accounts of the quantum domain must then be based on interactions of macro domain instruments and sense organs with physical events, and only those interactions give us some (but not all) of the information we seek. This was actually the resurrection of the Renaissance view that "man was the measure of all things". The logical consequence of this old form of human arrogance was that nothing existed in the world unless a human observed it happening or could observe its consequence; thus, trees never fell in ancient forests that subsequently burned down before humans walked the earth. The other possibility (more likely) was that we are seeing the revival of the mathematicians' ancient **Platonic** philosophy: "only timeless objects and statements have any reality".

Werner **Heisenberg** (1901-1976) made a brave attempt [13] in 1958 to defend his own so-called *Copenhagen Interpretation*:

> *We can say that physics is a part of science and as such aims at a description and understanding of nature. Any kind of understanding, scientific or not, depends on our language, on the communication of ideas. Every description of phenomena, of experiments and their results, rests upon language as the only means of communication. The words of this language represent the concepts of daily life, which in the scientific language of physics may be refined to the concepts of classical physics. These concepts are the only tools for an unambiguous communication about events, about the setting up of experiments, and about their results. If therefore the atomic physicist is asked to give a description of what really happens in his experiments, the words "description" and "really" and "happens" can only refer to the concepts of daily life or of classical physics. As soon as the physicist gave up this basis, he would lose the means of unambiguous communication and could not continue in his science. Therefore, any statement about what has "actually happened" is a statement in terms of the classical concepts and -- because of thermodynamics and of the uncertainty relations -- by its very nature incomplete with respect to the details of the atomic events involved. The demand to "describe what happens" in the quantum-theoretical process between two successive observations is a contradiction in adjecto, since the word "describe" refers to the use of the classical concepts, while these concepts cannot be applied in the space between the observations; they can only be applied at the points of observation.*

## 2.1 DISCRETE INTERACTIONS

There are **six** major experiments that showed that the **interactions** that underlie the observed world **cannot** be continuous, as had been assumed, since Newton's theories were first formulated using continuum mathematics (differential calculus). Some of these were critical to introducing discrete concepts that resulted in quantum theory. Unfortunately, this conceptual realization was too weak to threaten the assumption that calculus was still the best mathematical representation of discrete reality.

### 2.1.1 BLACKBODY RADIATION

It was the heat studies of Gustav **Kirchhoff** (1824-1887), which finally resulted in the necessity for introducing the quantum hypothesis. Kirchhoff was studying the heat characteristics of solids that had reached a stable temperature everywhere (a condition known as "thermal equilibrium"). He studied the heat emerging from a hole into a cavity carved out of such a hot body, which he called a *blackbody*, as all the radiation reaching such a hole is absorbed 100% into the cavity. It is a pity that in 1859, he called the resulting radiation "blackbody radiation" instead of cavity-wall radiation, as this diverted later attention to the **empty space** surrounded by the actual hot body; however, since this was the æther era, it is understandable. Twenty years later, Ludwig Boltzmann (1844-1906) created a statistical/probability model, using only the second law of thermodynamics. In 1896, Wilhelm Wien measured the complete energy spectrum of a blackbody, as a function only of the **frequency** of the radiation produced. He found that the frequency at which the maximum energy is radiated increases as the temperature increases; this spectral distribution was independent of the type of material forming the hot body. Using classical methods, both Lord Rayleigh and James Jeans independently created mathematical models that derived Wien's findings but only in the low frequency spectral range. Their theories predicted that the heat emitted at high frequencies (in the ultra-violet or UV) would become infinite: a result known as the "UV Catastrophe". In 1900, Max Planck (1858-1947) created his own theory that fitted the experimental results at all measured frequencies, thus avoiding the UV Catastrophe. However, Planck was forced to introduce a "mathematical fiction" (later called the *quantum of action*) to achieve [14] this result. Planck's radical hypothesis was the critical step that introduced the **quantum** era into modern physics, much to Planck's later chagrin (as he was a devoted believer in classical physics, particularly Maxwell's theory of EM radiation). Planck's hypothesis was driven by mathematical necessity.

### 2.1.2 SPECIFIC HEATS

Classical physics was able to calculate how rapidly a solid lattice of atoms reacted to heat (a measure known as its specific heat). The French experimentalists, Dulong and Petit had shown that this value was independent of temperature for most solids at room temperature; diamond was a rare exception. Dewar's invention in 1898 of techniques for liquifying hydrogen allowed scientists to investigate matter at extremely low temperatures, where experiments showed that the heat capacity of all materials goes to zero as the absolute temperature goes to zero, while as temperatures rise its value gradually approaches the Dulong-Petit limit. This was another embarrassment for theoretical classical physics.

In 1907, Einstein was the first [15] to extend Planck's blackbody radiation approach to new areas. He invented a very simplified model of a crystalline solid by replacing each atom with 3 harmonic oscillators (one for each direction) and also assumed that these atoms (or oscillators) were only 'lightly' interconnected, i.e. effectively independent. He also simplified his model by assuming all the oscillators could only vibrate at the same *single* frequency f. Like Planck, he assumed that the energy of each oscillator (E) could only take on discrete values; i.e. $E = n\,h\,f$. Each solid was characterized by its own so-called Einstein temperature, $T_E$. Einstein could curve fit his formula to experimental results and found that $T_E \approx 1300K$ for diamond, so it behaved like a "cold solid" at room temperature (300K). In this model, the specific heat (incorrectly) goes exponentially fast to zero at low temperatures. Debye improved on this by 1912 with a solid model including sound waves.

### 2.1.3 PHOTOELECTRIC EFFECT

In 1887, Heinrich Hertz discovered the revolutionary photoelectric effect when he shone UV light on metallic electrodes finding that the voltage needed to induce sparking was lowered. Hertz's student, Philipp Lenard (1842-1947), soon replicated this effect using the recently discovered electrons; but in 1899, he proved that the electrodes themselves were emitting extra electrons when he again focused UV light on metal foils. By 1902, he had discovered that the energies of the ejected electron where completely independent of the incoming light intensity but depended (linearly) on the frequency of this light. In fact, Lenard found that there was a minimum frequency, below which no electrons were ejected for a given type of metal foil. However, increasing the intensity of the light (of a given frequency) did increase the number of ejected electrons but only when the frequency exceeded the minimum. In 1905, Einstein proposed that the UV light was behaving like the concentrated electrons and was transferring energy to the foil's electrons in discrete "packets of energy" or light **quanta** (later called '*photons*'). These quanta were proposed to obey an energy exchange law, similar to Planck's blackbody formula: the energy exchanged $\Delta E = h\,f$, where f was the light frequency and $h$ was Planck's quantum of action ($h = 6.6 \times 10^{-27}$ erg secs): a very tiny quantity.

### 2.1.4 ATOMIC STABILITY

In 1914, the German physicists James Franck and Gustav Hertz sought to experimentally probe the energy levels of the atom, without involving explicit radiation. This famous experiment [16] supported Bohr's atomic model although they later claimed they were unaware of Bohr's paper at that time; they were awarded the Nobel Prize in Physics in 1925 for this work. They accelerated **electrons** in a mercury-filled tube and found that at certain kinetic energies the current dropped suddenly. At low voltages, the accelerated electrons acquired only a modest amount of kinetic energy, so when they interacted with the mercury atoms in the tube, they participated in purely elastic collisions. Quantum mechanics predicts that an atom can only absorb energy when the collision energy exceeds that required to lift an orbital electron into a higher energy state. With purely elastic collisions, the total amount of kinetic energy in the system remains the same. Higher voltages increased the observed current, until the accelerating potential reached 4.9 volts. The lowest energy electronic excitation a mercury atom can participate in requires 4.9 electron volts (eV). When the voltage reached 4.9 volts, each free electron possessed exactly 4.9 eV of kinetic energy. Consequently, an inelastic collision occurs transferring energy from a free electron to the mercury atom. With the loss of all its acquired kinetic energy in this way, the free electron can no longer contribute to the measured current. This experiment demonstrated that the electronic structure of atoms required relatively large finite energies: too large to be disturbed by heat collisions.

### 2.1.5 NUCLEAR STABILITY

The phenomenon of **radioactivity** was discovered in 1896 by the French scientist Henri Becquerel (1852-1908) while working with phosphorescent materials that glow in the dark after exposure to light. Other early researchers, such as Rutherford, Villard and the Curies, discovered that other 'heavy' elements, such as radium also exhibited similar features that were soon realized to be a new form of **radiation**, as suggested by the recent discovery of X-rays. This new radiation was more complicated: several different types of radiation were found. Nonetheless, Ernest Rutherford (1871-1937) demonstrated that the intensity of radiation diminished with time according to a simple exponential decay formula, differing only by a single factor (later called the half-life for that material and decay mode). It was soon found that there were three types of radiation, named alpha, beta and gamma, in increasing order of their ability to penetrate matter. **Gamma** radiation was found to be purely high-energy electromagnetic (like X-rays) while the other two reacted differently to electric and magnetic fields. The **alpha** rays were found to be positively charged helium nuclei while the **beta** rays were shown to be high-energy electrons. Radioactive decay is found only with some elements with an atomic number of 83 (bismuth) or higher. Alpha decay is only seen with heavy elements that ultimately end with non-radioactive lead. Rutherford demonstrated that many of these decay processes actually changed one element into another: shattering the classical ideas that atoms were eternal and unchangeable (although they still appeared to be 'indivisible' at that time).

### 2.1.6 LINE SPECTRA

The spectrum of light emitted by a gas heated to very high temperatures is very different from that (continuous rainbow) found emitted by very hot solids (blackbody radiation). It is found to consist of only a very few special frequencies and these are uniquely characteristic of the gas material. In a complementary manner, cool gases absorb these same frequencies when exposed to a continuous light spectrum. This implies that the atoms in a gas can exist in discrete energy states. Anders Angstrom (1814-1874) measured the frequency lines of hydrogen and found they fitted closely to a numerological formula suggested by Johann Balmer (1825-1898) that involved the differences in the inverses of squared integers.

### 2.1.7 THE PERIODIC TABLE

Bohr's research programme claimed to be able to explain the structure of atoms and implicitly their chemical behavior, so from 1920 he spent three years investigating this problem (equivalent to providing a mechanism leading to the Periodic Table). Contrary to the common perception, Bohr did **not** make much progress with this problem [17] but it cleared the way for Pauli to make his major contribution with his "exclusion principle" so that QM could later evaluate good approximations later. This is now viewed as the most significant achievement of QM but as will be described later (§4.8.5) there are major problems with this solution that still exist today.

## 2.2 CONTINUOUS WAVE EFFECTS

In addition to the above **six** experiments that are most easily understood in terms of discrete concepts, such as the **particle**, there are another **five** major experiments that atomic scale phenomena are more easily understood using continuous, **wave** concepts - even when they involve electrons that were traditionally described as fundamental particles. It is the co-existence of these eleven experiments, which challenges physicists to develop a coherent and consistent model of reality. So far, quantum theorists have created two mathematical schemes (one for each set of experiments) that work well in their own domain but have long resisted a single, unified interpretation. The related paper addresses this challenge but here we will review more of these mysterious experiments. The challenge of QM is to create a **unitary** 'picture' of the electron, which explains all experiments, using a single coherent imagery (a consistent object of existence). QM has only been able to invoke a different mathematical scheme for the discrete and continuous domains.

## 2.2.1 X-RAYS

German physicist Wilhelm Röntgen (1845-1923) is usually credited as the discoverer of X-rays in 1895, because he was the first to systematically study them, though he is not the first to have observed their effects. He is also the one who gave them the name "X-rays", though many countries (including Germany) still refer to them as "Röntgen rays". He had modified a Crookes tube (invented about 20 years earlier that accelerated electrons) to include a thin aluminum window, protected by thin cardboard, when he noticed a fluorescent effect on a nearby cardboard screen painted with barium platinocyanide. He speculated that the tube might be emitting an invisible ray of unknown nature (hence 'X' for the unknown). Röntgen was awarded the first Nobel Prize in physics for this discovery. The maximum energy of the produced X-rays is limited by the energy of the incident electron, which is equal to the voltage on the tube times the electron charge, so an 80 kV tube cannot create X-rays with energy greater than 80 keV. When the high-energy **electrons** hit the metal target, X-rays are then assumed to be created by two different atomic processes:

1) If the electron has enough energy it can knock an electron completely out of a metal atom's inner electron orbital; as a result, electrons from higher energy levels then fill up the vacancy and X-rays are emitted. This process produces an emission spectrum of X-rays at a few discrete frequencies, sometimes referred to as its spectral lines. The spectral lines generated depend on the target (anode) element used and are called characteristic lines. This process is similar to fluorescence but now at a frequency well above UV. It can be viewed as the complement of the Compton effect (§2.2.3).

2) When the target metal atom's electrons are not completely ejected, they are still accelerated for a while before returning to their normal orbit. During this brief time, they are scattered by the strong electric field from the strongly positive nucleus, emitting a continuous spectrum (many frequencies), known as 'Bremsstrahlung' (German for 'braking') radiation. The intensity of the X-rays increases linearly with decreasing frequency, from zero at the energy of the incident electrons.

## 2.2.2 BRAGG SCATTERING

The electromagnetic nature of X-rays became evident in 1913, when William H. Bragg and his son, William L. Bragg found that crystals bent their path in the same way as gratings bent visible light: the orderly rows of atoms in the crystal acted like the larger grooves of an optical grating. When X-rays impinge on an atom, they induce accelerations in some of the orbital electrons (as do all EM waves). If these electrons are only elastically scattered they do not leave their (long-term) stable orbits but they do generate interactions with other remote electrons; i.e. they produce secondary EM radiation at the <u>same</u> frequency (called Rayleigh scattering). The Braggs found that regular crystals, at certain specific wavelengths and incident angles, produced intense peaks of reflected radiation (known as *Bragg peaks*). W. L. Bragg explained this result by viewing the crystalline solid as a set of discrete parallel planes of atoms separated by a constant parameter $d$. It was proposed (invoking wave interference ideas) that the incident X-ray radiation would produce a Bragg peak if their reflections off the various planes interfered constructively. The **interference** is constructive (like light) when the path difference is a multiple of the wavelength $\lambda$ of the incident wave; this condition can be expressed by Bragg's law: $n \lambda = 2d \sin \theta$, where $n$ is an integer, $d$ is the spacing between the planes in the atomic lattice and $\theta$ is the angle between the incident ray and the scattering planes.

## 2.2.3 COMPTON X-RAY SCATTERING

The Compton effect was first described by Arthur Compton; gaining him the 1927 Nobel Prize in Physics. Classical electromagnetism predicted that the wavelength of EM rays scattered by electrons should remain equal to the incoming wavelength but actual experiments with low-intensity, high-energy X-rays found that the wavelength $\lambda'$ of the scattered rays was longer (corresponding to lower energy) than the initial wavelength $\lambda$. In 1923, Compton explained this shift by attributing particle-like momentum to the X-rays using the photon concept that Einstein had used for his 1905 Nobel prize-winning explanation of the photoelectric effect.

## 2.2.4 ELECTRON DIFFRACTION

De Broglie's revolutionary hypothesis that matter particles should behave **as** waves inspired two independent experiments in 1927 that involved electron diffraction off crystalline structures. In Scotland, G. P. Thomson (1892-1975) observed the circular interference patterns created by a thin gold film, while at Bell Labs (New Jersey) C. J. Davisson and L. H. Germer used a nickel crystalline grid with slow electrons (10 ~ 500 kV) to measure the back-scattered electrons off the crystal surface. Ten years later, Thomson and Davisson shared the Nobel Prize for Physics for their experiments.

## 2.2.5 ELECTRON INTERFERENCE

One of the most dramatic experiments that had been used to claim that electrons have wave-like properties involves those experiments with both low-density electron beams and 'light' (photons) giving similar results. All these examples relate back to the original '**double-slit**' experiments of Thomas **Young** in 1801 with light. All these experiments involve "excitations" from a common source first 'illuminating' a pair of very close parallel slits before finally appearing at an observation location (usually a screen). The screen is found to display alternate bands (parallel to the slits) of enhanced and diminished 'arrivals'. This whole terminology is based on the **assumption** that an **entity** has **moved** from the source to the screen. Since covering just one of the slits removes the so-called "interference pattern", the usual interpretation is that the moving entity must usually go **through both** slits to create the bands. The wavelike explanation is based on analogies with large-scale water waves moving through two parallel gaps. It is the existence of this macroscopic **analogy** and the simplicity of the mathematical analysis that leads to the universal assumption that this interference experiment is the quintessential demonstration of the presence of real **waves**. This was the argument used successfully in the 19$^{th}$ century by Cambridge mathematicians to abolish Newton's corpuscular theory of light and establish the view that light was a wave phenomenon. This analogy was also crucial to Maxwell's invention of his EM theory of light and the ontological assumption that "light was a wave", which in Maxwell's theory was an oscillation in the supporting æther.

It is useful to analyze this liquid-wave analogy in more detail before jumping to 'obvious' conclusions. Liquids are now known to consist of myriads of molecules jostling against each other - this forms what is known as the 'medium'. In such a medium, waves are **collective** variations in a physical property (such as pressure or displacement from the average height) that communicates locally: one molecule to nearby adjacent molecules. The key to this analysis is that any localized variation is seen as the arithmetic sum of two or more independent variations that have arrived at the point via independent pathways (in the water case, one fluctuation through **each** of the gaps). The key is that the phase of the two waves either coincides at one point ('in phase'), thus "additive", or is completely out of phase (180°), thus "destructive". Critical to the success of all such experiments is that the source remains **coherent** – that is, it fluctuates consistently at the same frequency and all fluctuations are generated at very similar intervals, which in practice means the **same source** for all waves. In the water-wave case, it is obvious that the principle of locality applies – a water wave must go through a gap for it to arrive at the target point (at the screen), as water molecules are known to only interact at very short distances. **Locality** is an additional assumption when this model is applied to light (**that is never seen in passage**). Electrons can only be detected '**in passage**' by causing an additional interaction to occur near one of the slots but it may interact at very long distances. If the assumption of locality is dropped then the presence of both slits must be known ('non-locality') to all the electrons involved in this experiment: at the very least, the one when at the source and the one at the final destination (in the screen).

More sophisticated versions of this experiment have been conducted, using light or atomic particles, where the effects at the receiving screen are so far apart in time that it is unlikely that there is ever more than one object anywhere in the system from start to finish. This is usually interpreted as even more mysterious: a single wave 'splits' and then interferes with itself. When particles are used in this experiment, they always appear at the screen as **point** events, as is seen with low-density light - when the intermediate situation (prior to final arrival) is interpreted as due to waves, then the dualistic interpretation is that we are observing objects acting as both waves **and** particles: two very different concepts. It can be seen that this is a **crucial** experiment, which is often referred to by **all** authors writing on quantum theory. Sadly, (as physics is an empirical science) few writers include specific references to the actual experiments, especially the key low-density ones; these schemes were first introduced as 'thought-experiments' but were not performed until much later. Even the first ones involving electrons did not occur until the 1950s [18, 19, 20], the first interference experiments with neutrons occurred in the 1970s [21, 22] while similar experiments involving atoms and molecules had to wait until the 1990s [23, 24].

Some of the electron and atomic experiments actually used slits, while the neutron experiments used "equivalent" slits involving a narrow wire placed in a narrow gap. Tonomura's beautiful experiments involved 50 kV electrons passing through an "equivalent" slit of a narrow charged wire between two grounded plates while the electron current was increased from about 1,000 to 70,000 electrons per second. The arriving electrons individually produced flashes as they hit the final fluorescent film, which were eventually photographed. All results were very "grainy" but the interference bands could be seen building up over time, as more and more electrons reached the screen.

The wave/particle duality mystery began [25] in 1924 with de Broglie's PhD thesis. He failed to clarify his hypothesis of a wave "associated with a particle"; as a result his hypothesis is given several very different formulations using phrases such as: a material particle "**has** a wavelike nature", "**is** a wave", "**exhibits** wave-like properties", "**behaves** like a wave"; or even "the electron is **transformed** from a particle into a wave and back again". This is the kind of bad language confusion calling out for a philosopher. This is not the model used in the mathematical description of such phenomena, where an abstract technique called Huygens' theory is used for the creation and destruction everywhere of new, 'secondary' centers of propagation is proposed.

### 2.2.6 ELECTRON SPIN

One of the most important experiments [26] in the evolution of quantum mechanics was performed in 1922 by Otto Stern and Walther Gerlach, who sent a beam of neutral silver atoms through a powerful magnet whose strength varied along its axis. If the particles were classical spinning objects, one would expect the distribution of their spin angular momentum vectors to be random and continuous. Each particle would be deflected by a different amount, producing some density distribution on the detector screen. Instead, the particles passing through the Stern–Gerlach apparatus are deflected either up or down by a specific amount. The observed **discrete deflections** were interpreted as indicating that particles possess an intrinsic angular momentum (or 'spin') that can only take a finite set of values; i.e. its angular momentum is quantized. These measurements also showed that the 3D spatial directions of this angular momentum are exclusive, which means that the measurement of the spin along the z-axis destroys information about a particle's spin along the x and y axis.

The observed results showed that the deflected silver atoms were deflected into two distinct groups, indicating that these silver atoms had a spin of one half quantum. The problem of quantum spin was addressed in depth in our fifth paper [5], when a new physical model of the electron also led to a new interpretation of the **positron** - the positively charged electron.

These new features of the electron were categorized as "the **digital** electron". It is the discrete properties of the electron, or rather, the discrete properties of the **interaction** between pairs of electrons, that accounts for all the observed quantum effects including the so-called "**photon**". Along with the rejection of asynchronous action-at-a-distance, it has been the ongoing, erroneous assumption that interactions are continuous that has led to the mathematical models known as classical mechanics. This error has persisted with the mathematical assumptions, which underpin quantum mechanics; these assertions will be demonstrated herein.

## 2.3 EXPLICIT ASSUMPTIONS

This section briefly reviews the assumptions that formed the foundations of **Classical Physics**. As we shall see, it was the challenge to **some** of these assumptions that led to the evolution of quantum theory. This review here follows some of the analysis presented by Christian Wüthrich in his presentation [27] on the early history of quantum theory.

### 2.3.1 THE CLOCKWORK UNIVERSE

The immediate result of Newton's revolutionary new physics, as described in his *Principia* [28], was the replacement of the medieval, religious view of the world (especially the Heavens) by an image that has been referred to as the "Clockwork Universe", extrapolating from the most complex, manmade device known at that time. The Universe was perceived as a giant machine that existed in a framework of absolute space and time, all of which was viewed by God throughout eternity. Complicated motions of any part were to be understood as simple, automatic movements of some of this machine's inner parts, even though they may be too small to be observed by humans. Parts could be isolated from the rest of the universe. The 'Deist' God only needed to build and wind his clock once. Central to Newton's *Principles of Natural Philosophy* was his invention of the concept of momentum, built around his key idea of mass.

### 2.3.2 SIMPLE CAUSALITY

Newton extended the philosophical ideas of his intellectual predecessor, René DesCartes and viewed all motion as having a direct cause; if any body exhibits relative change in motion (acceleration with respect to the distant, fixed stars) then this change was attributed to (one or more) **other** bodies that were seen as "causing this effect" through an intermediate '**force**'. **Time** was viewed as uniform across all of space based on our apparent simultaneous sense of vision ('God-like' view). Gravity was also assumed to interact simultaneously.

### 2.3.3 LAPLACIAN DETERMINISM

The Newtonian worldview consisted of a very large number of corpuscles (the smallest form of solid matter); each of which could be characterized by its location in space and its momentum (a combination referred to as its "**state**") at any one instant in time (e.g. the 'present'). LaPlace then proposed that a sufficiently informed "intelligence" (not God, as he was an atheist) could use Newton's Laws of Motion to calculate the state of the Universe at any time in the past or **future**. This assumption was grounded in the view that analytical mechanics (calculus) could represent the real world at the smallest level of reality. This calculation could never be done (only "in principle") as no one could ever measure the initial conditions accurately enough and he was dishonest in **not** admitting that Newton's mathematics could **not** solve even the **three-body problem**, as he knew only too well. LaPlace did recognize that Newtonian mechanics was constructed around the idea that a distinct interaction caused the immediate change in a particle's straight-line (inertial) motion. In fact, the presence of such an occurrence (or the existence of a causal 'force') was defined by the target particle's change in momentum.

## 2.3.4 MAXWELLIAN WAVE THEORY

### *2.3.4.1 Maxwell's Triumph*

Maxwell transformed the flux (or integral) equations resulting from the confirmed experimental observations of Ampère, Ørsted and Faraday into a mathematically equivalent set [29] of differential equations ("**Maxwell's Equations**") that described the spatial and time (field) variations of electric and magnetic forces at every point ("force densities"). With a few extra assumptions about the physical behavior of a universal **æther** (such as the reality of his Displacement Current), Maxwell was able to arrive at wave equations for these two fields that appeared to propagate through empty space at the speed of light. This convinced most scientists, by 1900, that they now **fully** understood the universal phenomena called "***light***". The ratio of moving to static units of electricity gave a value for light-speed, which was close to experiments; this helped convince many physicists of the truth of Maxwell's theory, which few knew or understood.

### *2.3.4.2 Maxwell makes his Religious Confession*

Most modern physicists do not realize that Maxwell was motivated to replace the Newtonian particle worldview with a continuous, **field** theory for sincere personal, religious reasons. As he admitted in a lecture on the **æther** in 1873 [30]:

> *"Interstellar regions will no longer be regarded as waste places in the universe, which the Creator has not seen fit to fill with the manifold order of His kingdom. We shall find them to be already full of this wonderful medium; so full that no human power can remove it from the smallest portion of space, or produce the slightest flaw in its infinite continuity."*

Only some historians of science know that Maxwell was more committed to his æther model than he was to his mathematical equations. He always viewed that matter and EM field be treated as a single dynamical system. Most physicists had great difficulty separating these ideas around 1900; British physicists saw the 'atoms' as singularities in the æther continuum. In Cambridge, where British theorists saw themselves as mathematicians, following the famous line of Lucasian professorships, few had much appreciation of EM physics. It is also important to know that Maxwell rejected the idea of **point** sources of electricity but this was lost as his equations were hijacked by Helmholtz, who used similar hydro-dynamical results with his very different model of moving electric-charge density: modern CEM. Lorentz was the 'Great Peacemaker' unifying EM researches across the UK and Europe; leaving CEM to dominate solid **matter**, while Maxwell's theory was banished to empty space, explaining **radiation**.

It should also be noted that Maxwell's aim (like Leibniz) was also to abolish instantaneous action - he did not; he created only a delayed field theory of magnetism. He still used Coulomb's **instantaneous** electrostatic model for electrical interactions [31]. This basic, but flawed, assumption was later retained in all quantum models of the hydrogen atom.

### *2.3.4.3 Constancy of Light Speed*

The previous paper [6] emphasized the critical role of **source** electrons when discussing optical phenomena. It was the omission of electron sources by Einstein, which enabled him to re-derive the Lorentz transformations (known to preserve Maxwell's calculation of the speed of light); this caused him to shatter the ancient views of space and time. However, it was Michelson's series of experiments (demonstrating the constancy of light speed), which destroyed the credibility of the existence of the universal luminescent **æther**, which both Maxwell and all the other 19$^{th}$ Century supporters of the wave theory of light relied upon. Maxwell had predicted that as the Earth moved through the fixed æther, experiments would show that light speed would vary with direction. It did not. It was appropriate that it was an optical experiment that first challenged the classical view of the world, as it was one of Maxwell's major goals to unify Newton's mechanical world model with an ætherial theory of electricity. It is ironic that it is Maxwell's theory that has led to the worst anomalies of our understanding of the quantum world. Modern physics is still obsessed exclusively with **field theories**.

Both quantum mechanics and special relativity began their divergence from classical physics by insisting on the primacy of observations and a refusal to admit unobservable entities. Thus special relativity rejects the absolute simultaneity assumed by classical mechanics; and quantum mechanics does not permit one to speak of properties of the system (the exact position, say) other than those that can be connected to macro scale observations. Position and momentum are not things waiting for us to discover; rather, they are the results obtained by **humans** performing certain procedures. These two proposals have shattered the very foundations that most humans have used for thousands of years to talk about the reality of the world.

## 2.3.5 EXISTENTIAL ENERGY

One of the great innovations of 19$^{th}$ century science and technology was the invention of the concept of energy, which played a major unifying role in physics (as discussed in our history of light [6]). Energy is exemplified by a particle in relative motion or by a wave propagating across space but never by both simultaneously. It was believed that when any amount of energy disappeared in one part of a system, an equivalent amount of energy must appear exactly at the same place, at the **same** instant (**locality**). The modern force-particle ("boson") concept was invented to maintain this perspective in modern physics.

## 2.4 HIDDEN ASSUMPTIONS

This section here extends the discussion of the above assumptions that formed the foundations of Classical Physics. This is an important section because the new quantum theory of the electron herein (UET) is based on these challenges to the standard assumptions that are very rarely made explicit. They are presented in the same order as the explicit assumptions.

### 2.4.1 CONTINUOUS INTERACTIONS (FORCES)

Medieval scholastics blindly followed the authority of Aristotle and misused his failure to find discontinuities in organic life and formalized this in the universal principle: *Natura facit Saltum* ("Nature never makes leaps"), assuming continuity existed everywhere throughout the natural world, including its representation in geometry and other mathematics. Although Newton recognized it was the interaction between particles that led to changes in the world, he introduced an artificial entity as an intermediate "carrier of action" that acted continuously over time; this was the new concept of **force** that appealed to human intuition and our experience of muscular activity. Actually, Newton first introduced this through the concept of abrupt **impulse** that he later made continuous to accommodate circular motion. Newton only discussed instantaneous action-at-a-distance between large bodies (gravity) and instantaneous, short range collisions between elastic bodies. The real world is dominated by electromagnetic forces that were still to be discovered in Newton's time. Physics has retained the idea of continuous forces, both mechanically and in EM interactions, at all scales. Ironically, Newton spent much of his life (particularly the latter half) trying to produce an understandable mechanism for gravity; frustrated, he failed.

### 2.4.2 LOCAL INTERACTIONS

**Causality** was always a hypothesis, again introduced to simplify the world through separability. It appealed to humans because of our **own** intentionality that underpins many human actions. Our own awareness only of past experiences led us to assume that only the past influenced the present (retarded action). This idea forced a temporal asymmetry into the world. It led to the **broadcast** model of field interactions. Classical physicists, such as Max Planck, were very reluctant to give up this old idea, as he discussed at length in one of his philosophical essays [32] when he suggested redefining physics from being an empirical science to one that "exists as an intellectual structure". This new approach would have one decisive advantage (in his eyes) - it would permit strict determinism; it would "replace particles with 'material waves', which would then preserve determinism." This reveals Planck's deep commitment to **Platonism**.

### 2.4.3 SINGLE-TIME DETERMINISM (**God's Time**)

Again to simplify the mathematical model of the world, an interaction was reduced to a single point in space and time. The two-sided interactions were reduced to a single point in time, so that the total temporal derivative technique could be used. It is a fact that the EM interaction takes a finite time to cross a finite extent of space, which is always the case when electrons are interacting. Several previous papers in this series have emphasized the need for a **two-time** model of the EM interaction, where distinct times for each electron involved (even in a pairwise interaction) must be maintained. At best, a single **time-difference** can be introduced to simplify the pairwise interaction. An earlier paper [3] showed that finite time delays (as in the EM interaction) are incompatible with the assumption that forces act continuously between localized *inertial* bodies. Furthermore, real systems cannot be isolated from the rest of the universe: an assumption that is always invoked when the world is reduced to a simplistic mathematical model (nice math – poor physics).

### 2.4.4 FIELDS ARE NO ÆTHER SUBSTITUTE

Maxwell introduced the field concept in an attempt to avoid facing up to the finite EM interaction delays. This was a valid approach as long as the **æther** was a real, physical possibility. The discovery of the electron as the source of electrical effects not only abolished the æther but abolished Helmholtz' concept of continuous **charge density** that had been smuggled into the classical theory of electromagnetism [30]. The fact that the definition of force field densities requires all electric charges to go to the **zero** limit does not seem to bother too many physicists, who are also still content to talk about EM waves propagating across empty space. The resolution of this contradiction was presented in our new theory of light [6]. Once again, with force densities, physics builds its theories on ideal concepts that have no experimental analogue to determine their value: contradicting the *Operationalism* that is claimed as its foundation.

### 2.4.5 ENERGY IS NOT AN ENTITY

The concept of energy was extensively analyzed in the previous paper [6] and only Leibniz's original formulation of kinetic energy (as **activity** between particles) was found to retain its validity. Einstein's **photon** hypothesis was also shredded in that paper and was seen to be no more than a "heuristic" (theoretical, non-physical) device. The explanations of the photoelectric and Compton effect are analyzed more extensively in the related paper [7], in terms only of fluctuating discrete, interactions between far electrons, while the assumption of all unseen intermediate entities (like '*light*') becomes redundant. Such artificial intermediaries were introduced by the opponents of Newton's radical concept of action-at-a-distance ('far-action'), who are still obsessed with Descartes' appeal to human touching.

## 2.4.6 INSTANTANEOUS VELOCITY

Central to Newton's revolutionary approach was his invention of the concept of **momentum** of an aggregated body. This involved the algebraic product of an invariant quantity (mass) and the instantaneous value of the velocity at that instant of time. The continuum mathematical limit has no correspondence in experimental determinations of velocity but this has not prevented this concept from playing a central role in mechanical theory. The present approach rejects the universal continuum assumptions underlying the use of the calculus for modeling physical reality; discrete mathematics is used to model discrete physical events. The return here to Newton's original **impulse** model of interactions leads to **finite**, **discrete** changes in velocity, whenever electrons interact. This revision eliminates the symmetry between position and momentum (that has been assumed from the original mathematical formulations of modern quantum theory and plays a key role in Fourier transforms of this quantity); these are always assumed to be well represented by a continuous function of a local time parameter.

## 2.4.7 THE WORLD MAY NOT BE RANDOM

Maxwell's gas model of heat provided a clear pictorial image for Boltzmann's more abstruse mathematical construction. Both were strong factors influencing the **statistical** formulation of quantum theory. Maxwell always presented his gas theory as "dynamical", by which he meant that it was a theory of particles in motion, regulated by laws of force. However, it is the enormous numbers of electrons involved in human scale systems (Avogadro's Number) and our reliance on the repetition of our measurements that lead to the mathematical necessity of humans having to use statistical descriptions (and probabilistic interpretations) of nature.

## 2.4.8 HARMLESS OBSERVATIONS

Heisenberg's proposal of the Uncertainty Principle was an acknowledgement that all attempts by macroscopic collections of electrons must inevitably interfere with the observation or measurement of microscopic (atomic-scale) systems. However, the philosophy of **Positivism** that was pervasive in intellectual circles at the birth of quantum theory still lingers. The quantum mathematics is formulated as eigenvalues of **observables**. The hidden Positivist assumption (then shared by Heisenberg) is that **no** part of the world can **exist** unless humans are measuring (or, at least, interacting with) that part. The concept of observables implicitly links the real world to humans, whether we are observing the micro- or macro-spheres. The resulting numbers are inevitably about the 'disturbed' system.

## 2.4.9 SIMPLE MATHEMATICS

When Newton was inventing his theory of material interactions, his focus was on the **objects**, which were involved. This was perfectly understandable because human psychology has evolved into paying attention to distinct examples of reality ("objects"); this obsession is reflected deep in many of our languages that focus on **nouns** and their properties. Newton was able to use DesCartes' new **algebra** for constructing his mathematical representation of material reality, as simple algebra is just a symbolic abstraction from simple arithmetic, which is itself constructed from the realistic operation of counting distinct objects. The basic property of countable, distinct objects is that they **exist**. However, our natural languages also are built around **verbs**, which not only capture the role of **time** in our world but map the relationships between objects. As we grow more sophisticated, we realize that relationships are far richer than simple existence and any representations (verbal or mathematical) must reflect these richer levels of complexity.

The founders of quantum theory (who were all skilled mathematicians) recognized that the **algebra** of classical physics was not suitable for describing atomic-scale phenomena. They still clung to the utility of Descartes' abstraction known as "*real*" numbers. Schrödinger's formulation of quantum mathematics also became the most popular technique because it was able to retain the well-developed mathematics of partial differential equations that had served physics for so long, not least in Maxwell's EM theory. Unfortunately, few physicists realize how limited is the use of Schrödinger's Equation for describing real-world physical situations but it is well suited to solving the kind of **artificial** models that mathematicians constructed for classical mechanics. The present theory believes that discrete integer mathematics is more suitable [4] for describing discrete reality. The fundamental suspicion here is that the relationships between **electrons** is not only universal but that their characteristics cannot be mapped by simple arithmetic; hence the need for 'operator' math or more appropriately: higher algebra. Nonetheless, we sincerely believe that many of the problems of QM can be traced to its retention of analytical calculus that has been retained too long in domains where it no longer is useful.

# 3. SUMMARY OF QUANTUM MECHANICS

It was only around 1900, that physicists finally had the chance to understand the real atomic basis of nature. It was only then the new discovery of the electron provided us with the true foundation of electricity. Before that event, there had been bitter controversies on the nature of Nature; many scientists (such as Ernst Mach) still disputed the reality of atoms. Unfortunately, science wishes to cling to its theories even when major discoveries cast grave doubt on their foundations. This was the case with light, where Maxwell's Æther-based theory of electromagnetism (EM) had become almost universally accepted by physicists with Hertz's revolutionary experiments on remote induced induction that was interpreted as a proof of Maxwell's EM wave theory. This research programme is dedicated to the proposition that Newton's metaphysical scheme (including his laws of motion) is a universal foundation for all of physics, at all scales of nature, while Maxwell's theory of electromagnetism is strictly limited to interactions of macroscopic collections of electrons. Indeed, Newton's corpuscular model of material reality is shown here to be sufficient to describe the interactions of microscopic collections of electrons, when close together; this provides a new, visualizable model of quantum mechanics that **avoids** all reference to fields as either mathematics or even existential entities. It is shown here that QM has been the rearguard defense of field theory that, (we believe) has been the stumbling block of understanding atomic systems. As historian Jones concludes [8]: '*There have been no new fundamental laws of nature discovered since the 1970s and there is no math-driven theory that can reconcile the classical and quantum worlds.*' In this programme's view, this is the inevitable result of the mathematics-only approach initiated by the quantum theorists in 1926. The obvious dead-end should have alerted physicists that they had taken the wrong turn and they have been driving down the wrong road for a long time.

## 3.1 EARLY QUANTUM THEORY

The study of EM radiation has been seen to be the foundation for most of quantum theory [§2.1.1]. In this regard, Planck's theory of Blackbody Radiation must be viewed as its earliest example. Although Planck provided no physical mechanism for his explanation, he established the tradition that a mathematical theory of such a basic physical phenomena is adequately 'explained' by a purely mathematical theory: an approach referred to here as *phenomenology*. In Planck's case, his major mathematical contribution was his quantum formula (guess) relating energy exchange E to the frequency f of the EM radiation involved in the energy transfer; that is to say: $E = h\,f$. Since f has the dimensions of [1/T] and [energy * time] has the dimension of **action**, this is why Planck's constant $h$ is correctly referred to as the quantum of action (not energy). Although energy may be exchanged across an inter**action**: it is the amount of the action exchanged, which is quantized; it is this composite (abstract) quantity, which constrains the magnitude of the interaction.

### 3.1.1 THE QUANTUM OBJECT: THE ELECTRON

It cannot be repeated enough that it was the "discovery" of the electron by J. J Thomson (1856-1940) that truly launched modern physics (and modern electrical technology) with his accurate measurements of the discrete electrical charge ($e = -4.8 \times 10^{-10}$ esu) and discrete mass ($m = 9.1 \times 10^{-34}$ gm). Prior to these investigations, even the reality of the atom was still in question while all quantum investigations can be shown to resolve back to the electron; this has been the central thrust of this research programme for many years. Even modern quantum physics has not properly absorbed this discovery; taking the electron for granted is now the norm.

It was the technological advance of vacuum technology around 1870 that allowed William Crookes (1832-1919) to develop the first cathode ray tube. This tube allowed a large external voltage to be applied between the two enclosed electrical terminals: the negative cathode and the positive anode. The "Crookes tube" permitted him to investigate the conduction of electricity in low-pressure gases. He discovered that as the pressure was lowered, the cathode appeared to emit rays, the so-called "cathode rays", showing that they travel in straight lines, cause fluorescence in some materials upon which they impinge and by their impact produce great heat. He believed that the rays consisted of ordinary matter (atoms or molecules). It was J. J. Thomson's investigations in 1897 that made him suggest that the particles in these rays were over 1000 times smaller than a hydrogen atom and the mass of these particles were independent of the emitting cathode material. He readily concluded that these rays were composed of very light, negatively charged particles, which were a **universal** building block of atoms. He called the particles "corpuscles" but later scientists preferred the name ***electron,*** which had actually first been suggested by G. J. Stoney in 1891, prior to Thomson's actual research. The electron's charge was more carefully measured by the American physicist Robert Millikan (1868-1953) in his famous oil-drop experiment of 1909, the results of which were published in 1911. This experiment used an electric field to prevent a charged droplet of oil from falling under the influence of gravity. This device could measure the electric charge ($e$) from as few as 1 to 150 ions with an error margin of less than 0.3%.

## 3.1.2 BOHR'S PLANETARY MODEL

### *3.1.2.1 Rutherford's Atomic Model*

Inspired by the discovery of the electron, the great experimentalist Ernest Rutherford (1871-1937) suggested a planetary-like model of the atom in 1911. Rutherford's team had been bombarding gold foil with the newly discovered alpha particles emitted by certain radioactive materials. He calculated that most of the backwards-scattering measurements could only be explained by assuming almost all the gold atom's mass and electrical charge was concentrated in a billionth of the atom, subsequently called the ***nucleus***. Electrically neutral atoms would have to include a cloud of electrons. His famous paper [33] mentioned the atomic model of Nagaoka, in which the electrons are arranged in one or more rings, with the specific analogical structure of the stable Rings of Saturn. A month after Rutherford's paper appeared, the proposal regarding the exact identity of atomic number and nuclear charge *was* made by A. van den Broek, and later confirmed experimentally within two years by H. Moseley.

### *3.1.2.2 Quantizing Angular Momentum*

In 1912, J. W. Nicholson (1881-1955) proposed [34] that the angular momentum (L) of an electron (mass *m*) circulating around the nucleus in an atom at a distance R with tangential speed V could only take on certain discrete values (the integers, n = 0, 1,2, ...); i.e. it must be quantized. He probably realized that the dimensions of Planck's quantum of action (*h*) were the same as the dimensions of angular momentum, so he suggested the powerful formula: $L = m V R = n h / 2\pi$.

### *3.1.2.3 Bohr's Radical Guess*

Following his 1911 PhD on Lorentz Electron theory, Niels Bohr (1885-1962) left his native Copenhagen and traveled through England, including some time with Ernest Rutherford. This exposed him to Rutherford's model of the atom and Nagaoka's planetary suggestion for the orbits of the electrons. He also became aware of **Nicholson**'s recent proposal for quantizing angular momentum. Bohr combined these ideas to construct a mathematical model of the atom that had a major impact on physics and the popular imagination. He ignored Maxwell's electro-dynamical theory that predicted that circulating electrons should continuously radiate away their energy and fall into the nucleus but he did use Coulomb's model of static electrical attraction to repeat the mathematical treatment that Newton had used for instantaneous gravitational attraction between the Earth and a smaller moon. Bohr dismissed Maxwell's EM theory, literally with the wave of his hand [35]: he just assumed this was so; or in the words of theoretical physics, "he postulated it". Like Planck's proposal, no mechanism was offered; it just had to be so. This model's major success was in explaining the empirical Balmer formula for the spectral emission lines of atomic hydrogen. Most importantly, Bohr assumed there was only **one** electron in the hydrogen atom; he actually began with the hypothesis that there was a fixed ratio between the electron's kinetic energy and its time of rotation when in a stable ring.

This model is now taught to high-school physics students as a simple introduction to quantum theory. The math is very straight forward, when it assumes the electron is moving at a tangential speed V in a low-speed circular orbit, where the centripetal force is 'caused' by the Coulomb force, at a distance R from the nucleus with its Z positive charges. The total energy of the electron E according to classical physics is the sum of its kinetic energy K and (negative) potential energy U.

**Classically**: Force: $m V^2 / R = Ze^2 / R^2$ Energy: $E = K + U = 1/2\, m V^2 - Ze^2 / R = -1/2\, m V^2$

**Quantum-Guess**: Angular momentum (only some speeds $V_n$ and orbital radii $R_n$ ): $L_n = m V_n R_n = n h / 2\pi$ {n=0,1,2, ... }

$$\therefore\ Ze^2 = m V_n^2 R_n = (m V_n R_n) V_n \Rightarrow L_n V_n = V_n n h / 2\pi \quad \therefore\ V_n = 2\pi Ze^2 / n h \quad \therefore\ E_n = -2 (\pi Z e^2/nh)^2 / m$$

For hydrogen, (Z = 1 ground-state n=1) speed, denoted as $V_B = \alpha c$. Sommerfeld's Constant $\alpha = 2\pi e^2/h$ $\therefore E_B = -1/2\, m V_B^2$

In order to fit Balmer's formula for hydrogen, Bohr had to assume (postulate) that the observed frequency f obeyed Planck's energy formula but now extended to the **difference** between two energy levels {n & m}: $\Delta E_{nm} = E_n - E_m = h f_{nm}$

$$\therefore\ f_{nm} = 2(\pi Z e^2)^2 (1/m^2 - 1/n^2) / mh^3 \quad \text{Balmer (m=2):}\ f_{nm} = \mathcal{R} (1/4 - 1/n^2) \ \therefore\ \text{Rydberg's constant, } \mathcal{R} = 2(\pi e^2)^2 / mh^3$$

The Bohr model gives almost exact results but only for a system where two charged points orbit each other at speeds much less than that of light. This not only includes one-electron systems such as the hydrogen atom, singly ionized helium (Z=2) and doubly ionized lithium (Z=3). Rutherford, reacting to a preprint, raised the issue of causality as a deep problem here. Einstein raised a similar objection and wanted to know how the created photon knew which direction to be emitted. Bohr, along with his protégé, Heisenberg later cavalierly dismissed these objections, on the grounds that: "*they were meaningless*".

As was to be expected, Bohr's older colleagues, across the physics community, were mostly **not** too impressed, seeing it as "*too complicated and upsetting*". Even, the 'father of the electron', J. J. Thomson did not mention Bohr's theory [36] until 1936 when he turned 80. In contrast, Bohr was very well received in Germany, especially at the leading mathematical centers in Göttingen, Berlin and Munich. Bohr himself was more circumspect, viewing his own theory as "*makeshift and too approximate*." He still felt guilty about rejecting Maxwell's EM theory, which was taking on its modern, almost sacrosanct status: doubts that delayed his Nobel Prize until 1922. What his theory demonstrated was Bohr's talents for intuition, picking up clues and interpreting the significance of experiments. In spite of its impressive successes, the Bohr model did have a few serious difficulties and conceptual failures, such as:

1. A rotating charge, such as the electron, classically orbiting around the nucleus, should (according to Maxwell) constantly lose energy in the form of electromagnetic radiation; **no** such radiation is observed (the model is EM inconsistent). No new mechanism or physical principle was offered as to why these "stationary" states were stable (no external radiation).
2. Energy levels for multi-electron atoms or molecules are wildly wrong, even for the neutral helium atom (2 electrons).
3. There is no explanation for the existence of extra lines in the hydrogen spectrum (called the 'Fine Structure'), which are today believed to be due to a variety of relativistic and subtle effects, as well as complications from electron 'spin'.
4. There is no explanation for the existence of very close twin and triple lines, which appear in the spectra of some atoms.
5. Bohr (and Heisenberg initially) could not calculate the relative intensities of the various spectral lines.

## 3.1.3 WILSON-SOMMERFELD QUANTIZATION

Some of the early theorists correctly focused on **action** as the focus of quantization; this has since been too-often forgotten. In 1915, Wilson extended the rule for quantization; the following year, a similar extension [37] was invented independently by Arnold Sommerfeld. They both realized that the action integral variable $J_k$, defined for the generalized co-ordinate $Q_k$ (and its conjugate momentum $P_k$) in **periodic**, classical systems could be subject to quantization (per cycle); that is:

$$J_k = \oint dQ_k\, P_k = n_k\, h \quad \therefore \quad \text{Radial: } \oint dQ_r\, P_r = n_r\, h \quad \therefore \quad \text{Azimuth: } \oint dQ_\theta\, P_\theta = k\, h \quad (\text{or } k = n_\theta)$$

## 3.1.4 SOMMERFELD ATOMIC MODEL

Although the Bohr atomic model was quite successful for predicting the spectrum of the hydrogen atom, it failed to include the fine structure found. Arnold Sommerfeld (1868-1951) extended Bohr's simple circular orbits to include elliptical orbits that Newton found were needed for Kepler's planetary orbits in the Solar system. In addition, he added Planck's relativistic mass correction to allow for the faster speeds [38] that might be present in extremely elliptical orbits. Sommerfeld used his quantization rule for the radial distance r and the azimuthal angle θ with corresponding integer quantum numbers $n_r$ and $k$. These could be combined into the principal quantum number $n = n_r + k$ ; this agreed with Bohr's quantum number, as $k$ refers to the (conserved) orbital angular momentum and $n_r$ was a measure of the radial fluctuations going around the orbit. The mathematics showed that for a given value of $n$ (e.g. $n = 3$) there could be a series of acceptable values: $k = 0, 1, 2, 3$; all of these values corresponded to the same energy, which only depended on the value $n$. The value $k = n$ corresponded to a circular orbit (Bohr) while $k = 0$ was an oscillating line going through the nucleus. The relativistic mass effect produced an orbit that took on the shape of a precessing rosette. The energy of the orbital now depended on both $n$ and $k$ according to:

$$E[n,k] = \{1 + \alpha^2/n^2(n\,/\,k - 3/4)\}\; E_B/\,n^2 = \{1 + (\alpha/[k + n_r])^2\,[n_r/k - ¼]\}\; E_B\,/\,[k + n_r]^2$$

This additional tiny correction term involves the azimuthal quantum number $k$, so that orbits with the same principal quantum number $n$ has $n$ different energy levels ($k = 1, 2, 3, \ldots, n$). Agreement with spectral observations is found if a **selection** rule is used to restrict the 'allowed' transitions to where k only changes by one quantum; i.e. $\Delta k = \pm 1$. In order to explain how the hydrogen spectrum behaved when the atoms were exposed to a strong magnetic field (the normal Zeeman effect) it was necessary to impose a further restriction on the orientation of the axis, around which the electron is rotating. This needed a third quantum number, called the magnetic quantum number, $m$ that could only take values: $k, k–1, \ldots, 1, 0, –1, \ldots, –k$; a result known as 'space quantization'. This new number then needed its own 'selection' rule: $\Delta m = 0$, or $\pm 1$. These constraints imply that "rotation" (k) is more significant than radial fluctuations ($n_r$).

## 3.1.5 PRACTICAL DIFFICULTIES

The most obvious problem with the original form of QM was that it could **not** be readily extended. Even Sommerfeld's model failed to predict the energy levels of the helium atom or the hydrogen molecule, being defeated by Newton's infamous **3-body problem** (once again). It also could not be applied to non-periodic situations, such as scattering problems. It also failed to predict the intensities of spectral lines and could not provide an explanation for the phenomena of light; nor could it explain the rotational spectra of diatomic molecules. At this stage, it was really just a theory for **one**-electron atoms, as became the case for later versions of QM.

## 3.1.6 CONCEPTUAL DIFFICULTIES

The original form of QM provided no explanation of why the Coulomb electrostatic interaction between the hydrogen nucleus and its electron should be effective while other parts of Maxwell's EM theory failed to apply so that the "stationary" orbitals did not radiate EM energy at all times. Other rules, such as the EM emission mechanism and the quantization rules, appeared arbitrary but these did not disappear in the more modern form of QM, when they were hidden by more-complex mathematics. New "explanations" such as that quantum objects did **not** follow a trajectory, did nothing to expand our understanding of these experimental mysteries. These problems are reviewed later when the philosophical meaning or "interpretation" of QM became major issues, as they remain outstanding even today, almost 100 years after Bohr launched his radical theory of the atom. As a "classicist", Bohr had a very strong belief in the validity of classical mechanics. Bohr's default position was that all predictions of classical mechanics apply whenever quantum effects appear to be minimal. Unlike his admiring German colleagues, Bohr was not prepared to replace his classical physical intuition with mathematical elegance, of which he always remained suspicious. However, as a theorist he was overwhelmed by the tsunami of mathematicians that entered theoretical physics in the 1920s. Nonetheless, like Einstein, his strength as a physicist was his powerful, physical **intuition**. Much of classical physics had been built upon Newton's model of planetary systems; but this was NOT appropriate for understanding atomic systems as there are **massive differences**, between these two areas of reality. As we will show, quantum mechanics (QM) should have been expected to be totally different from classical mechanics (CM); electrons are not billiard balls, which only interact on contact, while no-one expected the electron to be 'in contact' with the nucleus. Macro-objects are vast collections of interacting electrons.

Planetary systems involve huge (literally astronomical) numbers of atoms, covering human timescales, where **visual** measurements can span years, days or even seconds, observing the **same** objects. This implies that there are vast numbers of interactions occurring between any two human measurements. Our observations of the planets are actually electrical interactions that are so tiny that they do not alter the internal planetary dynamics that are determined only by massive inertia and gravitational attractions (both proportional to the masses involved). Mathematically, as Newton demonstrated, simple algebra is sufficient to map the two-body model of the situation and the resulting numbers are sufficiently accurate to agree with our statistical measurements.

Atomic systems are completely different, as only a few atoms are involved and the electrical effects are proportional to the number of electrons interacting. Indeed, atoms are so tiny that we can never be assured that we are actually observing the **same** atom over the course of a **single** measurement. During these measurement time intervals, the extent of the atomic interactions are comparable to our own interfering interactions and we can never distinguish time frames as small as those **in** the atoms. Unlike planetary observations, we cannot extrapolate back to the ideal of "instantaneous" velocity that always needs two measurements of location, separated by a finite time interval (e.g. miles per hour). Such concepts lie at the heart of CM and work quite adequately for planetary systems. Conceptually, physicists have reduced both planetary and atomic systems, each to continuous interactions between two **objects**: planetary bodies and electrons respectively. Metaphysically, each pair of objects have been idealized as "billiard balls" – just differing in size. Theoretically, they have then both been described by Hamiltonian particle mechanics based on the continuum mathematics of the calculus that reduces all time differences to almost zero, so everything is happening simultaneously. The net result of making these assumptions of comparability is that QM has had to replace the simple algebra of CM with the more complicated mathematics of linear operators (matrices or calculus operators). By focusing primarily on the new mathematics, physicists have lost sight of reality; a direct consequence of over-extending a **bad analogy**, while relying on the sanctity of numbers produced from mathematics and experiments.

In reality, the biggest problem with the Bohr/Sommerfeld theory (like its successor) was that it was only a theory of the **one electron**, hydrogen-like atom. It resisted all subsequent attempts to be extended to more complicated atomic systems; including the next simplest atom in nature: the **helium** atom with its two electrons moving around the nucleus. This should have been no surprise to anyone very familiar with Newton's model of the planets: for he too had run in to computational difficulties when three (or more) massive objects interacted gravitationally together. This challenge always defeated Newton; it may have contributed to his decision to give up physics. This situation is now called the **Three-Body** problem; its ongoing analysis, using computers, has shown that: (in most cases) it is the result of continuous interactions that lead to inherent instabilities. Ironically, these studies led to the science of *Chaos Theory*. What is disappointing is to see that so few scientists were prepared to challenge the assumption of continuous interactions to further their research on this problem; again pointing at the excessive respect for Ancient Theories that dominate many academics.

#### *3.1.6.1 Planets versus Atoms*

The major differences between real planetary and atomic systems are summarized in the following table.

| Feature | Planetary Systems | Atomic Systems |
|---|---|---|
| Objects | Planets | Electrons |
| Number of objects | 2 | Several (minimum of 10) |
| Number of atoms | Gigantic (trillions of trillions) | Few ( < 3) |
| Interaction Number | Gigantic | Several hundred |
| Measured Time | Days to years | Millionths of a second |
| Interaction Type | Gravity | Electrical |
| Observations | Same object | Statistical |
| Inertial effects | Huge | Tiny |
| Interaction Effects | Huge | Tiny |
| Math Model | Continuous | Discrete |
| Interaction Model | Force | Impulse |
| Math Technique | Calculus | Finite differences |
| Philosophical Model | Deterministic | Statistical |
| Mechanics | Hamiltonian Particles | Hamiltonian Particles |
| Algebra | Simple | Linear operators |

Moral: physicists should **not** build their theories by extrapolating medieval generalities, such as the Hermetic principle: "as above, so below", which has been assumed in expecting the atomic system to behave like a mechanical planetary system.

## 3.2 A BRIEF HISTORY OF QUANTUM MECHANICS

The puzzling duality of the nature of light was compounded by **de Broglie**'s dramatic hypothesis that **all** material particles would also exhibit this **duality** between waves and particles (see later). It is not clear what motivated the second generation of quantum pioneers to dismiss the Bohr-Sommerfeld model of the atom so readily. Many of the deficiencies of this early approach persisted in the later, mathematical formulations although some improvements in the interpretation of some of the finer details of the hydrogen emission spectrum were achieved. Perhaps, some insight may be gained from quoting Heisenberg's own words when in 1958 he reflected [39] on his original contributions in his book: *Physics and Philosophy*.

He acknowledged that: "*In the simple case of the hydrogen atom, one could calculate from Bohr's theory the frequencies of the light emitted by the atom, and the agreement with the observations was perfect. Yet these frequencies were different from the orbital frequencies and their harmonics of the electrons circling around the nucleus, and this fact showed at once that the theory was still full of contradictions.*" He continued almost immediately [40] with the duality paradox that Bohr's theory failed to address, concluding with: *"Again and again one found that the attempt to describe atomic events in the traditional terms of physics led to contradictions."* He omits to mention the fact that his own failures to calculate using the traditional orbital methods was central to his critical views, while his own matrix methods were near useless for calculations.

Heisenberg never considered that the electron was not pursuing a circular or even elliptical orbit around the hydrogen atom but some other more complicated motion that was consistent with the observed results; he simply dismissed [41] all attempts to imagine a more appropriate trajectory as a "*limitation of the concept of the electronic orbit*." He was too eager to push the contradictions in the classical physics approach, so that he could introduce his **own** revolutionary mathematics. In this regard, he was following the *Zeitgeist* at Göttingen, where he was Max Born's assistant. Here, they together applied an adaptation of the classical perturbation methods of the astronomers to atomic systems, as both problems were examples of the infamous **Three-Body** problem that had sunk Newton's attempts to go beyond the 2-body simplification. As Born described later: "*these results did not agree with the spectroscopic results for the helium atom*". As a result, [42] the whole team became "*more and more convinced that a radical change of the foundations of physics was necessary*." It became clear that a powerful clue was hiding in Bohr's need to focus on the difference between **two** stationary states, not on one orbit alone, as in classical mechanics. This direction emphasized 'transition quantities' that always seem to correspond to the squares of vibration amplitudes in classical theory. Born was the first to actually suggest that these transition amplitudes might be handled by some kind of symbolic (**matrix**) multiplication.

## 3.3 HEISENBERG's MATRIX MECHANICS

While acknowledging that Bohr's so-called *Correspondence Principle* (initially called the **analogy** postulate) indicated the reality (or at least, utility) of the concept of the electronic orbit in the limit of high quantum numbers i.e. for large orbits, where the Fourier expansion of the orbital motion did approach the observed values. Ironically, Bohr's atomic theory works best for small quantum numbers ($n < 7$). Heisenberg then seized on this [36] and writes: *"The idea suggested itself that one **should** write the mechanical laws not as equations for the positions and velocities of the electrons but as equations for the frequencies and amplitudes of their Fourier expansion."* Perhaps this motivation is obvious to a mathematician but it is meaningless for a physicist, who still conceives of an electron as a particle with at least a unique location in space at every moment. This approach resulted in Heisenberg's radical paper [43] introducing **Matrix Mechanics**. The net result was that Newtonian equations of motion for the electron were no longer written using the traditional algebra of arithmetic but now replaced by similar equations between **matrices**. Later investigations [44] claimed that these matrices "representing" position and momentum of the electron did not commute. *"This demonstrated clearly the essential difference between quantum mechanics and classical mechanics."* Note: the generic term "**quantum mechanics**" was invented by Born.

The historian of science, Edward MacKinnon has done a fine job [45] reconstructing Heisenberg's convoluted route to Matrix Mechanics. He correctly points out Heisenberg's new methodology was ostensibly justified by the Göttingen belief (Born and Pauli) that atomic models could not be considered realistic representations of atoms and the **Positivist** view that scientific formulations must be restricted to **observable** quantities. Yet, Heisenberg's success was actually built on a model embodying virtual processes (which are in principle unobservable) and mathematical fictions, such as anharmonic oscillators. MacKinnon describes Heisenberg's frustration as a post-doctoral student at Göttingen, failing to solve the helium atom or hydrogen molecule energy spectra using Bohr-like models; he was further frustrated by his attempts to crack the anomalous Zeeman effect before Pauli's proposal of electron spin was introduced. MacKinnon convincingly shows that Heisenberg was strongly influenced by his early success using virtual oscillators but this approach would be difficult to convince others that he had created a fundamental theory. Ironically, (as he later confessed to Thomas Kuhn) Heisenberg was quite unfamiliar with the mathematics of matrices when he wrote his most famous paper. It required Max Born (a top mathematician) to point out in a subsequent paper [46] that the failure of these objects to commute was a key characteristic of matrix multiplication. No one ever explained why algebraic differences were sufficient to explain physical differences between CM and QM.

Useful lessons can be learned by analyzing some of the key assumptions used by Heisenberg in this famous paper. He decided to build his theory only on the **final** results: in this case, the frequencies $f_{nm}$ corresponding to the observed emitted frequencies f when an electron makes its instantaneous transition between two non-radiating states with energies $E_n$ and $E_m$. This was defined using Bohr's (magical) postulate: $h\, f_{nm} = E_n - E_m$ ; this avoided calculating each $E_n$ separately. He still started with a supposed real equation of motion for an orbital electron Q[t] but decided not to interpret this as a displacement from the 'neutral' position at time t (the usual oscillator interpretation) - he certainly did not view this quantity as the distance from the target atom's nucleus. As he had done recently with Hendrik Kramers, he focused on the Fourier transform of Q[t] into the frequency domain but simply assumed he could use a double-index scheme (n and m), not just the traditional single index (n) that is normally used in this kind of analysis. The assumption here is that this is a model of the emission and absorption of a single photon by one electron, with ideas taken from Einstein's earlier mathematical (Fourier) model of light emission and absorption.

$$\therefore\ Q[t] = \Sigma_{n,m}\, a(n, m) \exp[\, i\, 2\pi\, f_{nm}\, t]$$

Like Einstein, Heisenberg assumed that the absolute square of the matrix a(n, m) was proportional to the relative intensity of each frequency, which he reinforced by changing the symbology to **A**(n, m) that are complex vectors that determine the phase and polarization of the emitted light. The earlier work had justified this analogy with classical EM theory when large values of the energy indexes were used (corresponding to very large distances from the nucleus). But most real spectra used small values for n and m or small n and large m (ionization) but this analogy was based on Q being identified with the distance from the nucleus, so that the electrical separation between the nucleus and the electron acted like an electric dipole. Even the famous editor of these early quantum papers (B. L. van der Waerden) had to admit [47] that Heisenberg seems to have made this substitution ($a \Rightarrow \mathbf{A}$) so as to comply with his own requirement for observable quantities in the EM radiation.

As all mathematicians know, multiplying exponentials effectively just adds the exponent arguments, so that:

$$\exp[\, i\, 2\pi\, f_{nk}\, t] \exp[\, i\, 2\pi\, f_{km}\, t] = \exp[\, i\, 2\pi\, (E_n - E_k) + 2\pi\, (E_k - E_m)\, ]\, t] = \exp[\, i\, 2\pi\, (E_n - E_m)\, ]\, t] = \exp[\, i\, 2\pi\, f_{nm}\, t] = \mathbf{A}_{nm} = \mathbf{A}(n, m)$$

This led to Heisenberg proposing the multiplication rule: $\mathbf{A}(n, m)\ \mathbf{B}(n, m) = \Sigma_k\, \mathbf{A}(n, k)\ \mathbf{B}(k, m)$

This was subsequently found to be the rule for multiplying fictitious square matrices with an infinite number of rows and columns.

Unlike Sommerfeld, who had created a 2D model of the hydrogen atom, Heisenberg limited his model to **one** dimension but still used Sommerfeld's quantization rule for its action variable while integrating over a full period of the motion but failing to notice that two different orbits had two different periods, neither of which was to appear in the final result. Since he also assumed that these squares were proportional to the probabilities of the transition m ⇒ n he could justify the following rule for forbidden transitions from the ground state (n = 1): A(1, 1 – m) = 0. Heisenberg applied these techniques to his central **artificial** system (anharmonic oscillator) and to another artificial, simple model: the rotator; the results agreed with earlier theoretical models. He concluded with the hope that this new approach could be used in real, physical systems. After Born was shown a draft of Heisenberg's paper, Born tried to recruit Wolfgang Pauli to collaborate to investigate this new approach further. Pauli rudely brushed him off with the remark [48] that Born was "*too fond of tedious and complicated formalisms*" so Born asked his own pupil, Pascual Jordan to help. Jordan quickly returned with some extensions that soon appeared in a related paper [49], which claimed that this new approach can "*build up a closed mathematical theory of quantum mechanics which displays strikingly close analogies with classical mechanics, while preserving the characteristic features of quantum phenomena*." They admitted they had only addressed 1D periodic systems. Jordan believed he had proved the key, new **quantization rule** for any pair of action variables, P (e.g. momentum) and Q (position); namely:

$$Q\,P \;-\; P\,Q \;=\; i\,h\,/\,2\pi.$$

They also demonstrated the conservation of energy in systems described by Hamiltonian functions: quadratic in P, involving potential energy functions of Q, assuming the equations of motion are of the same form as in classical theory. A third paper was written [49] by all three men that presented their considered views on their new, purely mathematical approach.

The final paper written by this quartet of mathematicians was penned by Wolfgang Pauli, who showed (after pages of difficult mathematics) that Lenz's classical proof of solutions [50] to the central Coulomb problem (e.g. hydrogen atom) can be mirrored in matrix mechanics.

## 3.4 QUANTIZED WAVE MECHANICS

### 3.4.1 DE BROGLIE WAVES

Louis Victor, Duc **de Broglie** (1892-1987), became the Prince de Broglie in 1960 after his brother died, is famous for making the most radical proposal in 20th century science. As a man fascinated by music, he viewed the atom as "humming with vibrations" so that he saw the electron in Bohr's model of the hydrogen atom [51] as a mysterious wave spread out along the orbit, so that only full waves ("standing-waves") were stable and incapable of emitting EM radiation until they jumped to another, standing-wave orbit. He hypothesized that the $n^{th}$ circular electron orbit, of radius $R_n$, carries n waves of wavelength $\lambda_n$, so that: $n\,\lambda_n = 2\pi\,R_n$ . Since Bohr had already assumed the electron's angular momentum was quantized (§3.2.3), then: $m\,V_n\,R_n = n\,h\,/\,2\pi$. This gives de Broglie's brilliant **hypothesis**: $\lambda_n \;=\; h\,/\,P_n$ ; where the electron's momentum, $P_n = m\,V_n$. De Broglie then made the revolutionary proposal that **all** material particles in motion are *accompanied* by such a mysterious "matter-wave". This was too radical a suggestion for his PhD committee, who submitted it to Einstein, who had made a similar proposal for dual characteristics of light with his famous photon proposal. Einstein thought this was a magnificent hypothesis; indeed, it was so important that it gained de Broglie the Nobel Prize in Physics only five years later. In his 1924 **thesis**, de Broglie [25] also explained this periodicity by conjecturing that every electron had its own **internal clock** - a view accepted in this research. This matter-wave proposal implied that electrons could undergo diffraction when impinging on a periodic structure such as a crystal with inter-atomic separations of about $10^{-8}$ cm. This was immediately found to be the case, as was described above (§2.2.4), although no one understood what these waves consisted of (what medium they existed in), or how they could 'bend' around an orbital.

In the second part of his 1924 thesis, de Broglie reminded his readers of an equivalence first pointed out by the Irish genius, William Rowan Hamilton in 1830, long before scientific attention had included either electromagnetic waves or any atomic phenomena. De Broglie wrote: *"Fermat's optical principle applied to phase waves is equivalent to Maupertuis' principle of least* ***action*** *applied to a moving body; the possible dynamic trajectories of the moving body are identical to the possible rays of the wave."* This was the reason the mathematics of waves and particles appears in (quantum) mechanics: this subtle linkage between two abstract areas of mathematics linked through the concept of ACTION.

### *3.4.1.1 Centrality of the de Broglie Wavelength*

Many modern expositions of quantum mechanics begin by focusing on de Broglie's hypothesis that a wave is '*associated*' with an electron. Attempts are then made to merge the equation of motion of an isolated particle with the standard wave equation in a continuous medium as a rationalization for the **plausibility** of Schrödinger's Equation, which is the most popular form for representing the QM of a non-relativistic electron. Such attempts zero in on de Broglie's equation that relates the linear momentum (P) to the new wave's wavelength ($\lambda$), namely: $\lambda = h/P$, where $h$ is Planck's quantum of action. The final step is to show that using *eigenfunction* mathematics can readily generate QM's central equation by hypothesizing that the momentum variable P can be replaced by the corresponding **linear operator** form: $\mathbf{P}_x = ih\ \partial/\partial x$. As is readily seen, this is a purely **mathematical** approach and gives no physical insights into why such a method should work for electrons. It is not surprising that such a symbolic approach should have generated extreme semantic argumentation on what all this 'machinery' means. In contrast, this research programme positions itself in the middle of the Natural Philosophy tradition that attempts to make physical hypotheses first (such as: *all matter is universally attracted to itself*) and only then try to transform these philosophical guesses into mathematics. The evolution of this research programme has been a gradual exposition of such new properties of the electron; in particular, the focus has been on understanding the interactions between electrons. The latest chapter of this saga now focuses on how these inter**actions** quantize the activity of pairs of electrons.

## 3.4.2 SCHRÖDINGER's WAVE MECHANICS

Although the "Old Quantum Theory" (Bohr through Sommerfeld) actually provided a very good quantitative account of the energy levels in simple atoms, its quantum 'postulates' and its introduction of various quantum numbers seemed a little arbitrary. This is why Heisenberg's new ideas were initially found acceptable (especially to his mathematical colleagues in Göttingen). However, even much of Heisenberg's approach could be subject to similar criticisms. It was de Broglie's radical proposal of universal **physical duality** that really launched 'modern' quantum theory, supported by Einstein's duality view of light. As Einstein earlier proposed, a photon of 'mass' $\mu$, velocity V (or $c$), momentum P and energy E is '*associated*' with an EM wave of frequency f, wavelength $\Lambda$ and **phase** velocity $c$ (where: $c = f\,\Lambda$); these are related by:

EM Radiation (Einstein): $E = h\,f = \mu\, c^2$ and $P = \mu\, V = \mu\, c = E / c = h\, f / c = h / \Lambda$

De Broglie generalized these relationships to his concept of the 'matter wave' "*associated*" with **any** particle of finite mass M:

Matter Wave (de Broglie): $P = M\,V = h / \lambda$ ($\lambda$ = matter wave length).

Following up on de Broglie's ideas, physicist Peter Debye made an offhand comment that if particles behaved like waves, they should satisfy some sort of wave equation; inspired by Debye's remark, Erwin Schrödinger (1887-1961) decided to find a proper **three-dimensional** wave equation for the electron. He was guided by William Rowan Hamilton's analogy between classical mechanics and optics, summarized in the known observation that the zero-wavelength limit of optics resembles a mechanical system: the trajectories of light rays become sharp tracks that obey Fermat's optical principle of least time (an analog of Maupertuis' principle of **least action**). At first, Schrödinger was inspired to think of a particle as a group or 'packet' of waves that traveled together at the "group velocity" ($V_G$) but all real examples of waves rapidly spread apart over time, while the electron's charge and mass remain always together. It is easy to show that it is the phase velocity $V_P$, which corresponds to the average speed, for all waves (by definition), the "phase velocity" always satisfies: $V_P = \nu\, \lambda$. Actually, this can only be made consistent if the particle's kinetic energy K and average velocity $\langle V \rangle$ values are used:

Average Speed: $\langle V[t] \rangle = \{V[t+\delta t] + V[t-\delta t]\} / 2 = V[t]/2$ & Matter Wave: $P[t] = M\,V = h / \lambda = h\,\nu / V_P$

$$K[t] = 1/2\ MV[t]^2 = M\,V[t] \langle V \rangle = P[t] \langle V \rangle = (h\,\nu / V_P) \langle V \rangle = h\,\nu \qquad \therefore \langle V \rangle = V_P$$

It was Schrödinger's move, in 1926, to view a **plane** wave not as a sine wave (or cosine) but to express the phase of a **plane wave** as a **complex**, phase factor; i.e. $\psi = \exp[2\pi i\,(\nu t - x/\lambda)]$; i.e. the complex sum of both cosine and sine waves together. He realized that using the first order derivatives (necessary for linearity - see later) leads to very interesting relationships, when viewed as operators **P** instead of algebraic variables, p:

$$\mathbf{P}_x\, \psi = p\, \psi = (h / \lambda)\, \psi = (i\, h / 2\pi)\, \partial\psi / \partial x \qquad \therefore\ \mathbf{P}_x = (i\, h / 2\pi)\, \partial / \partial x$$

Similarly, Schrödinger proposed: $\mathbf{H}\, \psi = E\, \psi = (h\, \nu)\, \psi = (-\, i\, h / 2\pi)\, \partial\psi / \partial t \qquad \therefore\ \mathbf{H} = (-\, i\, h / 2\pi)\, \partial / \partial t$

Here, **H** is the Hamiltonian (energy) operator of classical physics; for a particle in a potential U[x]: $H = P^2 / 2m + U[x]$
The key quantum assumption is that the classical Hamiltonian can be converted to differential form: $\mathbf{H} = -\,(h/2\pi)^2 / 2m\ \partial^2/\partial x^2 + \mathbf{U}[x]$
If the energy of the system has several discrete constant values, $E_n$ then: $\{-\,(h/2\pi)^2 / 2m\ \partial^2/\partial x^2 + U[x]\}\ \psi_n = E_n\, \psi_n$

This now has the form of the Wave Equation of classical physics (hence **"Wave Mechanics**"): it is also in the form of the eigenvalue equation of classical physics that received a lot of attention in late 19th Century vibrational physics. It is also called the time-independent **Schrödinger Equation** to acknowledge his key role in its development. It can now be used in several problems in classical physics where the energy of the system is conserved (independent of time). The wave (or psi functions), $\psi_n[x,t]$ lead to standing waves, called **stationary** states (or orbitals in atomic chemistry). This wave corresponds to a quantum state of the **whole** system with a unique total energy; as such, it is sometimes called the energy *eigenstate*. It has a solution (as was used in its derivation) for any time after an observation at time $t_0$ : $\psi_n[x,t] = \exp[2\pi i\,((t - t_0)\, E_n / h]\ \psi_n[x, t_0]$ .

Schrödinger wanted to impose the condition of **linearity**, as he wanted to be able to combine its parts (like Huygens) to produce the experimental interference effects and create wave packets. This implies that the most general solution is a linear combination (**superposition**) of plane waves; this is similar to the mathematical discovery by Joseph Fourier (1768-1830) that **any** finite continuous curve may be represented by an infinite **sum** of suitably weighted harmonic functions (i.e. plane waves).

$$\Psi_n[x,t] = \sum_n A_n \exp[2\pi i\,(\nu_n t - x / \lambda_n)] = \sum_n A_n \psi_n$$

The superposition **hypothesis** has the mysterious consequence that allows every particle to **exist** in two or more states with different classical properties at the **same** time. For example, a particle can have several different energies at the same time, and can be in several different locations at the same time. This superposition is still viewed as a single quantum state, as shown by the interference effects, even though this idea conflicts with classical intuition. One problem was solved by creating a very much deeper one.

The wave function $\Psi_n$ is assumed to provide a quantum-mechanically complete description of the behavior of a single electron and hence, in some undefined manner, to be **analogous** to a classical trajectory x[t], at all times t. "*We would like to assume that when the value of the psi function is large where the particle is likely to be and small elsewhere*." Anticipating problems [52], Professor Leonard Schiff admits that: *"the correctness of our interpretation of this wave function must be judged by logical consistency and appeal to experimental results."* With this viewpoint, one expects that the wave function will vanish at infinite distances from the center of a laboratory, where investigations on localized electrons are being undertaken unless open scattering experiments are being considered. This suggests that these functions may be made finite (or even normalized to unity), then: If $\sum_n \psi^*_n \psi_m = 1$ then $\sum_n A^*_n A_n = 1$

This kind of thinking led Max Born (1882-1970) to propose the **Statistical Interpretation** of Wave Mechanics. He proposed that the square of modulus (its absolute value) of the wave function (centered in a differential region of space at location $\underline{x}$ at a time t) corresponds to the **probability** of finding the particle in this region (i.e. $\mathscr{P}[\underline{x}, t]\ dx\ dy\ dz$). It's only valid when a large number of **identical**, precision measurements are made on independent particles, in identical situations. This leads to the key interpretive equation:

$$\mathscr{P}[\underline{x}, t] = |\,\psi[\underline{x},t]\,|^2 = \psi^*[\underline{x},t]\ \psi[\underline{x},t]$$

Assuming the psi function, $\psi$ is continuous in the spatial variables, then the condition that the particle must be somewhere in space at every time t, leads to the integral (over **all** space) being normalized:

$$\int dx \int dy \int dz\ \ \psi^*[\underline{x},t]\ \psi[\underline{x},t] = 1$$

This interpretation is consistent with the conservation of probability; if the electron is known to exist, somewhere then its existence is guaranteed at another location. This is a direct consequence of the Continuity Equation that results from the total time derivative of any continuous density function $\rho[\underline{x},t]$ and resulting in a flow (or flux) density function $\underline{J}[x,t]$.

Since: $d/dt\ \rho[\underline{x},t] = \partial/\partial t\ \rho[\underline{x},t] + \nabla \bullet \underline{J}[\underline{x},t]$ where the gradient operator $\nabla = \underline{i}\ \partial/\partial x + \underline{j}\ \partial/\partial y + \underline{k}\ \partial/\partial z$ & $\underline{J}[\underline{x},t] = \underline{V}\rho[\underline{x},t]$

Letting $\rho[\underline{x},t] = \mathscr{P}[\underline{x}, t]$ the probability density per unit volume & $\underline{J}[\underline{x},t]$ is the probability current flow (flux) per unit area; then if the electron exists anywhere in a region of space, then:

$$\therefore\ \underline{\mathbf{J}}[\underline{x},t] = \underline{\mathbf{V}}\ \boldsymbol{\rho}[\underline{x},t] = 1/m\ \underline{\mathcal{P}}\{\psi^*[\underline{x},t]\ \psi[\underline{x},t]\} = (i\ h / 2\pi m)\ \nabla\{\psi^*[\underline{x},t]\ \psi[\underline{x},t]\} = (i\ h / 2\pi m)\ \{(\nabla\{\psi^*)\ \psi + \psi^* \nabla\ (\psi)\}$$

Since the Statistical Interpretation introduces probability concepts into quantum mechanics, the result of any series of real experiments generates an average (or expectation) value of any real, continuous property $B[\underline{x},t]$; this is written:

$$\langle B \rangle = \int dx \int dy \int dz\ \ \psi^*[\underline{x},t]\ \mathbf{B}[\underline{x},t]\ \psi[\underline{x},t]$$

It is interesting to put Schrödinger's Equation in its **historical** context. After first working on color optics, he wrote his first quantum paper as an extension of Sommerfeld's 1916 atomic theory that investigated the very elliptical electron orbits in the sodium atom, where it was supposed to experience the enhanced (unshielded) effect of the full nuclear charge. Like most work on multi-electron atoms, this proved quite unfruitful. Schrödinger was working (like de Broglie) on the theory of ideal gases and later said that Wave Mechanics was born in statistics. Schrödinger's first attempt at Wave Mechanics was fully relativistic; (he created a variant of the Klein-Gordon Equation) in a failed attempt to recover Sommerfeld's fine structure results; but quantum "spin" had not yet been "discovered". So, Schrödinger tried to just recover the results of Bohr's non-relativistic model of the hydrogen atom (see later). In 1926, when he was an 'old man' of 38, Schrödinger published four famous papers. In the first [53], inspired by de Broglie's thesis, Schrödinger offered three 'derivations' of his equation, starting from Classical Mechanics but these are now seen as *post-facto* justifications. This first paper used a variational approach to the Hamilton-Jacobi equations of Classical Mechanics. With Herman Weyl's help, and the earlier analysis of vibrating 3D solids, Schrödinger was able to solve the non-relativistic radial part of the hydrogen atom. In his second paper [54], Schrödinger derived this equation again but this time using the Hamiltonian analogy between optics and mechanics; he also applied this approach to a theoretical harmonic oscillator model of diatomic molecules. In his third paper [55], Schrödinger applied standard perturbation theory to account for the effect of a strong electric field on the hydrogen atom (the Stark Effect). His fourth paper [56], introduced the time-dependent version of his eponymous equation for a semi-classical treatment of optical scattering, where he treated the EM radiation classically (using Maxwell's Equations). In the next 30 years, over 100,000 scientific papers were published that used Schrödinger's Equation - a huge impact; and a demonstration of the large number of mathematicians now practicing theoretical physics, seeking a new mathematical tool, so that they could conduct their "calculations".

### *3.4.2.1 Bohm's Quantum Text Book*

For all his controversial hypotheses, David Bohm made a permanent contribution to physics with his massive text [57] on quantum theory. In contrast to most texts that have addressed this subject (see later), Bohm made a major effort to place wave mechanics in its **historical** context and made a valiant attempt to present the main ideas in non-mathematical terms; indeed, he explicitly does not introduce the mathematical formulation until his second part, after 170 pages. Bohm had a lifelong interest in history and philosophy and a deep admiration for Einstein and his work. Thus, Bohm reminds us (unlike most accounts) that Planck's original idea in 1900 was **not** to quantize the *radiation* oscillators. Instead, Planck assumed that the EM cavity radiation was in equilibrium with *material* oscillators in the walls around the cavity, so that these material oscillators could give up or absorb radiant energy only in quantized exchanges of energy: $\Delta E = n\, h\, f$. It is a pity that at this point, Bohm falls into the common assumption that there must be quantized radiation oscillators to explain the fact that the blackbody spectrum is independent of the materials forming the cavity walls. The present theory prefers an explanation that acknowledges that all material atoms involve electrons, which are here treated as the sources and sinks of all the <u>remote</u> interactions with other electrons. This view avoids any need for introducing a new class of fundamental entity [6] called "*light*" (or EM radiation) that travels from sources to sinks (an almost universal assumption made by most physicists).

Bohm continues his historical story of the quantum by examining Einstein's model of specific heats of crystals (§2.1.2). Here, Einstein assumed each crystal had a preferred single oscillation frequency; so that a crystal could be viewed **as if it were** a collection of independent, harmonic oscillators. Debye improved on this simple model by allowing for coupling between the atoms, leading to the idea of quantized sound waves in crystals, at low temperatures. Bohm jumps from these examples to the mathematical conclusion that **all** harmonic oscillators require similar quantization, where energy levels in all matter are restricted to discrete values: though oscillators are a mathematical idealization while quantization is real action. It's interesting to note the vital role of oscillators and harmonic mathematics.

Bohm, like most authors, first develops a wave equation for a free electron, although he chooses to convert finite motion (inside a finite fixed box, using finite Fourier analysis) into continuous motion (across an **infinite** box, as a technique to justify <u>continuous</u>, Fourier integrals). Using standard partial derivatives on these continuous functions, he readily derives the standard partial differential equation linking the first time derivative to the second spatial derivative. Like all other QM authors, at this point, he invokes de Broglie's wavelength **equation** (§4.3.1) and "derives" Schrodinger's Equation. Here, he casually comments that: "*Practically, the entire quantum theory is contained in this equation*; <u>*once we know how to interpret the psi function*</u>." [Bohm's own emphasis]. Recognizing that this **interpretation** is the central philosophical challenge of QM, Bohm makes a massive effort to introduce some coherence into Bohr and Heisenberg's confused metaphysical ramblings. Bohm builds his entire case around de Broglie's wave-particle hypothesis ("matter is somehow 'associated' with oscillatory phenomena") without any more justification than that this "explains" the scattering effects from crystals. Since he views *light* and *electrons* as two distinct types of natural entities, he is pleased to see this "great unification" of two mysterious quantum objects that both sometimes behave like waves and sometimes like particles. Unfortunately, Bohm never reconciles the ontological view (existence) with the conventional epistemological view (knowledge). He rejects the epistemological view of the "*collapse of the wave function*" when he dismisses the sometimes-used analogy of a life-insurance company suddenly discovering the real age of a client and recalculating the client's new life expectancy. Bohm tries to contrast this statistical 'knowledge' interpretation with the deterministic view of classical mechanics, where he claims we could predict, **in principle,** a person's lifespan in terms of the motions of all his atoms and molecules.

Even though this LaPlacian dream could never be done, this would still be insufficient to anticipate all the events that might occur in any one person's life, such as diseases or accidents. This was always the bogus claim of Newtonian mechanism that needs a **total**, detailed model of **all** of reality. Bohm retreats into the mysteries of phase relations. This brief example illustrates the worst excess, used far too often, when faced with overwhelming complexity, to imply greater power than they ever possess by claiming that their calculations could be accomplished "**in principle**". The truth is that when making this excuse they are privately admitting their complete defeat. This is part of the greater conceit that views determinism as the ability to calculate the future, when it is really just needed to create the mathematical model itself, using the differential calculus.

Bohm is adamant that the wave properties of the electron are just as real as its particulate properties; indeed, he explicitly writes of the electron-wave as an existent, as when it interacts with a position-measuring device: "*after the interaction takes place, the wave function is broken up* ***into*** *independent packets with no definite phase relations between them. But as the electron exists* ***in*** *only one of the packets, while the wave function represents only the probability, then only one packet is the correct one*." Frequently, Bohm writes of the electron being transformed into a wave-like object and later being then transformed back into a particle-like object, particularly when it interacts with a high-energy photon. He uses these types of descriptions to give meaning to Heisenberg's vague references to "*potentia*" or tendencies to appear **as** different entities. These 'transformation' tricks would make any stage magician die of envy.

Bohm emphasizes in his preface that he is introducing a "*new conceptual framework*" to express our newly gained quantum knowledge. Near the end of his extensive introduction to 'explicate' these concepts, he condemns skeptics (like Landé) who continue to view electrons as really being particles (*with definite momentum and position)* but adds his own key, positivistic qualifier: *that can be measured simultaneously*. Bohm seems to ignore the fact that most Western people are not physicists but they do view the world in terms of ancient concepts of separable things (material **objects**). They do not care if they have measurable, mathematical properties such as momentum - but they do generally conceptualize reality (based on centuries of experience) as objects that are either localized **OR** spread over extended volumes of space (like waves) but **not** at the same time. Regular people are not going to introduce bizarre philosophical models into their language [58] to accommodate some rare physics experiments, only accessible to a few scientists. Rather, it is up to scientists to construct models that span all scales of reality that make sense to all human beings. Unfortunately, the proponents of the Copenhagen Interpretation (including Bohm and most of the modern physicists) have failed to deliver such a theory, believing that only the High-Priests of mathematics really understand material reality: a truly Pythagorean conclusion.

## 3.5 DIRAC's QUANTUM FORMULATION

### *3.5.1 Dirac's Quantum Text Book*

Paul Dirac (1902-1984) was studying for his PhD at Cambridge when his supervisor showed him a difficult preprint from Heisenberg. While reviewing this paper, Dirac's attention was drawn to a mysterious mathematical conclusion that Heisenberg had reached. Several weeks later, Dirac suddenly realized that this mathematical form had the same structure as the Poisson Brackets that occur in the classical dynamics of particle motion. From this thought, he quickly developed a quantum theory that was based on non-commuting dynamical variables. This led him to a more profound and significant general formulation of quantum mechanics than was achieved by any other physicist in this field. For this work, first published in 1926 [59], he received a PhD from Cambridge; it was the first in a series of quantum publications that eventually led to his award of the Nobel Prize in physics at the age of 31. In 1930, it was the publication of his textbook [60], (*Principles of Quantum Mechanics*) which spread Dirac's ideas around the world; so that now, many of today's theoretical physicists learn his approach to quantum physics. It is not a coincidence that the title of Dirac's masterpiece alludes to the seminal work by his predecessor, as Lucasian Professor of Mathematics at Cambridge. No other originator of quantum mechanics has documented their thoughts so extensively, nor made so many original contributions.

In the first two chapters of his book, Dirac tries to relate his radical new mathematical scheme to the physics of the micro-world. Then a Positivist, he assumed that: "*science is concerned only with observable things and that we can observe an object only by letting it interact with some [human] outside influence*." He quite reasonably assumes that: *"there is a limit to the fineness of our powers of observation and the smallness of the accompanying disturbance - a limit which is inherent in the nature of things and can never be surpassed by improved technique or skill of the observer."* He concedes that the idea of "*causality applies only to a system which is left undisturbed*." As a result, he is still prepared to assume that for undisturbed systems, differential equations may be established that express a causal connection between conditions at one time and a **later** time. He believed that these equations will be in close correspondence with the equations of CM but they will be connected only indirectly with the results of observations. Dirac defines any atomic system as a collection of particles interacting according to specified laws of force. There will be various possible motions of the particles consistent with these forces; each such motion is called a **state** of the system. These states may be defined as an undisturbed motion that is limited by as many conditions or data as are theoretically possible without mutual interference or contradiction. These conditions are usually imposed by a preparation or prior measurement; Dirac sometimes uses the word 'state' to mean the state at one particular time **or** sometimes even the state throughout the whole of time **after** the preparation (sometimes called a 'state of motion').

Dirac then spends two pages trying to justify his use of the crucial ***Principle of Superposition of States***. This assumes that there are *"peculiar relationships such that whenever the system is definitely in one state, we can consider it as being partly in each of two or more other states. In other words, the original state must be regarded as the result of a kind of superposition of the two or more new states, in a way that **cannot** be conceived on classical ideas."* Dirac admits that: *"although this is a mathematical procedure, it is <u>always permissible</u>, ... **like** resolving a wave into Fourier components."* For example, if an observation is made on a system in a state A is certain to lead to one particular result, say a; and when made on the system in state B is certain to lead to some different result, say b. Thus, when an observation is made on the system when it is in a state superposed of A **and** B then the results will always be a **or** b (not a+b) according to a probability law depending on the relative weights of A and B in the superposition process. If a specific experiment is <u>repeated</u> several times under **identical** conditions, then several different results will be obtained. Dirac's theory was able to calculate these probability distributions.

Dirac writes [61] that: *"The assumption of superposition relationships between the states leads to a **mathematical** theory in which the equations that define a state are linear in the unknowns. In consequence of this, people have tried to establish analogies with systems in Classical Mechanics (CM), such as vibrating strings or membranes, which are also governed by linear equations and, for which, a classical superposition principle holds. Such analogies have led to the name 'Wave Mechanics' being given to quantum mechanics (QM)"* However, Dirac emphasizes (by his italics) that: "***QM superposition is of an essentially different nature from any occurring in CM****, as indeterminacy must result from a <u>series</u> of experimental observations*."

### *3.5.2 Dirac's Hilbert Vectors*

This extensive preamble leads Dirac to the conclusion that atomic states and dynamical variables have to be represented by mathematical quantities of a different nature from those ordinarily used in CM, with the justification for the whole scheme depending on the agreement of the theoretical results with experiment. Since Dirac wants to use the <u>addition</u> operation to reflect the superposition principle, he chose mathematical objects known as vectors that when added generate new vectors. Recognizing that he wants to use <u>infinite</u> sets of vectors, he turned to the recently invented **Hilbert Vectors** that were then known to offer some attractive mathematical features. Like his earlier rivals in QM, Dirac never doubts that the popular Hamiltonian model of a central force system, developed for astronomy, works equally well inside the microscopic atoms.

One of Dirac's strengths was his invention of powerful notation. He did this with his QM state vectors that he called '**ket**' vectors [62], denoted by |a> and its mathematical 'dual', called '**bra**' vectors, denoted by <b| that could be combined (scalar product) to form a complex number by a '**bracket**' multiplication: <b|a>. The bra vectors are claimed by Dirac to be just the complex imaginaries of the corresponding ket vectors; i.e. $<b| = \{|a>\}^{\dagger}$. Dirac emphasizes that bra [row] vectors are of a "different kind" than kets [columns] while neither can be split into a sum of real and imaginary sub-vectors.

This scheme maps perfectly to Dirac's requirements. He assumes that: *"each state of a dynamical system at a particular time corresponds (maps) to a ket vector, such that if this state results from the superposition of certain other states, it may be expressible linearly in terms of the ket vectors of the other states."* He quickly shows that only the <u>direction</u> of the vector is important, not the vector's size or the order of its components. This illustrates the difference with classical superposition, where the superposition of a state with itself is twice as powerful as the single state; i.e. classically, they are actually <u>different states</u>. (e.g. 2 waves are bigger than one of them.)

Dirac demonstrates that bra vectors can be represented as linear functions of a ket vector but linear functions of bra vectors result in linear operators (analogous to differential operators). The order of multiplication of two such linear operators **F** and **G** may not commute, so the order becomes crucial, i.e. $\mathbf{F}\,\mathbf{G}\,|a> \neq \mathbf{G}\,\mathbf{F}\,|a>$ . Note also that: $\mathbf{F} = |c><d|$ & $\mathbf{F}^{\dagger} = |d><c|$. The key equation is the eigenvalue (proper) equation: $\mathbf{F}\,|a> = a\,|a>$, where the eigenvalue a and eigenvector |a> are usually unknown. This leads to the **central** proposition of the theory that if a dynamical system is represented by an eigenstate |a> of a real linear operator **F** then a measurement of the system will certainly produce the real number a that is its eigenvalue. Dirac appeals to physical continuity to argue that even if every measurement results in a disturbance then an <u>immediate</u> second measurement must produce the same result as the same, first measurement. (This seems quite implausible.) He uses this assumption to claim that a measurement always causes the system to jump into an eigenstate of the dynamical variable that is being measured. This means that the set of eigenvalues of a real dynamical variable are all the possible results of that type of <u>measurement</u>; this class of dynamical variables is called ***observables***. Dirac makes the fundamental claim that if an experiment is <u>repeated</u> several times under **identical** conditions, then the measured <u>average</u> result of the dynamic variable **F** (corresponding to the observable) will equal $<a|\,\mathbf{F}\,|a>$ for **all** normalized states |a> of the same dynamical system. Dirac's focus on eigenvalues seems a little anomalous, remembering his initial emphasis only on the **direction** of a state vector.As in classical mechanics, all dynamical operators can be represented by functions of the position and momentum ones: **X** and **P**, respectively. The connection between this representation and the more usual wave function representation is given by the eigenstate of the <u>position</u> operator **X** for a particle at position *x*, which is denoted by an element |x> in the Hilbert space, and which satisfies: $\mathbf{X}\,|x> = x\,|x>$. Then, $\psi[x] = <x|\psi>$ i.e. Schrödinger's wave function.
Likewise, the eigenstates: |p> of the momentum operator **P** specify the momentum representation: $\psi[p] = <p|\psi>$.

All of this theory so far has been concerned only with one moment of time but **dynamics** requires relationships across time. Dirac claims that **causality** applies between two distinct measurements with the equation of motion totally determining the evolution of later states from an earlier state as long as the system is **not** disturbed by another measurement. In particular, if a given superposition applies at the initial time, $t_0$ then it will apply during the subsequent (causal) period up to time t. This leads Dirac to introduce the Time Evolution operator, **T** that relates the evolving states to an earlier one: $|A, t> = \mathbf{T}\, |A, t_0>$. This implies that the linear operator **T** is the unitary time displacement equivalent of the spatial displacement operator. He then assumes perfect continuity to introduce the calculus form of the time derivative, along with (obviously $\mathbf{T}[t, t_0] \to 1$ as $t \to t_0$ ):

$$d/dt_0\, |A, t_0> \;=\; \lim_{t \to t_0} \{(\mathbf{T} - 1) / (t - t_0)\}\, |A, t_0> \;=\; \mathbf{H}[t_0]\, (2\pi/ih)\, |A, t_0> \quad \text{i.e. Schrödinger's Equation of Motion.}$$

Here, Dirac just assumes **H** is the Hamiltonian or total energy of the system because of the direct analogy with CM and is independent of time (i.e. constant) unless the system is not isolated; that is, it is acted upon by time-based external forces.

Replacing $t_0$ with t: $\mathbf{H}[t]\, |A, t> = \mathbf{H}[t]\, \mathbf{T}\, |A, t_0> = (ih/2\pi)\, d/dt\, |A, t> = (ih/2\pi)\, d/dt\, \{\mathbf{T}\, |A, t_0>\} \quad \therefore\ (ih/2\pi)\, d\mathbf{T}/dt = \mathbf{H}[t]\mathbf{T}$

Solving this: $\mathbf{T} = \exp[-(t - t_0)\, (i2\pi/h)\, \mathbf{H}]$ which is the direct link to Schrödinger's time independent equation [63].

The equivalent equation for operators is shown to be: $d\mathbf{F}/dt = \mathbf{F}\,\mathbf{H} - \mathbf{H}\,\mathbf{F}$ which is Heisenberg's Equation of Motion [64].

### *3.5.3 Dirac's Poisson Brackets*

In one formulation of Hamilton's Classical Mechanics of a particle, there are pairs of variables called canonical coordinates ($x$) and momenta ($p$), which completely specify the ***State*** of a classical system. Anti-symmetric pairs of derivatives [65] of these co-ordinates are used to create a mathematical function, called their **Poisson Bracket**.

This quantity plays a central role in Hamilton's equations of motion of the particle, which govern the time evolution of the system. The Poisson Bracket also defines sets of so-called canonical transformations, which map one set of canonical co-ordinates into another canonical set. This inspired Dirac to seek similar sets of transformations that would preserve the dynamics of quantum systems. Dirac assumed that the method of **classical analogy** [66] was appropriate for quantum mechanics on the grounds that CM provides a valid description when the particles composing the dynamical system are sufficiently massive (electrons?) for the disturbance accompanying an observation to be negligible, so that CM must be a limiting case of QM. Dirac was attempting to develop his quantum conditions, which would be a simple generalization of the classical condition that all classical variables commute; this is always the case with standard algebra, based on arithmetic. Dirac, by analyzing the Poisson Brackets of pairs of double products of variables, convinced himself that the quantum form of the Poisson Bracket (also known as a commutator), of linear operators **U** and **V**, designated $[\mathbf{U}, \mathbf{V}]$, must be related to the classical Poisson Bracket, designated here $\{[U, V]\}$. This relationship required an imaginary constant that also needed to be related to Planck's action constant $h$ to retain agreement with experimental results.

$$\therefore\ \mathbf{U}\,\mathbf{V} - \mathbf{V}\,\mathbf{U} \equiv [\mathbf{U}, \mathbf{V}] = i\,(h/2\pi)\, \{[U, V]\}$$

Dirac knew that the simple sets of canonical co-ordinates $P_r$ and $Q_r$ $\{r = 1, 2, ..., N\}$ satisfied the following classical PBs:

$$\{[Q_r, Q_r]\} = 0 \qquad \{[P_r, P_r]\} = 0 \qquad \{[Q_r, P_s]\} = \delta_{rs} \text{ (the Kronecker delta function)}$$

This leads to the quantum conditions: $\mathbf{Q}_r\, \mathbf{P}_s - \mathbf{P}_s\, \mathbf{Q}_r = i\,(h/2\pi)\, \delta_{rs} \qquad [\mathbf{Q}_r, \mathbf{Q}_s] = 0 \qquad [\mathbf{P}_r, \mathbf{P}_r] = 0$

The first (non-commuting) pair was exactly what Heisenberg had found intuitively, as Dirac knew. $\therefore$ QM $\Rightarrow$ CM as $h \Rightarrow 0$

Dirac easily showed that the derivatives: $\partial/\partial Q_k$ also obeyed similar relationships, so that he proposed: $\mathbf{P}_k = -i\,(h/2\pi)\, \partial/\partial Q_k$

Since this was similar to Schrödinger's momentum assignment, he called this the Schrödinger representation, thus **unifying** QM.

Dirac went further mathematically than his contemporaries when he related the quantum momentum operator $\mathbf{P}_x$ in the x-direction to the infinitesimal spatial displacement operator in the same direction, $\mathbf{D}_x$. Dirac demonstrated mathematically, using several 'plausible' assumptions [67] that: $\mathbf{P}_x = i\,(h/2\pi)\, \mathbf{D}_x$

However, Dirac had previous defined a finite spatial displacement operator as one that linearly effected state vectors or observables and corresponded to a *"perfectly definite physical process"* wherein the experimenter *"should merely have to displace all the apparatus used in preparing the state, or all the apparatus required to measure the observable."*

This is an explicit usage of the assumption that infinitesimal mathematical operations have a correspondence in the real world: - an assumption that has **never** been demonstrated but is needed to preserve the use of the differential calculus throughout QM. In reality, no experimenters, whatever their skill level, can replicate experimental setups to such accuracy. This means that all experiments that are repeated are different at extremely small distances; this will inevitably introduce statistical spreads. This is an early clue that the concept of instantaneous velocity is deeply flawed.

It is significant that Dirac takes the first 100 pages of his text to create (what he believed to be) a firm mathematical foundation for his theory before addressing any real physical problems, which only included the fictitious, harmonic oscillator and the two-body (planetary) central force problem. It is not a coincidence that these were the two classical problems leading to exact solutions. They are central to the education of physicists but only 'exist' in the imaginary worlds (minds?) of mathematicians.

## 3.6 BOHM's PERSPECTIVE

### *3.6.1 Bohm's Career*

David Bohm (1917-1992) was a throwback to an earlier age, in which physics involved quiet, deep contemplation of nature; as a result, he hated the undergraduate grind at Cal Tech. Bohm probed deeper and deeper into the underlying assumptions to enhance his comprehension. He wished to understand the underlying principles, not just how to calculate results from formal mathematical models. At first, Bohm strongly resisted the Copenhagen Interpretation as too mathematical, going so far as calling it "*Pythagorean Mysticism*". This is a view we share but as we shall now demonstrate, Bohm only added to the QM mysteries. Bohm knew that during the '**Golden Age of Physics**', the then physics-giants (e.g. Bohr, Einstein) had been interested in the physical **meaning** of their theories and their philosophical underpinnings. In those days, he knew *understanding was seen as more important than problem solving or producing some number*. Today, theoretical physicists are more interested in displaying their math skills than their physical intuition. Bohm always distrusted mathematical proofs, as he knew there are usually unstated assumptions in any piece of mathematics; while the more complicated the mathematics, the easier it is for undetected errors to creep in.
Like Feynman, Bohm's own problem solving was guided more by his visual imagination and **intuition**, not by deductive logic. Bohm also liked to look at the Big Picture and then develop a more radical theory. He was one of the few theorists, after the quantum pioneers, to think deeply about the meaning of QM. The writing of his major text [57] on quantum theory gave him the opportunity to review QM in true depth, although he went to great lengths in that text to dismiss the possibility of '**hidden variables**' – a deeper level than the variables measured explicitly in experiments. For a long time, theorists have assumed that such hidden variables must enable them to calculate observed results as if they were comparable to classical variables subject to continuous evolution but at a finer level of temporal differences. This seems more than bizarre because the statistical theory of heat computes only observable averages without calculating the detailed motions of the molecules involved. Again, classical mechanics provided a false image of the capabilities of mathematics. The **goal** is not to make better predictions but to gain deeper understanding of the objects of reality and their processes. This goal has nothing to do with QM being a "complete theory" or whether "God plays with dice". It may simply reflect the fact that electrons are very much smaller than the molecules and matter aggregates that we usually interact with, so that the number of objects is hugely overwhelming and certainly exceeding the two-body models calculated by mathematicians. Even Bohm himself skews the game by insisting that: "*we would certainly have to **first** prove that QM is not in complete accord with experiments*." This has never been the way physics makes progress: even when a better theory provides an alternative explanation for the observed phenomena, such as occurred with Copernicus's theory of planetary cycles. Indeed, Bohm's own later theory followed this deeper path, as consistent with experiments, **without** proving that QM was incorrect; illustrating the **ambiguity** of several theories to generate consistent numbers matching experiments. In 1954, Einstein wanted Bohm to be his personal assistant at the Institute of Advanced Study at Princeton but this was vetoed by its current director (Robert Oppenheimer), who claimed this would embarrass him (he had also been Bohm's PhD advisor at Berkley). As in the present theory, Bohm viewed the Quantum as an interaction, in that both are indivisible, conceptually taking priority over independent entities. Many lazy physicists dismissed Bohm's theory, quoting von Neumann's proof that eliminated mechanical hidden variables from QM. Oppenheimer even said that: "*if we cannot disprove Bohm, then we must ignore him*." (never even reading his papers). This reflected von Neumann's astute remark that physics was organized like a church and Oppenheimer was at least a cardinal. Bohm despised contemporary physics for generating plenty of trivial results but not producing any real advances in twenty years. He paid little attention to scientific journals as most of what was published seemed of little value to him. He agreed with Feynman (one of Bohm's few admirers) that contemporary physics was stuck because of a lack of **imagination**. The infamous Einstein, Podolsky and Rosen (**EPR**) was a flawed thought-experiment [68] that tried to view two subsystems as distinct because they were outside the 'light-cone', so could not make fast enough material communications. This again relies on the presumed 'single-time' model of (God's) time that lies behind much natural philosophy. Post-facto correlations observed between these two parts due a physical change in one system generating a calculated result in the other have led to a new mystery [69] in QM, called "**entanglement**". Rival theorists throwing around their incompatible definitions of "completeness" in physics eventually shed minimal light on reality.

### *3.6.2 Hidden Variables*

Bohm published the first version of his non-local hidden variable theory in 1952 [70], only one year after his massive QM text appeared but now centered on his firm idea that the electron was a particle. Bohm built his theory [71] on an invisible '**pilot** wave' that guided every electron. He unknowingly rediscovered (and extended) the idea that Louis de Broglie had proposed in 1927 (and abandoned) — hence this theory is now commonly called the "**de Broglie-Bohm theory**". When a double-slit electron experiment is performed (§2.2.5), the electron goes through one slit rather than the other but the slit passed through is not random but is governed by the (hidden) guiding wave that is aware of the existence of a possible second slit, resulting in the interference wave pattern that is observed. Bohm posited an invisible new entity, the *quantum potential*, that was created by the existence of **all** matter and which then interacted or 'guided' any electron experiencing this new potential. Although many physicists thought this theory was "*too contrived*", its biggest problem was that it deeply resists the easy computations that under-lie standard wave mechanics. Bohm's theory produced all the same results as standard QM, he agreed that he was not offering a model of reality, as his quantum potential only '*existed*' in an abstract mathematical space (where many believe only the psi function also '*exists*'). A radical feature of Bohm's theory is that electrons have realistic **trajectories** while the modifications of the quantum potential propagate remotely at super-luminal speeds (the non-locality). This new theory is based on the velocity flow of probability and not the target particle's mechanical velocity; this was Bohm's innovative interpretation of de Broglie's 'pilot wave' hypothesis. UET uses a similar electron 'awareness' without waves – pilot or otherwise.

### *3.6.3 Aharonov & Bohm Effect*

In 1957, Aharonov and Bohm proposed an experiment [72] to confirm that the QM of electrons implied "far EM action". This experiment was soon performed in 1962 by Möllenstedt and Bahy [73] using a 'magnetic whisker' (a permanent magnet in the form of a very long, thin wire). Near the center of the wire, the electric field ($\underline{E}$) is zero and the magnetic field ($\underline{B}$) is almost zero but the vector potential ($\underline{A}$) is very large. QM predicts that it is $\underline{A}$ that influences electron momentum $\underline{P}$ even if $\underline{B}$ is zero; in other words, it is not the Lorentz force $\underline{E} \wedge \underline{B}$ that is important but the shift in the phase of the particle's wave function along its path due to the contribution from the EM momentum $\underline{P} \bullet \underline{A}/c$. This dramatic result will be used later in the new quantum theory of the electron, developed herein.

### *3.6.4 Bohm's Metaphysics*

Both Bohr and Heisenberg had a philosophical interest in the meaning of the work they were doing. They each tried to explicate their meaning, now referred to as The Copenhagen Interpretation. Unfortunately, Bohr's elaborations were always confusing and often contradictory. It is not clear if this was because Bohr never really understood QM or because English was not his native language. Even when Heisenberg wrote in German, he failed to convince his critics, perhaps because his views were presented as a set of incompatible domains. Fortunately, David Bohm wrote his textbook to provide an understanding of their views, before he mathematically elaborated QM (ironically) in its regular wave mechanical form. Bohm organized his text to emphasize the deeper meaning (or metaphysics) of QM in the first 170 pages of his book, so we will view this as the definitive presentation of the meaning of the de facto standard interpretation of QM. Ironically, Bohm later admitted he still failed to understand QM after he had finished writing his book.

The central assumption of this view is that quantum physicists could not renounce their 300 year commitment to the idea of continuous interactions (i.e. the concept of **force**), while they were equally convinced of the value of the concept of particle velocity (or momentum) continuously changing with time – both concepts derived from what is called here, the "Continuum Hypothesis". There is no evidence for the reality of this hypothesis at the level of electrons. These mathematicians jumped to the conclusion that it must be a particle's position that changes discontinuously at the quantum level as they viewed position and momentum as complementary quantities (in a Hamiltonian mechanics model of action). Bohr (and Bohm) tried to impose Zeno's paradoxes on the micro-world, when the electron is "*imagined to* ***be*** *at one fixed position and no other*." They did this by introducing the artificiality of the calculus to the real world: any moving object must cover a finite space over any time interval, including one that is infinitely small – a necessary concept for considering instantaneous velocity or momentum. The problem arises when the **Uncertainty principle** is considered fundamental, which excludes the idea of any object **having** both a position and an instantaneous momentum **simultaneously**. The metaphysics creeps in from also trying to preserve the standard meanings of the verbs 'to be' and 'to have' along with the core principle (as in normal usage of language) that objects exist and have properties. It is this key assumption that the mathematics of the differential calculus can be extended from the approximations of the macro-sphere down to the micro-world that has never been demonstrated empirically. When actually Newton's original formulation [74] involved discontinuous impulses for changes in momentum; the approximation of forces was introduced to accommodate what appeared to be continuous (planetary) motion to human observations. The key idea here is that at all scales: velocity is a space/time ratio and not an instantaneous idea. We know that objects move but we do not need to know their instantaneous velocities; this bogus concept was smuggled in to preserve the ancient metaphysical idea of a single, universal time across all of space: the religious notion of "***God's time***". On the scale of human involvement, such an idea is a useful approximation but has always presented a challenge to philosophers. Bohm points to our experience with planetary orbits and gun trajectories for clinging to the continuous motion assumptions while even admitting this is not because this is "*the most natural thing to do*" [75].

He even admits that although we can imagine any such instantaneous velocity, "*we can instead use the mathematical definition*" that has been "***proven to exist***" – although this is only **in** the abstract world of mathematics and not in the real world of existence. Thus, it is not the idea of continuous location that is at risk but the convenience of mathematicians using "smooth" (continuous) functions that will have to go. It is this mathematical obsession with canonical variables at one instant of time that has to be given up when we construct our theories of the micro-world. For physicists, this means giving up 19th century Hamiltonian mechanics and Fourier analysis – a painful loss of "*old friends*". Non-physicists have no problem imagining an object staying at a fixed distance and direction from us, at two distinct moments of time; we call such objects "*stopped*" (or '*stationary*'). This is a useful idea that we need not give up; certainly **not** because some quantum theorists say that this situation is "*impossible*". Implicit in these quantum fantasies, is the defunct theory of ***Positivism***: the world only exists when we measure it. The arrogance of this philosophy is mind-blowing and is probably a major reason why it has been rejected by most modern philosophers. Bohm not only rejects the limit definition of momentum (long adopted in classical mechanics - "*this limit does not really exist when the time-difference becomes too small*") but he still wants to regard momentum as a real quantity because it appears in de Broglie's foundational equation and it has "*significance in the classical limit*". Indeed, Bohm loses contact with reality when he summarizes his metaphysics with the critical climax: "*the statement 'an electron was observed to have a given momentum' stands on the same footing as the statement that it had a given position. Neither statement is subject to further analysis.*" [76]. His use of 'mystery physics' further deteriorates when he tries to understand those symbols in his mathematical model of QM that he calls 'energy'. Bohm rejects the classical view that energy is a property. He also explicitly rejects any suggestion that energy is a fundamental substance (implied by Einstein's most famous equation) as it can never be found in isolated form (the definition of a real entity), nor can it be added to matter but he still wants to hold onto Maxwell's EM waves and Einstein's photons as major concepts in QM. Bohm is reduced to proposing that energy is no more than a potential **ability** to do work on another body i.e. exert forces on other bodies [77], while '*empty space*' can have the ability to do work by virtue of its ability to support an EM field. Nonetheless, Bohm still insists that energy corresponds to a real physical attribute of matter because "*the total energy of any isolated system is conserved*". A peculiar rock to build one's temple on when next year he evolved his position to acknowledge that no system can ever be isolated. What is not emphasized is that experiments almost never attempt to **measure** instantaneous velocity (or momentum) as they cannot generate infinitely-small time separations. So, why so much fuss about Heisenberg's Uncertainty Principle? We suspect, it is because Heisenberg really wanted to destroy the ancient concept of a particle's path through space.

Bohm has some very sharp observations on the limitations of the ancient concept of **causality** but as a Positivist, he still gets confused between the idea of 'complete determinism' and the scientist's ability to make accurate predictions. Bohm traces our intuitions about causality back to our experience of making personal changes in the material world, so that he can identify causality with exerting human force. Magic is seen as related to influencing others to make such changes under the influence of language but still insists on real energy transfers (like sound and light) to effect such indirect changes. He dismisses Aristotle's "final causes" because they fail to comply with his own model of experimental material verification, while ignoring our own long-term commitments to future goals (i.e. psychological verification). Bohm decides that it was probably the invention of complex machinery (like clocks), along with Newton's differential equations of motion, which led to the scientists' obsession with 'complete determination'. He is even prepared to give up the idea of physical forces if we knew all the positions and momenta of all the objects in the universe at one time. Bohm pulls away from this Laplacian fantasy and decides to retain the model of material forces and causes, as "*this procedure appears to be the most **convenient** one to use in practice*." [78] Sadly, Bohm decides he must give up Newton's laws of motion in QM (unlike Dirac) when applied to a single electron "*because its momentum and position cannot even **exist***" as they cannot be simultaneously measured **by humans** with perfect accuracy. Indeed, his positivistic assumptions force him to reject Newton's model in the micro-world because **we** cannot manipulate single electrons with perfect accuracy although Nature appears to have no problem making all these interactions between electrons both consistent and stable over the lifetime of the universe. The great compromise, positioned at the very heart of QM, is the assumption that we can attempt to "*reproduce the **same** initial conditions as completely as the quantum nature of matter permits*." When we do this repeatedly then we can only obtain statistical results ('*scatter spreads'*).

### *3.6.5 UET Metaphysics*

The new **U**niversal **E**lectron **T**heory (**UET**) retains all the usual concepts of natural language and posits only the reality of electrons that are still viewed as particles of 'zero size'. In logic, it is only by interacting with other elements of reality can changes be introduced and detected. This leads to the foundational idea that material reality **is** the **totality of all electrons**. Anything that can interact with electrons also deserves to be credited with "*existing in reality*". In practice, it is only kinetic energy, which is detectable or exchangeable; potential energy (of position) was just a mathematical trick to eliminate temporal mutual actions. In fact, UET introduced the concept of **activity** [79] as the four-dimensional generalization of action, energy and momentum; so it is activity that is universally conserved and exchanged in two electron interactions.

The new physics is introduced by various radical hypotheses of how these electrons interact with each other. In UET, all objects have a unique position at all times (even though, for large objects this is no more than a mathematical average, when surrounded by a finite volume of matter).

In the new view: the velocity of these electrons changes discontinuously as they interact locally and remotely (i.e. a new theory of electromagnetism is being proposed). These interactions involve mutual impulses, so that all concepts of continuous forces are abolished at this level; no longer (except at aggregated macro collections) are the mathematical concepts of electric or magnetic fields ever needed (as '*potentia*'). With the abolition of one universal time and continuous forces, each electron may be imagined to be at a singular point in space (x[t], as its own local clock 'ticks away' at the same universal rate). Until an interaction occurs with this electron, (at a local time $t_\mu$), it continues to move according to Newton's universal laws of material motion; that is, in a recti-linear fashion, under its own **inertia**, as would be expected, when macro collections are also made only of electrons. The inertial mass of such larger collections will depend on their own internal interactions as well as their interactions with external electrons. This dynamic conception will be elaborated in later papers when the masses of other 'fundamental' particles will be calculated. The only conclusion on causality where we can agree with Bohm is his awareness that: "*We can no more say that the future is caused by the past than we can say that the past is caused by the future*." [80]. The UET makes explicit use of this insight (as no single electron defines the universal "**now**" and has its own relative past and future), so the traditional idea of electron spin is replaced by **interactions** forward or backwards in time (or "***tirection***" – the interaction's time direction relative to the time of its 'partner').

# 3.7 LANDÉ's REBELLION

### *3.7.1 Dualism*

Alfred Landé (1888–1976) was one of principal critics of quantum mechanics; as a natural philosopher, he objected to the duality approach (which he often scornfully referred to as the "double manifestation" view) and always sought a unified model of reality. He wrote many papers and a series of books on QM. His most readable book [81] offers his final summary of thinking about QM. The following (typical) quotation from this text is offered: "*Instead of trying to clarify the mystery {of dualism} on physical grounds, many physicists are committed to regard double manifestation as an unshakeable truth and evade the problem of the **real** constitution of matter, either waves or particles, by a sophisticated skepticism toward the idea of physical reality*." Like many critics of QM, Landé was treated as an outcast by many of the orthodox believers. Pointing out problems is not a way to increase one's popularity in any large collective, which actively makes great efforts to enforce conformity (orthodoxy) on its foundational ideas.

### *3.7.2 State Transitions*

Rather than begin with some "necessity" for a wavelike function, Landé focused on the radical idea of measurement as the determination of the probability of transitions between system states while returning to Leibniz's principle of the continuity of cause and effect: "*A very small change of cause never produces a final change of effect*". Shooting balls over the straight edge of a blade should never result in an abrupt change in the number of balls passing the edge. This result will be due both to the experimenter's inability to make infinitesimal adjustments in aim and to the non-existence of perfectly sharp edges in physical reality (or exactly identical real balls); even though every single ball must fall to above or below the edge. Landé generalizes this model for systems with two exclusive states (A and Ä) plus situations B, which are a mixture of these two. The idea of reproducibility leads to notions of transition probabilities, when trying to determine initial and final states. The generalization to more than two states leads to the analysis of relative frequencies or transition probabilities (P). Landé then appeals to symmetry to suggest that these transition probabilities are symmetrical;

$$\text{i.e. } P(A_k \gg B_j) = P(B_j \gg A_k).$$

### *3.7.3 Wave Functions*

Eventually, Landé introduces 'complex square roots' of his probability matrices by: $\psi = \exp[i\,\phi]\,\sqrt{P}$ ; this eventually leads to the form for the wave-function $\psi$ of two action complements Q and P as the probability 'root' : $\psi\,(Q,P) = \exp[i2\pi QP/h]$ . This is the only general form that satisfies the rules of symmetrical unitary transformations, while complex conjugation will ensure that multiplying these $\psi$ functions ensures that they only depend on the differences (Q – Q'); i.e. Galilean invariance. Furthermore, non-zero finite Fourier transforms result in harmonic periodicities, over spatial separations S, such as: $\Delta P = P - P' = n\,h / S$. The next step is to show how average (or mean) values depend completely on these transition matrices, tying back to Dirac's approach. Landé summarizes his approach [82] by stating that: "*A ψ-wave does not guide actual events any more than a mortality table guides actual mortalities and it shrinks no more than a mortality table shrinks when an actual death occurs*."

## 3.8 THE HYDROGEN ATOM

The hydrogen atom has remained the only real system that has permitted an analytic calculation of energy levels to be compared with experiment. Bohr achieved universal fame for his 1913 solution [35], while Sommerfeld, in 1916 [38], included relativistic effects by proposing elliptical electron trajectories to extend Bohr's original circular orbits. This was the baseline that each of the "*Young QM Turks*" in the 1920s set themselves as the target for their own innovative theories. At the very least, they had to match these early results and, preferably, improve upon them. Ironically, it was Wolfgang Pauli (1900-1958), who took the first step in 1926. He applied the new matrix mechanics to calculate the stationary states of the hydrogen atom, even though no one really understood this new theory. A few months later, Erwin Schrödinger used his own new wave mechanics to solve the same problem - but in a one-page calculation (building on the difficult mathematics of elastic solids developed in the nineteenth century): Pauli had needed 20 pages of high-powered (new) mathematics. Soon after, in his own inimitable style, Dirac achieved the same results [60] in a few pages. This was to be expected as Dirac had shown that all three approaches were **mathematically equivalent**, although this was not initially obvious.

Much of this information summarized here will still be at a greater level of detail than most professional physicists were exposed to in their career. It will come as a complete surprise to many who learned their physics from popularizers and introductory texts. It is included to show that most interpretations of QM, even in many introductory QM texts, have failed to cover the complexities and problems. Original references are provided to encourage independent access to the creators of these ideas.

There are useful insights to be gained from reviewing different parts of these three schemes; the overall approach here will mainly follow Born's summarized exposition in his famous text on atomic physics [83]. This begins with Schrödinger's Equation for the hydrogen atom viewed as a microscopic Kepler planetary problem of a single electron with energy E moving at a distance r around a nucleus of total electric charge $Ze$, where Z is the atomic number. The Hamiltonian H is just the sum of its instantaneous kinetic energy K and its Coulombic (static) potential energy U.

$$\therefore\ \mathbf{H}\,\psi = i\,(h/2\pi)\,\partial\psi/\partial t = E\,\psi \quad \therefore\ \mathbf{H} = \mathbf{K} + \mathbf{U} = \underline{\mathbf{P}} \bullet \underline{\mathbf{P}} / 2m - Ze^2/r \quad \therefore\ \{\nabla \bullet \nabla + 8\,\pi^2\, m / h^2\,(E + Ze^2/r\,)\}\psi = 0$$

The **Laplacian**, $\nabla^2$ is then written in 3D polar co-ordinates $\{r, \theta, \phi\}$: $\nabla \bullet \nabla = \nabla^2 \equiv \partial^2/\partial r^2 + 2/r\,\partial/\partial r + 1/r^2\,\mathbf{\Gamma}$

The **spherical-surface** operator $\Gamma[\theta, \phi]$ is defined to be: $\mathbf{\Gamma} \equiv \partial^2/\partial\theta^2 + 1/\sin\theta\,\partial/\partial\theta + 1/\sin^2\theta\,\partial^2/\partial\phi^2$

The electron's angular momentum $\underline{\mathbf{L}}$ has a simple quantized form when using the quantum form of the linear operator $\underline{\mathbf{P}}$.

$$\therefore\ \underline{\mathbf{L}} = \underline{r} \wedge \underline{\mathbf{P}} = \mathbf{L}_x\,\underline{\hat{e}}_x + \mathbf{L}_y\,\underline{\hat{e}}_y + \mathbf{L}_z\,\underline{\hat{e}}_z \quad \text{with: } \mathbf{L}_x = (y\,\mathbf{P}_z - z\,\mathbf{P}_y)\ ;\ \mathbf{L}_y = (z\,\mathbf{P}_x - x\,\mathbf{P}_z)\ ;\ \mathbf{L}_z = (x\,\mathbf{P}_y - y\,\mathbf{P}_x)\ ;$$

$$\therefore\ \mathbf{L}_z\,\Phi[\phi] = -\,i\,(h/2\pi)\,\partial\Phi/\partial\phi = m\,(h/2\pi)\,\Phi[\phi] \quad \therefore\ \Phi[\phi] = \exp[\,i\,m\,\phi] \quad \&\ \underline{\mathbf{L}} \bullet \underline{\mathbf{L}}\,\mathcal{P}_\ell{}^m[\theta, \phi] = \ell\,(\ell + 1)\,(h/2\pi)^2\,\mathcal{P}_\ell{}^m[\theta, \phi]$$

Here, $\mathcal{P}_\ell{}^m[\theta, \phi]$ is the **spherical-harmonic** function, defined in terms of the **surface** spherical-harmonic function $\Upsilon_\ell$ :

$$\mathcal{P}_\iota{}^m[\theta, \phi] \equiv \Upsilon_\ell[\cos\theta]\,\exp[i\,m\,\phi]$$

Here the angle θ is the colatitude (measured from the North Pole θ=0) and ϕ is the arbitrary azimuthal angle around the equator.
The surface spherical harmonic function is the eigenfunction of spherical operator $\mathbf{\Gamma}$ since: $\underline{\mathbf{L}} \bullet \underline{\mathbf{L}} = -\,(h/2\pi)^2\,\mathbf{\Gamma}$

$$\therefore\ \{\mathbf{\Gamma} + \ell\,(\ell + 1)\}\,\Upsilon_\iota = 0$$

These identities mean that the Schrödinger's Equation can be transformed into the '3D-crystal' form:

$$[1/r^2\,\partial/\partial r\,(r^2\,\partial\psi/\partial r) + 8\pi^2\,m/h^2\,(E + Ze^2/r)\psi] + 1/r^2\{\mathbf{\Gamma} + 1/\sin^2\theta\,\partial^2/\partial\phi^2\}\psi = 0$$

This can be split into 3 **separable** parts by letting: $\psi = \mathcal{R}_\iota[r]\,\mathcal{P}_\iota{}^m[\theta, \phi]$ & $[d^2/d\phi^2 + m^2]\,\Phi[\phi] = 0$

$$[d^2/dr^2 + 2/r\,d/dr + 8\pi^2\,m/h^2\,(E + Ze^2/r) - \ell\,(\ell{+}1)/r^2]\,\mathcal{R}_\iota[r] = 0 \ \ \&\ \ [d^2/d\theta^2 + 1/\sin\theta\,d/d\theta + \mathbf{\Gamma} - m^2/\sin^2\theta]\,\Upsilon_\iota = 0$$

Taking advantage of Bohr's solutions, let: $r = \rho\,R_B = \rho\,(h/2\pi e)^2 / mZ$ & $E = -\,2m\,(\pi e^2\,Z/nh)^2$

$$\therefore\ [d^2/d\rho^2 + 2/\rho\ d/d\rho + 2/\rho - 1/n^2 - \ell(\ell+1)/\rho^2]\ \mathcal{R}_\ell[\rho] = 0 \quad \text{leading to:} \quad \mathcal{R}_\ell[\rho] = \exp[-\rho/n]\ \rho^\ell\ \mathcal{L}_\ell[\rho]$$

This complicated solution introduces the **LaGuerre** polynomials, $\mathcal{L}_\ell[\rho]$ whose zeros define the solution and determine the position of the nodal surfaces r = constant; there are $n - (\ell + 1)$ nodes for a given value of $\ell$.

In the Sommerfeld theory, spatial quantization was interpreted to mean the orientation of the plane of the orbit relative to the fixed direction of the z-axis; the plane being normal to the z-axis for m = ± k and inclined at various angles for other m values. Note that the free hydrogen atom's electron's energy is independent of m, only varying with n and $\ell$ (max[m]).

In contrast to this enormously **opaque** derivation, Dirac cut to the chase (possibly using insights gained from the wave mechanical solutions). Dirac found that the following radial operator $\mathbf{P'}_r$ is the true radial momentum conjugate to the radius r.

$$\mathbf{P}_r \equiv 1/r\ \{x\,\mathbf{P}_x + y\,\mathbf{P}_y + z\,\mathbf{P}_z\} \quad \text{As: } \partial r/\partial x = x/r \qquad \text{Defining: } \mathbf{P'}_r \equiv \mathbf{P}_r - i\,(h/2\pi)\,1/r \qquad \therefore\ [\mathbf{P'}_r, r] = i\,(h/2\pi)$$

Dirac also quickly proved that: $\underline{\mathbf{L}} \bullet \underline{\mathbf{L}} = -(h/2\pi)^2\,\mathbf{\Gamma}$. Thus, he could convert the hydrogen atom's Kinetic Energy **K** to:

$$\mathbf{K} = 1/2m\ \{1/r\ \mathbf{P}_r^2\ r + 1/r^2\ \underline{\mathbf{L}} \bullet \underline{\mathbf{L}}\} \quad \text{with a **separable** solution:} \quad \psi = 1/r\ \mathcal{X}_\ell[r]\ \mathcal{P}_\ell^{\,m}[\theta, \phi]\ \ \&\ \ \mathcal{X}_\ell[r] \equiv r\ \mathcal{R}_\ell[r]$$

This is converged quickly to: $[d^2/dr^2 + 8\pi^2\, m/h^2\,(E + Ze^2/r) - \ell(\ell+1)/r^2]\ \mathcal{R}_\ell[r] = 0$ Thereafter, same solutions as Schrödinger.

There is an important difference here from the Sommerfeld approach, which **restricted** the electron's motion to **2D** planar motion, which is **valid** for continuous, central forces: a constraint **not** honored by the full quantum mechanical solution. The QM solution allowed the Bohr model to rotate in all directions, i.e. there is no fixed z-direction. Alternatively, the Bohr model may be viewed as the projection of the full 3D trajectories between nodes of the 3D spherical solutions onto the 2D x-y plane. The reason that the 2D constraint was not honored by the 1925 quantum revolutionaries is that they wanted the full 3D spherical harmonics as part of their solution. They knew this was the desired goal because this had been achieved by the 19th Century mathematicians in their extensive studies of vibrating elastic solids (this also helped Schrödinger get his answers so quickly). The benefit of **spherical harmonics** is that **any** motion in three dimensions can be represented by a weighted sum of these functions that form a complete set (the 3D equivalent - or extension - of plane wave Fourier harmonic analysis). This is an interesting requirement for the physicists, who rejected the idea of continuous, electron trajectories. Additionally, a lot of valuable knowledge was available on the continuous functions underlying the mathematics of "Spherical Functions", which had been developed by many years of analytical research by 19th Century mathematicians.

# 3.9 QUANTUM CONSEQUENCES

In contrast to the original quantum theory, the new QM introduced several new concepts, some of which have since presented major conceptual difficulties. These new concepts included the Uncertainty Principle, Superposition, Probability and QM Measurements. These ideas remain at the heart of the Interpretation Issues confronting the complete acceptance of QM.

## 3.9.1 THE UNCERTAINTY PRINCIPLE

The **uncertainty principle** is any of a variety of mathematical inequalities asserting a fundamental limit to the precision with which certain **pairs** of physical properties of a particle known as complementary variables, such as the position x and momentum p of an electron, can be **known** simultaneously. Each of the pioneers of QM had a different view of the meaning of this limit-on-precision in micro systems. Schrödinger's Wave Mechanics approach provides a more visually intuitive picture while Heisenberg's Matrix Mechanics provides for a demonstration of the uncertainty principle that is more easily generalized to cover a broader range of physical contexts, in a more rigorous, mathematical style, which are often insoluble.

### *3.9.1.1 Heisenberg's Microscope*

The central assumption in Heisenberg's atomic physics was that the classical concept of motion does not apply at the quantum level and that electrons in an atom do **not** travel on sharply defined orbits. Rather, the electron's motion is smeared out in a strange way: the Fourier transform of time only involve those frequencies that could be seen in quantum jumps. Heisenberg's views did not admit any unobservable quantities like the exact position of the electron in an orbit at any time; he only allowed the theorist to talk about the Fourier components of the motion. Since the Fourier components were not defined at the classical frequencies, they could not be used to construct an exact **trajectory** (the path that a moving object follows through space as a function of time). Thus, the formalism deliberately could not answer questions about **where** the electron was or how fast it was going, so this requirement was then considered '*meaningless*'. In March 1926, while working at Bohr's Copenhagen Institute, Heisenberg realized quantum non-commutativity implies the uncertainty principle. This implication provided (for him) a clear physical interpretation for the non-commutativity.

This became the basis for what became known as the Copenhagen Interpretation of quantum mechanics. UET explicitly accepts non-measurable trajectories. Any two "canonical" variables that do not commute cannot be measured simultaneously—the more precisely one is known, the less precisely the other can be known [see §4.8.1.3 below].

In his celebrated 1927 paper [43], in attempting to rebut Schrödinger's view of quantum reality, Heisenberg wrote (confusing our ability to predict motion from the complete accuracy available to the electron itself):

> *One can never **know** with perfect accuracy both of those two important factors, which determine the movement of one of the smallest particles—its position and its velocity. It is impossible to determine accurately both the position and the direction and speed of a particle at the same instant.*

He attempted to explain this dramatic result by appealing to an intuition of the minimum amount of unavoidable momentum disturbance caused by any position measurement. Soon after, Heisenberg offered a mathematical formulation in terms of the measurement uncertainties $\Delta x$ and $\Delta p$ : $\Delta x \, \Delta p \approx h$ (but unfortunately he did not give a precise definition of these quantities).

Throughout the main body of his original 1927 paper, written in German, Heisenberg used the word "*indeterminacy*" to describe the basic theoretical principle. Only in the final endnote did he switch to the word "*uncertainty*". In 1930, when the English-language version of Heisenberg's textbook [84] was published, the translation "*uncertainty*" was used and so it became the more commonly used term in the English language thereafter and became famous as the **Heisenberg Uncertainty principle**.

One way in which Heisenberg originally illustrated the intrinsic impossibility of violating the uncertainty principle is by using an imaginary **Gamma Ray Microscope** as a measuring device. He imagined an experimenter trying to measure the position and momentum of an electron by hitting it with a high-energy photon (gamma ray). This can then interpreted as:

View 1 – When the gamma ray has a short wavelength (therefore, a large momentum) the electron's position can then be measured accurately. However, the photon scatters off in a random direction, transferring a large and uncertain amount of momentum to the electron. When the photon has a long wavelength (low momentum), the collision does not disturb the electron's momentum very much but the scattering will reveal its position only vaguely.

View 2 – If a large aperture is used for the microscope then the electron's location can be well resolved (according to optical diffraction theory); but due to conservation of momentum, the transverse momentum of the incoming photon and hence, the new momentum of the electron resolves poorly. If a small aperture is used, the accuracy of both resolutions is the reversed.

### *3.9.1.2 Bohr is furious with Heisenberg*

Bohr was furious when he first saw Heisenberg's 14-page letter to Pauli describing his new Uncertainty Principle [85]. At first Bohr refused to let Heisenberg publish his paper; saying that Heisenberg had not provided any firm foundation for his argument, which was based entirely on the assumption (prior to de Broglie) that both light and the electron behaved like particles. Bohr, in his usual paradoxical style, insisted: "*they both must be understood as both wave **and** particle even though this cannot be imagined*."

Bohr's thinking in this area was stimulated by Heisenberg's early draft on the Uncertainty Principle in 1927. Bohr drafted a paper on these ideas and requested Pauli's reaction. Pauli responded [86] immediately. As a fellow mystic, Pauli agreed entirely with Bohr's thesis. Bohr presented his views soon after at two international conferences and these speeches were formally published in the journal *Nature* [87]. Some scientists, such as John Wheeler and Bohr's biographer, Abraham Pais viewed the **Complementarity** principle as a key step in the evolution of physics but many more just ignored it, as can be seen by checking the index of many texts on QM, including Dirac's masterpiece [60].

### *3.9.1.3 Schrödinger's Approach*

If a measurement of an observable $A$ is performed, then the system is considered to be in a particular eigenstate $\Psi$ of that observable. However, the particular eigenstate of the observable $A$ need not be an eigenstate of another observable $B$. If so, then it does not have a unique associated measurement for it, as the system is not in an eigenstate of the other observable. Let $|\psi\rangle$ represent an eigenstate of the position operator, **X** with eigenvalue $x_0$ and further assume that it **is** an eigenstate of the position operator, **P** with eigenvalue $p_0$.

$$\text{i.e.} \quad \mathbf{X}\,|\psi\rangle = x_0\,|\psi\rangle \quad \text{and} \quad \mathbf{P}\,|\psi\rangle = p_0\,|\psi\rangle$$

$$\therefore \quad [\mathbf{X}, \mathbf{P}]\,|\psi\rangle = (\mathbf{X}\,\mathbf{P} - \mathbf{P}\,\mathbf{X})\,|\psi\rangle = (\mathbf{X}\,p_0 - \mathbf{P}\,x_0)\,|\psi\rangle = (p_0\,\mathbf{X} - x_0\,\mathbf{P})\,|\psi\rangle = (p_0\,x_0 - x_0\,p_0)\,|\psi\rangle = 0$$

But, $[\mathbf{X}, \mathbf{P}]\,|\psi\rangle = i\,(h/2\pi)\,|\psi\rangle = 0 \quad \therefore \quad |\psi\rangle = 0$ Therefore, there is **no** state that can be an eigenstate of **both X** and **P**.

Soon after the publication of Schrödinger's famous wave mechanics paper, Earle Kennard derived a formal inequality relating the standard deviation $\sigma_x$ in the electron's position and the standard deviation [88] of momentum $\sigma_p$. This proof is worth repeating in a modern style, as presented in a recent book [89] on quantum theory: it exposes QM's **statistical** view. If a series of N macro experiments determining the value of an observable A result in a set of numbers $\{a_n\}$ with weighted factors $\{W_n\}$ then the average value found is defined as: $<A> \equiv \sum_n W_n a_n$ where the weights are normalized: $\sum_n W_n = 1$.

The variance (or spread) is **defined**: $\sigma_A{}^2 \equiv \sum_n W_n (a_n - <A>)^2 = \sum_n W_n \{(a_n)^2 + <A>^2 - 2a_n <A>)\} = \sum_n \{W_n (a_n)^2 - <A>^2\}$

Thus, the standard statistical deviation of A's measured results is: $\sigma_A{}^2 = \{< A^2 > - <A>^2\}$

When QM is interpreted in terms of <u>relative probability frequencies</u> then the corresponding quantity is called the **dispersion** of the observable A when the system is in the quantum state ψ, (writing $<\mathbf{A}>_\psi = < \psi |\mathbf{A}| \psi >$) denoted as:

$$(\Delta_\psi A)^2 = < (\mathbf{A} - <\mathbf{A}>_\psi)^2 >_\psi = <\mathbf{A}^2>_\psi - (<\mathbf{A}>_\psi)^2 = \sigma_A{}^2 \quad \therefore \ \Delta_\psi A = \surd\{< \psi \,|\, \mathbf{A}\,\mathbf{A} \,|\, \psi > - (< \psi \,|\mathbf{A}|\, \psi >)^2 \}$$

The average of the Hermitian self-product of any operator is always positive or zero: $<\mathbf{A}^\dagger\mathbf{A}> = < \psi |\mathbf{A}^\dagger\mathbf{A}| \psi > = (\mathbf{A}|\psi>)^2 \geq 0$

$$\therefore F[\lambda] = <(\mathbf{A} + i\,\lambda\mathbf{B})^\dagger (\mathbf{A} + i\,\lambda\mathbf{B})> = <(\mathbf{A}^\dagger - i\,\lambda\mathbf{B}^\dagger) (\mathbf{A} + i\,\lambda\mathbf{B})> = <\{\mathbf{A}^\dagger\mathbf{A} + \lambda^2\, \mathbf{B}^\dagger\mathbf{B} - i\,\lambda(\mathbf{B}^\dagger\mathbf{A} - \mathbf{A}^\dagger\mathbf{B})\}> \geq 0$$

When **A** & **B** are real, then: $\mathbf{A}^\dagger = \mathbf{A}$ & $\mathbf{B}^\dagger = \mathbf{B}$ $\therefore$ $F[\lambda] = <\{\mathbf{A}^2 + \lambda^2\, \mathbf{B}^2 - i\,\lambda(\mathbf{B}\,\mathbf{A} - \mathbf{A}\,\mathbf{B})\}> \geq 0$

$F[\lambda]$ is a minimum when: $\partial/\partial\lambda\{F[\lambda]\} = 0 \ \therefore \ \partial/\partial\lambda\{F[\lambda] = <2\lambda\mathbf{B}^2 - i\,(\mathbf{B}\,\mathbf{A} - \mathbf{A}\,\mathbf{B})> = 0 \ \therefore$ when $2\lambda_0 = i <[\mathbf{B}, \mathbf{A}]> / <\mathbf{B}^2>$

$$\therefore F[\lambda_0] = <\mathbf{A}^2> + <\mathbf{B}^2> \{i <[\mathbf{B}, \mathbf{A}]> / 2<\mathbf{B}^2>\}^2 + \{<[\mathbf{B}, \mathbf{A}]>\}^2 / 2<\mathbf{B}^2> \geq 0$$

$\therefore$ $<\mathbf{A}^2> <\mathbf{B}^2> \geq - \{<[\mathbf{B}, \mathbf{A}]>\}^2 / 4$ True for all pairs of real observables, **A** and **B**.

Defining deviations from the average: $\delta\mathbf{A} \equiv \mathbf{A} - <\mathbf{A}>$ & $\delta\mathbf{B} \equiv \mathbf{B} - <\mathbf{B}> \ \therefore (\Delta_\psi A)^2 \equiv < (\delta\mathbf{A})^2 >_\psi$ & $(\Delta_\psi B)^2 \equiv < (\delta\mathbf{B})^2 >_\psi$

$$\therefore (\Delta_\psi A)^2 (\Delta_\psi B)^2 \geq - \{<[\mathbf{B}, \mathbf{A}]>\}^2 / 4$$ **General Dispersion Theorem**

Thus, if **A** and **B** commute (i.e. $[\mathbf{B}, \mathbf{A}] = 0$) both observables may be measured together with extreme precision.

For canonical variables: $[\mathbf{P}, \mathbf{Q}] = i\,h / 2\pi \ \therefore \ (\Delta_\psi P)^2 (\Delta_\psi Q)^2 \geq (h / 4\pi)^2 \quad \therefore \ (\Delta_\psi P)\, (\Delta_\psi Q) \geq (h / 4\pi)$

This is only an equality for the special case of Gaussian states, as Heisenberg proved for the model of the linear oscillator. Note that nowhere in this derivation was any appeal made to the idea of waves, **only** the basic quantum commutation rules.

### *3.9.1.4 Uncertainty Discussion*

Chris Isham explicitly raises several points [90] about the General Dispersion theorem.

1. The uncertainty $\Delta_\psi A$ depends on the state (ψ) of the system. In particular, since a stationary state is an eigenvector of the Hamiltonian **H**, it cannot be an eigenstate of either the location **X** or momentum operator **P** but only a merged compromise; this is understandable because the basic Hamiltonian for a particle involves functions of both **P** and **X**.

2. If the state $|\psi>$ is an eigenvector of A (i.e. $\mathbf{A}\,|\psi> = a_n\,|\psi>$ ) then $\Delta_\psi A = 0$. This is consistent with the idea that an eigenstate will always produce the same result, so there is no dispersion, however often it is measured for observable A.

3. This result has **nothing** to do with performing '<u>simultaneous</u>' measurements, rather it refers to the <u>statistical spread</u> in the results of performing **<u>repeated</u>** measurements of position and momentum on **identically-prepared** systems and this does not require that they be measured at the same time. Isham suggests this may be a limitation on the possibility of **preparing** a quantum state: a view that is concurred with here. Also, note this derivation <u>excludes</u> Time and Energy: not a canonical pair. In his early writings, Heisenberg viewed the dispersion as an epistemological uncertainty of the possession of a quantity A. Meanwhile, Niels Bohr viewed the dispersion as an indicator of how much classical concepts **cannot** be applied to quantum systems. Heisenberg responded by re-interpreting one-shot probabilities as the **potentiality** for generating specific values.

Historically, many people, including Heisenberg, have interpreted the Uncertainty principle in terms of the disturbance on the system by attempts to measure properties; an approach called the "**Observer Effect**": extending this view to the Energy and Time exchanges. Others have claimed that Quantum Uncertainty is a result that always pertains to wave-based systems since de Broglie's proposal that all matter is associated with a wave implies that all quantum systems must suffer this type of dispersion whenever a macro system interacts with an atomic system. Waves, after all, are spread across space and cannot be constrained to a single point, like an electron but as pointed out, this is a result of simply QM mathematics (e.g. Dirac). Measurement disturbances may occur but it is problems with giants, like ourselves, attempting to set up identical experiments wherein lies the problem (see below).

The interpretation of these relations has often been debated: raising questions such as: - Do Heisenberg's relations express restrictions on the experiments we can perform on quantum systems (and, therefore, restrictions on the information we can gather about such systems (epistemology)? Or, do they express restrictions on the **meaning** of the concepts we use (semantics) to describe quantum systems? Or else, are they restrictions of an ontological nature (i.e., do they assert that a quantum system simply does not possess a definite value for its position and momentum at the same time)? The difference between these interpretations is partly reflected in the various names by which the relations are known, e.g. as 'inaccuracy relations', or: 'uncertainty', 'indeterminacy' or 'unsharpness relations'. The debate between these different views has been addressed by many authors, but it has never been settled completely to everyone's satisfaction (and very disappointing). These divergences play into the various conflicting interpretations of the meaning of QM (see later).

Alternative viewpoints to Heisenberg are still viable: e.g. the ontological meaning of the uncertainty relations is denied. The statement, often found in the literature of the thirties, that Heisenberg had *proved* the impossibility of associating a definite position and momentum to a particle is certainly wrong. But the precise meaning one can coherently attach to Heisenberg's relations depends rather heavily on the **interpretation** one favors for quantum mechanics as a whole. However, because no agreement has yet been reached on this latter issue, one can expect disagreement on the meaning of the uncertainty relations. It is always important to remember that the Uncertainty Principle is not only a statistical result of **many** measurements but that each **pair** of measurement is supposed to be performed **at the same time** in an **identical** context and then averaged.

## 3.9.2 QUANTUM PROBABILITY

### *3.9.2.1 Pauli trumps Born's Probability*

Although Max Born took the public credit (and the 1945 Nobel Prize) for the probabilistic interpretation of the wave function [§4.3.2] it was actually Pauli who first conceived of the wave functions as a probability density of an electron being found at a point in space. Pauli first described this in a private letter to Heisenberg and added it as footnote to his 1927 paper [91] on paramagnetism. This is perhaps why Born's contribution was ignored for such a long time. Nonetheless, this proposal eliminated all possibilities that the psi function actually represented a real physical wave in real 3D space; a view that, at best, could only be maintained for a single electron – i.e. one without any interactions (thus, unmeasurable).

### *3.9.2.2 UET Explanation of the Uncertainty Principle*

Many discussions of QM still obsess on the centrality of Heisenberg's Uncertainty Principle, as the limit at which human observations of the micro-world inevitably generate statistical results. This paper re-emphasizes that though this is a logical consequence of the operator mathematics of standard QM, there is a deeper level of reality at work here, which will always produce such statistical consequences when macroscopic attempts are made to exactly replicate "the same" experimental configurations. Indeed, this programme adopts a **many-body** view of the world where all attempts to isolate an 'ideal experiment' are doomed to failure, as electrons are shown here to retain a small finite interaction at extreme separations. These attempts to simplify our mental models of the world are viewed here as last-ditch attempts to save the Continuum model of reality and its associated continuum mathematics that have dominated mathematical physics for several hundred years. In addition, there has developed a well-established tradition of creating mathematical models of **isolated** systems, where the only objects in reality that correspond to the symbols in the model are assumed to be the only ones that exist in the whole universe. This has sometimes been called 'the universe in a box' as the box supposedly isolates the target system from any other influences in the universe. This approach leads (sometimes) to soluble mathematics but is equivalent to the assumption that the target objects do **not** interact with any other parts of the universe during an undisclosed time duration of the calculation. In particular, this assumes that the electrons in Bohr's atomic model only interact with the nucleus and no other electrons anywhere else (including those in the measuring apparatus). UET rejects this totally artificial approach; it is other electrons that prevent re-establishing **identical** atomic experiments. These confusions have persisted because philosophers and scientists have had different ontological commitments, partly because they maintain different philosophies of language. Einstein and Heisenberg viewed light and matter as a single entity expecting field theory to supply the fundamental ontology. Einstein pushed this perspective to where he called QM 'incomplete'; requiring the theory to reconcile field physics, deterministic causality and the physical continuum in 4 dimensions. These different perspectives result from deep differences in personal world-views that might even be termed 'religious' differences.

## 3.9.3 QUANTUM SUPERPOSITION

The observed interference effects involving waves have convinced physicists that should **interference** effects be observed then waves **must** be present since when real waves meet their amplitudes add, even destructively. This was the motivation to prefer 'Wave Mechanics' to Matrix Mechanics because otherwise it is very difficult to explain the interference effects of electrons passing through narrow slits (like light). This was also the reason that Dirac expended so much effort justifying his use of the **Superposition Principle** when he was building the foundations for his version of QM (see §4.4); particularly as he had a metaphysical preference for Newton's particle concept over the wave approach pioneered by Schrödinger. Dirac knew his theory needed this feature so it was embedded in his mathematics, even though he could find no physical justification for this 'weird' characteristic of QM systems. The other attractive feature of this principle is that nothing is added or lost when waves comes together; in particular, when a wave exits such an encounter with another wave then each of the waves emerge with exactly the amplitudes they went in; this is not the case, when particles interact.

Mathematically, this linearity feature lies at the heart of the new QM (Schrödinger's Equation). The critical factor is timing differences (or **phase**): how far apart are the peaks of the wave when they combine? The problem arises when the Psi wave is interpreted as implying that an electron **exists**, at one time in many distinct states but only manifests itself as **one** of these real possibilities when it is measured: a paradox often called the "**measurement** problem" or "wave function **collapse**". We will see that a conflict over timing issues is a much cleaner interpretation.

It is not that measurement disturbances occur but that the real atomic problem for electron 'giants', like our selves, are **our** problems with setting up similar (**not** <u>identical</u> experiments). This explains the **Superposition Principle** as a misunderstanding of QM calculating <u>average results</u> but NOT all at the same time. The **fundamental error** is trying to interpret the quantum state $\psi$ as existing at **one** single time (t), [i.e. believing $\psi$ is a continuous function of the universal, smooth temporal parameter t; i.e. $\psi(t)$] when it is a mathematical device for calculating the results of many series of similar experiments, over many different times. In fact, it might be more helpful to view the t parameter as <u>when</u> an attempt was made to <u>set up</u> an experiment and **not** when a single <u>observation</u> is made. Once again, implicit classical analogies have been made between classical experiments (insensitive to set up variations) and quantum experiments, which are always extremely sensitive to set up variations.

# 4. PROBLEMS WITH QUANTUM MECHANICS

## 4.1 RANGE OF PROBLEMS WITH QM

This section will explore several of the major difficulties centered on the current approach to quantum mechanics (QM); the topics covered here overlap with similar questioning raised by a few unorthodox critics of QM, who reject orthodox QM as 'proven truths'.

1. QM is not a physics theory but is formulated only as an **abstract**, mathematical scheme.
2. The role of the macroscopic observer of atomic processes is unclear in determining various outcomes;
3. Contradictory concepts are offered as "complementary" descriptions and others (e.g. the 'state' idea) are often undefined;
4. Locally formulated theories appear to result in unexpected, macroscopic correlations between remote objects;
5. QM generates rapidly rising intricacy, far exceeding humans' present calculational capacity, as a system's size increases;
6. As a result, QM fails to predict the energy levels of multi-electron (even 2) atoms (its explanation of the periodic table is invalid).

### 4.1.1 DUALITY

From a philosophical viewpoint, the theory of **matter-waves** has contributed greatly to the ruin of the atomism of the past. Originally, de Broglie thought that a real wave (i.e. one having a direct physical interpretation) was associated with material particles. In fact, the wave aspect of matter was formalized by a wave function, defined by the Schrödinger equation, which is a pure mathematical fiction having a probabilistic interpretation, without the support of real physical elements. This wave function gives an appearance of wave behavior to matter, without making real physical waves appear. However, until the end of his life, **de Broglie** returned to a direct and real physical interpretation of matter-waves, following the work of David Bohm. The de Broglie-Bohm theory [92] is today the only interpretation giving reality status to matter-waves while still maintaining the predictions of quantum theory. However, Bohm has a particle **and** its own pilot-wave moving together in a co-operative manner, so there is no ontological contradiction. The present theory extracts one feature from their theory: every electron is being influenced by the rest of the universe (non-locality).

The logical problem with associating a **real** wave function with the **existence** of a particle is that these two concepts are 100% diametrically opposed to each other. The key characteristic of the particle concept is that it exists only at **one** specific location in space at any one time, while the wave or field concept is defined to exist at **all** points in space at any **one** time. Even the introduction of probability concepts does not help resolve this 'paradox' of existence. Existence rejects doublethink. Ontology is not an option.

Useful insights can still be reached by studying Dirac's Preface to the first edition of his masterpiece on quantum mechanics. Dirac defined the classical tradition in physics [93] as one where "*the world was an association of observable objects moving about according to definite laws of force, so that one could form a **mental picture** in space and time of the whole scheme*." Once again, this slips in the hidden assumption of **Positivism**: only what humans observe exists; a viewpoint that does not apply to modern biology where all kinds of enzymes and tiny molecules are posited as present in cells to keep them alive. It is certainly true that human observations are a primary source of information for our visible imaginations but not exclusively. Dirac, like many of his contemporaries, could not imagine how a real entity could behave as both a widely dispersed wave and as a localized particle, so he retreated into mathematical mysticism. As an avowed atheist, he spoke of Mother Nature creating her fundamental laws controlling "*a substratum of which we cannot form a mental picture without introducing irrelevancies. The formulation of these laws requires the use of the mathematics of transformations*." It is surely not a coincidence that when mathematicians apply their talents to mapping the world, they find that the current developments in mathematics just provide the exact right tools. Dirac's faith in his own mathematics was manifest in his second paragraph where he believed that "*Further progress lies in the direction of making our equations invariant under wider and still wider transformations*". It was a wiser (and sadder) Dirac that looked back near the end of his life and acknowledged how little progress had been made in theoretical physics from pursuing this scheme for nearly 50 years. In the meantime, theoretical physics had been "*built up from physical concepts which cannot be explained in terms of things previously known to the [physics] student, which **cannot** even be explained adequately in words at all*." This divorce of the imagination, while relying 100% on mathematics, has to be seen as a major contributor to this embarrassing failure of so many thousands of minds dedicated to understanding the world. Dirac even admits that: "*All the same, mathematics is only a tool and one should learn to hold the physical ideas in one's mind without reference to the mathematical form*." He never suggests where in the mind, these physical ideas should be stored when both words and the imagination fail them. QM will never be understood if one accepts the Positivist philosophy.

Bohr and Heisenberg tried to hide their confusion by calling it the ***Principle of Complementarity***, which holds that no set of classical physical concepts can simultaneously refer to all properties of a quantum system. For instance, wave description *A* and particulate description *B* can each describe quantum system *S*, but not simultaneously. The specific aspect will reflect the nature of the experiment being undertaken to measure the property, each will require the **language** of classical mechanics. It is sometimes proposed that complementarity arises from the non-commuting property of the operators that describe quantum objects but this quantum rule is just one possible starting proposition for QM; in fact, it is traceable to the universal assumption that the complex form of plane waves is always a valid decomposition of any wave function.

### 4.1.2 REMOTE CORRELATIONS (EPR)

The assumption of superposition of states has implied that groups of atomic scale systems can become "**entangled**". In these situations, the knowledge of the state of one component of these correlated systems leads humans to be aware of values of properties in other components of the entangled set, such as in a disintegration pair. This might occur even when these components are so far apart that information would have to travel at superluminal speeds (above that of light) and then this would contradict the special theory of relativity. The first paper that raised these issues was authored in 1935 by Einstein, Podolsky and Rosen [68], so this is sometimes called the *EPR Paradox*. They showed that QM predicts non-locality unless the position and momentum are simultaneously real properties of a particle, which QM claims cannot be observed. Einstein always wanted locality in physics so that systems could be isolated; this was always assured when using local field theories. This is only a paradox for Positivists, who conflate epistemology with ontology. Simultaneous knowledge of an electron's position and momentum is never needed, so does not have to be measured. Even Heisenberg never needed this information. Only the energy schemes (Hamiltonians) used placeholders for the electron' s position and momentum in their starting equations but any and every compatible pair of values (along an orbit) would be quite sufficient. Throwing out the existential concept of a particle seems far too radical a step for a rational scientist.

The EPR paper was soon expanded in a satirical paper by Schrödinger [94] that is now called simply "**Schrödinger's Cat**". Einstein could not stomach this style of interaction and derided it as "*spooky action-at-a-distance*". Experiments in the 1970s [95] and 1980s [96] both demonstrated that QM's predictions were verified and this contradicted the idea of **local** realism, where an object can only be influenced by its immediate (local) surroundings. These mathematical predictions were ignoring the fact that real electrons cannot ever be isolated from each other and these electromagnetic influences will occur at all times and cannot be predicted, measured or ignored; particularly when only statistical averages are calculated. The present theory views these EM interactions as **non-local**, i.e. operating at all distances, in contrast to Maxwell's theory, who also had a hidden religious motivation to reject the non-touching idea of far action.

### 4.1.3 QM TEMPORAL CONTRADICTIONS

#### *4.1.3.1 God's View*

Much of the confusion around the subject of observation can be traced to the religious views of the founders of classical mechanics (CM). Their view of the cosmos was that of the universal God, who could see everywhere (i.e. all of space) at **one** instant of time. This led to the introduction of the one-dimensional parameter (usually written as t) that appears every-where throughout CM. It is interesting that most formulations of CM pay no attention to the results possible at a particular time but either look at averages (often over a complete cycle, in periodic systems) or integrate the t parameter away over a large (often infinite) range of values. God's View was also implicit in the timeless definitions of geometry, constructed as nearby imagery: all seen in **one** glance.

#### *4.1.3.2 Wave Function is not Time Sensitive*

The one particle wave function $\psi[\underline{x}]$ is purely statistical; it is the frequency-measure that the particle will be found 'near' the location referred to as $\underline{x}$, when the experimental setup is repeated at many, different times. Thus, the time dependent version $\Psi[\underline{x}, t]$ cannot be viewed as a probability for existence at a specific time t, which is considered to be 'evolving' over time to a nearby later time $(t+\Delta t)$. This implies that the 'evolution' parameter, "t" is actually not the human concept called "time", but rather a "**sampling index**" to the multiple measurement experiments.

#### *4.1.3.3 Discontinuous Interactions*

Since both Heisenberg and Schrödinger were implicitly thinking about continuous objects, they both automatically fell back on the venerable tradition, established by the founders of classical mechanics, that the world can be described by the tiniest variations, either in time or nearby in space. This continuity assumption then leads directly to the use of analytical **calculus**, even though this is far below the threshold of experimental verification. Worse, only the assumption of mathematical fields brings in the use of **partial** differential operators ($\partial/\partial x$) while real changes over time only invoke the **full** derivative ($d/dt$).

This issue is elaborated on further below (§4.1.8.2) in the sub-section on *Analytical Mechanics*.

#### *4.1.3.4 Velocity never Instantaneous*

The concept of **momentum** has been embedded in classical physics since Newton made this revolutionary suggestion in the *Principia* but hiding behind this central concept is the deeper assumption of continuous velocity **defined** at every moment, as required by the calculus. The definition of velocity V[t] at a **single** instant of time t is actually only a **mathematical abstraction**. It does **not** correspond to **any** possible human **measurement**; it is a 'limit' definition from either above $V^+[t]$ or below $V^-[t]$, where:

$$\underline{V}^{\lambda}[t] \;=\; \underset{\Delta t \to 0}{\text{Limit}}\ \{(\underline{x}[t + \lambda\, \Delta t] \;-\; \underline{x}[t]) \,/\, \lambda\, \Delta t\} \quad \text{where } \lambda \;=\; \pm 1 \text{ (above **or** below) .}$$

This is an extrapolation of a macroscopic definition of velocity when the separations in space and time are **both finite**. In fact, at the electron level, there is **no evidence** that velocity changes continuously ($\underline{V}^{\lambda}[t] \to \underline{V}[t]$); this has just been assumed because this was an adequate approximation in classical mechanics (CM), where periodic intervals were even measured in years. Even more sinister, is the assumption that the instantaneous momentum is a well-defined component of the classical and (therefore) quantum state. This assumption needs a very strong experimental confirmation because real atomic physics studies systems, at such small spatial scales, that tiny differences in time intervals become significant. Reality does not require that an electron has numerical values for all its properties at every instant of time (i.e. continuously, or all t) but only at those unique moments when an interaction occurs ($t_\mu$). This difference illustrates the deeper metaphysical assumptions being made about the very nature of material interactions: physics has had over 300 years to investigate the Continuum Assumption and has reached an impass at the quantum level, where discreteness seems appropriate. Fortunately, with CM the dimensions of space and time are so large that the tiny time differences can be readily ignored. This reinforces the ontological precedence to a particle's **position** so that momentum is **not** on an equal footing, as is usually assumed in QM.

#### *4.1.3.5 Complementary Variables*

Implicit in the idea of two complementary properties $P_1$ and $P_2$ is the observation that their definitions are intertwined; in fact, usually the definition of $P_2$ requires $P_1$; i.e. defn[$P_2$] = fn[$P_1$,etc.]. The most obvious pair are the position $\underline{X}$[t] and the momentum of a point particle $\underline{P}$[t], which is defined in terms of the particle's instantaneous velocity $\underline{V}$[t], which is itself only defined in terms of infinitesimal differences of position in time (see above), even though, in **practice**, $\Delta t$ never goes to zero. So, measuring $\underline{X}$ and $\underline{P}$ requires **two** events to measure X with the second one being influenced by the first, illustrating how human measurements 'mess' up the micro-world.

### 4.1.4 CALCULATIONAL DIFFICULTIES

Since the intricacy of a quantum system is exponential, it is difficult to derive classical approximations. Worse, no one has yet produced general analytical solutions in classical or quantum systems involving 3 or more point components that are all interacting via instantaneous, continuous forces [97] - the infamous **Three Body Problem**. Since this has been assumed to be the case in all real atomic systems, it is not surprising that no real progress has been made at the atomic scale. This challenge will be taken up directly in the next paper in this series, with analytic models of helium and $H^2$ molecules. Three **quarks** forming a proton is never discussed from this view.

### 4.1.5 PERIODIC TABLE EXAGGERATIONS

#### *4.1.5.1 Periodic Table Overview*

The periodic table is a tabular arrangement of the chemical elements, presented in order of increasing atomic number (the number of protons in the nucleus). The standard form of the table consists of a grid laid out in 7 rows and 18 columns, with a double row of elements at the bottom. The Russian chemist, Dmitri **Mendeleev** (1834-1907) is credited, in 1869, with the publication of the first widely recognized periodic table. He developed his 'short' version to illustrate periodic trends in the properties of the then known elements. The current 'long' version is attributed to the American chemist, H. G. Deming who created this standard version in 1923. A group (or family) is a vertical column in the table; elements in the same group tend to have a shared chemistry and exhibit a clear trend in properties with increasing atomic number.

The periodic table is currently explained by the Bohr-Sommerfeld atomic model and '*confirmed*' by the wave mechanical model of the hydrogen atom. Schrödinger visualized the motion of the electron in the hydrogen atom as being governed by a system of generalized 3D de Broglie waves surrounding the atomic nucleus, whose shapes and vibration frequencies were determined by the fields of electric and magnetic forces. How these 3D waves were redirected at points of interaction was never explained. Whereas, in Schrödinger's picture the emission of a spectral line with the frequency $f_{nm}$ was considered a "co-operative result" of two vibrational functions $\psi_m$ and $\psi_n$; in Heisenberg's model the same spectral line was emitted by a virtual oscillator vibrating at this frequency. Schrödinger's generalization was statistical and was not approved of by de Broglie, who said: "*the particle must be the seat of an internal periodic movement. The statement that it must move in a wave in order to remain in phase with it, was ignored by the actual physicists, who are wrong to consider a wave propagation without* ***localization of the particle****, which was quite contrary to my original ideas*." Even radical innovators can be ignored.

It was actually chemists who first emphasized that atoms and molecules (with an even number of electrons) were more chemically stable than those with an odd number of electrons. Gilbert Lewis proposed the stable eight-cornered cube [98] as the most stable arrangement of electrons as early as 1916. Soon after, in 1919, the chemist Irving Langmuir [99] suggested that the periodic table could be explained if the electrons in an atom were connected or clustered in some such manner. Groups of electrons were thought to occupy a set of electron shells about the nucleus. These ideas were adopted in 1922 by Bohr in his own atomic model when he assumed that certain stable numbers of electrons (2, 8, 18) corresponded to stable "closed shells": ($2n^2$). The principal quantum number (*n*) characterizes every atom in the same *shell*, which is then identified with the same row in the table. Electrons are added to the row by using the secondary quantum numbers $\ell$ and *m.* When all possible secondary numbers are used, then the period is complete and the shell is said to be: '*filled*'. Extra electrons added to the next shell are referred to as *valence* electrons and are believed to be totally responsible for the atom's chemical behavior. Each shell is composed of one or more subshells, which are composed of atomic orbitals. Each of the subshells are labeled "nQ", where Q uses a letter derived historically from X-ray studies, with s (sharp, $\ell = 0$), p (principal, $\ell = 1$), d (diffuse, $\ell = 2$) and f (fundamental, $\ell = 3$). The second shell has two subshells (2s and 2p), the third shell has three subshells (3s, 3p and 3d) and the fourth shell has four subshells (4s, 4p, 4d and 4f). Each subshell can hold up to $2(2\ell + 1)$ electrons; this is interpreted as the values of the magnetic quantum number *m* for the same azimuthal quantum number $\ell$. Bohr is often credited with this shell model but the key idea was provided by Sommerfeld's student, Walther Kossel in 1916, when he dismissed Bohr's 'pancake' model for a 3D arrangement of shells, filling at Z=2, 10, 18, 36, 54 and 86.

There are two well-known problems with this scheme. Firstly, the Bohr model (based on the hydrogen atom) predicts that the speed of the electron in the 1s shell is $Z\alpha c$, where $\alpha$ is Sommerfeld's fine structure constant ($\alpha = 1/137$), so that when Z is greater than 137 this electron would be moving faster than the speed of light, *c* although the maximum to date is Z = 118. Secondly, the relativistic Dirac equation approach to the hydrogen atom also has problems with elements with more than 137 protons. For such elements, the wave function of the Dirac ground state is oscillatory rather than bound with forbidden overlaps between the positive and negative energy states. For heavier elements, with large nuclear dimensions, the powerful electric field of the nucleus can generate a vacuum fluctuation resulting in the spontaneous emission of a positron. There is actually a third problem that is known only to *aficianados*, but not to most physicists, in that the fourth period does not correspond to completely filling the *n* = 4 shell. It only fills the three subshells (4s, 4p, 4d) and completes this period with the 3d, not 4f subshells. The critical problem is that measured atomic sizes [100] do not follow the Bohr model but seem to be almost approximately the same size (~ 200 pm).

The exact solution of the hydrogen atom, with one electron, gave physicists an excuse to over-generalize the solution to other atoms with two or more electrons as just combinations of the hydrogen atom wavefunctions. Ironically this approach gave a reasonable conceptual approach because the hydrogen atom's solutions involved spherical harmonics and these form a **complete set**: this means that any 3D shape (continuous function) can be represented by a valid, weighted sum of such functions (the 3D equivalence of the 2D Fourier analysis that lies at the heart of QM). This approach [97] even worked quite well (numerically) for the two-electron helium atom energy levels but failed utterly with atoms consisting of three or more electrons (the infamous **3-body problem**). Even in the case of helium, all interactions between the several electrons in a single atom are completely ignored, although sometimes two orbiting electrons might be even closer than the electron-nucleus separation. The spherical harmonic 'solution' still needed to justify why only an even number of electrons could occupy one "shell". The Exclusion principle does give an accurate prediction of the number of electrons in each "shell".

## 4.1.6 THE EXCLUSION PRINCIPLE

Pauli began looking for an explanation for this major constraint, as well as the Anomalous Zeeman Effect. He soon realized that the complicated numbers of electrons in closed shells could be reduced to the simple rule of *one* electron per state, if the electron states are defined using **four** quantum numbers, with a fourth number s, corresponding to the two valued quantum number. These proposals were formalized by Pauli in 1925 in his overly long entitled paper in *Zeitschrift* [101]. This now meant that if a 'shell' were characterized by the same principal quantum number, *n* then the number of electrons in each closed shell was $2n^2$. He went further and then proposed that each electron always had two values, regardless of whether the atom was in a magnetic field. Pauli could then explain the Periodic Table by imposing the rule that no two electrons can occupy the same shell with the same quantum numbers. The key insight came in 1925, when Pauli had his 'spin break-through' (see next); this allowed each of the $\{n,\ell,m\}$ states to be filled with exactly two electrons (m:spin 'up' and 'down') providing an "explanation" for Kossel's shell numbers ($2n^2$). Few people realize that this explanation is based purely on an analysis of the investigations of the simple hydrogen atom, whether this is the Sommerfeld model or the equivalent results obtained from the wave mechanical model. In each case, the levels of the hydrogen atom are filled with "inert" electrons, or rather 'special' electrons that **only** interact with the positive charges existing in the nucleus but **not** with each other. Again, Bohr formalized this assumption by naming it the *Aufbrau* principle. No EM interactions between any of these orbiting electrons **are allowed** (by decree); indeed, not even the simple two-electron helium atom has been solved analytically. It is simply assumed that these hydrogen atomic levels will remain unaltered when more electrons are added to form the more complex atoms. One of the safest ways to get a guess accepted in physics is to call it a 'principle'. It is the scientists' closest approach to passing a Law.

In reality, **any** motion of **any** of these "shell" electrons can be represented mathematically by a suitable, weighted **sum** of functions drawn from a complete set of 3D spatial functions (i.e. Fourier analysis). This is true for the spherical harmonics that "pop out" of the single-electron wave function hydrogen atom using only Coulomb's electrostatic interaction between a single orbiting electron and a single proton. This was actually the approach used by Hylleraas [97] when he claimed to have "solved" the helium atom problem. This example of claiming a major victory when confronted by a major problem is not worthy of the truth-seeking claims of science but can be a useful political strategy when physicists want to move on to more interesting challenges, as they did with subsequent nuclear investigations. Moving on, means never having to sweep one's problems 'under the rug'.

The **Exclusion principle** has now become the QM rule that no two identical fermions (particles with half-integer spin) may occupy the same quantum state simultaneously. An alternative wave mechanical statement is that the total wave function for two identical fermions is anti-symmetric with respect to exchange of the particles. For example, no two electrons in a single atom can have the same four quantum numbers; if $n$, $\ell$, and $m$ are the same, then the spin number $s$ must be different such that the electrons have opposite spins. This principle suffers from the same critique as applies to the periodic table. Note that integer spin particles (or bosons), are not subject to the Pauli exclusion principle: any number of identical bosons can occupy the same quantum state, as with, for instance, photons produced by a laser and so-called Bose-Einstein condensate. This reflects the fact that there are no restrictions on the number of interactions between electrons over any finite time duration in the standard QM theories.

#### *4.1.6.1 Ignoring Electron Interactions*

The one major problem that is rarely mentioned today (but was well-known to Bohr) is that all of this "shell modeling" is based only on the single-electron hydrogen atom, as **no** accurate models of more complex atoms have **ever** been created. All these solutions ignore the effects of powerful mutual repulsive electromagnetic forces between all these electrons that were assigned to the single-electron hydrogen-atom scheme that is all that has ever been fully analyzed by Bohr or the 'comprehensive' quantum mechanics. The infamous **3-body** problem has sunk all attempts to sail beyond the safe harbor of the one electron model. All such complex atomic models would have to incorporate the massive inter-electron interactions that exist in a single atom when many electron orbitals are present, if the standard view of electromagnetism (or even just Coulomb's electrostatic law) was to be included.

#### *4.1.6.2 UET View of the Exclusion Principle*

It should be noted by now that QM has continued the ancient tradition (going back to medieval times) of what is now being called "Principle Physics". In this style of metaphysics, a universal rule (or **principle**) is proposed that applies universally to all matter, at all times and in all circumstances. This approach can trace its roots to Ancient Greek philosophy, as it was reconstituted by medieval theologians, such as Aquinas. This is the quintessential 'rationalist' approach, where rules-of-the-world first appear in someone's mind and are then conceived to be universal. At the very least, this approach lends itself well to their translation into mathematics, where **First Principles** have long been held to be enshrined since Euclid. As a mathematician of extra-ordinary power, Wolfgang Pauli was adept at introducing new principles into quantum physics. One of his most successful was the so-called Exclusion Principle. It was critical to the early success of QM in providing an '*explanation*' for the Periodic Table of elements and even atomic stability. As is known to some students of QM, this was an *ad hoc* imposition to compel only one electron to 'occupy' one quantum state at a time, even though the key concept of *state* was never clearly resolved. This principle was given its mathematical form immediately by Pauli, who decreed that all quantum wave functions must be anti-symmetric, when the variables corresponding to two electrons are exchanged. This was a very useful constraint on quantum *recipes* but did not provide much insight, particularly as it only applied to so-called *fermionic* particles. However, the present theory abolishes all non-fermionic particles (also known as bosons) as no more than the real interactions between electrons, in what ultimately will be shown to be a *Universal Electron Theory* (**UET**). In the present case, the Exclusion Principle will be shown to be the result that two electrons cannot share the same sub-atomic orbital for more than one instant of time if their interactions are to satisfy the constraint of the finite exchange of one quantum of action. As will be seen, the UET does not feel constrained to abolish the intrinsic concept of a **trajectory** when discussing the dynamics of electrons, even though Heisenberg tried to remove this ancient corpuscular idea, *by decree*. Indeed, this was at the heart of Einstein and Schrödinger's objections to Heisenberg's revolutionary use of matrix mechanics to calculate 'observables' in atomic systems. The idea that below a certain scale of reality, the concepts of space and time were to be abolished seemed utter nonsense to them (and us). Meanwhile, wave mechanics drew in its armies of supporters, even though it retained classical particle ideas of Hamiltonians, angular momentum and energy.

### 4.1.7 ELECTRON SPIN

As spectral analysis techniques improved it became obvious that the spectra of some atoms (especially, alkali metals, such as sodium) were too complicated to be explained by either Bohr or Sommerfeld's theory or even the initial form of wave mechanics. In the alkali spectra, the principal lines were doublets that could not be explained by the three quantum numbers $n$, $\ell$, $m$ that defined orbitals or QM states. Wolfgang Pauli spent much of 1925 thinking about these anomalies; like his mentor and idol, Sommerfeld, Pauli was fascinated by integer **numerology** so he sought a solution around the number **two**. Pauli wanted a new two-valued property that eventually became known as electron "spin". The spectra of alkali atoms could be predicted from the lone electron and the core shells could be ignored.

Ironically, when Pauli sent a draft of this new 'Exclusion' paper to Heisenberg and Bohr [102] it was rejected with scorn, as "*every one knew that only 3 quantum numbers were needed to accommodate the* ***three-dimensional*** *nature of space*." Although Bohr characterized this suggestion as "*complete insanity*"; in this case, he was implying that it was probably right. A young, visiting German-American physicist, Ralph Kronig suggested that this new two-valued property could be interpreted as the rotation of the electron itself around its own axis of travel. Initially, Pauli dismissed Kronig's suggestion because the circumference of such a 'spinning top' would have to exceed the speed of light and thereby contradict Einstein's special theory of relativity. However, two young Dutch theorists soon came up with a similar idea of electron spin but they went ahead and got international fame for publishing their daring idea - relativity be damned. It must be noted that Pauli's focus on two-values for the electron's spin was really *ad hoc*, there was no deep reason for this (it could have been 3, 5, etc.) but 'two' fitted the experimental data - this is the modern form of numerology ("it just works"). The early pioneers of the spin concept saw it only in terms of self-rotational motion around its longitudinal direction of motion, like orbital angular momentum $\underline{L}$ around the nucleus. Since $\underline{L}$ had been found to be quantized, an integral number $\ell$ of units of angular momentum $(h/2\pi)$; i.e. $\underline{L} = \ell\,(h/2\pi)$ , then spin $\underline{S} = \pm 1/2\,(h/2\pi)$. As Landé suggested, these two vectors could be combined to form total angular momentum, $\underline{J} = \underline{L} + \underline{S}$, which solved the doublet problems. The present theory offers an additional interpretation of electron spin in terms of the time-direction ("**tirection**") of the interaction between electrons (the fourth dimension for the fourth quantum number).

## 4.1.8 QM - STILL BASED ON CLASSICAL PHYSICS

### *4.1.8.1 Invisible EM Radiation*

The problems of QM illustrate the difficulties in the evolution of physics when new phenomena arise that threaten long-held theories. The major problem facing early physics was to understand the nature of light. This led to bitter "theory wars" with rivals proposing particulate and wave theories. This was the core of our previous paper [6]. The wave theorists were very pleased when Maxwell's mathematical theory of electromagnetism finally appeared to offer a total solution to these challenges. As a result, there has been an implicit commitment to make Maxwell's EM theory an inviolable core of all future physics. The discovery of the particulate electron has threatened this dominance, as Maxwell very clearly built his theory on the reality of a continuous **æther** [2]. Even when this ancient concept was discarded [4] it was replaced with Helmholtz's proposal that electricity was grounded in a <u>continuous charge distribution</u>: a model now referred to as Classical Electromagnetism (**CEM**). Unfortunately, electrons have always been found to exist as **point** particles with no finite size and certainly not diffused across all of space even though some interpretations of QM wish to "smear" these electrons over small volumes of space. The present programme suspects that it is this contradictory attempt to hold on to the old (CEM), while recognizing the new (electrons), that has led to the difficulties of QM. This programme believes that understanding the quantum behavior of the electron is not helped by introducing an invisible, **fictitious** intermediary (*photons* or EM radiation) that links the activity of the source electron with the induced activity of the remote 'partner' electron. This was the solution to the problems of ***light*** presented in the previous paper on Quantum Optical Mechanics [6]. In the competition between the electron (facts) and QM (mathematics), this programme is betting 100% on the reality of the electron; this is why a new theory of electromagnetism was created.

### *4.1.8.2 Analytical Mechanics*

Bohr was convinced when he attempted to construct a model of the hydrogen atom that he could <u>not</u> use classical physics. He bravely rejected the use of Maxwell's EM theory in defining his stationary states and the transitions between them. Bohr, nor any physicist since, has been brave enough to reject the very foundation of classical physics - namely analytical mechanics: the use of the calculus to describe the dynamical changes of objects over time. Thus, even in Goldstein's famous graduate textbook on classical mechanics [103], **calculus** is used throughout. Even when relying on Newton's Third Law of Motion, Goldstein omits the temporal arguments of his internal action and reaction forces between pairs of particles, leaving them to operate, in a simultaneous or timeless manner. This allows him to eliminate them from consideration and progress with the traditional approach to the **rigid body**. No mention is made of this assumption, probably because the assumption of <u>simultaneity</u> pervades all of classical mechanics (CM) and allows the mathematical analysis to move smoothly forwards. CM seems to have been developed as an exercise in applied mathematics; more educational than a method to understand reality. Physicists like to think they defined the modern world; engineers know better.

### *4.1.8.3 Continuum Assumptions*

A few moments thought by anyone familiar with CM and QM will show that several key <u>Newtonian</u> ideas have been smuggled into QM; these include:

1) Continuous interactions ('force') 2) Instantaneous Velocity (temporal derivative) 3) Potential energy (spatial derivative).

Obviously, differential **calculus** plays a key role everywhere but there are other 'Old' Assumptions brought unquestionably into QM:

| | | | |
|---|---|---|---|
| 1) Universal (single) time | 2) Addition of Forces | 3) Local Interactions | 4) Isolatable Systems |
| 5) Energy as existent | 6) Energy transfers ("Radiation") | 7) Vacuum as Medium | 8) Fourier Analysis. |

In reality, all such interactions in real matter are dominated by electromagnetic interactions, which always require a **finite** time to act between the pairs of charged particles. This fact is critical when dealing with electrons, as in all atomic systems, since the low mass electrons react dramatically to even the smallest EM impulse. This means that classical mechanics is, at best, a theoretical exercise that only bears a statistical relationship to reality. These approximations were quite adequate for problems involving astronomical objects where the numbers of electrons runs into trillions upon trillions, while system time periods were also measured in billions of seconds; but this is not the case with atomic systems where a new form of electron dynamics is needed (§3.1.6.1). The present research programme addresses these issues: head on. **Finite** properties and changes are anticipated throughout this level of reality and finite mathematics, not calculus, is used to describe these systems. Newton's particle idea with invariant discrete mass is retained in the UET.

### *4.1.8.4 Semi-Classical Mechanics*

Alisa Bokulich, a professor of the philosophy and history of science at Boston University has written a book [104] that deserves much wider circulation. This book explores the mesoscopic idea of Semi-Classical Mechanics (**SCM**) and presents challenging evidence that imagining that the electron follows actual trajectories (contra the Copenhagen decree) provides surprisingly useful results. In particular, this approach has created a very good solution [105] for the **helium** atom (while offering new physical insights into the dynamical structure), understanding the spectra of highly excited atoms (including hydrogen) in very strong magnetic fields (**Rydberg** Atoms) and analyzing systems that are modeled as "quantum billiards", enclosed in stadium-shaped enclosures (*chaotic* systems).

QM **cannot** solve these problems and has to rely on the **W**entzel, **K**ramers and **B**rillouin (WKB) approximation method [106] that is actually closer to the original Bohr model than the later wave-mechanics techniques. Indeed, Kramers showed how this method ties back to the Wilson-Sommerfeld quantization rule, as long as the integer parameter (n) was extended to a half integer condition (n + 1/2) *h*. In 1958, Keller extended this approach, again by incorporating Einstein's 1917 generalization of the old quantization rule, so that this (**E**instein, **B**rillouin and **K**eller) EBK approach [107] could be extended to integratable, non-separable systems; a goal even wave mechanics never achieved; once again exposing the **very limited** range of conventional QM (Wave Mechanics).

Exciting, but little known results of SCM have been found in analyzing the spectra of so-called *Rydberg* atoms [108], where the outermost electron has been brought to a very high energy level. These atoms are almost as large as a fine grain of sand. When these atoms are exposed to strong magnetic fields, new generations of "anomalous" Zeeman spectra are produced (even above the ionization limit). These **defeat** all analysis [109] using standard QM techniques: "*The explanation of these new anomalous resonances seems to be intimately tied to the fictional assumption that these Rydberg electrons, instead of behaving quantum mechanically, are following definite classical trajectories.*" The key is to focus on stable **closed orbits**, for deep insights into complex QM systems (contra Heisenberg's Uncertainty Principle).

The experts in the SCM techniques are amazed at the accuracy of their results but still function in awe of 'Pope Bohr' and 'Cardinal Heisenberg' by hesitating to claim that their electrons are actually following classical trajectories. They do say [110]: "*When we speak of the '**classical trajectory** of an electron', we mean, of course, the path the electron would follow **if** it obeyed the laws of CM.*" They hold back because they cannot predict the electron positions as a function of time. However, this would involve interfering with these atoms to determine initial conditions; something that does not need to be 'observed'. This reluctance to suggest CM orbitals will **not** be copied here, even if this course leads to a rejection of the foundational mathematics of QM; sometimes rejection enriches the imagination.

## 4.1.9 STILL JUST MATHEMATICS

The greatest criticism of QM is that it is **only** a mathematical theory for making predictions: the modern version of Ptolemy's theory of planetary cycles, which lacked any awareness of the real, actual elliptical trajectories of the planets. This mathematical obsession is not surprising when one learns about the careers of many of the QM pioneers and the overlap (above) between CM and QM methods.

### *4.1.9.1 Mathematical Physics*

As a theoretical physics student [111], **Schrödinger** mastered the pre-World War I "bible" of mathematical physics (Riemann and Weber's *Partial Differential Equations of Mathematical Physics*). From his earliest theoretical research, Schrödinger had "*displayed superb mathematical facility combined with a lack of insight into the physical realities of the problem*." In his first wave mechanical paper, Schrödinger tried to put a "vibrational" interpretation on his equation but soon retreated to his earlier mathematical exposition. He ended that paper with the remark: "*We don't know for sure that these results may be merely a rehash of conventional (i.e. Heisenberg) quantum theory*." Schrödinger tried to recover the continuum results of classical mechanics by interpreting Bohr's frequency rule as 'beats' between high frequency fluctuations; he preferred this to the image of "jumping electrons". In his second wave mechanical paper, Schrödinger wrote that classical mechanics fails for very small dimensions and for very great curvatures. He suggested that the particle of a mechanical system must thus be represented by a wave group with small dimensions in every direction (i.e. a "**wave packet**") when the spreading of the waves is negligible compared with the length of the path in the system, (i.e. $v = V_G$) when there is a coalescence of waves with the same phase. The true mechanical process is represented by the wave patterns, not the 'mechanical particle'.

Schrödinger still claims: "*No special meaning is to be attached to the electron's path itself and still less to the position of an electron in its path*." He even felt that: "*This contradiction has been so strongly felt that it has even been doubted whether what goes on in an atom can be described within the scheme of space and time*." This programme (UET) strongly rejects **all** these conventional viewpoints of mathematical theorists.

### *4.1.9.2 Conflicted Thinking*

Schrödinger insisted (even to Lorentz) that the psi function was real, not appreciating that complex numbers were key to the unobservable phase information of this function. Schrödinger soon de-emphasized the wave packet picture, acknowledging that the quantum harmonic oscillator was a special case, where the unusual equidistant energy levels prevent the waves from spreading out across space. In his fourth paper [56] in June 1926, Schrödinger finally admitted that the wave function must be complex, just like Heisenberg and Dirac, who had to introduce the complex number (*i*) into their quantum commutation rule. Indeed, it is just this **phase** factor that is the source of all quantum interference effects, since exponential multiplication is equivalent to addition of phase factors (see §3.3), while complex exponentials re-invoke the implicit Fourier analysis involved. It also hints that it is "time" that drives quantum activity, not some mysterious rules of algebraic multiplication.

Even though the mathematics of QM, as developed by Schrödinger and Heisenberg, were shown to be equivalent, their basic physics was very different. Wave mechanics focused on a model of a single electron's canonical states, each one found with energy $E_n$, while Heisenberg explicitly modeled the transition between **two** electron states, with energies $E_n$ and $E_m$. It was only the calculation of dipole results in wave mechanics that showed no radiation could be emitted from stationary states but Heisenberg was quite happy to accept Bohr's postulate that this was the case. Both methods were quite happy to ignore the role of third-party electrons that remotely interact with the electron in a simple hydrogen atom, even though these remote electrons are critical to the detection of 'radiation' in all measurement schemes. These 'third' electrons lie at the very heart of human observations of all quantum systems.

Schrödinger and Heisenberg continued to slam each other's physical interpretation, using accusations like "*monstrous*" or "*abominable*". Older physicists (like Wien) locked into analytic approaches, hated the idea of quantum jumps but had no explanation for the photoelectric effect or blackbody radiation. Einstein, as a committed field theorist, always preferred the wave mechanical approach, as when he wrote [113] to Schrödinger: "*I am convinced that you have made a decisive advance with your version of the quantum condition, just as I am convinced that the Heisenberg-Born method is misleading*." Not only was it "misleading" but stillborn with no calculations to its credit.

### *4.1.9.3 QM assumes Positivism*

Hiding behind the mathematics of the originators of QM in 1926 was the philosophical theory of **Positivism**, which had taken the position where only what could be measured by humans, was to be considered real. This made this version of QM a **theory of measurement**, not a representation of reality. Positivism must be seen as philosophically arrogant that Earth (our planet) was located at the center of the universe but now this is elaborated to a point where **humans are at the center of all existence**. QM is also grounded in the ancient philosophical tradition of **Pythagoreanism**, the idea that number is the final foundation of everything; or in its modern version of **Platonism**: mathematics is the best (only?) description of reality: a view well accepted by most mathematicians.

### *4.1.9.4 Waves flow through*

The collision of two particles always exhibits the conservation of linear momentum while **altering** each but waves are readily seen passing through each other with **no effect** on either one. Experiment thus favors the primacy of real particles over theoretical waves.

### *4.1.9.5 Dirac's Objective*

In writing his famous textbook [60], Dirac went to great lengths to establish a sound mathematical foundation for QM; however, in the end, this huge effort produced little more than the centrality of the phase factors in complex harmonic functions and the differential operators on these functions; i.e. he ended up with Schrödinger's version of wave mechanics.

## 4.2 QM MEASUREMENT

The idea of macroscopic measurement of the target (atomic) system is intrinsic to the mathematics used in QM. The key assumption is that such a repeatable measurement (called an "**observable**") can be represented mathematically by a linear, differential operator **A** corresponding to the **property** A that has a possible set of **real** number values $\{a_n\}$ that are the eigen-values of **A**, each associated with a complex eigenfunction $\psi_n[x]$, through the equations: $\mathbf{A}\,\psi_n[x] = a_n\,\psi_n[x]$. Since the numbers $\{a_n\}$ are real, then the operators **A** must be Hermitian (or self-adjoint). This means that for any two regular functions $\Psi$ and $\Phi$ then the Hermitian operators, like **A** satisfy:

$$\int dx\, \Psi[x]\, (\mathbf{A}\, \Phi[x])^* = \int dx\, \Phi[x]^*\, (\mathbf{A}\, \Psi[x])$$

Where the integrals are taken over **all possible** parameter $\{x\}$ values, usually assumed to be ± infinity.

Since the eigenfunctions $\{\psi_n[x]\}$ are chosen to be a complete **orthonormal** set then: $\int dx\ \psi_n[x]^*\ \psi_m[x]\ =\ \delta_{nm}$

This implies a generalization of Fourier analysis such that any function F[x] can be represented as a linear combination (using complex weights $W_n$) of these eigenfunctions (known as "**linear superposition**").

$$F[x]\ =\ \Sigma_n\ W_n\ \psi_n[x]$$

The final mapping **rule** assumed between this set of mathematics and reality is that since any individual measurement only provides **one** number then the only possible result of measuring an observable A when a system is in a **state** F[x] is one of the eigenvalues of the self-adjoint operator **A** that represent this observable. This further implies that if the system is in the state F[x], then the **probability** that a measurement of A will yield a particular eigenvalue $a_n$ is (frequency interpretation):

$$\text{Prob}[A =\ a_n\ ;\ F[x]\}\ =\ (W_n)^*\ W_n$$

This means that the **long-term** average value, in state F, of the results of **repeated** measurements of an observable, A is:

$$< A >_F\ =\ \int dx\ F[x]^*\ \mathbf{A}\ F[x]\ =\ \Sigma_n\ (W_n)^*\ W_n\ a_n$$

It is important to notice that this key part of the theory **eliminates** explicit time from the theory; QM must then be statistical. Several features should be noted from this scheme. Firstly, all functions are of continuous parameters, like x. Secondly, the Fourier-like expansion of any function, like F[x], involves complex numbers, $W_n$. The Hermitian operators **A** will then end up being represented by continuous, differential operators. In particular, if the position of a single electron at a single point in time is represented by a real, continuous variable, then **X** = x. The QM canonical commutation rule for each electron's momentum must be represented by the imaginary, partial differential operator **P**, where: $\mathbf{P}\ \psi_n[x]\ =\ -\,i\ (h/2\pi)\ \partial/\partial x\{\psi_n[x]\}$

There is one final **rule** that must be introduced when mapping real systems, namely that the energy of a one electron system, with momentum P in a potential U, is represented by the **classical** Hamiltonian (energy) function H, where: $H\ =\ P^2\,/\,2m\ +\ U[x]$ .

The **key assumption** is that there is such a classical system description defined by a timeless function of potential energy U[x]. This is then transformed by substituting the operator forms for the classical linear variables, x and P. It is not a casual coincidence that the **only** two sets of complete, orthogonal functions that are used are simple harmonics (plane waves) and spherical harmonics. Nor, that the **only real world system** that has been solved with all this sophisticated mathematical machinery is the simple hydrogen atom (the analogue of the only real world solvable classical system: the 2-body Keplerian planetary system). Potential energy was invented to eliminate time; it has the very useful feature that it can be defined, so as to be added to kinetic energy for a conserved (time constant) total energy.

Even though there are physical systems whose states cannot be represented by such continuous functions, there is always a precise analogue of the central idea of linear superposition and this is the principal idea of Hilbert vector spaces - the method introduced by Dirac in his radical formulation, where states are represented by **infinite** vectors in this Hilbert space. Even this advanced mathematics still assumes that an experiment can be repeated a large number of times, with the system being assumed to be **in the same state** before each measurement. This then allows long-term average of measured values to be interpreted as relative frequencies. Despite the central idea of superposition, any one measurement only discovers one single value; this is referred to as the 'measurement problem' or the '**collapse of the wave function**' but this mechanism is not made explicit anywhere in the mathematics of QM. Any future evolution of the system **then** occurs according to the time-dependent Schrödinger equation, assuming the system **was** in the state corresponding to the measured value. There is a real need to revisit the interpretation of the 't' parameter in all these equations (see §4.1.3.2).

### *4.2.21 Micro-Macro Theory of Measurement*

This research programme takes the view that QM was the result of an illegitimate alliance between the ancient Platonic view of reality as mathematics and the obsession with anti-metaphysical (especially anti-religious) philosophies of certain modern thinkers, such as exemplified by the Positivists around 1900. Indeed, QM is analyzed here as only a theory of **measurement** and not as a theory of material reality (i.e. physics). This paper was motivated (in part) by the belief that the quantum wave function is only an eigenfunction of measured situations and only represents the microscopic reality of interactions between electrons in an idealized, statistical manner, so that the continuum mathematics, used in physics since 1700, can still be retained. Just as the Earth (since Copernicus) is no longer viewed as the center of the universe, it can no longer be maintained that humans are at the **center of existence** – a position implied by several Positivist interpretations of QM, including the orthodox 'Copenhagen Interpretation'.

### 4.2.1 UNCLEAR ROLE OF OBSERVATION

In most formulations of QM, the term 'observation' is synonymous with 'measurement'. The idea of 'observer' also spans any measurement equipment, so that an 'observable' is a subset of whatever can be measured (i.e. assigned a numerical value). This has led to the idea that "*consciousness causes the wave-function* ***collapse***" where only one of its orthogonal components is selected. The fact that a human being is introduced into the very heart of QM does not imply subjectivism; rather, **any** human is expected to generate the same observed results. Thus, the issue of interpretation of the act of measurement lies at the contentious center of QM. In particular, the orthodox interpretation (called the Copenhagen Interpretation) views all the myriad probabilities as unreal while the **act** of measurement results in a **single** real number. Coupling a system to a larger reality (e.g. a measurement) can generate a set of new possibilities; this is sometimes referred to as "*decoherence*".

### 4.2.2 STATISTICAL INTERPRETATION

Schrödinger assumed that an electron in an atom could be represented by an oscillating charge **cloud** of electricity evolving constantly in space and time according to his wave equation. He did not view the observed discrete spectral frequencies as being due to Heisenberg's "quantum jumps" but due to a resonance phenomena between these clouds. Born was dismissive of these interpretations but still recognized that the wave function $\psi$ needed to be interpreted in terms of probability ideas. He decided that a definite probability corresponds to a "state in space"; this is determined by the de Broglie wave associated with the state. Born was convinced of the reality of this wave process that "guided" the mechanical process. He believed that where the amplitude of the guiding wave is zero at a certain point in space then the probability of finding the electron at this point is vanishingly small. These ideas were analogies from his knowledge of light scattering by small particles. He was convinced that the experimental confirmations of such scattering, with the theoretical calculations, were sufficient grounds for the correctness of the principle [112] of associating wave amplitude with the number of particles (or probability). Born proposed [113] that if $E_n$ is the energy and $\psi_n$ the eigenfunction of such a state, then $\psi^*_n\psi_n\, d\nu$ is the probability will be found in the volume element $d\nu$; with this still being true even if such an experiment, if carried out, would destroy the connection with the atom altogether.

Even though Born correctly criticized Schrödinger's "cloud picture", he goes on to talk about a *density distribution* of the electron in the atom, or of an *electronic cloud* around the nucleus. By this, he means he means "*the distribution of charge which is found when we multiply the probability function for a definite state (mathematics) by the charge e (reality) of the electron*". Indeed, Born used this picture to explain why stationary states do not radiate appealing to a semi-classical model of the electric dipole moment. Nowhere, does he discuss the idea that the whole Hamiltonian equation is based on the classical model of a particle, where **all** the activity is only defined at **one** single point in space at one instant of time, where the Coulomb potential is concentrated on the total charge of the electron there. Physicists are just as likely as any one else to want to "eat their cake and have it, too".

## 4.3 QM PHILOSOPHY - WHAT DOES QM MEAN?

In addition to its failure to go much beyond the hydrogen atom (like the Bohr model), QM has introduced massive problems for physicists in trying to **understand** what all this "mathematical machinery" implies about reality. This section will explore this major area that has resulted in at least a dozen competitive interpretations. Unfortunately, today's theorists now reject any contribution to understanding QM by professional philosophers. This reminds one of the bleak response of medieval theologians to the critical questions raised by their own contemporary philosophers, who (initially) were too ready to propose critical questions challenging the certainty offered by the power of orthodox religion, until they were threatened with an *auto da fé*. Today, educated physicists who question the orthodoxies of quantum theory know they are liable to the extreme penalty of 'professional suicide'. It is not surprising then (as in medieval times) that a general consensus appears to exist between the professionals when viewed by outsiders.

Many of the present problems can be traced to what many physicists regard as one of the triumphs of classical physics: the EM theory of **Maxwell**. By assuming energy was an entity (a real substance) and not a relationship, both Maxwell and Poynting were misled into believing energy was an existent across time - the defining property of each example of an **entity**. This biased their preference for the fluctuation of æther fields across empty space, rather than asynchronous interactions between the real entities of electricity: the electrons. This is why, even today, the EM 4-potential is more useful than the two 3D field intensities ($\underline{E}$ and $\underline{B}$), as it represents the possible (i.e. **potential**) interactions between real electric objects. Maxwell had extensively studied Newton's work but could never follow Newton in his acceptance of the 'particle' as the fundamental object of existence, as this offended his deepest theological beliefs. It is interesting that Dirac was one of the few top theorists to question the validity of Maxwell's electromagnetism throughout most of his professional career; his stellar international reputation amongst physicists gave him the luxury of such unorthodox musings; unfortunately, he still only used Maxwell's Equations and never proposed an alternative.

## 4.3.1 ONTOLOGY & EPISTEMOLOGY

An **interpretation** of quantum mechanics is a set of statements, which attempt to explain how quantum mechanics informs our shared **understanding of nature**. Although quantum mechanics has held up to rigorous and thorough experimental testing, many of these experiments are open to different interpretations. This question is of special interest to philosophers of physics, while many physicists continue to show a strong interest in the **meaning** of QM. The heart of this problem is focused on providing non-mathematical interpretations of such terms as **states** and **observables**. This is the direct result of the 19th century evolution of phenomenological equations in physics where intermediate terms where introduced that were eventually integrated away in deriving results for quantities that could be measured in the laboratory, such as temperature. The key areas of philosophy that are always addressed in this activity are: ontology and epistemology. **Ontology** is the set of metaphysical claims about what **things**, such as entities and their interactions, actually **exist** in the real world. **Epistemology** arose in the 17th Century when it was realized that what humans perceive about the world may be different than the existents; it is now viewed as the set of claims about how humans can and do create **knowledge** of the real world. In the philosophy of science, the distinction of knowledge versus reality is termed epistemic versus ontic, especially when applied to the analysis of phenomena. Much heat is generated in this dispute because mathematicians view **geometry** as the one true model of **proof** and most experimental demonstrations fail to overcome Hume's skepticism about induction. Some philosophers of science have taken the view that scientific theorizing offers a model of scientific **realism**, which is seen to be providing an approximately true description or explanation of the natural world. In this model, even unobservable entities are assumed to exist. Since realists view the objective world as persisting over long time-periods then followers of this view believe they have good evidence for accepting the long-term truth of the statements describing some theories. This philosophy of scientific realism was developed as a reaction to the anti-metaphysical (anti-realist) stance of **logical positivism** that was really a modern re-positioning of mathematics' central role in ancient Platonism. Anti-realists usually put the mind at the center of their world-view and mathematics is seen by them as the quintessential human 'science', while accusing realists of putting their faith in objects that cannot be proven to exist. Thus, a realist stance seeks the epistemic and the ontic perspectives, whereas an antirealist stance seeks only epistemic justification but not necessarily the ontic. John Polkinghorne is one of the few outspoken realists today, perhaps because he has had a long-time interest in theology as well as mathematical physics [114]. Since the 1950s, antirealism has become more modest, evolving into a form now known as instrumentalism, permitting talk of unobservable aspects, but ultimately discarding the very question of realism and posing scientific theory only as a **tool** to help humans make predictions, not to attain metaphysical understanding of the world. The instrumentalist view is conveyed by the famous quote of physicist David Merman, "*Shut up and calculate*", often misattributed to Richard Feynman, who usually agreed with it. The central issue here is the metaphysical disputes about the **nature of reality**. If physicists cannot give a convincing picture of reality, limiting themselves to mathematics, then many common folk will revert to ancient religious views.

The crucial aspect of an interpretation is whether its elements are regarded as physically real. Thus, the bare instrumentalist view of quantum mechanics cannot be an interpretation at all, for it rejects all claims about **physical reality**. This ties back to the central problem of **semantics**: how do symbols relate back to reality? This problem invokes the broader issue of how any aspect of human language is grounded in reality; i.e. the relationship between epistemic and ontic statements.

A QM interpretation (i.e. a semantic explanation of the formal mathematics of quantum mechanics) can be characterized by its treatment of certain, additional matters addressed by Einstein, such as completeness and locality in his *EPR* paper [68]. In this paper, the authors proposed the concepts: *element of reality* and the *completeness of a physical theory*. They suggested that an element of reality is a quantity whose value can be predicted with certainty before measuring or otherwise disturbing it, and defined a complete physical theory as one in which every element of physical reality is accounted for by the theory. This is yet another example of early 20th century physicists forming their philosophy under the influence of Positivism. Even Einstein was stuck in Platonism, emphasizing the **number** aspect of properties that arose in measurements. His final position over-emphasized 'reality' as depending on human measurements (numbers): a very anthropological paradox. Physics then becomes a closed system: mathematical theories generating numbers that are then compared with numbers calculated from measurements: QM just devolves down to statistical averages.

One other concept has been implicit in much of CM and QM and that is ***locality***: objects only **interact** when positioned at the same location in space at the same moment of time. When this is combined with a philosophy of realism then the result is a worldview known as **local realism**. The Irish physicist, John Bell (1928-1990) developed a precise formulation of local realism using hidden variables. Bell proved [115] (later confirmed by experiments) that all theories **based on locality** must conflict with the predictions of QM. Bell's own preference was to focus on **entities** (or 'be-ables' as he called them), whose existence does not depend on human 'observations' (simple realism). **Ontology** plays a key role in the present programme, as it did for Bell.

#### *4.3.1.1 Determinism*

Many scientists have also made a commitment to the concept of **determinism** that is implicit in the use of calculus in analytical mechanics. This is because they view the subsequent state as being determined totally by the particle's state one infinitesimal moment earlier. Determinism is a property characterizing state changes due to the passage of time, namely that the state at a future instant is treated as a mathematical function of the state in the present. It may not always be clear whether a particular interpretation is deterministic or not, as there may not be a clear choice of a time parameter. Unfortunately, this concept is mistakenly believed to imply that humans can predict the future; this is **not** even true for real, many-body systems described by CM, as complete knowledge of the present would be needed. Determinism is an example of a metaphysical assumption.

### 4.3.2 THE FAILURE OF MATHEMATICS TO EXPLAIN

All 3 formulations of QM today are constructed on various representations of the modern abstract mathematics of Hilbert vector spaces. Worse, all these formulations are centered on the concept of "system state" that has no clear correspondence with reality. The result is that mathematical physics uses a "cookbook" approach to generate numbers that are compared with numbers calculated from experiments without any clear understanding of what this scheme means. This contrasts with classical physics, where innovative concepts (like momentum) were introduced first and then a mathematical scheme was later introduced to finally generate numbers for checking by experimenters: for consistency. In both cases though, only the two-body central force problem has been solved; all other examples are theoretical (ideal) systems, good for educating physics students, but with no examples in the real world.

### 4.3.3 ONTOLOGY & EPISTEMOLOGY

#### *4.3.3.1 Mach's Flawed Approach*

The influential Austrian philosopher of science, **Ernst Mach** and his followers (the Logical Positivists) declared, in their opinion, that "*atoms were not real*", as they could not be seen individually. They also insisted that every scientific concept must be measurable while they believed that scientists constructed their theories by moving logically (i.e. mathematically) from experimental data to theory. When this 'theory of theories' was put to the empirical test, scientists were unanimous in agreeing that their methods of research bore no resemblance to this viewpoint [116]. This is an example of when scientists should ignore the musings of armchair philosophers, in spite of their international reputations. Mach was driven by his obsession with Newton and the deterministic worldview implied by analytical calculus. He could not abide the new direction being pioneered by his fellow professor, Ludwig Boltzmann, who was not only committed to the atomic hypothesis but was developing a statistical approach to the micro-world. As a 'primitive' philosopher, Mach relied on the rhetorical trick of appealing to other people's common sense; a trick, which even works well with many scientists. In fact, he was a dishonest philosopher, who could decry metaphysics while accepting the metaphysical claims of determinism: he should have known better.

Few would argue with the proposition that humans exist but Mach then pushed this to the unjustifiable dictum that **only** what humans perceive **can** exist. The kinetic theory of gases should have been enough to give Boltzmann's approach credibility as the Royal Road to understanding atomic phenomena. In fact, microbes were killing humans long before they were discovered – or even seen! The narrow temporal ranges corresponding to the visible spectrum are grossly inadequate to appreciate the richness of reality. Standing for many minutes in front of a dangerous X-ray machine is not recommended, even though the 'radiation' is invisible to all unaided human senses.

#### *4.3.3.2 Planck's Holistic View of QM*

Max Planck in his final philosophical statement [32] claimed: "*Physics deals with actual events and its object is to discover the laws which these events obey.*" … "*Physicists continued to apply the principle of 'divide and conquer'; bodies divided into molecules, molecules into atoms, atoms into protons and electrons; space & time divided into infinitely small intervals*." However, he soon goes on to say that: "*Modern physics has taught us that the nature of any system cannot be discovered by dividing it into its component parts and studying each part by itself, since such a method implies the loss of important properties of the system*." … "*We must keep our attention fixed on the whole and on the interconnections between the parts*." In despair, he wrote: "*The QM wave function affords no help at all for an interpretation of the world of the senses; it denotes no more than that a certain state exists*." Unfortunately, he was not too clear on his meaning of the word "**state**"; nor was he ready to criticize the classical ideas of solid objects ('things') and move on to the less distinct world of relationships. It was good that, at least, Planck saw the weakness of Cartesian reductionism. Analysis has had its opportunity for over 400 years and has reached its ultimate physical limits (with cellular biology); there is now a desperate need for reversing this intellectual journey and for humans to focus on developing techniques that result in **synthesis**: emergent properties are the reward for moving down this new road.

## 4.3.4 EPISTEMIC INTERPRETATIONS

### *4.3.4.1 The Copenhagen Interpretation*

The Copenhagen interpretation is the "standard" interpretation of quantum mechanics formulated by Niels Bohr and Werner Heisenberg while collaborating in Copenhagen around 1927. Bohr and Heisenberg extended the probabilistic interpretation of the wave function proposed originally by Max Born. The Copenhagen interpretation rejects questions like "*where was the particle before its position is measured?*" as meaningless.

The measurement process 'randomly' picks out exactly **one** of the many possibilities allowed for by the state's wave function in a manner consistent with the well-defined probabilities that are assigned to each possible state. According to this interpretation, the interaction of an observer or apparatus that is external to the quantum system is the cause of wave function collapse [117], thus according to Paul Davies: "*Reality is in the observations, not in the electron*". There can be no entities with pre-existing properties, whose values are discovered by measurement. This challenge to commonsense was nicely summarized recently by Jim Baggott, an ex-academic scientist now turned popular science-writer, in his book [118] where he defined his own (Kantian) 'reality principle': "*Reality is a metaphysical concept and as such it is beyond the reach of science. Reality consists of things-in-themselves of which we can never hope to gain knowledge. Instead, we have to content ourselves with knowledge of empirical reality, of things-as-they-appear or as things-as-they-are-measured*." This despairing view is based on Baggott's conviction that QM "*is 'true'* " because "*it is a theory founded on solid observational and experimental fact*"; a conclusion that feeds part of his circular definition of reality and his implicit Pythagorean assumptions.

Bohr's viewpoint was based on an analysis of human communications; so that when (for example) scientists use the word "experiment" they are referring to a given situation where they can tell others what they have learned. Therefore, the account of the experimental arrangements and of the results of the observations must be expressed in unambiguous, natural language with suitable application of the terminology of classical physics. Implicit in Bohr's views were the assumptions of **Positivist** philosophy that were popular amongst intellectuals at the beginning of the 20th Century. This philosophy had absorbed the key ideas of **Operationalism**: scientific concepts only had a meaning in terms of the specific experiments that demonstrated them. In this case, atomic phenomena could not be perceived directly by humans but still needed macroscopic scale equipment (TVs) to interact with these, otherwise invisible, electrons. Consequently, evidence obtained under different experimental conditions cannot be comprehended within a single picture, but must be regarded as ***complementary*** in the sense that only the totality of the phenomena exhausts the possible information about the objects. Bohr was explicit when stating that micro objects did not possess intrinsic properties independent of their determination with a measuring device; this was a direct challenge to CM and its commonsense interpretation. Since the quantum conditions indicated that position and momentum were complementary variables (see 'Uncertainty' §3.9.1) and both of these properties were believed to be needed at every instant of time then the Complementary principle established a fundamental challenge to both the ancient idea of **Determinism** and the key concept of system "**State**" that were central to CM. The dual slit experiment (Young's Interference) with waves or particles is usually quoted as the exemplary crux of the problem (see §2.2.5).

### *4.3.4.2 von Neumann/Wigner Interpretation*

In his treatise, John von Neumann deeply analyzed [119] the so-called measurement problem. He concluded that the entire physical universe could be made subject to the Schrödinger equation (the universal wave function). He also described how measurement could cause a collapse of any wave function. This view was expanded on by Eugene Wigner, who initially argued that human experimenter consciousness (or maybe even an animal's consciousness) was critical for the wave-function collapse but he later abandoned this interpretation.

### *4.3.4.3 Quantum Information Interpretation*

This quintessential epistemic interpretation is centered wholly on an observer's knowledge of the world, rather than on the world itself. The problem of measurement collapse (also known as reduction) is now interpreted as an observer acquiring information only from an act of measurement, rather than as an objective event. Knowing how a system was prepared, this interpretation views the system state not as an objective property of an individual system but only as the information which can be used for making new predictions about future measurements. A quantum mechanical **state** being a summary of the observer's information about an individual physical system changes both by dynamical laws and whenever the observer acquires new information about the system through new processes of measurement. A system's state vector is no longer seen as an objective property of the system but only as a subjective property of a specific observer. Thus, the "reduction of the wave packet" only takes place in the **consciousness** of one observer, as the state concept is seen as only a construct of the observer and not an objective property of the measured physical system.

One of the most interesting evolutions of this interpretation is the view known as **Quantum Bayesianism** or 'QBism' [120] that applies the subjective or Bayesian approach to probability usage (versus frequentist) and expectations to the problem of quantum measurement. Supporters of this approach view QM to be "*a bizarre anomaly, a powerful recipe book for building gadgets but good for little else*."

QBism maintains that the wave function has no objective reality but is a user's manual to make informed decisions about the micro-world. Specifically, observers employ the wave function to assign their personal belief that a quantum system will have a specific property, realizing that their own choices and actions affect the system in an inherently uncertain way. In effect, one system can have as many different wave functions as there are different observers. After observers have communicated with one another and modified their private wave functions to account for the newly acquired knowledge, a coherent worldview emerges. Bayesianism is an alternative approach to probability, named after 18$^{th}$ century clergyman, **Thomas Bayes**, whose ideas were picked up and improved by LaPlace. It is grounded in a subjective degree of belief that a future event will occur and explicitly incorporates newly discovered information.

#### *4.3.4.4 Many Worlds Interpretation*

This popular QM interpretation posits a **universal wavefunction** (representing the totality of all existence) that obeys the same deterministic laws at all times; in particular, this solution avoids all nondeterministic and irreversible collapse that is associated with the act of measurement. Measurements are claimed to repeatedly **split** the universe into multiple mutually unobservable alternate histories — distinct universes within an even greater **multiverse**. This **bizarre** speculation does not account for why the recent arrival of human measurements in the 20th Century has taken on this cosmic significance. Its air of mystery contributes to the increasing religious aura developing around all aspects of QM, to the point where the adjective "*quantum*" has taken on almost magical qualities (as well as multiplying book sales, by including it in the book's title).

#### *4.3.4.5 Relational QM Interpretation*

The central idea behind relational quantum mechanics (RQM), following the precedent of special relativity, is that different observers may give different accounts of the same series of events. For example, to one observer at a given point in time, a system may be in a single, "collapsed" eigenstate, while to another observer at the same time, the system may (why?) be in a superposition of two or more states. If quantum mechanics is to be a complete theory, RQM views the notion of "state" only as the relationship, or correlation, between the system **and** its observer(s); i.e. it is observer-dependent. The state vector of conventional QM becomes a description of the correlation of some *degrees of freedom* in the observer, with respect to the observed system. Any "measurement event" is seen simply as an ordinary physical interaction, an establishment of this sort of correlation. Thus, the physical content of the theory has less to do with objects themselves but the relations between them and any possible set of distinct observers. It is not clear whether the variations are due to observers interacting at different times or simply because they are just different people viewing similar but different systems.

#### *4.3.4.6 Quantum Logic Interpretation*

Quantum logic was originated in 1936 by Birkoff and von Neumann, who first attempted to reconcile some of the apparent inconsistencies of classical Boolean logic with the facts related to QM measurement and observation. Quantum logic may be regarded as a kind of propositional logic suitable for understanding the apparent anomalies in quantum measurement, most notably those concerning composition of measurement operations of complementary variables.

### 4.3.5 ONTIC INTERPRETATIONS

#### *4.3.5.1 de Broglie-Bohm Interpretation*

The de Broglie-Bohm theory of QM [121] was created by Louis de Broglie and later extended by David Bohm [70] to include the act of measurements. **Particles**, which always have positions, are assumed to be guided by a **Pilot** wave, but still evolving according to the Schrödinger equation. The theory takes place in a single space-time and is always **non-local** so it claims to satisfy Bell's inequality. The simultaneous determination of a particle's position and velocity is subject to the usual Uncertainty principle constraint. This deterministic, "hidden variable" theory introduces an extra quantum potential from the rest of the universe. Wave function collapse is seen as due to random experimental variations.

#### *4.3.5.2 Statistical (Ensemble) Interpretation*

The statistical interpretation claims to be a minimalist QM interpretation as it makes the fewest assumptions associated with the standard QM mathematics. It pushes Max Born's statistical interpretation to the maximum. This interpretation states that the wave function does not apply to an individual system – for example, a single particle – but is an abstract, mathematical (statistical) function that describes an **ensemble** (a large collection) of similarly prepared systems or particles. Probably the most famous supporter of such an interpretation was Einstein and its most prominent current advocate is L. E. Ballentine, professor at Simon Fraser University, author of a graduate level QM textbook [122]. This interpretation is derived from the perspective that the squared modulus of the wave function is fixed for all time (for a given class of experiment) while each experiment produces only one of results from this predefined set - a clear example of statistical (or ensemble) mechanics. This interpretation makes some defenders of the QM orthodoxy very nervous and they would rather ignore it than refute it.

#### *4.3.5.3 Stochastic Mechanics Interpretation*

Edward Nelson of Princeton published a significant paper in 1966 [123] that showed that purely classical, random (Markov) processes acting on a point particle could result in an equation of motion that closely resembled Schrödinger's QM wave equation. Stochastic theories are indeterminate due to the random (Brownian motion) effects on the particle's motion. This result is very insightful.

#### *4.3.5.4 Objective Collapse Theories*

In contrast to the Copenhagen Interpretation, Objective Collapse theories regard both the wave function and the process of collapse as ontologically objective, in that something **real** is supposed to be occurring in the target system. In all objective theories, collapse occurs randomly ("spontaneous localization"), or when some physical threshold is reached, with observers playing no special role. Thus, they are realistic, non-deterministic theories, which do not rely on explicit hidden-variables.

#### *4.3.5.5 Elementary Cycles (Semi-Classical Mechanics)*

The basic idea underpinning the Semi-Classical Mechanics (SCM) interpretation (§4.1.8.3) is the empirical fact that, as noted by de Broglie, that elementary particles have recurrences in time and space determined by their energy and momentum. This view implies that every system in nature can be described in terms of elementary space-time cycles. These cyclic recurrences are imposed as SCM quantization conditions. This is an evolution of the 'old' QM (Bohr-Sommerfeld quantization). Physics Nobelist, Gerard 't Hooft has suggested in this regard that QM emerges as a statistical description of extremely fast, deterministic periodic dynamics.

### 4.3.6 MIXED INTERPRETATIONS

#### *4.3.6.1 Time-Symmetric QM*

Several theories have been proposed which modify the equations of quantum mechanics to be symmetric with respect to time reversal. This creates **retro-causality**: events in the future can affect ones in the past, exactly as events in the past can affect ones in the future. In these theories, a single measurement cannot fully determine the state of a system (making them a type of hidden variables theory), but given two measurements performed at different times, it is possible to calculate the exact state of the system at all intermediate times. The collapse of the wave function is therefore not a physical change to the system, just a change in our knowledge of it due to the <u>second</u> measurement. Similarly, they explain entanglement as not being a true physical state but just an illusion created by ignoring retro-causality. The point where two particles appear to "become entangled" is simply a point where each particle is being influenced by events that occur to the other particle in the target particle's future.

There is a need to <u>distinguish</u> the reversal of the flow of time (time-reversal) from interactions originating with events in the future effecting changes in the present (retro-causality), which have often been dismissed as causing temporal paradoxes, such as killing one's grandmother before one's parent was born. Philosophically, David Hume always **defined** the cause of a pair of correlated events as the one that occurs earliest in time. One of the earliest time-symmetric classical theories was the Wheeler-Feynman absorber theory [124] of electromagnetism. Most theories assume only a single, universal time evolution or a universal time extending across all of space.

#### *4.3.6.2 Transactional Interpretation*

The transactional-interpretation of quantum mechanics by John Cramer is an interpretation of quantum mechanics [125] inspired by the Wheeler-Feynman absorber theory. It describes a quantum interaction in terms of a **real**, standing wave formed by the sum of a retarded (forward-in-time) and advanced (backward-in-time) waves. Cramer argues that it avoids the philosophical problems with the Copenhagen interpretation and the role of the observer.

### 4.3.7 JUST ANOTHER OPINION

#### *4.3.7.1 Results of the QM Interpretation Game*

When the present author reviews all the confusion on the various QM interpretations, it seems that the **epistemic** viewpoint wins out. QM has created a theory to generate numbers in a human mind that can then be confirmed by experimentalists, who try to replicate the setup conditions in a similar (but not identical) manner. Schrödinger exposed the deep ambiguities implicit in the standard (Copenhagen) interpretation by writing a satirical paper [126]. It is absurd to claim that a macroscopic creature, such as a cat, is both alive **and** dead, prior to a human examining the situation. However, these two possibilities were present in the experimental setup. Thus, the wave function is a "prediction tool" for anticipating future results. The ontology remains hidden but no one would have any problem deciding, once the "*hellish*" box was opened that the cat had died several days **earlier**. In no way, can anyone claim that the act of 'opening the box' **caused** the cat to suffer its fate; there is no mechanism linking the door with the radio-active atom that initiates the event sequence that poisons the cat: nothing further can be claimed for QM. A **series** of experiments will show that **some** cats live while **others** die (and smell), based on random atomic decay. Similarly, many people alive yesterday will be alive today but some will die today due to accidents or biological process. The unknown nature of the future will remain a challenge for us for a long time to come.

#### *4.3.7.2 The UET View*

The Universal Electron Theory shares several key aspects of some of the ontic interpretations, as it rejects epistemic-only theories of physics. Since UET assumes that no real electron can ever be completely isolated from possible interactions with all other electrons in the universe, then it adopts key concepts from the stochastic mechanics interpretation (§4.3.5.3). These statistical extra interactions may sometimes be modeled by Bohm's so-called quantum-potential (§4.3.5.1). Any macroscopic attempts to repeat an experimental setup will be defeated by these indeterminate extra interactions; the various resulting measurements will then appear as if they were drawn from Ballentine's statistical ensemble (§4.3.5.2). Like SCM (§4.1.8.4) UET's electrons, when left to themselves, will follow trajectories across space over time, whether measured or not. Any attempt to measure (interact with) them will disturb their natural motions; this is the case when attempts are made to measure an electron near a slit (before or after) in the Double-Slit experiment (§2.2.5), especially as UET explicitly includes time symmetric interactions at all times, as in §4.3.6.1.

### 4.3.8 ICONIC THINKING

The modern debate about whether electrons are waves or particles is an attempt to force microscopic reality into a macroscopic mold where we can introduce familiar human scale objects, with which our minds are comfortable (icons). The two most popular analogies are billiard balls and water waves. The danger here is to expect the micro object to behave **exactly** as the iconic object behaves at the familiar macroscopic level. This is the wrong direction to view these relationships. The problem is that each of these large 'objects' consists of myriads of electrons themselves and these aggregates 'wash out' all the actual internal interactions that provide these objects with their observable structures. The only idea that is worth keeping from the **particle concept** is that it always has a location at any time (it is **not** that they bounce off each other when they collide because they have Descartes' spatial "extension"). Similarly, the key idea of the wave model is that there is a variation at any **periodic** instant of time at some locations. The overlap is that an electron may exhibit variations in its interactions at any time, while two waves may readily flow through each other without producing any observable effect on either wave. 20th century theoretical physics is still smarting from the **Ontological Wars** of the Nineteenth Century. That 'war' foreshadowed the problems faced in QM but then the issue was the *nature of light*. This has been reviewed extensively in the previous paper [6] but in summary, it had the supporters of Newton's corpuscular view of light defeated by the wave theorists, who were mainly academic mathematicians. Since these academics controlled the scientific journals and the next generation of students, they were successful in shutting out their rivals. Behind this confrontation, lay the deep, contentious issue of scientific methodology and the ancient, philosophical rivalry between static pebbles and dynamic water, as ancient models for the foundation of reality.

The Optical-Newtonians insisted that any theory of physics must be based on a satisfactory interpretation of the foundational concepts, whereas the wave theorists were quite satisfied with a mathematical exposition that fitted the experimental facts. The problem then (as now with the QM mathematicians) was the mathematicians had no physical model to fall back on. The 19th Century wave theorists were compelled to posit an all-encompassing **æther** that spread waves around just like sound or water, from the view that all waves required a medium to sustain them. Æthers have been very popular since ancient Greek times (world as fluid) and were given a major revival by Descartes [10] around 1600 and a massive boost by Clerk Maxwell. Even major (non-mathematical) supporters of the wave theory, such as Thomas Young, started with a structured æther in 1800 but after seven years only required that it exist. This was typical of wave theorists, who were so impressed with their mathematical predictions but needing a medium, they insisted that an æther **must** exist. Like many of the critics of Newton's theory of gravity, Thomas Young (like Einstein) could not comprehend the idea of action-at-a-distance: he needed an object for conveying action across space. This is why he first turned to hydrodynamics. As science historian Geoffrey Cantor [127] writes: "*Like many other English physicists, he found it very difficult to conceive of an abstract system unless he could reduce it to a more comprehensible, mechanical model*." This is a widespread extrapolation to scientific thinking of the universal, personal experience with **touching**, given even more veracity than possibly illusory vision and a basic sense still available to blind people.

Modern theorists, who are aware of the history of physics, are loath to revive this optical dispute; particularly as light was seen as critically involved in its relationships to matter. Indeed, the corpuscularists believed that in studying light they were actually studying a form of matter itself. The wave theorists were challenged to describe how the fluid luminiferous æther (required to transmit light waves) interacted with ponderable matter. Indeed, the champions of the wave theory were hard put to come up with strong physical arguments against the so-called '*emissionist'* views. For example, in the 1760s, Euler claimed that the Sun would shrink in size if it were emitting light particles, whereas according to the wave theory, the Sun behaved like a bell generating light vibrations into the surrounding æther. Young could not conceive how diverse sources, such as the Sun or flint shards, could create light that always traveled at the same incredible high speed across space. It was these bitter battles of the 19th century physicists, which motivated many today to avoid thinking about metaphysical issues. Two arguments were irrefutable by the wave theorists: the first was the knowledge that only solids could transmit transverse vibrations while no such medium had ever been observed. Secondly, it was impossible to see how such a powerful medium would not slow down the planets if such a medium were to be intimately involved with matter in its production. These disputes fed the development of Positivism around 1900 to abolish such embarrassing disagreements from public eyes.

It is no wonder that Maxwell's mathematical theory of light [128] was so readily accepted when it appeared in the 1860s. Even though Maxwell created his electromagnetic theory based on a firm conviction of the existence of the luminiferous æther (and confirmed in his own eyes at least by his own beloved æther model of "wheels and gears") it was soon divorced from its physicalist foundation and was transformed into a theory of mediumless force-densities. Just because Einstein initially refrained from calling on any properties of the EM æther, this did not mean that he thought there was no role for such a medium. This is one of those physics problems that gets "forgotten" rather than resolved. Its reappearance at the heart of QM is an embarrassment that would rather be ignored again, hoping it will fall back into the oblivion known as the History of Physics that only specialists study. Meanwhile, the æther has morphed into '**space-time**', and now plays a central role in mathematical models of the whole universe. One of the bravest of the Victorian opponents of the wave theory was David Brewster, who had no objection to the wave theory as a hypothesis or even a useful calculational tool, but demanded a causal theory of interaction. Modern critics of QM still repeat Brewster's basic objection: "*The power of a theory, ... to explain and predict facts, is by no means a test of its truth. This is a* ***necessary*** *condition for a theory to be true, but not a* ***sufficient*** *one, since other theories could also later account for the phenomena.*" Many physicists (even today), like Brewster, still expect a new, deeper understanding from a theory, such as QM.

## 4.3.9 THE HIDDEN PHILOSOPHY

### *4.3.9.1 Plato abolishes Time*

Plato viewed the world as flawed because natural things decay or even die. He formulated his philosophy of **timeless** forms to escape this fate. The only two examples he could reference that illustrated this timeless nature were mental concepts and mathematics, particularly **geometry**. Mathematicians have appreciated these praises from the western world's premier thinker and have reciprocated by producing timeless mathematical descriptions of the physical world. Fortunately, Aristotle and other biologists remained grounded in living systems. The mathematicians who created QM maintained this perspective, as both the canonical commutation rules and the measured expectation values are timeless: the commutation rules are only defined at the same, single moment of time while the quantum expectation values are averaged over all time (plus and minus infinity). Therefore, the single moment of time, characterized here by the parameter 't' has no physical significance but it may act as an identifier on the particular experiment – all assumed identical.

### *4.3.9.2 Matters of Principle*

Mathematical physicists, like Planck and Einstein, are always advocates of "theories of principle", since (like mathematics) they are synthetic and *a priori*. Such theories do not have to be grounded in any model of reality or dynamical interactions, unlike constructivist theories, such as Drude's theory of electrical resistance. Worse, they are often examined through the rhetorical device of the "thought" experiment, which rarely surprises or contradicts expectations, like real experiments. As the philosopher and historian of science Vico pointed out: **humans** can understand mathematics completely because **they constructed** this mental edifice but Descartes (and other mathematicians) were deluded [129] if they thought that this technique would help them understand the complexity of nature. A similar modern analogy would be our ability to design modern computers whose complexity pales in comparison to biological cellular processes; there is more complexity in a single ant's head than in the largest manmade computer but humans still fall into the trap of confusing size with complexity. Conversely, humans have a bad track-record of under-estimating the difficulties of **complexity**. Worse, there are far too often claims made that we understand a complex situation "*in principle*". LaPlace was one of the earliest offenders of this sin of 'Exaggerated Capability' as when, based on Newton's solution to the simple planetary model, LaPlace claimed that he could predict all future (and past) locations and speeds of all the particles in the universe. Of course, he should have known that even the **3-body problem** was insoluble to his continuum mathematics but scientists were still repeating this bogus claim until 1957 when the president of the Royal Society published a *mea culpa*, where he admitted that classical mechanics had always been defeated by what soon came to be known as Chaos Theory.

### *4.3.9.3 Quantum Field Theories*

The attempt to force a marriage between the facts of discrete electrons and the sanctity of Maxwell's (continuous) EM field theory was the compulsion to develop (first by Dirac), beginning in the 1930s, a **Q**uantum **F**ield **T**heory of EM (**QFT**) and later Richard Feynman's more widely known version of quantum electrodynamics (**QED**). This is widely believed to have provided a satisfactory theory of light, so QED was extensively and critically analyzed in the previous paper [6]. This material will only be alluded to here, rather than repeated in detail. The present paper still incorporates the new idea that interactions between electrons is still **saturated** (only one interaction per pair at a time) but extends it from 'far' interactions ("light") to 'near' interactions (atoms).

The most embarrassing feature of the mathematical theories of quantum fields is the appearance of mathematical **infinities** in quantities, calculated to be compared with real measurements, such as the mass of the electron, which is obviously **not** infinite. Various "tricks" have been introduced since they first appeared and a complex set of mathematics (known as 'renormalization') is believed to have got rid of them. Nonetheless, none of these fancy field theories are able to calculate the masses of any of the objects in 'Particle Physics'.

Dyson's S-Matrix/QED paper [130] in 1949 stated the basic problem with all such field theories is that they all include the Hamiltonian density of field interactions at <u>one</u> space-time point and this is always <u>infinite</u>. Dyson also recognized that the electron/positron field must always act as a unity and **not** as a combination of two separable fields. Similarly, the EM field itself must act as a unity and not as one part representing photon emission and another part representing some <u>later</u> and contingent photon absorption (the 'broadcast' model).

Although Dirac is viewed appropriately as 'the Godfather of QED', he was prepared to express his extreme dissatisfaction with all the theoretical efforts in this area, when he wrote in 1936: "*We may give up QED without regrets – in fact, on account of its extreme complexity, most physicists will be very glad to see the end of it*." In 1938, he wrote again: "*A new <u>physical</u> idea is needed which should be intelligible both in the classical theory and quantum theory and our easiest path of approach is to keep within the confines of the classical theory*." Unfortunately, Dirac did not then attempt to change the Maxwell-Lorentz equations but only to seek a new interpretation of them. Finally, in 1977, at the age of 75, he wrote: "*I really spent my life trying to find better equations for QED, and so far without success, but I continue to work on it*." The present theory replaces the Maxwell equations at the electronic level with a new quantized impulse scheme, which remains much closer to Newton's original conception of mechanics; hence the 'title' of Quantum Electron <u>Mechanics</u>.

# 5. A NEW PHILOSOPHY OF NATURE

## 5.1 RESTORING NATURAL PHILOSOPHY

One of the principal motivations behind this research programme is to help return physics to its original, productive role as a principal part of philosophy – the ancient study known as Natural Philosophy (NP). This was made very explicit in the second paper [2], where discussion of Clerk Maxwell's personal interest in NP was made. Few today know of Maxwell's scorn for "mathematics-only" style of physics as exemplified by his Continental rivals in electromagnetism (EM) research (one of history's superb ironies is that we have only been left with Maxwell's mathematics). The third paper [3] returned to the need for a metaphysical foundation to any fundamental EM theory. This programme's fourth paper [4] presented an alternative theory to Einstein's Special Theory of Relativity by refocusing on the remote and discontinuous interaction between pairs of electrons in relative motion. Major sections were devoted to an analysis of the metaphysics of space and time, subjects that have dropped below the modern physics student's horizon. The fifth paper [5] explored the impact of a new form of EM interaction on the relative motion of electrons. This involved a broad ranging analysis of causality and the nature of asynchronous interactions, especially the contentious subject of remote "action-at-a-distance" (far action). Obviously, any attempt to formulate a new theory of optics had to discuss the metaphysical nature of light; this was part of paper six [6].

## 5.2 REPRESENTING REALITY

### *Metaphysics*

This programme has been emphasizing the importance of philosophy in physics almost from the beginning since without this link to reality, physics degenerates simply into applied mathematics. This focus on the **nature of reality** has been long known as natural philosophy and can trace its roots to the Ionian philosophers. Stephen Toulmin and June Goodfield have written extensively [10] on the evolution of ideas in this area. As was introduced above, the deep areas here are often referred to as metaphysics, which many believe today as still having little relevance to modern physics. This dismissal is actually a metaphysical position in itself, which allows the symbolic mysticism of Pythagoras to subvert the investigation of material reality. As was discussed above (see §4.3.2), metaphysics has been usefully divided into questions of **ontology** (existence) and epistemology (knowledge). The earliest ontological disputes were on the nature of material reality, especially if all matter shared some universal, foundational substance. These discussions were soon extended into the study of matter in motion, which inevitably brought in questions about the nature of space and time. The ancient Greeks greatly simplified these later discussions by abolishing time and focusing only on space as they created their greatest intellectual edifice: Euclidean **geometry**. Thinking in these areas literally went around in circles until Galileo refocused experimental attention on matter and Newton invented his fecund concept of mass and its powerful twin: **momentum**. Immanuel Kant introduced the idea that there must be a distinction between levels of reality, known only to nature (*ding an sich*) and human awareness (knowledge) perceived through our senses. It took much investigation to determine the (narrow) limits of our sensory views of reality; both in our minds (psychology) and in the extreme smallness of the foundational objects of matter (physics) i.e. atoms.

### *Objective & Subjective Knowledge*

Phenomena are viewed as "objective" if they reference universally shared experience (e.g. the fact that most of us dream) while they are deemed "subjective" if they are private personal experience (e.g. my dreams). Similarly, 'thirst' is objective while 'guilt' is subjective, as not everyone experiences this feeling. Thus, our view of macroscopic reality is objective; most would agree that it would not be advisable to walk off the edge of a 500 meter cliff. The problems arise when we try to experience the micro-world that cannot be distinguished at the same level of detail. We therefore create technologies that expand our intrinsic sensibilities. If our technology told us that there was a high-energy beam of electrons across a doorway, we would be equally well advised not to cross the beam, even though we cannot see it. This preamble is a roundabout way to claim that electrons exist and are not theoretical constructs like quarks or strings. Modern people experience electrons every day, or at least through their television and digital technologies; no one doubts their existence. This new theory is grounded in the reality of electrons.

The heart of this theory is a set of new proposals on how electrons **interact** with one another. These interactions are **not** based on Maxwell's theory of electromagnetism that was a mathematical transformation of large-scale (space and time) experiments that were summarized as integral equations that were given a mathematical transformation into differential equations based on various, fictitious **continuous** media: first as the æther and then [2] to Helmholtz's electrical charge-density. The electrons are known to be **discrete** in all their mutual properties and need a completely new foundation at the smallest level of reality. Central to this new view of the inter-electron interaction is that it is **discrete** in its (inter)**action**, i.e. quantized dynamics; it is discrete in time, i.e. when interactions occur (pulsating possibilities); it is discrete when the number of interactions occur (i.e. finite interaction pairs).

## 5.2.1 TIME

Time is an integral aspect of reality; so much so, that it cannot be defined in terms of any other part of reality. However, time itself cannot be denied: everyone is going to die and most people would assign a role to time in these universal events. Every human becomes aware of the daily variation attributed to the relative position of the sun, whether we believe that the sun is rotating around the earth or the Earth revolves around the sun and rotates around its own axis. Many philosophers have thought extensively about the nature of time and have arrived at a consensual definition: the ordering of a sequence of **personally** experienced events. The deliberate introduction of this personal, intuitive perspective is to avoid getting caught up in the controversies associated with Einstein's Special Relativity Theory (SRT), which was reviewed extensively [4] before. Mature, healthy individuals rely on their memories to rank a set of completed events in their personal **past** while being aware of their immediate sensory inputs that are interpreted as constituting their personal **present** time. Our intentional acts are reserved for our personal **future**. Toulmin and Goodfield have documented our growing awareness of the extent and the role of time [129]. Until Galileo started his temporal observations, natural philosophers were only interested in explaining 'transitory flux'; it required the arrival of Newton before a dynamical theory of motion was available.

### *Measured Time*

Julian Barbour has expended a major intellectual effort in understanding the nature of time. One of his shorter publications provides a useful synopsis [131] of how astronomers have measured time over the last few hundred years. Barbour reminds us that when the venerable Ptolemy wrote his *Almagest* in 150 AD, he chose the reappearance of a star (*sidereal* time) as the basis for his theory of uniform motion of the solar system, rejecting the obvious solar day that was far too variable. This choice for the duration of time by astronomers remained unchallenged for close on two millennia. The radical invention of Huygens' pendulum clock showed that this was also a good choice **on** the Earth. Barbour then summarizes Henri Poincaré's resolution of the problem of variable, rotational periods of the moon and some of the planets using Newton's theory of gravity. However, even this approach fails to mention that Newton assumed that gravitational effects 'propagate' instantaneously, instead of at 'light-speed'; this enabled Poincaré to introduce the concept of timeless, gravitational potential. This approach leads to the concept of *ephemeris* time as ephemeris means the positions of celestial bodies. This new concept replaced sidereal time for synchronizing Earth-bound chronometers in 1952 and this persisted until 1979 when it was replaced by the *atomic clock*. Barbour reminds us of Mach's perception of the correlations in nature's motions and that the concept of time is abstracted from all these examples of regularities in nature. Barbour concludes his brief essay with a model of changes in **action** between celestial masses, still subject to Newton's instantaneous gravitational interactions. This is a model, to which the present theory can relate but now the masses involved are identical electrons and the interaction is the new form of asynchronous EM impulse (proposed here) between these electrons. Where we differ is that Barbour wishes to completely dismiss time from Nature while the new theory here wishes to ground itself in the universal cycle time (one **chronon**) that defines the very nature of the electron, so that time returns to the center stage of physics, just as the Greek dramatists realized its key role in human affairs.

### *Mathematical Time*

Isaac Newton realized that he needed a firm grip on the concept of time if he were to make any progress in his mathematical study of nature, particularly his 'science of motion'. Accordingly, he adopted a **realist** position that time must be considered a real foundation of nature but he knew that astronomers had distinguished time as measured by distant stars (*sidereal*) from variable *solar* time, which he called "vulgar time". Most astronomers were familiar with the periodic motions observed in the sky and these motions were assumed to define fixed durations of time. However, Newton wished to consider his atomic corpuscles continuing to exist as they moved through space, so he needed to interpolate his radical concept of continuously evolving time; thus, he defined his own: "*Absolute, true, and mathematical time, of itself, and from its own nature flows equably without regard to anything external*." This was a necessary step to developing his own theory of planetary motion that subsequently became the basis for defining time itself (incidentally, closing this circular definition). [132] Leibniz and Kant both disagreed with this view, rejecting the implication that time exists of itself, preferring a relational perspective. The new theory grounds time in the intrinsic property (the interaction-clock cycle: **chronon**) of all electrons.

## 5.2.2 SPACE

As Kant recognized, the intuition of space is just as necessary as that of time if humans are to create a symbolic (language) model of our common reality. In particular, all Indo-European languages make a fundamental distinction in their syntax between verbs, which are usually time-sensitive and nouns or objects that may be timeless. As part of his new scheme for mathematizing nature, Newton needed to be able to abstract the **relationship** between distinct objects that could be seen "at once" when near to one another. This was key because **geometry** is scale-less; its relationships work no matter how large the geometric diagrams; only angles and shapes are size-invariant. Thus, Newton first defined: "***Absolute space***, *in its own nature, without regard to anything external, remains always similar and immovable*." He recognized that relative space could be scaled arbitrarily and so assigned a corresponding, variable number (of spatial units). Newton was happy to invent an Absolute Space, defined relative to the distant stars as seen from Earth, wherein he could identify absolute (rotational) motion. Newton's Laws of Motion anticipate that inertial motion is uniform in such an absolute space.

DesCartes made the philosophical error in defining solid objects as 'completely filled space', whereas we now know there can be plenty of empty space in macroscopic solid objects and microscopic atoms. Contra Newton, Leibniz held that space was only the collection of relations between objects in the real world. Once again, this is another imaginative view of the metaphysics of reality.

Although space and time are useful concepts, the important question is: how do these ideas relate to reality? If they were only constructs of our minds then we could ignore them or alter them at will; this flexibility does not extend to reality - we are subject to reality at all times; viable animals must learn to respect reality. It therefore seems appropriate to view both space and time as **aspects** (foundations?) **of** reality but they are not objects **in** reality, so they cannot be said to 'exist' (see later) but humans must have useful intuitions of their characteristics if they are to form the basis of our mental models of reality.

The new theory introduces space as a natural part of the fundamental interactions between electrons (thus, a relational concept). No two electrons can ever get closer than one unit of space (the **luxon**, defined as light-speed multiplied by one chronon). Thus, two of the basic quantities of physics are given natural measures (not arbitrary, man-made units, such as meters and seconds). All real interactions will occur at integer multiples of these units, eliminating the need for using DesCartes' artificial construction of '**real**' numbers.

### *No Space-Time (Modern Æther Upgrade)*

At the beginning of the 20th Century, Albert Einstein tried to save Maxwell's theory of light by inventing schemes to synchronize remote clocks using light signaling. Maxwell had constructed his electromagnetic (EM) theory on the central assumption that all of space was filled with **æther** - a peculiar medium that "carried" the oscillations of light across space. Unfortunately, Maxwell had expected that the Earth, moving through this æther, would create variations in light-speed if the laboratory was moving with **or** across the velocity of the Earth relative to the permanent æther. In one of the most important experiments in the history of physics, Albert Michelson demonstrated that this was **not** the case; light always moved at the same speed in every direction. Einstein redeveloped the so-called Lorentz transformations of space and time differences (from his flash-point) to save the appearances. This episode was analyzed extensively earlier [4] in this series, where it was shown that these transformations were only needed in mathematical field theories (such as Maxwell's) and were not a feature of physical reality, so there is no need for a mangled concept such as 'space-time'.

## 5.2.3 EXISTENCE

### *Denying Reality*

There is a wide consensus amongst philosophers of physics that QM has abolished reality at the microscopic level. This seems an absurd conclusion if one admits that human existence is an undeniable fact of reality. How reality at our level could occur when it consists of components, such as electrons, that are deemed not to exist appears to be the epitome of logical contradiction. At the very least, for a philosopher to deny his own existence is an admission of failure in clear thinking and such an individual should withdraw immediately from the QM discussion. Anyone who denies that: "reality always trumps theory" is too much enamored of his own intellectual faculties. The present theory accepts that electrons are just as real as we are; both are necessary if humans are going to discuss the nature of the world. The difficulties faced by physicists in interpreting the meaning of QM would then imply that the problem is epistemological: how do humans learn about atomic-scale reality? The present theory resolves this problem by positing a real existence at the scale of electrons and these electrons interact with other electrons. Some of these interaction sets will be repetitive over relatively long time frames (compared to interaction times) and these will result in larger, stable systems such as atoms or molecules. Other interactions will occur infrequently and these will produce perturbations in these stable systems. Some of these remote interactions may well cause the system to transition from one configuration to another. When these remote transitions involve remote electrons that are themselves the start of a cascade of interactions that reach the human level of awareness then we can call them measurements or observations. This multi-level scheme will be described in the associated paper [7] in greater detail. It is important to acknowledge that no one scale is any more real than another. Depending on the duration of the time-period involved, a few interactions are important (as in atoms) or very many interactions are significant, as at the human scale. It would be unscientific today to deny the reality of the atomic world but it would be equally foolish to focus only on atomic scale phenomena and ignore the human scale, even though there is a vast chasm of complexity between the two. Only accountants would claim that larger numbers are important (to whom?).

Since the new theory posits the existence of electrons, whose existence is certainly known to each other through their interactions, it seems that a consistent definition of all **material** existence are the set of all material objects (things) that can interact with electrons. This guarantees that humans exist, as we suspected. If philosophers wish to extend this definition to other elements of reality, beyond material existents, then that too could be OK but for now, we are concentrating on Natural Philosophy and its sub-branch, known as physics, that concentrates on material reality; this is a sufficient challenge in one lifetime.

***Continuity of Existence***

The construction of an ontological hierarchy beginning with electrons, means that their relationships are also real but as such, these are not **entities**, defined as examples of **independent** existence (i.e. their existence is not dependent on the existence of any other object). Thus, atoms are real objects (made from electrons) but they are not entities; they need their component electrons to remain part of the interaction set that defines each atom. These interactions can alter the local characteristics or properties of the participating electrons. One of their real properties is their velocity computed between any two interactions; this leads to the calculated property of kinetic energy – another real property. Interactions can change the quantity of these types of property but the idea of **energy** as an independent existent is rejected. The vast majority of real material objects are actually composites that persist for variable durations of time but again they are not independent existents (entities). The fundamental relationship involving components and their parts (often components themselves) is the asymmetric relationship of the composite object having its parts during a given time period. These ideas: of being and having, lie at the very foundation of most natural languages; i.e. the verbs to **BE** and to **HAVE**.

Foundation of Existence implies that electrons are **eternal**: they are neither created nor destroyed, as energy is not viewed as an entity that can be transformed into matter. Einstein's so-called Matter-Energy Equation is viewed here as a deep misunderstanding of how electrons interact. He assumed that an excited electron exchanged some energy to a hypothetical intermediary (the EM field or photon), which carried this energy and momentum to another electron, where the process was reversed. The assumption that the EM interaction occurs as the generation of a photon, the propagation of this photon and the absorption of the photon by a remote electron is a complex and unnecessary scheme that was invented to preserve Maxwell's erroneous æther field theory. It is much simpler to imagine eternal electrons, which interact remotely. The medieval philosopher, William of Occam suggested hundreds of years ago that philosophers should keep their theories as simple as possible by minimizing the number of entity types they invent; Newton agreed with this advice. The apparent **disappearance** of an electron with its so-called anti-particle (the positron) will be revisited in a later paper on neutrinos. In order to qualify as eternal, then every electron must exist at two distinct times. Therefore, if a particular electron (j) exists at a time $t_1$ at a location $x_1$ (relative to an arbitrary reference frame) then this same electron must exist at the same or another location $x_2$ at a different time $t_2$, where $t_2 = t_1 \pm \eta\, \tau$, where $\eta$ is an arbitrary finite integer and $\tau$ is the universal electron cycle time (chronon). This requires the introduction of the universal existence operator $\exists$ (at $\underline{X}[t]$) with its two eigenvalues {1 ~ exist there and 0 ~ not there}.

***Existence and Predictability***

David Bohm's colleague, Basil Healey, distinguishes a quantum system's **dynamical** state $\mathcal{M}$ from its quantum 'prediction function', usually called the wave function $\psi$, which is only used to calculate the probability distribution of multiple results from **repeating** similar experiments. The dynamical state might eventually be viewed as a truth scheme assignment to sets of sentences describing properties at a single 'time'. In the new theory, we see these sentences as referring to the existence of a finite number of electrons interacting together in a system, each of them following a non-observable **trajectory**. Also, if we interpret this 'time' as laboratory time, $\mathcal{M}$ cannot be used to determine the location (or velocity) of any of these system electrons as their initial values must always be unknown.

## 5.2.4 MATTER

Although discussions on the nature of the world can be traced to Classical Greece [10], these remained purely speculative. Plato's geometrical attitude to Nature was a stimulus to Kepler, Galileo and DesCartes. Even DesCartes made little progress beyond introducing his pernicious definition that a material body was an object having spatial extension but Boscovitch pointed out that any evidence for the impenetrable solid atoms of finite size could equally well serve as evidence for 'point atoms' surrounded by a region of intense repulsive forces. It was Newton's theory of gravity that required a more precise understanding that eventually resulted in his revolutionary proposal of tiny corpuscles with mass. He demonstrated that the mass of a large body acted gravitationally at its center even when it was constituted out of myriads of individual tiny point masses. Newton refused to speculate on either the nature of mass or gravity but proposed these as basic hypotheses. The Neapolitan jurist, Giambattista Vico pointed out in 1725 that DesCartes and Plato had deceived themselves in building their philosophy of nature on the timeless certitudes of geometry since mathematics is a totally, transparent human creation, unlike nature itself. It is for this reason that physics requires experimentation to uncover Nature's secrets, rather than rely on the deductive powers of the human mind (unfortunately forgotten by too many who rely on 'thought experiments'). After 1700, matter was viewed as: "inert, passive, uncreative, soulless and static" so that with the exceptions of dynamics and astronomy the recent $17^{th}$ century amendments to the classical concepts of matter had been only marginal in their effects and had not greatly increased the explanatory power of the older tradition. Newton had hugely expanded the ancient atomistic model by adding remote attractions and repulsions, creating a mathematical model of the observations and discoveries of the previous 150 years. The present new theory extends the Newtonian tradition by positing point-masses (electrons) capable of remote attractions and repulsions between them.

The great French chemist, Antoine Lavoisier (1743-1829) was central to continuing the scientific investigation of matter by showing that Newton's mass concept was equally important for understanding chemical reactions leading to the idea that chemical compounds always combined in the same fixed proportions from their constituent parts. This was explained by the radical theory of John Dalton (1766-1844), who turned Newton's atomic hypothesis into a theory of chemical composition. Dalton's Rules only involved the relative weights of atoms and molecules relative to some arbitrary standard like one atom of hydrogen or oxygen; their absolute masses were quite unavailable at that time. Avogadro proposed that all gases always contained the same number of unit particles. William Prout (1785-1850) soon proposed (in 1815) that only the hydrogen atom was fundamental and was the basis for all the other chemical elements. This hypothesis later influenced Rutherford, who named the nucleus of the hydrogen atom: the *proton*. It also influenced J.J. Thomson in viewing the electron as the fundamental unit of all matter: an insight shared by this programme.

## 5.2.5 RADIATION

The idea that heat was just the vibration of atoms had to overcome the problem of how radiant energy could traverse a vacuum, which was defined as the complete absence of matter. This was compounded by the discovery that radiant heat shared all the same physical properties of light, even though it was not so readily observed. Both Young's experiments and identical mathematical equations had convinced many that similar interference effects observed with light and water surface vibrations 'proved' that light was a wave-like phenomenon. These similarities were reviewed extensively [6] in the prior paper, where it was shown that a new interaction model of light was possible beyond the ancient rivalry of wave and particle. Ironically, Maxwell himself anticipated the possible direction in his Treatise [133], covering electrolysis, where he speculated on a "molecule of electricity". He never developed this idea because his æther model was more likely to result in wave-like oscillations. Ironically, although Maxwell is best known today for his eponymous equations (actually due to his disciple, Heaviside), he himself [134] was more concerned about his explanatory model than his mathematics. Helmholtz's mathematics (similar to Maxwell's) derived directly from Euler's theory of hydrodynamics, where the motion of a continuous fluid had been 'explained' by the action of a '*field of force*' that acted at every point in the fluid while its strength varied continuously from place to place. Now, light was to be interpreted as the propagation of electric and magnetic influences in this æther.

## 5.2.6 NATURAL UNITS

Physics became an arithmetic science when it was realized that similar exemplars of reality could be compared with one another. This type of "ratio" thinking was formalized by Descartes when he invented his dramatic concept of the "**real number**" as many of nature's ratios did **not** fit exactly to the countable integers. This enabled Descartes to extend his algebra to the imaginative world of geometry. But, implicit in Descartes's scheme was his need to use agreed "**unit**" quantities, which were quite arbitrary in nature's eyes. This led to a whole branch of physics devoted to creating agreed "units of measure". Maxwell was instrumental in persuading physicists to use a canonical set of basic units that defined the three independent '**dimensions**' of nature: these were the abstractions of spatial extent [X], temporal duration [T] and mass [M]. Today, the international units of measure for these are [X] centimeter, [T] second and [M] gram. Only the second appears intuitive while the centimeter reflected attempts to measure the circumference of the Earth in an attractive, round number of units; the gram then became the agreed mass of one cubic centimeter of 'pure' water at zero degrees centigrade. This mish-mash approach has long been an embarrassment to physicists with an orientation to natural philosophy, who expected the basic units to be "more natural" and related to modern, physical constants, such as the speed of light ($c$) and Planck's constant of action ($h$).

Fortunately, this re-orientation is now at hand, building on the natural properties of the electron, including its source of interaction – the electron's unit electric charge ($e$), mass ($m$) and the missing piece of the puzzle – the interaction cycle time or chronon ($\tau$). Details will be reserved for the companion paper [7] but involve the deepest mystery number in physics:- Sommerfeld's Fine Structure constant:

$$\alpha \equiv 2\pi e^2/hc \approx 1/137.$$

## 5.3 TIME FOR SOME RADICAL IDEAS

By 1890, natural philosophers were convinced that they understood the panoply of Nature. On the one hand, there was matter: on the other hand, radiation. Both were actually best represented by **mathematical** theories: Newton's Laws of Motion for matter in motion and Maxwell's theory of electromagnetic radiation. Actually, both theories were theories of interactions in specific domains of nature. However, this implied that there must be some **objects that existed**, which then interacted. Matter was viewed as particulate while electromagnetism presented itself as waves in some mysterious, universal æther. By 1850, the new abstract concept of energy arose that eventually provided a bridge between them; indeed, Maxwell had already created a new 'heat-theory' that united this form [135] of energy into a Newtonian-style theory of 'matter in motion', while demonstrating that Maxwell's 'gas' (physical) atoms matched perfectly with Dalton's chemical atoms. Just prior to 1900, two discoveries (the electron and radioactive disintegration) exploded this complacent degree of self-satisfaction. All processes of mechanical matter were seen as conforming to two basic mathematical principles – the simple Principle of Conservation of Energy and the Principle of Least Action. Meanwhile, there was universal consensus amongst theoretical physicists that the repeated success of continuum mathematics meant that the **calculus** should still play a central role in representing material reality, although chemistry was strongly indicating that discrete numbers (integers) were important.

## 5.3.1 CONQUEST OF ABUNDANCE

One of the leading philosophers of the twentieth Century was Paul Feyerabend (1924-1994), who not only studied physics but thought long and hard about the subject of reality. In one of his last books, *Conquest of Abundance*, [136] he discussed how QM failed to approach reality close enough. His most powerful criticism of modern thought was it retreated too much into excessive **abstraction** - a view shared by this programme. The theoretical physicists of the 1920s were mystical Magi, who practiced unconscious self-deception in over-simplifying their representation of the world, so that they could 'solve' the resulting equations with linear mathematics. Even Bohr "slipped the rabbit into the hat" when he assumed that his planetary model of the hydrogen atom could be represented as a **one-body** equation. He sanctified this approach (blocking potential criticism) by calling it the "Correspondence Principle", whereby the Hamiltonian of classical mechanics (CM) became the starting point for all subsequent mathematical models of the hydrogen atom. Not surprisingly, they each arrived at similar conclusions. Thus, in the QM model, the orbiting particle was now 'attracted' to the central nucleus by a classical Coulomb (instantaneous) electrostatic force. In contrast, the astronomical proto-model (CM) always had a massive circulating body that was immune to all human observations; furthermore, Coulomb's approximation was, at best, analogical - there has never been any empirical evidence [138] that it describes actual electromagnetic interactions at the microscopic level of reality. At the atomic scale, the nucleus cannot be dismissed as simply 'fixed background' but needs to be thought of as an active participant in this atomic system (i.e. a true, two-body interaction model). The human observers (or, at least, some of the electrons in their equipment) are always significant because it is their response to variations within the atom, which are actually observed; this raises the complexity to a challenging **three-body** problem. Indeed, all of the laboratory electrons may form an important (non-reproducible) context for these so-called repeatable experiments. This implies that even measurements on a 'single' hydrogen atom may well be exhibiting characteristics of N-body problems. These ideas will be taken up later [7] when a new mathematical model of the hydrogen atom is developed.

## 5.3.2 PROUT'S HYPOTHESIS

It is time for another great unification: Prout's hypothesis (§5.2.4) that there is only one type of existent underlying reality, can now be recast in a modern role: electrons are the **only** foundational form of matter and all other examples are just combinations of this universal object of unit mass and unit charge. In particular, as the previous Quantum Optical Mechanics [6] showed there is no need for any form of existent to occur between variations in electron behavior by source electrons and those eventually influenced by this activity. In other words, "light" (or EM radiation) does NOT exist – only remote interactions are needed to describe material interactions, whether at near distances or far. The ancient prejudice against action-at-a-distance should have died with Newton's successful theory of gravity but the human preference for "touching" meant that "fields" had to be imagined crossing empty space – the paradoxes of quantum theory are the direct consequence of trying to hold on to human experience. Bad analogies, compounded by complex, opaque mathematics, generate bad physics, which remains hidden from most members of the public, who only hear 'popularized' versions (often via TV).

## 5.3.3 KEEPING SOME GOOD IDEAS

### *5.3.3.1 Need for Two-Time Interactions*

The present theory views the EM interaction as **asynchronous**, involving two times (one at each electron involved), so it rejects the CM concept of interaction as a spatial (timeless) potential U[x]. This implies that there is <u>no role</u> for **single**-time CM calculational schemes such as the Hamiltonian or Lagrangian models of mechanics, which use a single time parameter across the whole system. The Universal Electron Theory uses the multi-time Principle of Least Action; this can then recover both CM and QM by reverting to a single time usage and the re-introduction of potential functions to replace long-time averages. Earlier research in this programme [138] showed that <u>continuous</u> interactions between remote **inertial** particles (such as electrons) cannot occur, so that UET rejects the use of analytical mechanics (calculus) and the concept of force; these are replaced by finite differences and discrete impulses that implicitly introduce the possibility of quantization [139]. A Two-Time theory is inherently non-local, so it can still partially use local variables <u>at one electron</u> without contradicting Bell's theorem.

### *5.3.3.2 Electron Paths*

Humans cannot see atoms, not because they are too small, but because in the time of any one light oscillation (in the visible spectrum) the electrons have moved all over the atom - smearing any 'sharp' image: the human visual system cannot track changes at this high rate. It would be just as illogical to deny the existence of an airborne Mach 15 when it is flying low at its top speed when it goes by too fast nearby for us to 'see' a distinct image (ignoring any vapor trails or sonic booms). Heisenberg was much too eager to abolish electron trajectories; perhaps, he was seeking a new level of mystical reality at the atomic scale or he was just too frustrated at his own failures to create a new particulate model of the atom.

The parameter $c$ was introduced in the first paper in this series [1] to homogenize the quaternion-based *Natural Vectors* that are used to represent the 4D interactions between electrons. The notion of interaction on the light-cone was formally introduced in the third paper that replaced continuous EM forces with discrete, asynchronous electron interactions [140].

This view agrees with the conventional Minkowski space-time interval. Two electrons (labeled #1 and #2) may only interact [141] when their 4D traditional spatial vector and time co-ordinates $\{\underline{x}_1; t_1\}$ and $\{\underline{x}_2; t_2\}$ satisfy (and nothing to do with 'light' moving through a hypothetical medium):

$$(\underline{x}_1 - \underline{x}_2) \bullet (\underline{x}_1 - \underline{x}_2) = c^2 (t_1 - t_2)^2$$

Subsequent papers showed that although this was a necessary condition, it was not sufficient: satisfying the global condition of saturation amongst a group of electrons is also required.

#### *5.3.3.4 Reference-Frames*

René DesCartes (1596 - 1650) was a much better mathematician than philosopher; the peak of his many great mathematical innovations was his invention of the 3D co-ordinate reference frame, which facilitated the merger of algebra and geometry. This will be the basis for all mathematical representations of reality in this programme. In all these schemes, a point in 3D space is referenced by three signed numbers, each magnitude indicating the number of spatial units (luxons) along its associated axis. The intersection of these perpendicular axes defines the origin. When used to represent activity across real space, a human observer, when used here is located at its origin and this person 'carries' his own electron-clock that is used to synchronize times at all locations. It will be noticed that only whole numbers of units (i.e. integers) are used in this scheme; all references to imaginary **infinities** are rejected as unrealistic; in other words: "**real numbers are not real**". The trick is to use the appropriate units for space and time (see §5.2.6). An earlier paper, analyzing Einstein's SRT, also critiqued the assumption that reference frames [142] had any physical significance – another example of mathematical physicists conflating epistemology and ontology. The conventional three spatial dimensions and one for time are quite adequate for humans and scientists. We are happy to leave the concept of space-time with mathematicians and believers in field theories.

#### *5.3.3.5 QM's Necessary Features*

The following physical features need to be incorporated in any theory of electrons i.e. quantum mechanics:

1) Variations over time will become variations over space when the locus of the variation moves through space (in other words, the pulsating particle model can explain the apparent appearance of wave behavior in the world, not vice versa). In particular, the resulting Fourier transforms introduce the mathematics of waves (but not physics – as there is no medium).

2) No two real consecutive measurements of velocity (or any of its related concepts, such as momentum or kinetic energy) can be made in the limit of zero time separation. Differential calculus is simply a mathematical fiction.

3) All interactions between electrons must occur at two distinct times and each (inter)**action** must always be quantized.

4) No measurement between macro observers and atomic scale electrons can occur without a finite momentum exchange.

5) No repetition of micro systems (or their context) can be repeated exactly, so variations are inevitable, as are statistics.

6) The idea of a common existence (ontology) must ground any model of electrons and their interactions with humans.

7) All measurements must be traceable to variations in location (relative to a given reference frame).

8) The variable effects of the environment (context) of any system must be recognized as destroying any experimental possibility to recreate 'ideal' isolatable systems. All repetitive experiments must generate statistical scatter (big numbers need statistics).

### 5.3.4 THINGS, NOT SYMBOLS

Modern physicists need to remember that although mathematics is seen by them as central to physics it does not play such a powerful role amongst the general population. Newton's theory produced a radical change in European thought because it provided an understandable explanation of the (nearby) cosmos. Similarly, Bohr's image of the planetary model of the atom still gets a lot of interest because it is readily understandable (even though it has been superseded by quantum mechanics). If physics is to only offer mathematical symbols as its representation of reality then physicists should not be surprised that increasing numbers of non-scientists will reject their 'explanations' and retreat into the older but equally mysterious religious views. All the talk about things not existing at the atomic scale or that nature only appears in logically contradictory modes, such as waves **and** particles, will corrode the population's faith that physicists knows what they are talking about. Commonsense may be uneducated but it is not stupid.

## 5.3.5 POURING CONCRETE

When the Quantum Mechanics created their new models of the atom, they cleverly spent a lot of time defending their new theories against future, possible criticisms (a tactic referred to here as 'pouring concrete' – as in building a Maginot Wall). QM's survival for 100 years points to their success.

### *5.3.5.1 Pre-empting Criticism*

When Heisenberg and Bohr first established their **Copenhagen Orthodoxy**, they were attempting to block off any potential attacks on their theory by establishing a 'sacred' trinity of assumptions that had to be present in any rival QM theory; these included:

1) All references to the EM interactions in the atom had to be presented in terms of Maxwell's EM theory;
2) All mathematical formulations had to use the differential calculus (i.e. continuous interactions);
3) Therefore, all rival theories had to be implicit field theories, i.e. particle trajectories were totally banned.

This strategy has been overwhelmingly successful, perhaps for institutional reasons, but it has meant little progress since 1930. This attempt to issue a 'Papal Decree' dictating the form of future research is completely rejected in this programme. Einstein proposed his famous classification in 1919. **Constructive** theories are schemes, which postulate the existence of simple entities behind the phenomena. They endeavor to reconstruct the phenomena by framing hypotheses about these entities. **Principle** theories, in contrast, start from imaginative principles, i.e. general statements of nature'sl regularities, employing no (or only a bare minimum of) theoretical terms. The purpose is to build up the theory from such principles. That is, one tries to show how these empirical principles provide sufficient conditions for the introduction of further theoretical concepts and structure. Different philosophers prefer one approach or the other (by temperament?).

### *5.3.5.2 Heisenberg's Mistake*

As discussed above, Heisenberg made a huge mistake exaggerating the importance of his Uncertainty Principle, as has later been shown in Semi-Classical Mechanics (§4.1.8.4). In fact, the concept of a **particle** having a unique location at any one time was one of Newton's most fruitful innovations, when a particle moves, it must inevitably define a path through space (trajectory) since it continues to exist. Our own models of atomic systems have shown that this concept is still immensely valuable in predicting the energy levels of all kinds of atomic systems, including those with multiple electrons, such as the helium atom, which defeated all of Heisenberg's attempts, including his own fruitless Matrix Mechanics, which remains only of interest to historians of mathematics.

### *5.3.5.3 Schrödinger's Philosophy*

Schrödinger often said that philosophical conclusions cannot be derived from physics, whereas philosophy could influence physics; this was his gnostic (or Vedantic) world view of the unity of nature. He always viewed waves as fundamental, seeing all particles only as epi-phenomena. Schrödinger utterly rejected Bohr's view that a space-time description of atomic processes is impossible, stating that: "*Physics does not only consist of atomic research, science does not only consist of physics and life does not consist only of science*." He continued: "*All our other thinking is active in space and time. If QM cannot be fitted into space and time, then it fails in its whole aim and one does not know what purpose it really serves*." After Bohr's interrogation (rather brow-beating) of Schrödinger, such that Bohr appeared to Heisenberg to be the actions of a fanatic, Schrödinger never agreed that that it was necessary, or how it was possible, to destroy the space-time descriptions of atomic processes. He recognized the necessity of both waves and particles but sadly, he never devised a comprehensive interpretation of quantum phenomena to rival the Copenhagen interpretation or any reconciliation of this contradiction. Unfortunately, he was neither as good a politician or polemicist as Heisenberg, so Schrödinger's opinions have gradually faded away over time compared to his rival. It is hoped that UET helps preserves Schrödinger's philosophy and reputation even if it utterly rejects his mathematics (Wave Mechanics).

# 6. SUMMARY & CONCLUSIONS

In this final section, the results and conclusions from this paper will be briefly summarized in order to draw out the major implications from the material. The paper concludes with summaries of the future papers in this programme. We will let the comparison of the analytic predictions of this theory with experiment be the justification for the assumptions made here, as is usually done with all QM hypotheses.

## 6.1 SUMMARY and OBJECTIVES

One of the personal objectives of this research is to continue with the research programme of J. J. Thomson, who by 1900 wished to "*rewrite physics in terms of the newly discovered electron as well as to get beyond Maxwell*".

### 6.1.1 HISTORICAL & PHILOSOPHICAL INTEGRATION

One of the principal objectives of this research programme is to restore philosophy to the study of nature. Far too often, very old ideas from Ancient Greece have persisted deep into the heart of modern science. One of the key roles of philosophy is to clarify our thinking about our concepts. Thinking about reality inevitably forces everyone to face up to the issue of existence – a central area of philosophy known as **ontology**; however, modern quantum theory has vigorously tried to deny this fact. This is mainly because quantum specialists have constructed a **mathematical** theory of the micro-world that cannot be given an objective, non-contradictory interpretation. These theorists have ejected most philosophers from their private temple because these rivals persisted in pointing out their shortcomings and inconsistencies. **Mathematicians prefer their symbolic view of the world to a conceptual understanding**. However, the history of science shows the value of clarifying our ontological ideas. The study of heat persisted with the old idea that it was one of the four basic substances of the world (along with air, earth and water). Scientists persisted with this ancient, wrong idea even when they had renamed it "*caloric*". This was originally thought of as just the basic stuff exchanged between bodies to explain our experience of hot and cold. It was only when Maxwell and others at the end of the 19th Century developed the kinetic theory of heat was it acknowledged that heat was simply the agitation of matter but even then the temptation to invent a new fundamental substance could not be resisted; now it was to be known as *energy*. The recognition that heat was just another mode of matter (agitated) led to rapid progress in chemistry and eventually to an awareness of its atomic forms.

The present research believes that similar benefits will flow from rejecting an ancient, mistaken view of ***light***, actually tied back to the Greeks' fifth fundamental element: *æther*. Maxwell's EM theory was a mathematical renaissance of the ancient theory of waves in the æther. Scientists have claimed to reject this ancient substance but still speak of oscillations in the electric and force field densities; simply a mathematical, semantic switch. **Light** has long been seen as some form of fundamental stuff that travels across space but models based on iconic images of billiard balls or water waves fail to explain all its mysterious behaviors. The present theory also views light (like heat) as an agitated mode of matter but now one that communicates this agitation from a single source electron to another, remote (receiving) electron. Contrary to long-held human prejudices that only direct touching can communicate changes, this remote agitation does not need a carrier of some magical substance. It proposes to use another property of matter (called electromagnetism) that communicates **action-at-a-distance**; these intrinsic interactions between electrons are similar to Newton's views of gravity but now there is a finite (non-zero) time required for the interaction to span the separation across space: a mode called **asynchronous** action.

Physics is the latest manifestation of the ancient tradition called natural philosophy; unfortunately, contemporary physicists have stopped studying their roots, which are firmly embedded in western history. All they have retained is the original obsession with geometry. Much of modern physics can be seen in the views of **Demokritos**, one of the followers of Thales, the first of the pre-Socratic philosophers, who wished to understand the nature of 'things' or what is now often called "material objects". These philosophers appreciated that language was a powerful tool for representing reality. Demokritos focused on the key verb in European languages: the verb 'to BE' – or what **IS**. This was a logical approach (developed in philosophy as the topic of **ontology**), as reality must involve things that **exist**. Since large-scale objects can be cut in half, it seemed intuitive that this process could be repeated indefinitely – an idea that underlies the Continuum Hypothesis. **Zeno** of Elea also assumed that time itself could also be divided infinitely, especially into equally sized units (by analogy with similar days). This hidden assumption resulted in a set of famous verbal paradoxes. However, Demokritos rejected this implicit infinite process and proposed that there must be a finite end to the division of matter, which he called "**atoms**" – the smallest unit of matter that cannot be divided (or "cut") any further.

The Renaissance Revival of ancient philosophy, beginning with Galileo and Descartes, accepted the mainstream approach to Nature, especially the commonsense Continuum Hypothesis of matter, as proposed by Parmenides in his model of solids and liquids but rejected most of Greek metaphysics, including the atheistic model of atoms. Their revolutionary innovation was to reject Aristotle's kinematics, which viewed the natural state of objects to be stationary, so that continuous effort was then needed to maintain any state of motion.

Newton was powerfully influenced by his immediate, renaissance predecessors and his knowledge of ancient philosophy. In particular, he adopted Demokritos's atomic model of matter while retaining Zeno's continuum view of time. Newton also accepted Galileo's radical model of material inertia, so that objects continued to move at a steady speed in a straight-line until they were influenced by an external force, originating with remote matter. Newton also elaborated on the new concept of vanishingly-small time differences (or "infinitesimals") that were vigorously rejected by Jesuit intellectuals [143] but accepted by Galileo and John Wallis (Newton's colleague in the Royal Society). These ideas converged in the key concept of **force** and formed the foundation of what became known as Classical Mechanics, grounded in the mathematics of infinitesimals or calculus. Maxwell extended these ideas by filling continuum space with continuous EM forces (fields) that appeared as **waves** when periodic activity was introduced.

The discovery that matter did occur as atoms was a radical shock for Classical Physics but these were soon found to be not the ultimate, smallest level of matter – a role reserved for **electrons**, which have never been found to consist of anything smaller. The present theory (UET) accepts the finitude of matter, grounding its ontology on the electron, but extends this finitude to the time intervals characterizing the interactions between electrons. In contrast to the oldest human prejudice that an object must be observable to exist, UET proposes that the existence of electrons is unconditional and since it views "light" as the interaction between electrons then they can never be observed (nor measured) without changing their invisible dynamics.

## 6.2 THE FAILURE OF CLASSICAL PHYSICS

One of the principal objectives of this research programme is to restore philosophy to the study of nature. Far too often, very old ideas from Ancient Greece have persisted deep in the heart of science. One of the key roles of philosophy is to clarify our thinking about our concepts. The most undeniable fact that all humans face is that of existence: a central area of philosophy known as **ontology**. Thinking about reality inevitably forces everyone to face up to the issue of existence; however, modern quantum theory has vigorously tried to deny this fact. This is mainly because quantum specialists have constructed a mathematical theory of the micro-world that cannot be given an objective, non-contradictory interpretation. These theorists have ejected most philosophers from their private temple because these rivals persist in pointing out their shortcomings and inconsistencies. Mathematicians prefer their symbolic view of the world to a conceptual understanding.

However, the history of science shows the value of clarifying our ontological ideas. The study of heat persisted with the old idea that it was one of the four basic substances of the world (along with air, earth and water). Scientists still persisted with this ancient, wrong idea even when they had renamed it "*caloric*". This was basic stuff that was exchanged between bodies to explain our experience of hot and cold. It was only when Maxwell and others at the end of the 19th Century developed the kinetic theory of heat was it acknowledged that heat was simply the agitation of matter but even then the temptation to invent new fundamental stuff could not be resisted; now it was to be known as *energy*. The recognition that heat was just another mode of matter (agitated) led to rapid progress in chemistry and eventually to an awareness of its atomic forms.

The Renaissance Revival of ancient philosophy, beginning with Galileo and Descartes, accepted the mainstream approach to Nature, especially the commonsense Continuum Hypothesis of matter, as proposed by Parmenides in his model of solids and liquids but rejected most of Greek metaphysics, including the atheistic model of atoms. Their revolutionary innovation was to reject Aristotle's kinematics, which viewed the natural state of objects to be stationary, so that continuous effort was then needed to maintain any state of motion.

**Newton** was powerfully influenced by his immediate, renaissance predecessors and his knowledge of ancient philosophy. In particular, he adopted Demokritos's atomic model of matter while retaining Zeno's continuum view of time. Newton also accepted Galileo's radical model of material inertia, so that objects continued to move at a steady speed in a straight-line until they were influenced by an external force, originating with remote matter. Newton also elaborated on the new concept of vanishingly small time-differences (or "infinitesimals") that were vigorously rejected by Jesuit intellectuals but accepted by Galileo and John Wallis (Newton's colleague in the Royal Society) [143]. These ideas converged in the key concept of **force** and formed the foundation of what became known as Classical Mechanics, grounded in the mathematics of infinitesimals or calculus. Maxwell extended these ideas by filling continuum space with continuous EM forces (fields) that appeared as **waves** when periodic activity was introduced. Maxwell's idea of space was flawed (based on the experimentally discredited idea of the æther) but it has conveniently evolved into the abstraction known as '**space-time**'.

This paper critiques quantum mechanics (QM) from the perspective that most physicists have constructed their personal knowledge base on their study and education in classical mechanics (CM). Not only did CM reinforce their commonsense interpretation of the world around them (as this too is a macroscopic perspective) but CM was developed from idealistic and isolated '**perfect**' models, where the objects forming the 'target' system are isolated from all other interactions in the universe and subject only to 'internal' interactions.

Even more so, our **imagination** creates mental models of these perfect CM models that can be harmlessly scanned, like our normal vision allows us to look at macro-objects with no obvious consequences; this reinforces our 'Godlike' view of human-scale reality. We have come to expect these features to operate equally well at all scales of reality, including the micro-world of atoms and electrons. It is no wonder that a series of revolutionary experiments shattered our assumptions about our foundational scales of reality. The paper began with a quick summary of these key **experiments**, as physics **must** be grounded in in empirical roots. A comprehensive physics must be able to develop a **unitary** set of concepts and techniques, which can work effectively for us in the micro-world and then show how they can be approximated into the older approach (which worked so well for us in CM). Failure to create such a unitary view will mean that we will be forced (like Heisenberg) to adopt the dual-domain approach with different styles for handling CM and QM.

## 6.2.1 DISCRETE INTERACTIONS

The understandable urge to preserve the advances made by **Maxwel**l in his field theory of light meant that the discovery of the electron was easiest to accommodate by assuming **both** were basic entities of reality: an electromagnetic (EM) **wave** of fluctuating electric and magnetic force-densities and a localized, mass **particle** for the electron. The problem here was that these two phenomena are aspects of the **same** component of reality when one interprets *light* as the far interaction between electrons; they **cannot** be separated. There are six major experiments that showed that the **interactions** underlying various configurations of matter can **not** be **continuous**; a key universal assumption made always in CM since **Newton** introduced the continuous concept of **force**, which facilitated the powerful mathematical techniques (later called the infinitesimal **calculus**) he also invented to describe his corpuscular (particle) model of matter. Kirchhoff's heat studies in the 19th century of what he called "*blackbody* radiation" were the starting point of what eventually became quantum theory. This radiation was correctly assumed to be electromagnetic, so that 1896 Wien could analyze this phenomenon in terms of its frequency components (as all wave phenomena could be deconstructed into their Fourier frequency components); he found that the energy/frequency spectrum was independent of the type of material forming the walls of the hot body. Using classical EM wave models, Lord Rayleigh and Jeans independently created mathematical models that derived Wien's spectrum curve but only in the low frequency range. These models represented the cavity, within the hot hole, by sets of independent harmonic oscillators: a well-used math model. In 1900, Planck created his own theory that fitted the experimental results at **all** measured frequencies, thus avoiding the high-frequency (UV) Catastrophe, predicted by Rayleigh-Jeans. Although Planck still used harmonic oscillators to model the EM waves in the hot cavity, he was forced to introduce a "**mathematical fiction**" (later called the *quantum of **action***) to achieve this result: Quantum Theory was born. Although this paper eventually made Planck world-famous, he was hugely discomforted by his arbitrary (but necessary) break with the Continuum Hypothesis of classical physics and the implied threat to the universally revered Maxwellian theory of EM.

The related theory of **specific heats** studied solid materials but at low temperatures, trying to see how much external (heat) energy would be needed to raise the temperature by one degree of one unit (gram) of various pure substances. Theorists could not create a math model that matched the experimental findings. In 1907, **Einstein** was the first to extend Planck's blackbody radiation approach to new areas. He invented a very simplified model of a crystalline solid by replacing each atom with three independent harmonic oscillators (one for each direction in space). Like Planck, Einstein found he could only match the experimental results if he made two arbitrary assumptions, namely: that each oscillator's energy E, when vibrating with the same frequency f, could take on only multiples of a quantum of energy ($h$ f), where $h$ was the constant of **action** assumed by Planck for his blackbody radiation theory. Note: the quantity action $\mathcal{A}$ is defined as energy multiplied by time T; i.e. $\mathcal{A} = E\,T = E / f = n\,h$, {where n is an integer, including zero; $n = 0, 1, 2, \ldots$}. It was in 1902 when Lenard realized that another anomalous interaction phenomenon occurred when he measured the electrons he found being emitted from a solid body, when it was illuminated by high frequency (UV) light. The classical mystery was that the energies of the ejected electrons were independent of the incoming light intensity (brightness) but increased directly with the frequency of the light. Once again, Einstein played his powerful Planck card (that was still widely viewed as too radical) and proposed that light was itself **acting** like a particle of energy (he called it a '***light-quantum***') that was bouncing electrons directly out of the target's solid surface. These quanta, from light of frequency f, exchanged energy in 'packets' like Planck's radiation model; i.e. exchanged energy $E = h$ f.

The most dramatic paper in 'Old Quantum Theory' was the mathematical model of the **hydrogen** atom published by Niels Bohr in 1913. Bohr combined several ideas that he picked up in his post-doctoral visit to England. He selectively adopted the static Coulomb part that had been adopted unchanged by Maxwell in his radical EM paper in 1865 but ignored all the parts that showed that an electron moving at high-speed in a curved orbit should radiate all its energy quickly to other electrical charges. He accepted Nagaoka's suggestion that angular momentum (with the same dimensions as action) might also be quantized, as Planck had suggested. This gave Bohr a series of quantized energy orbits surrounding the nucleus in a model that deliberately resembled Kepler's planetary model of the solar system. Bohr finally had to make a further assumption: only changes in an atom's energy levels manifested as EM radiation. Astonishingly, this collection of assumptions gave excellent agreement with the very few special frequencies measured with heated hydrogen atoms, which Bohr now knew had been 'number-fitted' (without explanation) by Balmer several years before. Even more astonishing was that Bohr could populate the various energy levels of his hydrogen atom with several electrons that did **NOT** interact with each other and then provide a plausible explanation of all the atoms organized chemically into the Periodic table.

One year after the publication of Bohr's paper on his planetary model of the hydrogen atom, Franck and Hertz reported on their results of accelerating electrons through a gas of mercury vapor. They discovered that at certain accelerating voltages (energies) the electron current dropped abruptly. Classical physics could not explain these observations and would have expected a gradual change in current strength as the electrons moved faster. Quantum theory could explain regular collisions between the electrons in the external current until a threshold energy was reached that could excite the electrons in the mercury atom to absorb enough energy to move around the atom at a higher 'quantum' level. This was one of the first experiments to demonstrate that quantum effects occurred in atoms other than hydrogen and that the electronic structure of atoms gave them the observed stability, which had always mystified classical physics.

The unexpected discovery of **radioactivity** found in certain 'heavy' elements (such as uranium and radium) also seemed to indicate that discrete effects might be present in the cores of certain atoms. This new radiation was later shown to be either very high-energy EM rays (called '**gamma** rays'), or tiny but energetic particles (electrons – **beta** rays or helium nuclei – **alpha** particles). All of these 'rays' would prove to be a useful tool for exploring an even smaller scale of matter, subsequently called '**nuclear physics**'.

It can be readily seen that these six discrete phenomena shared a common focus on **the interaction between light and matter**. Indeed, if we adopt the UET view that light is just an interaction between electrons and atoms involve electrons, then we can see that we are looking at multiple examples of just **electrons interacting with electrons**. Before the discovery of electrons in 1897, one can also see why so many theoretical physicists, including Maxwell, would try to create mathematical models of light, by filling empty space with simple harmonic oscillators – one of the easiest physical abstractions (models) to describe with simple mathematics. It is also suitably appropriate that early quantum theory was built on a synergistic relationship between **Planck** and **Einstein**. In 1905, Planck played a key editorial role in getting (the unknown) Einstein's **Relativity** paper published in the top German physics journal ('*Zeitschrift fur Physik'*). As an unknown physicist with little to lose (but with a fantastic imagination), Einstein could see the revolutionary implications of Planck's Quantum Hypothesis in his theory of EM radiation. Einstein's equally unwarranted mathematical assumptions in deriving his mathematical explanations for the mysterious experimental phenomena of specific heats and the photoelectric effect did much to establish the truly revolutionary quantum theory (and their international reputations). Unfortunately, it also established the tradition that mathematical models were assumed to provide a sufficient explanation of electron activity in the micro-world.

### 6.2.2 CONTINUOUS WAVE EFFECTS

The above six crucial electron experiments that have been interpreted from the particle perspective, there are another five experiments at the atomic scale that have been traditionally interpreted in terms of continuous wave concepts. It is the co-existence of these eleven key **experiments**, which challenge physicists to develop a single and coherent model of reality; instead too often the phrase "**both** particles **and** waves" have been offered as a 'paradoxical' view, since these two concepts are **contradictory** (not 'complementary' as in the Bohr – Heisenberg orthodoxy). This contradiction is often hidden as each domain is only described with its own mathematical techniques.

**X-rays** were discovered about two years before the discovery of electrons. The high-speed electrons were able to cause the emission of EM beams at higher frequencies than UV light. The EM nature of X-rays was shown by the father/son **Bragg** team, who produced normal scattering off crystals that were viewed as atomic scale diffraction gratings; the results were readily interpreted from similar optical scattering in terms of interference effects based on exact multiples of the X-ray wavelengths. Arthur **Compton** also demonstrated unexpected effects by measuring the shift in wavelengths when X-rays scattered off free electrons; this effect was interpreted as a remote analog of the photoelectric effect, where the X-ray was behaving like one of Einstein's momentum carrying photons.

Some of the earliest crucial experiments again involved electron scattering directly off regular crystals to test de Broglie's electron Wave Hypothesis: G.P. **Thomson** observed circular interference patterns using thin gold film targets, while C. J. **Davisson** measured the back-scattered electrons off polished nickel surfaces. Both sets of measurements showed that the electrons, with momentum P were 'behaving like' waves, with a wavelength $L = h / P$.

The most mysterious of the electron-wave experiments involved using electron beams instead of light in a Young-style **Double-Slit** Interferometer. This quintessential QM phenomenon remained only a 'thought-experiment' until the 1950s when experimentalists actually succeeded in demonstrating these mysterious effects, first with electrons, later with neutrons and finally with molecules. The idea that the singular electron "must behave as a wave" is that both slits must be open simultaneously while the electrons may be so far apart in time that there can only be one passing through the screen at a time, excluding the possibility of interference between two moving electrons. This led to the analogy with water waves going through both slits and interfering at the target screen.

Leaving aside the Double-Slit experiments for the moment, the electron-scattering experiments actually exhibit delayed electron/electron interactions, which have been **assumed** to involve real intermediaries, such as X-rays, but these are never seen directly for to interpose an intermediate observation would be to totally alter the global nature of each experiment.

Electron beams hitting a metal source (at A), then 'emerging as X-rays' and interacting with a target system (at B), whether gold foil or nickel surfaces or even 'free' electrons (like Compton), can instead be interpreted here as energized electrons in A asynchronously interacting directly with secondary electrons in B. Every such EM electron interaction is constrained to exchange only multiples of the quantum of action, as Planck first proposed in 1900. This is an intrinsic constraint on how electrons interact with one another.

### 6.2.3 CLASSICAL ASSUMPTIONS

It is the primary contention of this paper that when physicists are trying to understand quantum experiments, they are unconsciously using their assumptions based on their **formal education in classical physics**, especially the mathematical tools they are familiar with. In addition, physicists were reluctant to abandon (or even challenge) their two major classical theories: Newtonian mechanics and Maxwell' EM theory, whose foundational concepts are still being imported implicitly ('smuggled') into quantum mechanics.

The most important is what is called here the **Continuum Assumption**: the guess that bodies continuously interact together – a harmless idea when calculus is mapping macro-interactions (such as gravity), when they are referred to as **forces** but unwarranted when dealing with novel particles like electrons. The alternative approach here is to assume discrete **impulses** occurring at finite time intervals. Again, few would challenge the assumption of **time asymmetry**, when only events in the past seem to influence the present (retarded), as this appears to be how all animal memories operate. Again, based on human observations, classical physics assumed that all interactions occurred simultaneously; this meant that only single-time physics, such as the use of **Hamiltonians**, were appropriate in all situations. Tragically, even Newton contributed to this error, even though he did introduce the revolutionary concept of **Action-at-a-Distance** (or 'Far-Action'). Newton was fortunate that the time-periods involved in planetary interactions are so long that his assumption of gravity acting instantaneously was accurate enough to comply with Earth-bound observations. In extending his original model of particle interaction from the discrete **impulse** concept to the continuous **force** concept, Newton closed the gap of 'obviously' continuous planetary motion but left mathematical physicists with the dangerous assumption that **ALL** particle interactions were continuous. Again, Newton and his successors had no problems co-opting the medieval metaphysical ideas of **determinism** and local **causality**. Both concepts readily slipped into the mathematical machinery of calculus: the **continuum** differential mathematics of simple change.

Central to Newton's revolutionary mechanics was his invention of the concept of **momentum** of a particle, based on the mathematical idea of **instantaneous velocity**. There has never been any method of ever measuring this concept. Classical mechanics accepted its mathematical definition (although never attempted to measure its value) but it was Heisenberg, who obsessed on this idealization in his attempt to eliminate the useful idea of a particle's **path** from any valid theory of QM. The discrete form of this concept is key to understanding quantum interactions, manifesting as impulses producing **finite** changes in velocity and energy. Finally, physicists have to accept that all macroscopic measurements involve finite interactions with the micro-world that will change their inherent, natural behaviors. Indeed, the world may be far more complex than we could ever imagine (or compute) if electrons are **aware** of each other at **all** finite separations of space and time (including the future). Statistical results in all atomic measurements are inevitable.

Furthermore, another very old concept from Ancient Greece continued to survive into modern times; especially the foundational idea of **substance**, with its own independent existence. The most problematic of these invisible entities was the idea of **energy**; what should have remained only a property of particles in relative motion became the magic ingredient underpinning force **fields** of EM and gravity.

It was not surprising that the empty parts of space were soon filled with the all-pervasive **field** concept, as **Maxwell** wished (for religious reasons). Even though he filled space with his fantastical **æther**, he was then able to establish a suitable theory of light as electric and magnetic forces fluctuating across this invisible medium. When Helmholtz later replaced the æther with continuous **charge-density**, Maxwell's mathematics were found to work just as well, so it evolved into Classical Electromagnetism (waiting to be quantized in the 20th century).

Again to simplify our mathematical models of the world, an interaction was reduced to a single point in space and time (**localization**). Two-sided interactions were reduced to a **single** point in time, so that the total temporal derivative technique could be used. However, we have already shown that finite time delays (as in the EM interaction) are incompatible with the assumption that forces always act continuously between localized *inertial* bodies. Maxwell deliberately introduced his field concept in an attempt to bypass the finite EM interaction delays. This was a valid approach as long as his foundational **æther** was a real, physical possibility. This inevitably led to the **broadcast** model of interaction, where an agitated electrical source generated an EM wave moving spherically outward until it was totally absorbed by several (random) remote absorbers.

The discovery of the electron smashed Maxwell's source of electrical effects and destroyed Helmholtz' concept of continuous **charge density** that had been smuggled into the classical theory of electromagnetism (CEM). All field theories have evolved from these basic assumptions and today dominate all present models of basic reality (e.g. Quantum Field theories). We are building on sand.

# 6.3 A SUMMARY OF QUANTUM MECHANICS

In their rush to generalize, physicists were eager to extend their research to the tiny center of the atom (the nucleus) by simply assuming that the recently discovered electron was now fully understood. In contrast, this research believes that it is the extended, new properties of the electron (especially its interactions) that must be investigated further to understand the significance of quantum mechanics, which more accurately should have been called "Electron Mechanics". Feynman's radical theory of Quantum Electro-Dynamics (QED) made the situation more difficult to understand as he entangled the source of EM activity (the electron) with its mutual interactions ("light"). Worse, his computational method ("Sum over Histories") could be presented as very appealing visual images ('Feynman Diagrams') that persuaded many that these were pictures of reality, with his 'wavy' lines representing photons and his solid lines representing possible electron trajectories (that Heisenberg had supposedly banished from orthodox QM).

It is disappointing and it may surprise many readers to discover that most professional physicists have only a limited knowledge of QM. Most of the early education of people, who end up as physicists, is focused on 'solving' famous examples in classical mechanics; this teaches an approach ("Physics-in-a-Box") where idealized models have been constructed that are solvable with the mathematical 'tools of the trade'. Even as undergraduates, few physics students read original papers or even 'classic' texts. There is so much material to cover for exams in the curriculum that even foundational topics, such as relativity and quantum mechanics, get only a superficial review. It is for these reasons that much of the material in this section was included. It provides information and perspective to even senior physicists, who have been pursuing their own specialty during their career and never got down into the details of their own science.

## 6.3.1 EARLY QUANTUM PHYSICS

The third section was included to make manifest the **assumptions** often hidden in many presentations of quantum mechanics and to emphasize that it is **action** (really inter**action**) that is quantized, **not energy** because it is this perspective that explains the wavelike properties of electrons. This important feature was included herein by reminding readers of the usually forgotten quantization rules of Wilson and Sommerfeld. Bohr's planetary-like model of the hydrogen atom was examined in some detail because it has captured the imagination of physicists and the general-public, alike. The one key idea to emerge from Bohr's model of the hydrogen atom was the central importance of quantized angular momentum (originally from Nicholson). Additionally, Bohr had assumed that observed EM emissions from the hydrogen atom **only** occurred when the electron made transitions between different energy 'states'. Unfortunately, this was the start of the era of mathematical "explanations", when philosophical (meaningful) questions were beginning to be dismissed as "*meaningless*". Discussion is also included on the venerable Sommerfeld atomic model of the hydrogen atom that showed his rules, plus high-speed (relativistic) corrections (generating elliptical orbits – like the planets) could produce **all** the small corrections (except 'spin') of the advanced, 'Second-Quantum-Generation' Dirac relativistic, model of the hydrogen atom. A table is included here to compare and contrast the differences between atomic and planetary systems to remind physicists of the dangers of using bad analogies.

## 6.3.2 BRIEF HISTORY OF QUANTUM MECHANICS

The criticism of orthodox QM is most easily appreciated when QM's evolution is viewed in its historical consequence, especially as *time* is viewed here as the most under-appreciated factor in electron interactions. This is why the History of QM forms a major part of this section: historians of science also play a major role (retroactively) in uncovering little known facts on how a scientist's ideas evolve.

### *6.3.2.1 Heisenberg's Matrix Mechanics*

Heisenberg's matrix mechanics are critically examined even though this approach was soon bypassed by Schrödinger's more popular wave mechanics. Although these, at first, seemed diverse mathematical techniques (consolidated later by Dirac), these two physicists tore into each other's philosophical interpretations of QM. By associating with the more famous Bohr, Heisenberg seemed to have won this rhetorical war with the general acceptance of the confusing Copenhagen Interpretation of QM.

### *6.3.2.2 Wave Mechanics*

Although Schrödinger's name is most famous for his approach to QM, it was actually Louis de Broglie, who proposed the truly radical concept, which made people (including Schrödinger) associate the **mathematics** of waves with electrons. In fact, de Broglie's thesis hypothesis: that an electron with momentum P is associated with a wavelength $\lambda$ is no more than Planck's hypothesis of action $\Delta\mathcal{A}$ being quantized: $\Delta\mathcal{A} = P\,\lambda = h$. Schrödinger's trick was to suggest replacing the algebraic variable P, representing the electron's instantaneous momentum with the corresponding **linear operator** form: $\mathbf{P}_x = ih\,\partial/\partial x$ in the electron's classical Hamiltonian to produce his eponymous equation. It was the need to provide the resulting differential operators with a function to act upon that introduced the mysterious 'wave function' $\psi_n[x,t]$. This was all purely a mathematical proposal and offered **no** physical insights into the resulting hydrogen atom. Further mathematical hypotheses linked all this mathematical 'machinery' to the **averages** of sets of corresponding experimental measurements. Bohm's quantum text was introduced as one of the most extensive discussions of the Wave Mechanical approach to developing QM.

### *6.3.2.3 Dirac's Quantum Formulation*

Major emphasis was made here on Dirac's formulation of quantum mechanics because he not only unified the earlier rival methods, he also wrote much more explicitly on QM's foundations; furthermore, his approach has become much more accepted in the last 50 years. Dirac's approach was explicitly built on older ideas of classical mechanics and was the only one to include systems involving high-speed (relativistic) electrons. Unfortunately, Dirac's approach to quantization was also ***heuristic***, like his contemporaries; he appeals to the agreement of the theoretical results with experiment to justify his whole scheme. Again, his heavily oriented mathematical approach offers few insights into the mysteries of quantized atomic systems; it has never been extended to multi-electron atoms.

### *6.3.2.4 The Hydrogen Atom*

The later "Young Quantum Turks" might dismiss the Bohr/Sommerfeld solutions with the label 'Old Quantum Theory' but their own numerical predictions were only a few percentages away from Bohr's original results, while they failed to offer any useful imagery for anyone (including themselves) to form a firm foundation for future conceptual advances. 'New QM' quantum models of the hydrogen atom are revisited here, because this simple atom is the only **real** system that has been analyzed successfully by all versions of QM. The ready solution of Schrödinger's Equation was only possible due the extensive efforts made in the $19^{th}$ century to solve similar differential equations that arose from models of vibrating spherical crystals. Like all the other solutions, Schrödinger begins with the classical model of a particle, at a single point in space, being acted upon continuously by a static, central electric force (Coulomb's) with the conserved energy represented at a single moment of time by its Hamiltonian function. Unlike Old QM (with its 2D classical, planar view), New QM always (why?) began with a three-dimensional perspective that introduced 3D spherical polar co-ordinates. This allowed the total angular momentum of the particulate electron around the nucleus to be entered, which greatly simplified the analysis, as this quantity was a constant in similar classical models by invoking the well-understood surface spherical-harmonic functions. A separable, mathematical solution introduces related LaGuerre functions of multiples of Bohr's atomic radius. Finally, it is the zeros of this latter complicated function, which define the solution and determine the position of a set of radially constant surfaces with related nodes distributed around the sphere. In practice, only the discrete energy level solutions are extracted. It can be readily seen that highly sophisticated mathematics is needed here, compared to the simple ideas and mathematics used by Bohr. The tiny improvements in numerical accuracy seem a small reward for the exceedingly difficult mathematics that offers only an opaque view of this simple one-electron atom. Dirac's approach was much cleaner but still resulted in the same differential equations. The major benefit of ending up with spherical harmonics is that **any** motion in three dimensions can be represented by a weighted sum of these functions that form a complete set (the 3D equivalent - or dual - of plane wave Fourier harmonic analysis). This implies that any motion of the electron in the hydrogen atom can be covered by this style of solution. Indeed, the UET theory has the electron moving linearly between the nodes of these solutions – only interacting spasmodically with the nucleus and not continuously as in QM. Therefore, one is **not** entitled to claim that this is a wave mechanical model of this atom, when a particulate trajectory satisfies the same energy levels.

### *6.3.2.5 Quantum Consequences*

The preceding details of the New QM were analyzed because they introduced several new concepts, some of which have presented major conceptual difficulties. These new concepts included the Uncertainty Principle, Superposition, Probability and Measurements. These ideas remain at the heart of the Interpretation Issues confronting the complete acceptance of QM; they were examined further in this subsection. In particular, Heisenberg's **Uncertainty** principle was shown to be only a statistical result of the mathematics used. There was no logical connection between its statistical spread of expected pairwise measurements and Heisenberg's vehement rejection of the principal characteristic of using the particle concept to describe the electron; namely the idea of a singular position at any one moment of time and the implicit generation of an orbital path over time.

**Quantum Superposition** is the mathematical assumption that a linear combination of solutions is as valid as any one of them alone. The position taken here on probabilities is that there is **no way to exactly repeat** a real experiment; these are many body situations, so one should always expects several results (spread) from trying to repeat the setup of similar (never identical) **measurement** experiments. Superposition is a pseudo-problem invented to solve a major error in theory **interpretation**.

## 6.4 THE PROBLEMS WITH QUANTUM MECHANICS

This section was included because too many accounts of QM believe this fundamental theory is both complete and **absent** any major problems. Too many quantum enthusiasts wish to preserve the magic and mystery of science's foundational subject. However, to be just, before pointing out the major problems with quantum mechanics again, **it is only fair** to allow one of QM's best qualified defenders make the orthodox case.

### 6.4.1 THE ORTHODOX VIEW

The orthodox view of quantum mechanics (QM) is well presented in the definitive article in *Encyclopedia Britannica* [144] by J. H. van Vleck, who in 1971 was the emeritus professor of Mathematics and Natural Philosophy at Harvard University. This is a 15-page article, which begins with the admission: "*Quantum mechanics is the **mathematical** system for describing the behavior of light, molecules, atoms and subatomic particles*." Unfortunately, **van Vleck** continues by making the common mistake of thinking the quantum concept is about **energy**: "*the quantum concept concerns all forms of energy released in discrete units or bundles called quanta*." In reality, as both Planck and Bohr proposed in their revolutionary papers, this new mechanics is about the quantization of the mechanical property known as **action**. Indeed, van Vleck defines 'small-scale' as phenomena, where the action (which he defines only as the time integral of the kinetic energy) is comparable to Planck's constant of action, *h*. Since many atomic systems (like the hydrogen atom) conserve energy (there is even no explicit release of energy within the system), then this definition implies that both the atomic system's energy and its characteristic time periods are **both** small. The professor points out correctly that in all macro-scale phenomena (with which we are all familiar) there must be huge numbers of quanta involved, so that the laws of classical mechanics (CM) appear to apply. Then he falls into the analytic (arithmetic) error of assuming since all matter must be built out of atomic 'ingredients' then it must be possible for us to describe all the properties of large-scale bodies by means of QM. (This totally ignores the synthetic (**holistic**) view that new, emergent properties (like life) arise when many parts are integrated together, wherein these surprising new properties do not exist in any of the parts but emerge from unanticipated interactions from many parts and subsystems.) This surprising claim also ignores the **Three-Body** problem that van Vleck (later acknowledges repeatedly) has defeated all analytic solutions to quantum (and classical) systems involving **continuous** interactions between all system components (this is why physics concentrates on so many **two-body** 'toy' problems).

Professor van Vleck's **Positivism** also emerges when he implies that the real meaning of the quantum only remained hidden before 1913 (Bohr's atomic paper) or even more so until 1926, when the "*true QM was discovered*". The use of this style of language is typical of a **Platonist** (and most mathematicians), who sees mathematics as the Royal Road to the discovery of true knowledge. An extensive quote from one of Dirac's famous QM papers in 1930 proudly concludes his introduction: "*the general theory of QM is now almost complete. ... The underlying laws of the whole of chemistry are thus completely known and the difficulty is only that the exact solutions of these laws leads to equations much too complicated to be soluble*." Furthermore, this 'cheerleading' style gives the impression (also widely shared) that QM is a great triumph with minimal problems. The present paper contradicts this overly positivistic view especially as professor van Vleck's other main interest is Natural Philosophy, where QM's problems are most dramatic but unacknowledged in this article.

Like most classical theorists, van Vleck is happy to accept an approach to blackbody radiation built only on the idealization of myriads of harmonic oscillators, claiming that even though the material æther does not exist, EM waves can be handled by the same **mathematics** as those of a material medium surrounding the radiation enclosure. Moreover, the classical problems were encountered most commonly when atomic scale objects interacted with EM radiation. This has been the most fruitful perspective for physicists, beginning with Bohr, to explore the "mysteries of the quantum". Van Vleck begins his exposition with three pages dedicated to the 'Old' QM, as this is easier to comprehend, both conceptually and mathematically. Like everyone else, he limits this discussion to the atom of hydrogen (with its one electron) and to similar 'hydrogenic' (simple, heavily ionized) atoms, like: $He^{+}$, $Li^{++}$, $Be^{+++}$, $B^{++++}$ and $C^{+++++}$., acknowledging that the dynamics of multi-electron systems are too complex as they are exposed to the "enormous" math difficulties of the infamous **3-body** problem. The hydrogen atom story begins here with the arithmetically simple **Balmer** formula, discovered in 1885, which fits much of the radiation spectrum of the hydrogen atom but which defeated all attempts at understanding by classical theorists. Bohr succeeded by building on his two unjustified hypotheses (or "**postulates**"), namely: 1) there are stable (no radiation) atomic orbitals 2) EM radiation is only emitted when the electron transitions between two distinct energy orbitals, when he used an equation analogous to the one Einstein invented for the photoelectric effect (i.e. $E_1 – E_2 = h f_{12}$). As we have pointed out several times, Bohr's stable ('**stationary**') orbitals used the timeless Coulomb electrostatic force but readily ignored the dynamic radiation features of Maxwell's classical electrodynamics. Thereafter, Bohr simply treated the electron as a classical mechanical particle, subject to all the usual laws of classical mechanics (CM).

In revisiting the Bohr circular orbital model of period $T_n$, van Vleck begins with his action quantization rule: $\langle K_n \rangle T_n = ½ n h$ , where $\langle K_n \rangle$ denotes the average kinetic energy of the atom when in its $n^{th}$ stationary state. Note that the 'natural' frequency of rotation ($1/T_n$) is **not** equal to any of the observed emitted EM frequencies (i.e. $f_{nm} \neq 1/T_n \neq [1/T_n – 1/T_n]$ ) : this was classically totally unacceptable.

**Sommerfeld**'s 1916 relativistic result (using high-speed elliptical orbits) is briefly discussed with all comments on its incredible match with Dirac's solution for the hydrogen atom using his (double spinor) relativistic wave equation of the electron reserved for the end. Other successes of the Bohr/Sommerfeld model ("Old QM") included two other **artificial** 2-body systems, such as the harmonic oscillator and the rigid rotator (or rotating dumb-bell).

Eventually, professor van Vleck gets around to the "New QM" after explaining that the 'New Quantum Turks' (all mathematicians) were truly motivated by the view that QM be grounded on a "rational" mathematical framework. In 1926, the mathematical physicists thought this was supplied by de Broglie's suggestion that an electron had a wavelength λ associated with its motion, characterized by its linear momentum P (mV); i.e. the **Wave-Particle hypothesis**: $\lambda = h/P$. Although de Broglie claimed this was inspired by Hamilton's classical analogy between wave optics (based on Fermat's principle of **Least Time**) and classical particle mechanics (based on the CM principle of **Least Action**), van Vleck criticizes this hypothesis as "*highly artificial*". None-the-less it was really Schrödinger's Wave Equation (with its full retention of **calculus**), which clinched it for mathematical physicists. This deal was sealed with Dirac's demonstration of the mathematical equivalence of all three new mathematical quantum theories and the crystal diffraction experiments on electrons. Interestingly, there is **no** explicit quantization rule in wave mechanics (although Dirac showed its connection) but the conviction rapidly grew that "*the Truth had been discovered*." Discrete results arise in New QM by insisting that the wave function (Ψ) have only '**proper**' mathematical solutions; like being continuous, single-valued and 'well-behaved'; this generates associated characteristic energy values (eigenvalues), with integer number constraints. When QM uses Schrödinger's Wave Equation, it is usually referred to as 'Wave Mechanics' (WM) to distinguish it from the approach used by Heisenberg, when it is referred to as 'Matrix Mechanics'. Van Vleck mainly describes Wave Mechanics (WM) instead of the "New QM". WM uses the polynomial method to force integers to appear when using (continuous) differential equations, especially when only one variable (say x) is involved; this tries for a solution as a power series: $\psi(x) = \sum^{n}_{j=k} c_j x^j$ . In order for x to be a real quantity, the series must be limited, say at j = n; satisfying the Schrödinger equation means that there are restrictions imposed on the constants, $c_k$ and $c_n$. This level of mathematics is usually much too difficult for all but the highest-educated mathematicians (and even they cannot solve other problems with it) but fortunately, Schrödinger realized: several top 19th century mathematicians had explored solutions to some of these types of equations, so he could use their results directly for the hydrogen atom. This polynomial 'trick' could only be used in three dimensions if the variables are separable (see §3.4.2). Physical quantum systems that conserve total energy (well isolated) always generate complex (wavelike) 'harmonic' solutions: $\Psi_n(x) = \psi(x) \exp[-i\, 2\pi\, E_n\, t /h]$. This makes the Superposition Principle (see §3.9.3) just a sum of such waves.

Professor van Vleck only gives one page to Heisenberg's even more difficult '*Matrix Mechanics*', as its mathematics is less familiar and quite useless for real problems. He does describe how Heisenberg's colleague (Max Born) at Göttingen had persuaded him to give up on conventional ideas and adopt the new **positivistic** philosophy: "*Space and time only have a meaning when measured (which is impossible for humans inside an atom)*". What is not often appreciated is that Heisenberg's matrices need an **infinite** set of numbers in each row and needed an **infinite** number of rows, and his physics (like Schrödinger's) relied on direct **analogies** drawn from CM.

Dirac's so-called 'transformation' theory (see §3.5.3) is only assigned a quarter page as its details "*are much too intricate and abstract*" but they do appeal to academic mathematicians, who appreciate their "*elegance, generality and unifying viewpoint*". The only physical interpretation given to all this mathematical 'machinery' is that the expression: $P = \Psi^* \Psi$ (dx dy dz) is given a probabilistic description but one where "*We do not say that an electron **is** in the infinitesimal spatial volume (dx dy dz) at any one time, but there is a certain probability (P) of it **being** there*." In other words, it is never possible to say **when** an electron is anywhere; how this fits in with the operational/positivistic view is never discussed.

Much is made about the wave function Ψ corresponding to 'Probability Amplitudes', although van Vleck writes about them, saying: "*No logical consistencies are involved but this curious way of linking to probability ideas leads to many* **paradoxes***, which look rather strange from the standpoint of large-scale statistical mechanics*." In desperation, the well-informed professor falls back here on Bohr's principle of **complementarity** (§4.1.1), claiming these concepts are not contradictory when one relies on optical similarities and analogies. An informed reader has to be suspicious though when van Vleck resorts to the erroneous view that Heisenberg's Uncertainty principle (§3.9.1) limits the accuracy of specifying the **simultaneous** values of an electron's position and its momentum, when we saw that this is always a statistical result arising from **multiple** "similar" measurements of both of these values. This produces another common mistake in claiming that this 'uncertainty' also applies to energy and time, with a vague appeal to "*wave packets*".

Before the article ends, there are brief discussions of electron "spin", the Dirac Electron Equation and quantum electrodynamics (QED), all of which have been "*discovered*"; however, these are not central to the meaning of QM so they will be skipped. Van Vleck does mention that the Dirac Equation gives "*exactly*" the same final formula as Sommerfeld for the hydrogen atom but only comments: "*this must be regarded as one of the strangest **coincidences** in all of physics*." However, he is honest enough to note that the famous Dirac Equation has problems with negative energy states and how it too has not been shown how to extend its techniques to multi-electron atoms.

## 6.4.2 RANGE OF QM PROBLEMS

### *6.4.2.1 Wave/particle Duality*

The failure to see QM as only a mathematical theory manifests as the paradox, wherein an electron (a real object) is presented as existing in reality as both a particle and a wave. These two concepts are totally contradictory: one implies that the object is localized, at all times, in a small region of space – even a mathematical point with zero spatial extent. The other view is to see a wave (certainly a plane wave) as extending, at any single time, across all of space. Real waves are a many-body phenomenon (e.g. water waves) that require an existing medium – even Maxwell believed in the reality of his æther to support the phenomenon of EM waves and light. How these 'plane' waves are viewed as relevant inside the hydrogen atom, where spherical surface functions are central to the solution, is never explained. The resolution of this 'paradox' is presented here as not simply (à la Bohr): different experiments needing different 'domains' but that the electron reacts to other electrons only on a **periodic**, not continuous, basis. This appears as spasmodic interactions, which, when the electron is moving, can be described easiest by the mathematics of waves: in reality, the electron remains as a localized particle, at all times.

### *6.4.2.2 Multi-Electron Atoms*

QM enthusiasts, since Bohr, have claimed that QM 'explains' the chemical **Periodic Table**, using only Bohr's one electron model of the hydrogen atom. Every attempt to use the mathematics of QM for multi-electron systems has been a complete analytical failure; probably because they ignored powerful repulsions between electrons and because physics has always 'sunk' on the **three-body** reef, when three or more objects try to mutually interact continuously with each other.

Worse, the leading members of the "Gottingen gang" (Heisenberg, Pauli, Born) made a huge critique of the failure of the 'Old QM' to solve the helium atom but they themselves [§4.1.4] never solved it either with all their more sophisticated mathematical tools.

### *6.4.2.3 No Instantaneous Momentum*

Heisenberg never stopped re-iterating that his Uncertainty Principle forbade the use of particle concepts like location an momentum, at the same time, so that 'old' ideas, like an electron's path (as used in "Old QM") could no longer be used. As shown earlier (§3.9.1.3), Heisenberg failed himself to understand the mathematical nature of his own statistical spread of the measurement of pairs of such canonical variables. Worse, he failed to appreciate that the foundational idea of "instantaneous" momentum was deeply flawed (§4.1.3.4) and should never have appeared in any formulation of QM. As such, one should not hesitate, as the proponents of Semi-Classical Mechanics (§4.1.8.4) have shown that Bohr-like electron paths are rich in computational and explanatory results.

## 6.4.3 QM MEASUREMENT

Most of the approaches in the New QM focus on the concept of **observables** – this is the concept that repeated experiments of atomic systems will provide numbers corresponding to the sets of measurements. The mathematical schemes of QM each offer a formula for calculating such numbers; for simple systems, like the hydrogen atom, these mathematical predictions are acceptably good enough. The present theory offers the view that QM is only a theory of measurements of electron-based systems. The mathematics wraps the idea of interfering with such a small system simply by attempts to observe the system with macroscopic measuring instruments. QM theory also assumes the long-established approach of assuming a system can be isolated sufficiently from its surroundings that the experiment can be exactly repeated (known as "**physics-in-a-box**" and hence "objective"). UET denies that humans will ever have the skill to **isolate** natural systems of electrons from all the other electrons in the universe, so that repetition is a mathematical ideal, not an experimental reality. Therefore, attempts to repeat experiments will inevitably produce statistical results: these are **not** probabilities (except of our ignorance, like betting on horseraces before they occur. Worse, **all** attempts to measure an atomic-scale system will generate only numbers corresponding to the combination of target system **plus** measuring interference, not of the target system when left undisturbed. We are not extracting knowledge of the world, left to itself, but only of how humans interact with the micro-world. Humans are not at the center of existence. Kant knew there was a distinction between phenomena and noumena (perceived things and the real things in themselves), although, in 1770, he would have been astonished at the power of our measuring technology to extend our senses.

## 6.4.4 WHAT DOES QM MEAN?

This important section reminded the reader that there are two basic philosophical divergences deeply embedded in the foundations of QM:

a) Is the most useful interpretation of QM based on an epistemological or ontological metaphysical perspective?
b) Is the task of physics to create a positivistic or realistic view of reality?

Section 4.3 exposed readers to the broad range of interpretations of QM, which have evolved since 1925. Such a range of unresolved differences indicates deep problems with a theory that has been offered by physicists as the foundation of the scientific world-view.

This ongoing promise of solutions also indicates that a purely mathematical theory of nature is profoundly unsatisfying. Most theorists today still retreat to the consensus positivistic philosophy that has dominated physics since the 1920s but there are a few (like Einstein) who still insist that understanding reality is a far more pressing concern. Even Galileo was propositioned by the Roman Curia to adopt a positivist view of the solar system and view the Copernican model as another calculational approach (ironically, the Ptolemaic scheme offered even better accuracy). As realist John Polkinghorne has written on this issue: "*If science is just about correlating data, and is not telling us what the physical world is actually like, it is difficult to see that the scientific enterprise is worth all the time, trouble and talent expended upon it*." [145]. If all we are going to do is construct mathematical schemes and note marks on photographic plates and dials then physics is indeed little worthy of public respect and certainly not the trillions of dollars currently expended on it. Indeed, the most natural explanation of a theory's ability to "***save the appearances***" would surely be that it bore some correspondence to the way things are. In other words, its statements are approximating the truth. The conviction that the world actually consists of real objects, with no spatial extent (i.e. point particles) is the **ontological foundation** of the present programme of material reality. The goal is to reconstruct all of microscopic (atomic and nuclear) reality exposed by many years of experiments using **only** electrons. Just predicting the numbers subsequently found in measuring sets of thought-to-be identical experiments is a fruitless exercise in epistemology.

## 6.5 A NEW PHILOSOPHY OF NATURE

### 6.5.1 RESTORING NATURAL PHILOSOPHY'S ROLE

One of the principal motivations behind this research programme is to help return physics to its original, productive role as a principal part of philosophy – the ancient study known as Natural Philosophy (NP); this area of scholarship was professionalized in the Victorian era and adopted the neologism of 'physics'. Earlier experts in this area would be shocked at the degree of technical specialization and narrowness of interest exhibited today in this central area of science. Three of the greatest physics heroes (Newton, Maxwell, Einstein) were each obsessed with NP and it appeared to have played a major role in their professional success. It is surely not a coincidence that the major contributions physics have been making in the last 100 years have had the most interest to governments and weapons makers.

### 6.5.2 REPRESENTING REALITY

The deepest level of NP, when it focuses on reality, is known as **metaphysics**: this covers those questions that cannot yet be answered by science: many of them ask about the very nature of existence (ontology). Mathematicians rarely show much interest in this area as they already have a pre-commitment to their own metaphysical worldview: **Platonism** and its foundational layer of Pythagorean mysticism ("number is the basis of the universe"). The history of abstract thought, in the European tradition (dominated by theology), demonstrates how the idea of '**time**' has almost disappeared being replaced with a focus on the timeless nature of **space** (the 'Heavens' and geometry). A subtler problem is how much of our psychology is driven by viewing the world in terms of objects, rather than the more abstract nature of **relationships**. This refocus in physics will involve directing our efforts away from the study of properties of isolated objects towards the **interactions** between them. Metaphysically, it seems difficult to imagine objects that do **not** interact with one another. So, the study of interactions will close the recursive circle on the metaphysical nature of material objects. The discovery of electrons finally gives us a chance to end the analytic quest at a level that is foundational and still relevant to human beings (electrons exist in terms of each other; everything else is a dynamic electron composite). The study of challenging phenomena of matter since 1900 (see §4.1) has shown that it is the inter**action** that imposes discrete **quantum** restrictions on the exchange of **action**. The very idea of action implies time and dynamism, so its investigation will restore some balance with our European past obsessions with space.

Central to any fruitful investigation of the interaction between electrons is the need for a new theory of electromagnetism as the revered Maxwellian EM theory always resisted the idea of particulate electricity. A successful EM theory must recognize the finite time delays of interactions between remote electrical sources are an **experimental** fact of nature. Our new EM theory reflects this in its inclusion of Newton's proposal that gravitational interactions exhibit action-at-a-distance ('**Far-Action**'). For far too long, this revolutionary concept has been rejected by most natural philosophers. Even Newton's great rival, Leibniz was reluctant to give up his Aristotelian education and the personal experience (e.g. touching) that was used to justify these ancient prejudices. Worse, Newton was too timid to defend his own radical idea; however it was picked up by the great Gauss, who added the idea that Far-Action might not act simultaneously, as Newton had believed was the case for gravity. UET fully adopts this suggestion: in an asynchronous, time-symmetric manner.

# 6.6 CONCLUSIONS

## 6.6.1 SEMANTICS BEATS MATHEMATICS

Quantum mechanics (QM) is now approaching its centenary and it is promoted by most professional physicists as "*the best theory in science*"; this is **not** the conclusion reached here, where the focus has been on the **semantics** of this theory. The wide range of interpretations into the meaning of QM indicates the broad support for the primacy of semantics over mathematics only. Obviously, the ideal solution would combine both, hence the new theory developed in this research programme. The new quantum theory (UET) of the hydrogen atom [7] gets the energy numbers but avoids all the arbitrary 'postulates' that Bohr needed to contradict electromagnetism; additionally, UET offers a (**discrete**) return to the simpler algebra that inspired early mathematical approaches to classical physics.

When there are at least a dozen distinct interpretations of what is no more than a set of mathematical recipes (equations) for one simple model of the micro-world, it is intellectually distasteful to swallow this academic hagiography. The ongoing failure to extend this theory to realistic, **multi-electron** atoms emphasizes that even its basic mathematical assumptions are suspect. This paper has suggested the psychological commitment to **calculus** (the mathematics of classical mechanics) as the likely cause for these failures to understand or to progress quantum mechanics. Implicit in this mathematical commitment has been the retention of Newton's original assumption that interactions between mass particles always occurred **continuously** (referred to here as the Continuum Assumption) leading to the foundational concept of **force**. Instead, building on insights from discoveries in electromagnetism, the present theory builds on the hypothesis of discrete impulses. In particular, this theory adopts de Broglie's suggestion that electrons have a universal clock that determines **when** an electron may interact with another electron. This introduces a new universal constant, called here the '***chronon***' for this quantum of time. This concept was used in the previous paper [6] to eliminate all continuous electromagnetic interpretations, which had been used first in the $19^{th}$ century to propose a wave model of the phenomenon called '*light*'. Light was shown there to be no more than the cyclic interactions between pairs of remote (far) electrons; **interference** was seen just as interaction timing effects. The next paper will also show that a similar approach can account for the so-called 'wave' explanations of electrons in relative motion.

The Göttingen Gang of mathematicians (see §3.3) in the 1920s had their own hidden agenda to take over quantum physics after failing repeatedly to extend the First-Generation Atomic Theory of Bohr and Sommerfeld that only solved the hydrogen atom. This required that they 'overthrow' the ideas of the 'Old Guard' by designating their own work as '*modern*' and "*mathematically sound*". Since this conspiracy was hatched on the high peaks of the Mountains of Mathematics, few outsiders (like non-mathematical philosophers) could criticize their actions. Once 'successful', the New Turks came down from their rarified heights with the New Commandments of their new mystery religion, ensuring that their hidden Pythagoreanism would remain unchallenged for another 100 years. Like all successful revolutions, the new regime was consolidated by seizing control of key institutions: major physics departments around the world. It is a great irony of the History of Physics that thousands of mathematical physicists have **failed** to solve the multi-electron atom problem, using all the mathematics of the New Quantum Theory and its evolutionary descendants, like QED and String Theory.

## 6.6.2 ELECTRO-MAGNETIC WAVES

There has never been any physical analogy between light and electrons to justify the use of Huygens' principle for gaining any understanding of the micro-world. The idea that every location in space could be the origin of a new wave has never been more than a mathematical scheme to imagine propagation of waves across a region of space. The previous paper proposed a detailed model of how pairs of electrons might select each other for each pairwise interaction; this mechanism showed how such remote interactions could generate so-called "interference effects", while avoiding all propagating EM waves. Maxwell's Theory was a huge mathematical edifice that few could understand (and fewer criticize) but it was based on a flawed model of reality – the æther. Michelson's experiments showed that Maxwell's own prediction about "light traveling through moving æther was wrong". Nonetheless, physicists have still gone to great lengths to preserve it in its 'classical' form (when it was Helmholtz's hijacking of the equations using his own equally flawed hydro-dynamical model of charge-density as the source of electrical reality). Today, the dominance of mathematical physicists means that theoretical physics is still obsessed with preserving Maxwell's style of doing physics by forcing all phenomena into a mathematical field theory straitjacket. Ironically it is the 'simple' electron (found as the point-charge of electricity), which has become the worm that ate Newton's Apple and Maxwell's Æther.

As will be demonstrated in the companion paper [7], a 'pulsating' object, like de Broglie's electron, appears to generate oscillating features (describable by the mathematics of waves) when in motion, including its mysterious 'interference' effects. It is this insight, which provides a simple, unitary explanation of the diverse physical phenomena when an electron interacts with other electrons at the atomic scale.

## 6.6.3 QM: AN OVER-HYPED THEORY

Disappointingly, the huge mathematical effort of the 'New QM' only produced minor variations from Sommerfeld's 'old' elliptical solution. This new approach pleased high-end mathematicians but was completely **opaque** to everyone else, including philosophers. If all that had been 'discovered' had been the even more difficult Matrix Mechanics, then few physicists would have bothered with the 'New' QM. In fact, classical mechanics **never** measured the instantaneous momentum of any of its objects of interest, especially planets moving around the sun. It is the **path** of the object, over time, which is the trajectory of interest. In fact, there is not even any need to see an electron on its path to calculate its spatial distance traversed and the time required if we are just measuring the average energy of these systems – all that QM ever succeeded in doing theoretically and experimentally. In fact, Heisenberg's so-called Uncertainty Principle (see §3.9) is irrelevant (and often misunderstood: §3.9.1.3) in most investigations of atomic systems. Ironically, it will be the 'Old QM', which inspires future progress in the investigation of the world of the micro-cosmos while providing simple imagery that is comprehensible to everyone. Returning our focus to the electron will reward humanity with all kinds of new and unexpected technologies without spending billions smashing nuclear particles or speculating on the Origins of the Universe.

# 7 REFERENCES

[ 1] Spencer HJ, *An Algebraic Representation for Action-at-a-Distance*, to be published, (2007)
[ 2] Spencer HJ, *Continuous Natural Vector Theory of Electromagnetism*, to be published, (2007)
[ 3] Spencer HJ, *Continuous Two-Electron Theory of Electromagnetism*, to be published, (2007)
[ 4] Spencer HJ, *Classical Two-Electron Relativistic Dynamics*, to be published, (2009)
[ 5] Spencer HJ, *Discrete Electron Relativistic Dynamics*, to be published, (2011)
[ 6] Spencer HJ, *Quantum Optical Mechanics*, to be published, (2012)
[ 7] Spencer HJ, *Quantum Electron Mechanics*, to be published, (2016)
[ 8] Jones S, *The Quantum Ten*, Toronto, ON: Thomas Allen Pubs, (2008)
[ 9] Kuhn TS, *The Structure of Scientific Revolutions*, Chicago, IL: University of Chicago Press, 2nd edition (1970)
[10] Toulmin S, Goodfield J, *The Architecture of Matter*, Chicago, IL: University of Chicago Press (1962)
[11] Herman A, *The Cave and the Light: Plato versus Aristotle*, New York, NY: Random House (2013)
[12] Greenblatt S, *The Swerve – How the World became Modern*, New York, NY: Norton & Co. (2012)
[13] Heisenberg W, *Physics and Philosophy,* New York, NY: Harper Collins (1958) p. 144;
reprinted NY: Prometheus Books (1999)
[14] See ref [6] [Spencer] §4.1
[15] Einstein A, *Planck's Theory of Radiation & the Theory of Specific Heat*, Ann. Phys. **2** 180 (1907)
[16] Franck J, Hertz G, *Collisions between Electrons and Molecules of Mercury*, Verh. Dtsch. Phys. Ges. **16** 457 (1914)
[17] Pais, A, *Niels Bohr's Times*, Oxford, UK: Clarendon Press, p. 67 (1991)
[18] Möellenstadt G, Düker H, *Observation and Measurement of Bi-prism Interference with Elect. Waves*, ZfP, 377 (1956)
[19] Donati O, et al, *An Experiment on Electron Interference*, Am. J. Phys., **41** 639 (1973)
[20] Tonomura A, et al, *Demonstration of Single-Electron Buildup to an Interference Pattern*, Am. J. Phys., **57** 117 (1989)
[21] Rauch H, et al, *Verification of Coherent Spin Rotation of Fermions*, Phys. Letters **A**,425, (1975)
[22] Gähler R, Zeilinger A, *Wave-Optical Experiments with very cold Neutrons*, Am. J. Phys., **59** 316 (1991)
[23] Carnal O, Mylnek J, *Young's Double-slit Experiments with Atoms*, PRL, **66** 2689 (1991)
[24] Eibenberger S, et al, *Matter-Wave Interf. with Particles exceeding 10,000 AMUs*, Phys. Chem. Phys.,**15** 1469 (2013)
[25] de Broglie L, *Research into the Quantum Theory*, (PhD thesis), Paris: Masson (1963)
[26] Gerlach W, Stern O, *The Magnetic Moment of Silver Atoms*, Z. f. Phys. **9** 353 (1922)
[27] Wuthrich C, *Early History of Quantum Mechanics*, p.63
http://Philosophy.UCSD.Edu/faculty/Wuthrich/teaching/2013_146/146QLect01_EarlyHistQT.pdf
[28] Newton I, *Philosophiae Naturalis Principia Mathematica*, (1687);
reprinted as *The Principia*, translated by A. Motte, Amherst, NY: Prometheus Books (1995)
[29] Maxwell JC, *Treatise on Electricity and Magnetism,* Oxford, UK: Clarendon Press (1873); 3rd Ed.;
reprinted New York, NY: Dover Books, (1953)
[30] See ref [2] [Spencer] §2.2.1 ; §4.1
[31] See ref [2] [Spencer] §2.2.2
[32] Planck M, *The Philosophy of Physics*, New York, NY: Norton & Co., p. 97; pp. 53-55 (1963)
[33] Rutherford E, *The Scattering of $\alpha$ and $\beta$ Particles by Matter and the Structure of the Atom*, Phil. Mag. **21** 669 (1911)
[34] Nicholson JW, *Constitution of Solar Coronas,* Monthly Notices Royal Astronomical Society, **72** 677 (1912)
[35] Bohr N, *On the Constitution of Atoms and Molecules*, Phil. Mag., **26** pp. 1, 476, 875 (1913)
[36] Navarro J, *A History of the Electron*, Cambridge, UK: Cambridge University Press, (2012)
[37] Yarwood J, *Electricity, Magnetism & Atomic Physics* (Vol.2), London, UK: University Tutorial Press, p. 107 (1960)
[38] Sommerfeld A, *On the Quantum Theory of Spectral Lines*, Ann. der phys., **51** 1 (1916)
[39] See ref [13] [Heisenberg] p. 39
[40] See ref [13] [Heisenberg] p. 35
[41] See ref [13] [Heisenberg] p. 38
[42] Van der Waerden BL, *Sources of Quantum Mechanics*, (Ed.), Amsterdam: North-Holland Publishing (1967);
reprinted New York, NY: Dover Books (1968)
[43] Heisenberg W, *On the Intuitive Content of Quantum Theoretical Kinematics and Mechanics*, Z. Phys. **43** 172 (1925)
[44] Born M, Jordan P, *On Quantum Mechanics*, Z. Phys. **34** 858 (1925); translated into English in [42] p. 277
[45] MacKinnon E, *Heisenberg, Models and the Rise of Matrix Mechanics*, Hist. Studies in Phys. Sci., **8** 137 (1977)
[46] Born M, Heisenberg W, Jordan P, *On Quantum Mechanics II*, Z. Phys. **35** 557 (1925);
translated into English in [42] p. 321

[47] See ref [42] [Waerden] p. 34
[48] See ref [42] [Waerden] p. 37
[49] Born M, Heisenberg W, Jordan P, *On Quantum Mechanics II*, Z. Phys. **35** 557 (1925); translated into English in [42] p. 321
[50] Pauli W, *On the Hydrogen Spectrum from the Viewpoint of the New Quantum Mechanics*, Z. Phys. **36** 336 (1926); translated into English in [42] p. 387
[51] Gamow G, *Thirty Years that shook Physics*, London, UK: Constable & Co. (1966); reprinted NY: Dover Books, p. 81 (1966)
[52] Schiff LI, *Quantum Mechanics*, 2nd edition, New York, NY: McGraw-Hill Book Co., p. 21 (1955)
[53] Schrödinger E, *The Non-Relativistic Equation of the de Broglie Waves*, Ann. der Phys. **79** 361, 489, 734 (1926)
[54] Schrödinger E, *Continuous Transformation from Micro- to Macro- Mechanics*, Naturwiss. **14** 644 (1926)
[55] Schrödinger E, *Quantization as an Eigenvalue Problem*, Ann. der Phys. **81** 109 (1926)
[56] Schrödinger E, *An Undulatory Theory of the mechanics of Atoms & Molecules*, Phys. Rev **28** 1049 (1926)
[57] Bohm D, *Quantum Theory*, Englewood Cliffs, NJ: Prentice-Hall Inc. (1951); reprinted New York, NY: Dover Books p. 335 (1989)
[58] Kulmann M, *Not Particles or Fields*, Scientific American, p. 42 (Aug. 2013)
[59] Dirac PAM, *The Fundamental Equations of Quantum Mechanics*, Proc. Royal Soc. London, **A109** 642 (1926)
[60] Dirac PAM, *The Principles of Quantum Mechanics*, Oxford, UK: Clarendon Press; 4th edition (1958)
[61] See ref [60] [Dirac] p. 14
[62] See ref [60] [Dirac] p. 16
[63] See ref [60] [Dirac] p. 110
[64] See ref [60] [Dirac] p. 112
[65] See ref [60] [Dirac] p. 85
[66] See ref [60] [Dirac] p. 88
[67] See ref [60] [Dirac] p. 103
[68] Einstein A, Podolsky B, Rosen N, *Can a QM Description of Physical Reality be Considered Complete?* Physical Review **47** 777 (1935)
[69] Aczel AD, *Entanglement*, Vancouver, BC: Raincoast Books (2002)
[70] Bohm D, *Suggested Interpr. of the Quantum Theory in terms of Hidden Variables*, Physical Review **85** 166, 180 (1952)
[71] Bohm D, *Reply to a criticism of a Causal Reinterpretation of Quantum Theory*, Physical Review **87** 389 (1952)
[72] Bohm D, Aharonov Y, *Discussion of Experimental Proof of the EPR Paradox*, Physical Review **108** 1070 (1957)
[73] Mollenstedt G, Bahy W, *Continuous Variation of the Phase of Electron Waves*, Naturwiss. 49 81 (1962)
[74] See ref [4] [Spencer] §5.4.3
[75] See ref [57] [Bohm] p. 147
[76] See ref [57] [Bohm] p. 155
[77] See ref [57] [Bohm] p. 153
[78] See ref [57] [Bohm] p. 151
[79] See ref [5] [Spencer] §4.2.7
[80] See ref [57] [Bohm] p. 152
[81] Landé A, *New Foundations of Quantum Mechanics*, Cambridge, UK: University Press, p. 4 (1965)
[82] See ref [81] [Landé] p. 88
[83] Born M, *Atomic Physics*, London: Blackie & Son, p. 365, seventh edition (1962)
[84] Heisenberg W, *The Physical Principles of the Quantum Theory,* New York, NY: Harper Collins (1930)
[85] Miller AI, *123: Jung, Pauli & the Pursuit of a Scientific Obsession*, New York, NY: Norton & Co., p. 101 (2009)
[86] See ref [85] [Miller] p. 102
[87] Bohr N, *The Quantum Postulate and Recent Developments of Atomic Theory*, Nature, **121** 580 (1927)
[88] Kennard EH, *On the Quantum Mechanics of Simple Movement*, Z. Phys. **44** 4 (1927)
[89] Isham C, *Lectures on Quantum Theory*, London: Imperial College Press, p. 140 (1995)
[90] See ref [89] [Isham] p. 141.
[91] Pauli W, *On Degenerate Gases & Paramagnetism*, Z. Phys. **41**, 81 (1927)
[92] Holland PR, *The Quantum Theory of Motion: An Account of the de Broglie-Bohm Causal interpretation of Quantum Mechanics*, NY: New York, Cambridge University Press (1993)
[93] See ref [60] [Dirac] p. vii
[94] Schrödinger E, *Probability Relations between Separated Systems*, Math Proc. Camb. Phil. Soc., **31** 555 (1935)
[95] Freedman SJ, ClauserJF, *Experimental Test of Local Hidden-Variable Theories*, Phys. Rev. Letters, **28** 938 (1972)
[96] Aspect A, Grangier P, Roger G, *Experimental Realization of EPR, Bohm Gedanken Experiment*, PRL **49** 91 (1982)

[97] Hylleraas E, *Reminiscences from early Quantum Mechanics of two-electron Atoms*, Rev. Mod. Phys., **35** 421 (1963)
[98] Lewis GN, *The Atom and the Molecule*, J. Am. Chem. Soc., **38** 765 (1916)
[99] Langmuir I, *The Arrangement of Electrons in Atoms and Molecules*, J. Am. Chem. Soc., **41** 868 (1919)
[100] Gray T, *The Elements*, New York, NY: Black Dog Publishers (2009).
[101] Pauli W, *On the Connection between the Completion of Electron Groups in an Atom with the Complex Structure of Spectra*, Z. Phys., **31** 765 (1925)
[102] See ref [85] [Miller] p. 61
[103] Goldstein H, *Classical Mechanics*, Reading, MA: Addison-Wesley Publishing, p. 4 (1959)
[104] Bokulich A, *Re-examining the Quantum-Classical Relation: Beyond Reductionism & Pluralism*, Cambridge (UK): Cambridge University Press, p. 104 (2008)
[105] See ref [104] [Bokulich] p. 110
[106] See ref [104] [Bokulich] p. 106
[107] See ref [104] [Bokulich] p. 109
[108] See ref [104] [Bokulich] pp. 114-134
[109] See ref [104] [Bokulich] p. 118
[110] See ref [104] [Bokulich] p. 123
[111] Moore W, *A Life of Erwin Schrödinger*, Cambridge (UK): Cambridge Univ. Press (1994)
[112] Born M, *The Quantum Mechanics of the Impact Process*, Z. Phys., **37** 863 (1926)
[113] See ref [83] [Born] p. 149
[114] Polkinghorne J, *Quantum Theory: A Very Short Introduction*, Oxford (UK): Oxford University Press (2002)
[115] Bell JS, *Speakable and Unspeakable in Quantum Mechanics*, Cambridge (UK): Cambridge University Press (1987)
[116] See ref [81] [Miller] pp. 92-3
[117] Davies PCW, *Space and Time in the Modern Universe*, Cambridge (UK): Cambridge University Press, (1977)
[118] Baggott J, *Farewell to Reality,* London (UK): Constable Press, p.53 (2013)
[119] Von Neumann J, *Mathematical Foundations of Quantum Theory*, Princeton, NJ: Princeton University Press (1955)
[120] Baeyer HC, *Can Quantum Bayseanism fix the Paradoxes of QM?*, Scientific American, (June, 2013)
[121] Bohm D, Hiley BJ, *De Broglie pilot Wave Theory – further Developments*, Found. Phys., **12** 1001 (1982)
[122] Ballentine LE, *Quantum Mechanics: A Modern Development*, River Edge, NJ: World Scientific Publishing (1998)
[123] Nelson E, *Derivation of the Schrödinger Equation from Newtonian Mechanics*, Phys. Rev., **150** 1079 (1966)
[124] Wheeler JA, Feynman RP, *Interaction with the Absorber as a Mech. of Radiation*, Rev. Mod. Phys. **17** 157 (1945)
[125] Cramer JG, *The Transactional Interpretation of Quantum Mechanics*, Rev. Mod. Phys. **58**, 20 (1986)
[126] Schrödinger E, *The Opposite Situation in Quantum Mechanics*, Naturwiss. **23 (49)** 823 (1935)
[127] Cantor G, *The Changing Role of Young's Ether*, Brit. J. Hist. Sci, **5** 44 (1970)
[128] Maxwell JC, *Dynamical Theory of the Electromagnetic Field*, Phil. Trans. **155**, p. 459 (1865) reprinted and edited by T. F. Torrance, Eugene, OR: Wipf & Stock (1996)
[129] Toulmin S, Goodfield J, *The Discovery of Time*, Chicago, IL: University of Chicago Press (1965)
[130] Dyson FJ, *The S-Matrix in Quantum Electrodynamics*, Phys. Rev. **75** 1736, 1754 (1949)
[131] Barbour J, *The Nature of Time*, www.Platonia.com/nature-of-time-essay.pdf
[132] see ref [28] [Newton] p. 13
[133] see ref [29] [Maxwell] p. 380
[134] see ref [10] [Maxwell] p. 256
[135] Maxwell JC, *Matter in Motion*, Amherst, NY: Prometheus Books (2002) orig. published London: 'Soc. For Promoting Christian Knowledge' (1876)
[136] Feyerabend P, *Conquest of Abundance*, Chicago, IL: University of Chicago Press (1999)
[137] Heering P, *On Coulomb's Inverse Square Law*, Am. J. Phys., **60**, p. 998 (1992)
[138] See ref [3] [Spencer] §6.4
[139] See ref [2] [Spencer] §2.4.2
[140] See ref [3] [Spencer] §6.3
[141] See ref [4] [Spencer] §5.2.4
[142] See ref [4] [Spencer] §4.6
[143] Alexander A, *Infinitesimal*, Sci Am Books, New York,NY: (2014).
[144] Van Vleck JH, *Quantum Mechanics* Chicago: McGraw-Hill Books, *Encyclopedia Britannica* 14th ed. **18** 918 (1971)
[145] Polkinghorne J, *Quantum Mechanics* : *A Very Short Introduction*, Oxford (UK): Oxford University Press, p. 83 (2002)

1. INTRODUCTION & OVERVIEW .......... 2
1.1 INTRODUCTION .......... 2
1.1.1 RESEARCH PROGRAMME .......... 2
1.2 OBJECTIVES .......... 3
1.3 OVERVIEW .......... 3
1.3.1 APPROACH .......... 3
1.3.1.1 History .......... 4
1.3.1.2 Philosophy .......... 4
1.3.1.3 Ontology of Matter .......... 5
1.3.2 FAILURE OF CLASSICAL PHYSICS .......... 5
1.3.3 QUANTUM MECHANICS .......... 5
1.3.4 PROBLEMS WITH QM .......... 6
1.3.5 NATURAL PHILOSOPHY .......... 6
2. THE FAILURE OF CLASSICAL PHYSICS .......... 7
2.1 DISCRETE INTERACTIONS .......... 8
2.1.1 BLACKBODY RADIATION .......... 8
2.1.2 SPECIFIC HEATS .......... 8
2.1.3 PHOTOELECTRIC EFFECT .......... 8
2.1.4 ATOMIC STABILITY .......... 9
2.1.5 NUCLEAR STABILITY .......... 9
2.1.6 LINE SPECTRA .......... 9
2.1.7 THE PERIODIC TABLE .......... 9
2.2 CONTINUOUS WAVE EFFECTS .......... 9
2.2.1 X-RAYS .......... 10
2.2.2 BRAGG SCATTERING .......... 10
2.2.3 COMPTON X-RAY SCATTERING .......... 10
2.2.4 ELECTRON DIFFRACTION .......... 10
2.2.5 ELECTRON INTERFERENCE .......... 11
2.2.6 ELECTRON SPIN .......... 12
2.3 EXPLICIT ASSUMPTIONS .......... 12
2.3.1 THE CLOCKWORK UNIVERSE .......... 12
2.3.2 SIMPLE CAUSALITY .......... 12
2.3.3 LAPLACIAN DETERMINISM .......... 12
2.3.4 MAXWELLIAN WAVE THEORY .......... 13
2.3.4.1 Maxwell's Triumph .......... 13
2.3.4.2 Maxwell makes his Religious Confession .......... 13
2.3.4.3 Constancy of Light Speed .......... 13
2.3.5 EXISTENTIAL ENERGY .......... 13
2.4 HIDDEN ASSUMPTIONS .......... 14
2.4.1 CONTINUOUS INTERACTIONS (FORCES) .......... 14
2.4.2 LOCAL INTERACTIONS .......... 14
2.4.3 SINGLE-TIME DETERMINISM (God's Time) .......... 14
2.4.4 FIELDS ARE NO ÆTHER SUBSTITUTE .......... 14
2.4.5 ENERGY IS NOT AN ENTITY .......... 14

2.4.6 INSTANTANEOUS VELOCITY ........ 15
2.4.7 THE WORLD MAY NOT BE RANDOM ........ 15
2.4.8 HARMLESS OBSERVATIONS ........ 15
2.4.9 SIMPLE MATHEMATICS ........ 15
3. SUMMARY OF QUANTUM MECHANICS ........ 16
3.1 EARLY QUANTUM THEORY ........ 16
3.1.1 THE QUANTUM OBJECT: THE ELECTRON ........ 16
3.1.2 BOHR'S PLANETARY MODEL ........ 17
3.1.2.1 Rutherford's Atomic Model ........ 17
3.1.2.2 Quantizing Angular Momentum ........ 17
3.1.2.3 Bohr's Radical Guess ........ 17
3.1.3 WILSON-SOMMERFELD QUANTIZATION ........ 18
3.1.4 SOMMERFELD ATOMIC MODEL ........ 18
3.1.5 PRACTICAL DIFFICULTIES ........ 18
3.1.6 CONCEPTUAL DIFFICULTIES ........ 19
3.1.6.1 Planets versus Atoms ........ 20
3.2 A BRIEF HISTORY OF QUANTUM MECHANICS ........ 20
3.3 HEISENBERG's MATRIX MECHANICS ........ 21
3.4 QUANTIZED WAVE MECHANICS ........ 22
3.4.1 DE BROGLIE WAVES ........ 22
3.4.1.1 Centrality of the de Broglie Wavelength ........ 23
3.4.2 SCHRÖDINGER's WAVE MECHANICS ........ 23
3.4.2.1 Bohm's Quantum Text Book ........ 25
3.5 DIRAC's QUANTUM FORMULATION ........ 26
3.5.1 Dirac's Quantum Text Book ........ 26
3.5.2 Dirac's Hilbert Vectors ........ 27
3.5.3 Dirac's Poisson Brackets ........ 28
3.6 BOHM's PERSPECTIVE ........ 29
3.6.1 Bohm's Career ........ 29
3.6.2 Hidden Variables ........ 30
3.6.3 Aharonov & Bohm Effect ........ 30
3.6.4 Bohm's Metaphysics ........ 30
3.6.5 UET Metaphysics ........ 31
3.7 LANDÉ's REBELLION ........ 32
3.7.1 Dualism ........ 32
3.7.2 State Transitions ........ 32
3.7.3 Wave Functions ........ 32
3.8 THE HYDROGEN ATOM ........ 33
3.9 QUANTUM CONSEQUENCES ........ 34
3.9.1 THE UNCERTAINTY PRINCIPLE ........ 34
3.9.1.1 Heisenberg's Microscope ........ 34
3.9.1.2 Bohr is furious with Heisenberg ........ 35
3.9.1.3 Schrödinger's Approach ........ 35
3.9.1.4 Uncertainty Discussion ........ 36

3.9.2 QUANTUM PROBABILITY ........ 37
3.9.2.1 Pauli trumps Born's Probability ........ 37
3.9.2.2 UET Explanation of the Uncertainty Principle ........ 37
3.9.3 QUANTUM SUPERPOSITION ........ 38
4. PROBLEMS WITH QUANTUM MECHANICS ........ 39
4.1 RANGE OF PROBLEMS WITH QM ........ 39
4.1.1 DUALITY ........ 39
4.1.2 REMOTE CORRELATIONS (EPR) ........ 40
4.1.3 QM TEMPORAL CONTRADICTIONS ........ 40
4.1.3.1 God's View ........ 40
4.1.3.2 Wave Function is not Time Sensitive ........ 40
4.1.3.3 Discontinuous Interactions ........ 40
4.1.3.4 Velocity never Instantaneous ........ 41
4.1.3.5 Complementary Variables ........ 41
4.1.4 CALCULATIONAL DIFFICULTIES ........ 41
4.1.5 PERIODIC TABLE EXAGGERATIONS ........ 41
4.1.5.1 Periodic Table Overview ........ 41
4.1.6 THE EXCLUSION PRINCIPLE ........ 42
4.1.6.1 Ignoring Electron Interactions ........ 43
4.1.6.2 UET View of the Exclusion Principle ........ 43
4.1.7 ELECTRON SPIN ........ 43
4.1.8 QM - STILL BASED ON CLASSICAL PHYSICS ........ 44
4.1.8.1 Invisible EM Radiation ........ 44
4.1.8.2 Analytical Mechanics ........ 44
4.1.8.3 Continuum Assumptions ........ 44
4.1.8.4 Semi-Classical Mechanics ........ 45
4.1.9 STILL JUST MATHEMATICS ........ 45
4.1.9.1 Mathematical Physics ........ 45
4.1.9.2 Conflicted Thinking ........ 46
4.1.9.3 QM assumes Positivism ........ 46
4.1.9.4 Waves flow through ........ 46
4.1.9.5 Dirac's Objective ........ 46
4.2 QM MEASUREMENT ........ 46
4.2.21 Micro-Macro Theory of Measurement ........ 47
4.2.1 UNCLEAR ROLE OF OBSERVATION ........ 48
4.2.2 STATISTICAL INTERPRETATION ........ 48
4.3 QM PHILOSOPHY - WHAT DOES QM MEAN? ........ 48
4.3.1 ONTOLOGY & EPISTEMOLOGY ........ 49
4.3.1.1 Determinism ........ 50
4.3.2 THE FAILURE OF MATHEMATICS TO EXPLAIN ........ 50
4.3.3 ONTOLOGY & EPISTEMOLOGY ........ 50
4.3.3.1 Mach's Flawed Approach ........ 50
4.3.3.2 Planck's Holistic View of QM ........ 50

4.3.4 EPISTEMIC INTERPRETATIONS ..... 51
4.3.4.1 The Copenhagen Interpretation ..... 51
4.3.4.2 von Neumann/Wigner Interpretation ..... 51
4.3.4.3 Quantum Information Interpretation ..... 51
4.3.4.4 Many Worlds Interpretation ..... 52
4.3.4.5 Relational QM Interpretation ..... 52
4.3.4.6 Quantum Logic Interpretation ..... 52
4.3.5 ONTIC INTERPRETATIONS ..... 52
4.3.5.1 de Broglie-Bohm Interpretation ..... 52
4.3.5.2 Statistical (Ensemble) Interpretation ..... 52
4.3.5.3 Stochastic Mechanics Interpretation ..... 53
4.3.5.4 Objective Collapse Theories ..... 53
4.3.5.5 Elementary Cycles (Semi-Classical Mechanics) ..... 53
4.3.6 MIXED INTERPRETATIONS ..... 53
4.3.6.1 Time-Symmetric QM ..... 53
4.3.6.2 Transactional Interpretation ..... 53
4.3.7 JUST ANOTHER OPINION ..... 53
4.3.7.1 Results of the QM Interpretation Game ..... 53
4.3.7.2 The UET View ..... 54
4.3.8 ICONIC THINKING ..... 54
4.3.9 THE HIDDEN PHILOSOPHY ..... 55
4.3.9.1 Plato abolishes Time ..... 55
4.3.9.2 Matters of Principle ..... 55
4.3.9.3 Quantum Field Theories ..... 55
5. A NEW PHILOSOPHY OF NATURE ..... 57
5.1 RESTORING NATURAL PHILOSOPHY ..... 57
5.2 REPRESENTING REALITY ..... 57
Metaphysics ..... 57
Objective & Subjective Knowledge ..... 57
5.2.1 TIME ..... 58
Measured Time ..... 58
Mathematical Time ..... 58
5.2.2 SPACE ..... 58
No Space-Time (Modern Æther Upgrade) ..... 59
5.2.3 EXISTENCE ..... 59
Denying Reality ..... 59
Continuity of Existence ..... 60
Existence and Predictability ..... 60
5.2.4 MATTER ..... 60
5.2.5 RADIATION ..... 61
5.2.6 NATURAL UNITS ..... 61
5.3 TIME FOR SOME RADICAL IDEAS ..... 61
5.3.1 CONQUEST OF ABUNDANCE ..... 62
5.3.2 PROUT'S HYPOTHESIS ..... 62

5.3.3 KEEPING SOME GOOD IDEAS ..... 62
5.3.3.1 Need for Two-Time Interactions ..... 62
5.3.3.2 Electron Paths ..... 62
5.3.3.4 Reference-Frames ..... 63
5.3.3.5 QM's Necessary Features ..... 63
5.3.4 THINGS, NOT SYMBOLS ..... 63
5.3.5 POURING CONCRETE ..... 64
5.3.5.1 Pre-empting Criticism ..... 64
5.3.5.2 Heisenberg's Mistake ..... 64
5.3.5.3 Schrödinger's Philosophy ..... 64
6. SUMMARY & CONCLUSIONS ..... 65
6.1 SUMMARY and OBJECTIVES ..... 65
6.1.1 HISTORICAL & PHILOSOPHICAL INTEGRATION ..... 65
6.2 THE FAILURE OF CLASSICAL PHYSICS ..... 66
6.2.1 DISCRETE INTERACTIONS ..... 67
6.2.2 CONTINUOUS WAVE EFFECTS ..... 68
6.2.3 CLASSICAL ASSUMPTIONS ..... 69
6.3 A SUMMARY OF QUANTUM MECHANICS ..... 70
6.3.1 EARLY QUANTUM PHYSICS ..... 70
6.3.2 BRIEF HISTORY OF QUANTUM MECHANICS ..... 70
6.3.2.1 Heisenberg's Matrix Mechanics ..... 70
6.3.2.2 Wave Mechanics ..... 70
6.3.2.3 Dirac's Quantum Formulation ..... 71
6.3.2.4 The Hydrogen Atom ..... 71
6.3.2.5 Quantum Consequences ..... 71
6.4 THE PROBLEMS WITH QUANTUM MECHANICS ..... 72
6.4.1 THE ORTHODOX VIEW ..... 72
6.4.2 RANGE OF QM PROBLEMS ..... 74
6.4.2.1 Wave/particle Duality ..... 74
6.4.2.2 Multi-Electron Atoms ..... 74
6.4.2.3 No Instantaneous Momentum ..... 74
6.4.3 QM MEASUREMENT ..... 74
6.4.4 WHAT DOES QM MEAN? ..... 74
6.5 A NEW PHILOSOPHY OF NATURE ..... 75
6.5.1 RESTORING NATURAL PHILOSOPHY'S ROLE ..... 75
6.5.2 REPRESENTING REALITY ..... 75
6.6 CONCLUSIONS ..... 76
6.6.1 SEMANTICS BEATS MATHEMATICS ..... 76
6.6.2 ELECTRO-MAGNETIC WAVES ..... 76
6.6.3 QM: AN OVER-HYPED THEORY ..... 77
7 REFERENCES ..... 78