FALSE FORMALISMS AND ENDS JUSTIFYING MEANS: THE CASE OF QUANTUM THEORY

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Abstract – It is argued that the wave-mechanical formalism that serves as the basis of quantum theory is fundamentally flawed on several counts. Primarily, the de Broglie equation is manifestly invalid as it implies that even macroscopic objects would acquire a substantial wavelength as they approach resting velocities. Furthermore, ostensible diffraction phenomena are not only logically dubious but also amenable to alternative explanations (including in the case of Newton's rings). A subliminal thread apparently links diverse observations via the standing-wave idea, with the Planck treatment of black body radiation likely having inspired the particle-in-a-box model, which serves as the gateway to quantum chemistry via a quantum mechanical analogue of the Bohr orbits. These arguments apparently indicate that quantum theory is best regarded as an empirical model for dealing with certain natural phenomena, but also raise epistemological questions as to whether natural phenomena can at all be modelled by exact theories.

INTRODUCTION

Quantum theory originated from a proposal by Planck (1900) that the assumption of quantization of energy led to a satisfactory explanation for the observed distribution of electromagnetic radiation emanating from a black body cavity. The proposal is enshrined as the Planck equation (Eq. 1, h being Planck's constant and f the frequency of the radiation). In conjunction with the then evolving atomic and molecular theory of matter, as also observations on the line spectra of the elements, the Planck proposal led to the view that energy changes in sub-microscopic systems were quantized. This apparently signalled a break from previous Newtonian ideas, which required continuous changes in energy.

$$E = hf \qquad (1)$$

$$\lambda = h/p \qquad (2)$$

$$H\Psi = E\Psi \qquad (3)$$

However, a formal justification for the said quantization had to await the idea of wave-particle duality, with the de Broglie equation (1924, Eq. 2) proposing a quantitative relation between the wavelength (λ) associated with a particle and its momentum (p). This subsequently led to the Schrödinger equation (1925, Eq. 3) as a complete description involving the wave function (Ψ) and the total energy (E, H being the Hamiltonian operator).

These historic developments constitute the foundations of quantum theory, which prevails to this day as an overarching reigning paradigm for addressing the entire gamut of atomic and molecular phenomena, indeed leading science to the very gates of life and of consciousness itself. Understandably, the revolutionary departure from common-sense Newtonian ideas has enveloped quantum theory in its legendary mystique, its allure a siren call to abandon the shackles of a classical past, science now the standard bearer leading humanity towards a new understanding of Man's place in nature.

However, despite its theoretical fascination and undoubted practical utility, the foundations of quantum theory – intriguingly – do not withstand closer scrutiny, as argued at length below.

DISCUSSION

Waves and wave functions

The concept of the wave function (Ψ) that was introduced with the Schrödinger equation (Eq. 3), apparently, is not only complex but also allows a number of interpretations. In a relatively prosaic sense, however, Ψ is essentially a mathematical representation of a wave describing changes in amplitude with time. An important attribute of Ψ is that it leads to quantitative value(s) of certain physical parameters of the system when Ψ is operated with an appropriate operator. A particular case is that of the Hamiltonian operator which derives the energy states of the system from the wave function (Ψ).

Thus, although originating in the physical wave idea of classical mechanics, the wave function concept extends far beyond in a very abstract sense. Practically, however, Ψ offers a mathematical justification for quantization as solutions to Eq. 3 can lead to discrete values of the energy states. Also, the Schrödinger equation has both time-independent and time-dependent variants, the former applying to the special case of standing waves, of particular importance to atomic and molecular systems.

It is undoubtedly true, however, that Ψ represents a mathematical and philosophical efflorescence of the original wave idea! Whilst Maxwell's earlier proposal that electromagnetic radiation was propagated in wave form serves as a cornerstone of modern science, the extension of the wave concept to particulate matter (Eq. 2) represents a departure from all known conventions. The corpuscular nature of light, of course, leads to Eq. 2, although intriguingly, the original Maxwell proposal itself apparently needs closer scrutiny.

Purported interference phenomena

Diffraction patterns

Indeed, the phenomenon of diffraction which is considered as clinching evidence for the wave theory of light is likely dubious, although the so-called diffraction patterns themselves are experimentally well established. Thus, as has been previously argued [1], the construction of a diffraction grating with line spacing of the order of a millionth of a centimetre (10^2 Å) appears practically impossible (wavelength of light ~ 10^3 Å). Furthermore, the conventional explanation for the observed diffraction patterns is also dubious, as the distance between the grating and the observation screen is practically infinity relative to the wavelength of light. This should give rise to an infinite number of interference events of the wavelets purportedly emerging from the grating before they reach the screen, resulting in a smeared-out haze rather than the sharp lines observed.

Newton's rings

A related phenomenon often touted in support of the wave theory of light is that of Newton's rings. These rings are observed when a light source is placed in extreme proximity to a flat surface, and are believe to arise by interference between the incident light rays with those reflected off the flat surface. However, this requires the assumption that the incident light rays all possess the same phase, which is clearly not the case. Thus (again), an infinite number of phases and interference events should lead to a haze rather than the relatively sharp, regularly spaced concentric rings observed.

Possible explanations

A possible explanation for Newton's rings is based on repeated reflection of the light between the two surfaces, as determined by the geometry of the light source and the surface, and the laws of reflection. Thus, the light from the source first bounces off the flat surface but back on to the surface of the source, which is then bounced back to the flat surface at a different angle from the initial impingement. The repetition of this process, at ever widening angles and practically ad infinitum, can lead to the concentric pattern observed.

The origin of the linear pattern observed in the case of a diffraction grating is less clear, although a similar explanation to the above is possible. Thus, a ‘chink’ in the grating would let through a tiny beam of light that is scattered off the screen back on to the grating, and back again on to the screen, ad infinitum. Also, attempts to space the lines as closely as possible (although futile, *vide supra*) during the construction of the grating would likely have created only a few ‘chinks’. The pattern emanating from the largest of these, and directly in line with the light source, would be the dominant one.

Matter waves and the de Broglie condition

As mentioned above, the de Broglie equation (Eq. 2) historically served as the gateway to quantum mechanics. However, a particular problem is that Eq. 2 requires that even macroscopic objects should acquire wave properties as they approach resting velocities. (This is because $p = mv$, m being mass and v velocity, so p tends to 0 as v approaches 0.) In other words, stationary objects encountered in normal life should be perceived as waves rather than solid objects.

In fact, Eq. 2 requires that an object with a momentum of the order of h (6×10^{-34} J s), say $p = 10^{-34}$ kg m s^{-1}, would possess a wavelength of ~ 6 m. This is clearly unviable and strikes at the foundations of quantum theory itself. (Intriguingly, an object of 1 g moving at 1 km s^{-1} would possess a wavelength of ~ 6 m!)

Thus, the view that the de Broglie proposal (Eq. 2) distinguishes sub-microscopic phenomena from macroscopic ones seems unviable. Also, the relativistic de Broglie equation greatly narrows the scope of the original formulation, and manifestly excludes its application to substantially massive particles, *e.g.* the electron.

Electron diffraction

The phenomenon of electron diffraction, discovered in the aftermath (1927) of the de Broglie proposal (Eq. 2), was touted as evidencing the wave nature of electrons. However, as has been previously argued in the case of X-ray diffraction [2], the observed diffraction patterns are almost certainly a result of ‘synchronized scattering’ from stacked planes of atoms in a crystalline lattice. This invalidates the Bragg model based on constructive and destructive interference, which requires that the receiving surface (on which the pattern is recorded) possess a graininess of the same order as the wavelength of the radiation employed. This is certainly impossible, as the surface is a macroscopic object with a surface graininess which would be several orders of magnitude greater than the wavelength employed.

Planck's radiation law

Intriguingly, a rather similar critique applies to the derivation of Planck's black body radiation law, based on the key phenomenon that led to the search for quantum mechanics and its subsequent evolution. (Planck's radiation law is not given here and is not to be confused with Eq. 1.) The derivation is based on the idea that the radiation inside a black body cavity exists in the form of standing waves, an integral number of wavelengths being thus accommodated exactly. However, as argued previously [1], this requires that the inner surfaces of the cavity be defined to an accuracy at least of the same order as the average wavelength of the radiation. This is clearly impossible to obtain in the case of a macroscopic object such as a black body cavity, hence the derivation is *per se* invalid.

The significance of Planck's radiation law lies in the fact that the assumption that the cavity radiation existed in quantized states (Eq. 1) was the key to reproducing the experimentally observed distribution of wavelengths with temperature. The subsequently developed de Broglie and Schrödinger equations (Eqs. 2 and 3 respectively) thus represent theoretical and mathematical approaches towards justifying the quantum assumption introduced by Planck.

Standing waves – the subliminal thread

Standing waves (also termed stationary waves) have apparently played a key role in the founding and evolution of quantum mechanics. As discussed above, the derivation of Planck's radiation law is based on the idea that a black body cavity acts as a resonator that supports standing waves of electromagnetic radiation of various frequencies. The de Broglie proposal of matter waves led to the particle-in-a-box model – representing the first steps of a nascent wave mechanics – again based on a standing wave model.

The time-independent Schrödinger equation, applied to the standing wave model, led to the mathematical justification of the quantization condition, in terms of the discrete energy states corresponding to allowed solutions to the Schrödinger equation. These events represent the emergence of quantum mechanics as understood and perceived to this day.

The application of these ideas to the Bohr model of the atom led to the birth of atomic and molecular quantum mechanics. This was based on the idea that orbiting electrons could be represented as circular standing waves and treated to the Schrödinger equation. (The idea of circular and spherical waves is itself a significant – perhaps egregious – departure from the classical assumption that light travels in a straight line!) Intriguingly, the success of the original Planck approach apparently served as the inspiration for subsequent approaches towards understanding quantization. The common theme – a subliminal thread perhaps – underpinning these approaches is the standing wave concept, which enabled the application of the time-independent Schrödinger equation.

Critique

There are several problems with the above described evolution of quantum theory, as argued below.

A problem of precision

Firstly, standing waves have undoubtedly been observed in macroscopic systems, and electromagnetic radiation may also form standing waves. However, the assumption that these can be mathematically analysed in terms of a cavity geometry in relation to the wavelength is dubious, as argued above in the case of black body radiation [1]. (These involve comparison between macroscopic and sub-microscopic measures, which cannot be defined to the same levels of accuracy [2].)

Waves, matter waves and wave mechanics

The application of the standing wave idea to the particle-in-a-box and subsequently to the Bohr atomic orbitals, is an extension of the de Broglie idea of matter waves. As argued above, even the wave theory of light does not rest on firm foundations, so a wave theory of matter is inherently dubious. The de Broglie equation (Eq. 2) also leads to preposterous results when applied in a general sense (*vide supra*).

The quantization requirement is apparently bolstered by the experimental observation that energy changes in atoms and molecules are discontinuous, only certain transitions being allowed. These developments occurred in the interim between the Planck (1900) and de Broglie (1923) proposals. Thus, the Planck model of quantized oscillators was apparently adapted to atomic and molecular systems, matter waves then representing means towards certain ends.

The de Broglie condition – a slippery stepping stone

The de Broglie equation (Eq. 2) links the Planck and Schrödinger equations (Eqs. 2 and 3 respectively). However, a serious problem is that Eq. 2 is based on Eq. 1, which applied uniquely to electromagnetic radiation. This implies that Eq. 2 only applies to photons, and the tacit extension of Eq. 2 to other particles seems unjustified. Wave-particle duality, in fact, was apparently inspired by the explanation offered for the photoelectric effect, itself arising out of a series of observations over the preceding decades. The specious extension of the duality idea from the massless photon to massive particles underlies the key physical ambiguities of quantum mechanics, notwithstanding its mathematical rigor. (In fact, that the photoelectric effect can be understood only in a billiard-ball sense is itself questionable!)

The then emerging corpuscular theory of light posed a challenge to the established wave theory of electromagnetic radiation. The de Broglie approach apparently exploited these developments in an inverse sense, by invoking wave properties for particulate matter. The relation (Eq. 4) linking radiant energy with momentum and frequency was originally derived for the case of the (massless) photon (c is the speed of light):

$$\mathrm{E} = pc = hf \qquad (4)$$

Eq. 2 follows from Eq. 4 in straightforward fashion ($c/f = \lambda$). The extension of these ideas to the case of massive particles was likely facilitated by an apparently pervasive belief in the validity of putative diffraction phenomena (*vide supra*). However, the invalidation of these phenomena, along with the above facile extension of Eq. 4, practically invalidate quantum mechanics itself.

The Schrödinger wave function and its ambiguities

The wave function concept was a key element in the Schrödinger equation (Eq. 3), which represents the climactic conclusion to the dramatic sequence of events beginning with the Planck proposal (Eq. 1). Eq. 3 essentially treats the trajectory of a particle as the motion of an associated wave, thus replacing changes of position in time domain (trajectory) with changes of the wave function in distance domain. Thus, a faster moving particle is associated with a wave function which undergoes greater changes relative to an infinitesimal change in distance. This implies a disappearance of the time domain in the case of the wave, which thus apparently moves with an assumed velocity. If this be the speed of light, the exercise would tend towards a relativistic formulation.

These apparently contradictory ideas seem to imply that there is no moving particle, only a non-localised wave with a wave function whose rate of change depends on the kinetic energy of the associated particle. If the relativistic condition is also assumed, this also implies that the kinetic energy is itself a function of only the mass. These anomalies apparently arise from the contradictory assumptions leading to Eq. 2, which are carried over to Eq. 3. (*vide supra*).

Whither quantum theory?

It is particularly noteworthy that quantum mechanics uniquely applies to the interaction of electromagnetic radiation with matter [1]. It is in this interaction that the quantization requirement finds its grandest manifestation (the very warp and woof of spectroscopy). However, quantum theory is presented as a general theory of energy transformations, and departures are explained away as arising from closely spaced energy levels. This appears disingenuous and also hinders alternative approaches to understanding quantization. Perhaps a new theory of matter itself, and the possibility that quantization is the result of a resonance condition which is wavelength dependent, need to be explored. And the idea of wave-particle duality possibly abandoned altogether.

The foundations of quantum theory are lost in the mists of a bygone era, and the theory now possesses an aura of infallibility. The exotic counter-intuitive appeal of quantum theory, overlaid on its fabled mathematical sophistication, has inspired intellectual endeavour and spawned a quasi-philosophical subculture all its own. Yet critical questions about the fundamental basis of quantum theory remain, need to be addressed – and truthfully answered.

CONCLUSIONS

Quantum mechanics is essentially a mathematical exercise that aims to explain the apparent quantization of certain energy changes. The original Planck proposal of quantized oscillators, as also studies in atomic and molecular spectra, served to propel the evolution of quantum mechanics into a quasi-theoretical paradigm of overarching significance. The apparent success of quantum mechanics is perhaps unrivalled in terms of its impact on various facets of modern civilization. It thus serves as a poster boy of modern science in a technologically driven world.

However, closer scrutiny reveals that quantum mechanics is founded on highly debatable theoretical assumptions, which are themselves the products of dubious experimental observations. These constitute the clutch of examples of ‘diffraction’ garnered over centuries of sporadic experimentation with ‘gratings’, including (relatively recently) crystal lattice surrogates. It can be argued that no diffraction occurs in all these cases, the observed patterns arising out of either repeated reflections (gratings) or ‘synchronized’ scattering (lattices). These observations apparently facilitated the specious generalisation of the wave-corpuscular duality proposed earlier in the case of light.

Thus, much of the mathematical *tour de force* in quantum mechanics is apparently misdirected if not quite futile. The iconic de Broglie and Schrödinger equations should thus be viewed as quasi-empirical constructs, as the idea of wave-particle duality cannot be justified in view of the above ambiguities. It is particularly noteworthy that quantization is uniquely associated with the interaction of electromagnetic radiation with matter, which indicates the existence of a possible resonant condition, hence calling for a renewed theoretical effort to unravel these effects.

The evolution of quantum mechanics into an intellectual cult in certain circles raises intriguing questions about the nature of scientific knowledge, its acquisition, storage, retrieval and dissemination over successive generations. This study in epistemology indicates that once a scientific theory crosses a certain threshold of acceptance it is subsumed in the collective unconscious of a people, an intellectual dynamic thus metamorphosing into dogma or even a religion.

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