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Bridging Kant and Quantum Mechanics: The Enduring Relevance of Things in Themselves and Appearances

Kant ve Kuantum Mekanik: Kendinde Şeyler ve Görünümlerin Süregelen Geçerliliği

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ABSTRACT

This article aims to contribute to the literature by demonstrating the relevance and applicability of Kant's distinction between things in themselves and appearances within the framework of wave-particle duality. The paper is divided into three sections. The first section clarifies two conceptions of appearances: as representations and as objects of representations. It also raises three key questions: (1) How can we access knowledge of the existence of things in themselves, if at all? (2) What roles do things in themselves play in Kant's epistemology and metaphysics? (3) What, if anything, is lost if things in themselves are omitted from Kant's system? The second section provides an analysis of the two-aspect interpretation of Kant's distinction and examines the phenomenological, ontic, and epistemic dimensions of the distinction. The third section introduces key concepts of quantum mechanics, such as superposition and the uncertainty principle in relation to Kuhn's incommensurability thesis. The study concludes that, in the tercentenary of his birth, Kant's distinction between things in themselves and appearances continues to offer profound insights in the context of quantum mechanics.

ÖZ

Bu çalışma, Kant'ın kendinde şeyler ile görünümeler arasındaki ayrımının dalga-parçacık ikiliği bağlamında geçerliliğini ve uygulanabilirliğini göstermeyi amaçlamaktadır. Çalışma üç bölüme ayrılmıştır. İlk bölüm, görünümelerle ilgili iki farklı kullanımının ayrıntılarını ortaya koymaktadır: temsiller olarak görünümeler ve temsillerin nesneleri olarak görünümeler. Kendinde şeylerin Kant tarafından sunulan negatif özelliklerini anlatan bu bölüm, kendinde şeyler bağlamında üç temel soruyu gündeme getirir. Bunlar, (1) Kendinde şeylerin varlığına dair bilgi erişilebilir ise buna nasıl eriştiğimiz, (2) Kendinde şeylerin Kant'ın epistemolojisi ve metafiziğinde oynadığı rollerin neler olduğu, (3) Kant'ın sisteminden şeylerin kendinde hallerinin çıkarılması durumunda bir kayıp olup olmayacağı sorularıdır. İkinci bölüm, Kant'ın ayrımının iki-veçhe yorumunun bir analizini sunmakta bu ayrımın fenomenolojik, ontik ve epistemik boyutlarını incelemektedir. Üçüncü bölüm, süperpozisyon ve belirsizlik ilkesi gibi kuantum mekaniğinin temel kavramlarını Kuhn'un uyumsuzluk tezi bağlamında tanıtarak başlamaktadır. Ardından, dalga-parçacık ikiliğini, Kant'ın kendinde şeyler ve görünümeler arasındaki ayrımı temel alarak yeniden yorumlamaktadır. Çalışma, doğumunun 3. Yüzyılında, Kant'ın kendinde şeyler ve görünümeler arasındaki ayrımının kuantum mekaniği bağlamında derin içgörüler sunmaya devam ettiği sonucuna varmaktadır.

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1. Introduction

As is known, there is a vast body of literature on Kant's distinction between appearances and things in themselves, a central theme that continues to resonate in analyses of contemporary scientific paradigms. Given its importance, Kant extensively explains what he means by the terms *appearance* and *thing in itself* in many of his works. For instance, in the *Prolegomena*, he asserts that

In fact, if we view the objects of the senses as mere appearances, as is fitting, then we thereby admit at the very same time that a thing in itself underlies them, although we are not acquainted with this thing as it may be constituted in itself, but only with its appearance, i.e., with the way in which our senses are affected by this unknown something (4:315).¹

Ontologically, appearances are grounded on things in themselves, as explicitly stated in the first critique, things in themselves “exist independently of us and our sensibility” (A396), appearances “must not be regarded as in themselves, in the same way, as objects (outside the power of representation) (A104). Although Kant claims that “it should exist in itself without relation to our senses and possible experience, could of course be said if we were talking about a thing in itself” (A493), he hints at the phenomenological aspect of appearances by stating that “appearances do not exist in themselves, but only relative to the same being, insofar as it has senses” (B164).

Evidently, all we can intuit are appearances, things in themselves are not within our epistemological scope of sensibility. We cannot cognize them through sense data, yet we can think of them since understanding has more comprehensive scope than senses, i.e., if we “isolate sensibility by separating off everything that the understanding thinks of through its concepts, so that nothing but empirical intuition remains” (A22).

At this point, one may naturally ask the underlying reason why Kant felt the need for such a distinction. Dicker points out that the first critique has both constructive and destructive tasks. While it responds the Humean skepticism by constructing “a system of substances causally interacting in time and space”(Dicker, 2004, 34), it also demonstrates the impossibility of the dogmatic metaphysics by asserting that “we can have no knowledge of a nonempirical, transcendent reality; since we cannot know things apart from the ways they appear to us in sensibility and are conceptualized by our understanding” (Dicker, 2004, 34). Dicker's assessment of dogmatic metaphysics has an important implication: the reality as a thing in itself is veiled in Kant's epistemology.

The veil of reality has long been a target for many philosophers such as Schopenhauer, Mach, Vaihinger, Lange, etc. However, the debates gained significant traction after the 1920s, particularly in the context of various interpretations of quantum mechanics, including the Kantian interpretations of wave-particle duality.² This study aims to contribute to the literature by demonstrating the strength and applicability of Kant's distinction between thing in themselves and appearances, specifically through an analysis of this distinction in the context of wave-particle duality.³

To achieve its aim, the article is structured in three sections. The first section begins by distinguishing two different conceptions of appearances, i.e., appearances as representations and appearances as objects of representations. It then raises three questions: (1) how one acquires the knowledge of the existence of things in themselves, if it is accessible at all, (2) what role things in themselves play in Kant's epistemology and metaphysics, and (3) whether anything would be lost if things in themselves were omitted from Kant's system.

¹ When quoting Kant, I utilize the original German pagination to facilitate readers' ability to track the citations accurately. Whenever available, I appeal to the Cambridge translations to ensure clarity and accessibility.

² Among these names Mach (1838-1916) lived long enough to see the early developments in quantum mechanics, yet the advanced issues such as wave-particle duality came out by the studies of physicists such as Broglie, Schrödinger, Heisenberg, etc. Thus, despite his enormous influence on the development of quantum mechanics, Mach himself never provided a strong criticism of the Kantian interpretation of quantum mechanics, as he did not live long enough to see the aftermath after the introduction of the wave-particle duality and its philosophical implications. See, Mach, 1914.

³ There is a substantial body of literature on Kant's influence on Bohr and the Copenhagen interpretation of quantum mechanics (Folse, 1985; Faye, 1991; Howard, 2004; Kaiser, 2011). However, this study aims to demonstrate the applicability of Kant's distinction between things in themselves and appearances to quantum mechanics, rather than exploring Kant's influence on various schools of interpretation. Therefore, it will not delve into that area.

The second section provides an extensive analysis of the two-aspect interpretation of Kant's distinction between things in themselves and appearances. While there is enormous literature on this distinction, for the sake of brevity, the second section discusses the key points of the two-aspect interpretation through the analyses of van Cleve, Westphal, and Langton, emphasizing the phenomenological, ontic and epistemic aspects of the distinction.

The third section begins with a simple introduction of some key notions of quantum mechanics, such as superposition, uncertainty principle, presented in an accessible tone for the non-experts and in relation to Kuhn's incommensurability thesis. The section then interprets the relevant elements of quantum mechanics through the example of the wave-particle duality, demonstrating that, in the tercentenary of his birth, Kant still provides deep insights into the new paradigm of physics through his distinction between things in themselves and appearances.

2. Appearances, Things in Themselves and Their Roles in Transcendental Philosophy

As is known, there are two different conceptions of appearances in the critiques, i.e., appearances as *representations per se*, and as *species of representation*. The former conception posits that appearances are representations; for Kant the representation of a body in intuition contains nothing "but merely the appearance of something" (A44/B61). The latter conception treats appearances as objects of representations, as seen in the assertion that "all our intuition is nothing but the representation of appearance" (A42/B59). The main questions are: (1) how to construe the two different conceptions of appearances and (2) how these conceptions contribute to the analysis of the distinction between appearances and things in themselves. While there are plausible explanations addressing the first question, the second is somewhat more intricate.

Beginning with (1), there are various interpretations of Kant's definitions, each leading to different conclusions about the nature of the distinction between the two senses of appearances. For instance, drawing the attention to the *-ing* and *-ed* ambiguity in the word *representation*, van Cleve suggests that the distinction between appearances_R and appearances_O is more a conceptual or a cognitive one than ontological. According to him, "We should construe him [Kant] as saying that appearances are represented that have no being apart from the representing of them" (1999: 7). He essentially argues that Kant's use of appearances is more coherent if we understand them primarily as appearances_O, where the act of representing gives rise to representeds, which exist only as a result of our capacity for representation. In other words, the representeds can be ontologically reduced to representing, namely, representations. Van Cleve downplays the distinct role of appearances_R by arguing that the representations are already objects of representation in Kant's system. This interpretation suggests that the distinction between representations *per se* and objects of representation is not as stark or meaningful, as appearances (as objects) do not *exist* independently of being represented.

In comparison, Gardner distinguishes between two conceptions using the terms *appearances_O* and *appearances_R*, where *appearances_O* refers to *objects of representations* while *appearances_R* refers to the *representations per se*. Gardner argues that "appearance_R is the sensible appearing that provides an intuitive datum for cognition, and appearance_O is the object cognized as so appearing" (1999: 181). Yet, they are related through cognitive processes; it is understanding that "converts ('objectifies') appearances_R into appearances_O" (Gardner, 1999: 181). According to Gardner's interpretation, appearances_R (representations *per se*) are the immediate sensory data or intuitive content we receive through perception, while appearances_O (objects of representation) are the objects we cognize as a result of the understanding's processing of that sensory data. Gardner emphasizes that the cognitive processes, particularly the understanding, play a crucial role in converting appearances_R into appearances_O. In other words, the raw sensory input (appearances_R) is processed and organized by the understanding to produce appearances_O.

Having briefly explored the two distinct conceptions of appearances, let us consider how these interpretations extend beyond mere representations and engage with (2), —namely, how different conceptions contribute the analysis of the distinction between appearances and things in themselves. The notion of *appearance* is closely tied to the cognitive faculties of the subject, where our epistemic access to the world is framed through the act of cognizing. In contrast, our relationship with things in themselves is more elusive, understood not through cognition but through the act of thinking. This shift from cognizing appearances to thinking of things in

themselves signals a fundamental aspect of Kant's philosophical position.⁴ In *Prolegomena*, Kant contends that "The sensible world is nothing but a chain of appearances connected in accordance with universal laws, which therefore has no existence for itself; it truly is not the thing in itself" (4:354). By distinguishing between things in themselves and appearances, while attributing no ontologically self-sufficient reality to the sensible world, Kant separates his approach from that of empirical realism. A similar move can be found in the first critique, where Kant claims that "even if we cannot cognize these same objects as things in themselves, we at least must be able to think them as things in themselves. For otherwise, there would follow the absurd proposition that there is an appearance without anything that appears" (Bxxvi). By asserting that things in themselves ontologically ground appearances, yet do not do so epistemologically, Kant distinguishes himself from subjective idealism.

Taking things in themselves as the ontological ground of appearances while allowing only appearances to be epistemically accessible necessitates an analysis in relation to three questions: (a) How do we know their existence?, (b) What is the role of things in themselves in Kant's system?, and (c) Would anything be lost if things in themselves were omitted from Kant's system?

Starting with (a), Gardner contends that conceptual interdependence does not yield metaphysical results: "although Kant's concept of appearance certainly implies the *concept* of the thing in itself, and there are objects satisfying the concept of appearance, none of this implies that there are any objects satisfying the concept of the thing in itself" (1999: 184). By arguing that without things in themselves there would be peculiar instances where "there is an appearance without anything that appears" (Bxxvi), and asserting that despite inferring their existence, "The non-sensible cause of these representations is entirely unknown to us" (A494/B522), Kant makes two key points: first, one cannot cognize things in themselves because they are not spatiotemporal; second, existence claims are not synthetic but analytic, adding no information to the concept of a thing (A597/B625). When combined, these two points suggest that one can neither prove nor refute the existence of things in themselves on epistemological or logical grounds. In other words, epistemologically things in themselves serve only as "contentless negative knowledge" (Gardner, 1999: 65), which does not constitute knowledge but function as a merely delineating concept. Metaphysically, they function as the unknowable ontological ground of appearances. Philosophically, they function solely as a boundary between transcendental idealism and subjective idealism.

These three results make it straightforward to consider what would be lost from Kant's system if things in themselves were omitted. Let me explore the first option: if things in themselves were omitted, there would be nothing lost. In this scenario, "God and the soul cease to be candidates for real existents" (Gardner, 1999: 185), which further "frustrates the contribution which Kant ultimately intends theoretical philosophy to make to practical philosophy" (Gardner, 1999: 185-186). Regarding the second option, which suggests that there would be a loss from the omission of things in themselves, I believe it is possible to enumerate several reasons. However, even the three roles of things in themselves—categorized as epistemological, metaphysical, and philosophical—suffice to make the point.

3. Two-Aspect Interpretation of the Distinction

Unsurprisingly, there are numerous interpretations of the distinction between appearances and things in themselves in the literature. For the purposes of this study and for brevity, I will discuss the two-aspect interpretations of van Cleve, Westphal and Langton. In a nutshell, the two-object view posits appearances and things in themselves belong to distinct realms of reality, while the two-aspect view maintains that they are ontologically same. However, from one aspect, they are objects of possible experience as appearances, and from another aspect, they are unknowable *noumena*.⁵

Starting with van Cleve, he addresses the issue through the three models proposed by Devitt to determine the most suitable interpretation of Kant's distinction:

⁴ In English, there is a distinction between 'to think about' and 'to think of', where the former *positively* implies the object of thought, whereas the latter does not carry the same implication.

⁵ While nearly all Kant scholars support the two-aspect view, there are notable exceptions. This article focuses on demonstrating the applicability of the two-aspect view to scientific phenomena and does not delve into the one-world view. For prominent proponents of the one-world perspective, see Guyer, 1987; Walker, 1978; and Ameriks, 1982.

First model: ‘Square on the third floor, round on the fourth’. Here it is really different things (different segments of the same building) that have the contrary predicates.

Second model: ‘Honest according to the *News*, crooked according to the *Times*’. Here different papers tell different stories, and at least one of them gets things wrong.

Third model: ‘Tall compared to Ed, short compared to Fred’. Here different relations are borne to different individuals. What would be a contradiction if we were dealing with a one-place predicate expressing a monadic property is no longer a contradiction once the predicate is properly understood as a two-place predicate expressing a relational property (Devitt, 1986: 200-204, quoted in van Cleve, 1999: 147).

According to van Cleve, the first two of these models do not convey their views. Unlike the one-object view, the first model refers to completely different objects with distinct qualities, while the second model, contrary to the one-object view, assumes that one of the perspectives is erroneous, even though both perspectives must be equally correct. The third model, however, addresses the shortcomings of the first two; it does not the first two models do and unlike the first model, it does not reference two distinct objects, and unlike the second model, it exemplifies the intuition of a quality of an object in relation to the perceivers’ forms of sensibility (van Cleve, 1999: 147). Although van Cleve aligns with one-worlders only on the condition that the inhabitants of that world are defined solely as things in themselves, his position is ontologically monist but phenomenologically dualist. He describes the distinction as “the distinction between appearances and things in themselves is a distinction between two separate universes of discourse—not between two ways of discoursing about the same class of objects” (van Cleve, 1999: 150).

The phrase ‘two separate universes of discourse’ implies that appearances and things in themselves belong to entirely different conceptual domains or categories of understanding. In van Cleve’s interpretation, appearances and things in themselves are treated as part of fundamentally distinct realms of discourse with no overlap. They are not merely two aspects of the same entity but are instead entities or modes of being that we approach with completely different kinds of discourse. The two universes of discourse remain entirely separate, meaning that discourse in one domain cannot be adequately translated into or understood through the terms of the other. Since the phenomenal and noumenal discourses are completely isolated, we can never bridge the gap between them. Appearances reveal nothing about the true nature of things in themselves, because they belong to an entirely different universe of discourse.

Westphal contends that Kant embraces a two-aspect view, which is clearly expressed in the following quote from the first critique:

Now the propositions of pure reason, especially when they venture beyond all boundaries of possible experience, admit of no test by experiment with their objects (as in natural science): thus to experiment will be feasible only with concepts and principles that we assume *a priori* by arranging the latter so that the same objects can be considered from two different sides, on the one side as objects of the senses and the understanding for the experience, and on the other side as objects that are merely thought at most for isolated reason striving beyond the bound of experience. If we now find that there is agreement with the principle of pure reason when things are considered from this twofold standpoint, but that an unavoidable conflict of pure reason with itself arises with a single standpoint, then the experiment decides for the correctness of that distinction (Bxviii, fn.).

Westphal does not view the two-aspect interpretation simply as “two ways of thinking about or describing objects” (2004: 58). The form of two-aspect view that Westphal seeks to distance himself from interprets one and the same object from two different angles: as *intuited* and as *not intuited objects*. According to this interpretation, an apple would be considered an appearance and phenomenal when it is intuited, but a thing in itself and noumenal when not intuited by anyone. Such an interpretation would imply accepting the non-intuited apple as a thing in itself, suggesting it exists in a spatio-temporal domain, which contradicts Kant’s views about the distinction.

On Westphal's account, "Kant's transcendental idealism is a baroque, decidedly metaphysical view" (2004: 61) due to four reasons: (1) "the entire spatiotemporal realm is merely an appearance to us, because space and time are nothing but forms of human intuiting, through which alone things in themselves acquire spatiotemporal characteristics" (2004: 60), (2) "spatiotemporal objects exist only in their being represented by us" (2004: 60), (3) "'causal relations' among 'phenomenal objects' is commonsense shorthand for (at least possible) representations of certain rule-like relations among manifest objects or events" (2004: 60), and (4) "causal relations in the empirical realm are not self-sufficient; they are nothing but relations constructable by us in our representing manifest objects and events" (2004: 60-61).

Westphal's interpretation is based on two key points: the spatio-temporality of appearances and their lack of ontological self-sufficiency. If there are beings that exist self-sufficiently, they are classified as things in themselves only, and only appearances have spatio-temporality because they can be objects of intuition, thus of pure forms of intuition. While denying the distinction to be ontological, he reduces appearances to things in themselves ontologically, separating them epistemologically.

Langton argues that the distinction between things in themselves and appearances is not metaphysical; rather, she asserts that they constitute one world and are metaphysically identical. She suggests the following quote from the first critique as the textual evidence of her argument:

Nevertheless we call some objects, as appearances, beings of sense (*phenomena*), because we distinguish the way in which we intuit them from their constitution in itself, then it already follows from our concept that to these we as it were oppose, as objects thought merely through the understanding, either other objects conceived in accordance with the latter constitution, even though we do not intuit it in them, or else other possible things, which are not objects of our senses at all, and call these beings of understanding (*noumena*) (A248/B306).

The quote suggests that when we refer to appearances as phenomena, we distinguish the way we intuit appearances and their intrinsic nature, which pertains to their noumenal aspect. The crucial point is that, although we make this distinction, we are still discussing the same objects—namely, appearances. Langton contends that, metaphysically speaking, the terms *noumena* and *phenomena* signify the very same objects, contrary to the misinterpretation where "Phenomenal and noumenal 'entities' are described and put 'in opposition' to each other, as if they are two nonoverlapping sets of things" (1998: 12). She argues, "There is one world: there are simply, as Kant says with appropriate vagueness, objects, or things. But there are two, non-overlapping sets of properties" (Langton, 1998: 12).

Clearly, Langton's interpretation is in line with Devitt's third model, which defends the metaphysical identity of things in themselves and appearances. Furthermore, her view resonates with the third model as she posits that "The nature things have in themselves is different from what we encounter when we intuit them: the inner or *intrinsic* predicates are different from the predicates encountered by us" (Langton, 1998: 12). This implies that there is one set of things but two sets of properties or discourses. Ultimately, this means that the distinction between things in themselves and appearances is not a metaphysical, but rather epistemological and discursive one.

To sum up, van Cleve's interpretation aligns with a strict Kantian reading, where Kant insists that we can never know things in themselves. We are confined to our own forms of intuition (space, time) and categories of understanding (such as causality) when talking about appearances. Things in themselves exist, but they are inaccessible to us in any meaningful way. Thus, our discourse about appearances and things in themselves cannot overlap or intersect in a meaningful way because we lack the conceptual and sensory tools to bridge that gap, where appearances are evaluated from a phenomenological perspective and treated as "intentionalia and that intentionalia are logical constructions out of states of perceivers" (van Cleve, 1999: 150). Westphal's interpretation aligns with van Cleve's, maintaining that causal relations ontologically dependent on things in themselves and epistemologically dependent on the categories, aligning with Devitt's third model that there is one world belonging to two different universes of discourse. Langton's interpretation, as mentioned, also aligns with Devitt's third model, advocating for the metaphysical identity of things in themselves and appearances and arguing that the distinction is primarily epistemological and discursive.

4. Interpreting Wave-Particle Duality from Kantian Lenses

Kant's scientific views were profoundly influenced by the Newtonian paradigm, which dominated the intellectual landscape of his time. However, as physics evolved, this paradigm underwent significant changes, leading to considerable challenges for Kant's epistemology. For instance, the pure forms of intuition—time and space—are no longer understood in the way Kant conceived them; the concept of space-time has taken on a fundamentally different meaning within the new paradigm of quantum mechanics. Despite these epistemological losses, his transcendental philosophy still offers valuable insights for interpreting phenomena within this new paradigm. One particularly compelling case is wave-particle duality. To illustrate the resilience of Kant's transcendental philosophy in light of these shifts in physics, I will first explain the concept of wave-particle duality.

Wave-particle duality refers to the phenomenon whereby subatomic entities, such as photons and electrons, exhibit particle-like behavior in some experiments and wave-like behavior in others. Importantly, this dual behavior should not be interpreted as mutually exclusive; as De Broglie noted, we should understand wave-particle duality “not in terms of waves *or* particles, but in terms of waves *and* particles” (Baggott, 2011: 116). The observed behavior of these subatomic particles is contingent on how they are measured or observed, highlighting the significant role of the observer and the effects of measurement instruments.

Feynman captures the peculiar nature of this observer-dependent behavior by stating, “No reasonable model could explain this fact, so there was a period for a while in which you had to be clever: You had to know which experiment you were analyzing in order to tell if light was waves or particles. This state of confusion was called the ‘wave-particle duality’ of light” (1985: 50, Endn. 3). For instance, in experiments analogous to the famous double-slit experiment, particles behave like waves, while in others, such as Einstein's Nobel Prize-winning photoelectric effect experiment, they exhibit particle-like behavior. This seemingly paradoxical behavior is often regarded as strange by those attempting to understand the new paradigm of physics using the concepts of classical mechanics, where waves and particles are traditionally viewed as mutually exclusive categories.

In classical mechanics, as formulated by Newton, calculating the movement of an object requires that the state of the object be known. This state encompasses critical information such as the object's position and velocity. Physicists initially attempted to apply classical mechanics to measure the position of electrons. However, they soon discovered a fundamental limitation: “the electron's position prohibits an exact measurement of its velocity; and it was further found that the inaccuracy of the latter measurement varies inversely with the accuracy of the former, and vice versa” (Planck, 1936: 18-19).

Clearly, quantum mechanics cannot be understood merely as a micro-level version of classical mechanics. Unlike the realist interpretations of classical mechanics, quantum mechanics presents a reality that is fundamentally veiled. Planck articulates this obscurity, stating, “If the position of the electron is known exactly, its velocity is not known at all, and vice versa” (1936: 19). Because subatomic particles exhibit both wave-like and particle-like properties yet reveal only one property at a time, it is impossible to formulate a mechanical theory in quantum mechanics that standardizes the behavior of these particles. Instead, one can only derive results from specific experiments conducted with particular measurement instruments. Baggott encapsulates this veiled nature of reality in quantum mechanics, noting that depending on the experiment, “we can ask questions concerning the electron's wavelike properties and we can ask mutually exclusive questions concerning the electron's particle-like properties, but we cannot ask what the electron *really* is” (2011: 97).

At this point, one might naturally wonder whether the limitations of classical measurement instruments are what prevent us from fully grasping the behavior of particles as they are in themselves. From this perspective, it seems plausible—and perhaps even optimistic—to assume that with sufficiently advanced measurement tools, we might eventually be able to capture the essential properties of particle behavior. However, the problem lies not in technological limitations but in the fundamental nature of quantum reality itself, which does not conform to the classical conception of how things should behave. This observation has broader implications, particularly regarding the disparity between the capacities of our sensibility and our understanding. Before delving into this discrepancy, it is crucial to first clarify the terminological and conceptual differences between classical and quantum mechanics.

The first key concept to note is superposition. According to this principle, quantum particles exist in a superposition of all possible states before being observed or measured. For instance, an electron can be in a state where it simultaneously passes through both slits in the double-slit experiment. This indicates that prior

to observation, quantum states represent merely a set of possibilities. Only when we measure the system does it collapse into a specific state; however, this measurement does not reveal the particle's true nature—it reflects what we observe following the interaction. Thus, in every quantum experiment, the outcomes are influenced by the observer and the interactions between the measurement instruments and the subatomic particles themselves.

When viewed in light of Westphal's and Langton's interpretations, superposition does not suggest the absence or non-existence of things in themselves when no appearances are intuited. Nor does it imply the existence of two different sets of objects belonging to distinct ontological realms; rather, it indicates two distinct sets of properties. Recall the distinction between the two senses of appearances: as represented and representings. The ontological hierarchy is such that representeds depend on representings, which in turn rely ontologically on things in themselves. Within this framework, appearances exhibit different properties depending on the type of experiment conducted and the interactions between subatomic particles and measurement instruments, all without raising further concerns regarding the epistemic inaccessibility of things in themselves.

Superposition is closely related to the second principle known as *Heisenberg's uncertainty principle* (Heisenberg, 1927), which states that we cannot precisely measure both the position and momentum of a particle simultaneously. The more accurately we know one, the less accurately we can know the other. The principle reveals a fundamental limit to our understanding of a particle's behavior, suggesting that some aspects of quantum reality are veiled and beyond human comprehension. This situation parallels Kant's concept *noumenon* that can only be known as they appear to us, reminiscent of appearances. Furthermore, due to the probabilistic nature of the quantum mechanics, Planck asserts that "In classical physics a wave is a definite physical process, a movement perceptible by the senses or an alternating electrical field admitting of direct measurements, whereas in quantum physics it really denotes no more than the probability that a certain state exists" (1936: 67).

The problem can be analyzed from a third perspective: Kuhn's incommensurability thesis (Kuhn, 1962). In addition to our inability to observe the reality of particles as they are in themselves, Kuhn's thesis highlights another critical factor. According to the incommensurability thesis, different scientific paradigms are often not directly comparable because their foundational assumptions and languages are incompatible. The shift in terminology arises from the shift in underlying assumptions. During a paradigm shift, scientific communities adopt new terminologies, and even when old terms are reused, their meanings may change so significantly that understanding the new paradigm through the lens of the old one becomes challenging, if not impossible. Consequently, attempting to make sense of quantum mechanics using the conceptual and terminological framework of classical mechanics leads to a dead end, revealing a deeper reason for this difficulty:

The uncertainty in forecasting events in the world of the senses disappears and in its place we have an uncertainty with regard to the connection between the world image and the world of the senses. In other words, we have the inaccuracy arising from a transfer of the symbols of the world image to the sense-world and vice versa (Planck, 1936: 66).

When analyzed, Planck's explanation sheds light on the origins of our inability to comprehend the new paradigm using the terminology of the old one. In the case of classical and quantum mechanics, classical mechanics operates on the basis of sensibility, assuming that all physical phenomena are observable (Tekin, 2025). In contrast, quantum mechanics is grounded in a probabilistic framework that relies on understanding. One of the key characteristics that distinguishes sciences from pseudo-sciences is their ability to provide explanations that make future phenomena foreseeable. Unlike classical mechanics, which presents a coherent world-image, quantum mechanics introduces a level of chaos, leading to a fundamentally different understanding of reality. Consequently, the symbols, terminology, and scientific assumptions rooted in the world-image of classical mechanics do not effectively capture the behavior of subatomic particles or provide a framework for predicting their behavior.

When evaluated from the perspective of the two-aspect interpretation of Kant's distinction between things in themselves and appearances, quantum mechanics underscores the strength of this interpretation. To illustrate this, let's first recall the third model provided by Devitt. Unlike the first model, this model does not posit two distinct objects. Similarly, when viewed through the lens of the third model, quantum mechanics does not treat

subatomic particles and macroscopic objects as belonging to two separate realms of reality. Furthermore, superposition does not imply the existence of two ontologically distinct entities—wave-like particles and particle-like particles—but rather describes particles that exhibit wave-like or particle-like behavior depending on the type of experiment conducted and the measurement tools employed. These considerations suggest that, in light of Kant's distinction between things in themselves and appearances, the third model offers a more robust explanation of quantum mechanics than the first model.

In contrast to the second model, the third model does not presuppose the falsity of any interpretation of physical phenomena. If it did, one could argue—similar to the bi-valent expression, 'Honest according to the *News*, crooked according to the *Times*'—that the behavior of subatomic particles exhibits wave-like properties in one type of experiment and particle-like properties in another, with one experiment being incorrect. However, in quantum mechanics, the logic employed is primarily ternary, fuzzy, and paraconsistent rather than strictly bivalent, which incorporates the law of excluded middle. This means that while different types of experiments may yield varying properties regarding the behavior of subatomic particles, both assumptions can coexist as true without one negating the other. This characteristic highlights the strength of the third model over the second.

The third consideration emphasizes that the third model interprets the distinction between things in themselves and appearances as a differentiation between two separate universes of discourse, rather than two ways of discussing the same class of objects. This aspect of the third model effectively elucidates the incommensurability of the old and new paradigms in physics, where appearances and things in themselves reside in entirely different conceptual domains or categories of understanding, rather than in distinct ontological realms. Beyond the incommensurability of the new and old paradigms based on the distinction of the universes of discourse, there is also a further distinction regarding things in themselves and appearances. This explains why one cannot comprehend the noumenal and *in itself reality* of subatomic particles through the discourse of macro-objects, which correspond to appearances in this analogy.

5. Conclusion

In conclusion, Kant's distinction between things in themselves and appearances retains significant relevance in the context of contemporary physics, particularly in the interpretation of quantum mechanics. Despite the paradigm shift from Newtonian mechanics to quantum theory, which has displaced some key elements of Kant's epistemology—such as the pure forms of intuition (space and time)—his transcendental philosophy offers valuable insights for understanding the complexities of quantum phenomena, especially the wave-particle duality. The wave-particle duality, where sub-atomic entities exhibit both wave-like and particle-like behaviors depending on the experimental context, highlights a deeper, more complex layer of reality that defies classical mechanical interpretations. Kant's framework, particularly the two-aspect interpretation of the distinction between appearances and things in themselves, proves useful for navigating this complexity. Just as quantum mechanics reveals that sub-atomic particles can exist in superposition states before being observed, Kant's view that appearances are representations dependent on our mode of perception mirrors the observer-dependent nature of quantum phenomena. The veil between appearances and the noumenal reality parallels the way quantum particles behave in probabilistic, indeterminate ways until they are measured.

Superposition and the uncertainty principle further emphasize the limits of classical conceptions of reality, supporting Kant's argument that certain aspects of reality are inaccessible to human cognition. The impossibility of precisely measuring both the position and momentum of particles reflects the epistemic boundary Kant described with things in themselves—subatomic reality remains fundamentally elusive, much like the noumenon, which can only be known through its appearances. The incommensurability between classical and quantum paradigms, as highlighted by Kuhn, also echoes Kant's distinction. Just as different paradigms have distinct sets of concepts and terminologies that are not easily reconcilable, Kant's distinction suggests that we cannot use the same categories of understanding (which apply to appearances) to comprehend things in themselves. Thus, any attempt to explain quantum phenomena using the concepts and tools of classical mechanics is bound to fail, as these belong to different "universes of discourse". Kant's two-aspect interpretation provides a philosophical structure that accommodates the shifts in scientific paradigms while preserving the distinction between the world as it appears to us and the world as it is in itself.

Therefore, Kant's transcendental philosophy, particularly his distinction between things in themselves and appearances, remains a robust interpretative tool for understanding the complexities and paradoxes of quantum mechanics. It highlights the limitations of human cognition in accessing the true nature of reality while offering a framework that aligns well with the probabilistic and observer-dependent nature of quantum mechanics. In this light, Kant's insights continue to resonate, showing that his philosophy transcends its original context and remains relevant to contemporary scientific inquiries.

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