On the usefulness of philosophical terminological rigorousness in Quantum Mechanics

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Abstract:
A lot of the confusion with regards to the meaning of Quantum Mechanics arises from improper use of language (in the philosophical sense). The following brief discussion demonstrates how this could be avoided, and the benefits of using more philosophically rigorous language and concepts.

Let’s start with the statement "The results of quantum mechanical phenomena depend on the observer". This idea is misleading; there is no such thing as "observer" or "observation" in quantum mechanics and definitely not a "conscious observer". Observation means "interaction". There is no way to know a property of an object or particle without interacting with it. This creates the problem, described by Heisenberg, that any interaction necessarily affects the state of object under study, which leads to a limit in what is knowable about its state.

It is a truism to say that “things that don't interact, don't exist”. Anything that isn't in any way interacting with the rest of the universe is by definition not a part of the universe. This is also a corollary of Occam's razor. The really interesting question is: Does the universe itself "know" the state of a particle that isn't interacting with anything during a given period of time? Is there any actual object permanence in the universe, with regards to things/particles that are temporarily not interacting with anything in the universe? The wave-particle duality suggests that, no, there is no object permanence in the universe - as soon as a photon stops interacting, it's just an expanding sphere of a wave-front, centered at the last interaction, until that wave-front interacts with something else.

The sum-over-paths interpretation of the double-slit experiment is a good example of terminological confusion. This interpretation suggests that "a photon takes all possible paths and the observed end result is the sum of those paths".

The problem with this explanation lies in the usage of the words "path" and "observation". No photon ever has "a path" completely on its own. If a photon is left to its own devices, then it's just an ever-expanding spherical bubble. The existence of a "path" implies interaction with either obstacles, such as the solid parts of a slit or a pinhole, or with mirrors. Therefore, "path" means "interaction with something along the way". Equally, there is no "observation", this is just the interaction with the screen at the far end of the experiential setup or a photon detector. So, the sum-over-paths explanation can be re-written as "A photon interacts with all obstacles (path walls/mirrors) along the way before deciding how to interact with last obstacle (screen)", which really means "a photon interacts with all obstacles collectively", which really means "all possible interactions of a photon do happen and they are equivalent to one another and they can be summed up as just one single interaction by superposition".

"Collective interactions" could potentially mean than all interactions of a photon are simultaneous. Cause-and-effect means that “cause” always precedes “effect” in time. Without time, there is no possibility for cause-and-effect and all events (or states) are equivalent to one another; "time" and "cause-and-effect" are tautological concepts, if only because cause-and-effect is the direction of time by definition. Hence, a single possible interaction of a photon cannot "cause" another possible interaction to not take place, because that would imply a temporal relationship between the two, which is impossible without "time". This might be what gives rise to "multiple" parallel paths- if all interactions with both distant and close by obstacles are equivalent to one another from the point-of-view of the photon, then no single path can have precedence over another path.

This ties in well, conceptually, with Special Relativity. The speed of light is the speed of causality (or the speed of "time"). We could speculatively interpret this as meaning that all events along a spatial chain that runs at the speed of light, such as the path of a photon, cannot be causally distinguished from one another. Special relativity necessitates that time slows down the closer you are to the speed of light. So, taking the point-of-view of the photon which is moving at the speed of light - the imaginary clock inside the photon that is showing which interaction preceded which other interaction can be seen as literally frozen in place, which means that any events that occur according to this imaginary clock are "simultaneous".

There is no reason why the observed and measured behaviour of a photon should depend on the frame of reference. A simple thought experiment can help demonstrate this idea. If the photon was a massless spaceship moving at the speed of light and there was a physicist inside it recording all events that happen to the spaceship, would this physicist be able to determine which bit of the universe was the first thing that the spaceship ran into, or collided with? According to this frame of reference - no, all possible collisions happen simultaneously and instantaneously.

This thought experiment might also help explain why a photon “goes everywhere” i.e. expands outwardly as a “bubble” or as a spherical wave-front: the imaginary physicist inside the massless spaceship “sees” all of the universe as a single point dead ahead, due to relativistic effects; no measurement inside the ship can determine the direction of travel of the ship.

The apparent information loss experienced by the imaginary physicist on board the massless spaceship matches well the observed information “uncertainty” experienced in the third-person frame of reference of conventional observations on the behaviour of photons. This suggests that the two discussed frames of reference must be equivalent to one another, with regards to actual measured physical state(s) and total information availability.

At the speed of light, you have as much information about the rest of the universe, as the universe has about you (not a lot); there is a symmetry in the reduction of "bandwidth" for both frames of reference, when it comes to information about interactions.