Re-Examining the Copenhagen Interpretation with Feynman Path Integrals

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ABSTRACT

Feynman path integrals may be all we need to remove any paradox introduced by the Copenhagen Interpretation of quantum mechanics.

1. Introduction

One of the great things about quantum mechanics has been its accuracy in predicting the behavior of small atomic and molecular systems, or even free particles. One of the drawbacks is the conservative approach to its interpretation. One way to think about the Copenhagen Interpretation, is simply to say we never know where an elementary particle is until we perform a measurement to find it; another way is that it is possible to think of a particle as being distributed throughout all of space until we collapse a wave function which provides data to justify our awareness of its location.

Suppose we no longer need to worry about this, because Richard Feynman already solved the problem for us in the 1950s.

2. Feynman Diagrams and Path Integrals

Beginning with the simplest of concepts:

\[ S_{ij} = \langle f | S | i \rangle \] (1)

Where \( S \), the \( S \)-matrix, is used to quantify the scattering of initial \( |i \rangle \) and final \( |f \rangle \) states of a quantum system, we then dare the treacherous paths of perturbation theory. After crafting a complicated expression for the \( S \)-matrix, perturbation theory is next applied to isolate how the \( S \)-matrix perturbs particle interaction amplitudes. These perturbation terms are then expanded as a series which can sometimes be truncated at a convenient and particular place to obtain an approximation for an interaction which can be tested experimentally.

Here is an example of an expansion term for Fermion scattering, to refresh memories, with the integral representing how a fermion and anti-fermion can either repel each other or attract.
At any rate, we do not need to become very involved with path integrals at the moment, we only need to apply the rudiments of Feynman diagrams. My claim is very simple, that with the application of graph theory to particle physics, Feynman resolved any ambiguity regarding the Copenhagen interpretation of quantum mechanics.

Recall the double-slit experiment (Figure 1):

According the wave function $|\psi> = 0.5|\psi_{left slit}> + 0.5|\psi_{right slit}>$, the particle is conceptually in both states until a measurement is made and so can pass through both slits as a wave at the same time.

I would like to propose that this manner of thinking may be incorrect, and that – if the double slit is treated as a quantum mechanical object – then the incoming particle stream interacts with the double slit through their Feynman diagrams (see Figure 2, below). So, although the interaction is non-local because Feynman diagrams are non-local, the particles are passing through either one or the other slit. There is no need to consider the particles distributed throughout all space, they are simply following the geodesics as instructed by the non-local Feynman diagrams.
3. Conclusion

In an attempt to reconcile what some indirect laboratory experiments indicate (non-local quantum behavior) with the traditional Copenhagen quantum conventional wisdom, we invoked Feynman diagrams to be a liaison. If we treat the double slit wall like the quantum mechanical object it is, the Feynman diagrams tell a (non-local) story over time regarding the geodesics that particles are required by Nature to follow.

Figure 2. Quantum Mechanical Double Slit