Math Noise and the Inverse Aharonov-Bohm Effect

Terry Bollinger
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https://www.youtube.com/watch?v=i7Du1J6t8qo&lc=Ugwkq75dueIgtZXbiY94AaABAg

Comment on YouTube Parth G post:
Here's What a Quantum Wave Function REALLY Represents
https://youtu.be/i7Du1J6t8qo

4:43 — "… the wave function doesn't have to be real all the time — it can also be imaginary." This apt comment raises an interesting question: Can our math models, even ones as simple and incredibly useful as complex amplitudes, distort our understanding of reality as seen in experiments? For example, the distinction between real and imaginary quantum amplitudes arises solely from the structure and labeling of the complex plane. Aharonov-Bohm and other experiments demonstrate that only the _phase difference_ between two points has any meaning. In that sense, quantum amplitudes are more like pistons on a crankshaft since, unlike complex numbers, crankshafts similarly make no distinction between "real" and "imaginary" angles and phase differences.

But Terry, this must be nothing more than a nitpick that makes no real difference?

Try this: Take a vast room designed for problem-solving and run a line of masking tape down the middle. Tell everyone with a problem to solve to choose whichever side has resources that look more promising for their problem. While this efficiency-oriented strategy sounds innocuous enough, from that moment forward, solutions that involve _crossing_ the tape become implicitly forbidden and, in time, forgotten even as options. Similarly, thinking that the amplitudes of Schrödinger wave functions _are_ complex numbers locks out the idea that both the amplitudes might be anything other than abstract numbers, unrelated to any other phenomena in physics.

That's unfortunate since, in this case, the real and imaginary labels are nothing more than a bit of math noise introduced by the "programming language" of complex numbers. They belong to humans and human cognitive styles, not physics.

And _yes,_ everything I just said about complex numbers introducing non-physical noise also applies to the U(1) or unitary symmetry group. The physical systems that implement unitary group behaviors are neither matrices nor sets of unit-length complex numbers, and thinking they are is never a good idea. Matrices and complex numbers are nothing more than human models of the less noisy natural versions that show no more signs of real and imaginary axis distinctions than do crankshafts.

So, a question: If the physical phenomena modeled by amplitudes and U(1) are _simpler_ than the very models we use to "abstract" them, is it possible folks might also be missing some absurdly simple connection between phase and other natural phenomena, simply by focusing too much and too confidently on the tape across the floor? Only time will tell.

Bonus: The Inverse Aharonov-Bohm Effect

Since this video also mentions Parth's earlier video on the Aharonov-Bohm effect, I can't resist mentioning a related example of how subtle boundaries can block problem-solving.

There are two ways to represent a magnetic field: By using field lines, which is the version most folks know; or by using an entirely different set of directed lines that looks more like an abstract version of the quite real electron flow paths used to create magnetic fields. These more abstract lines extend well beyond the bounds of the actual field-generating electron flows and are called the "vector potential" of the magnetic field. The name reflects that, as with gravitational potential, these lines represent the potential energy of the magnetic field.

The Aharonov-Bohm effect relies on a simple point: Relevant energy potentials _alter_ the phases of quantum wave functions. Thus, in principle, if you pass electrons through the nominally invisible and undetectable "vector potential" representation of a magnetic field, you should see changes in their behaviors if you can use the vector potential to create phase differences between them (sound familiar?). The simplest versions divert electrons to one side by creating measurable interference in their wave functions.

For half a century, folks have focused on the side of the room in which classical solenoids create phase changes in electrons that then measurably divert electrons to one side.

But what about the other side of the room?

As Newton once noted, nature is fond of action-reaction. The Inverse Aharonov-Bohm effect thus is nothing more than this: If a solenoid can create a vector potential field that diverts electrons to one side, then the diversion of electrons should at the same time impart an equal and opposite transverse momentum into the solenoid, and do so by way of the "invisible" vector potential.

I've not researched this idea of an Inverse Aharonov-Bohm idea yet, but if it's out there, it's not anywhere near the top of the literature, or I would have seen it already.

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