Physics and Physicists
Monday, September 25, 2006

Why is Quantum Mechanics SO Difficult?

Strangely enough, QM's formalism isn't any more difficult than other areas of physics. The mathematics of the "standard" QM isn't any worse than, let's say, electromagnetism. Yet, to many people, especially non-physicists, QM presents a very daunting effort to understand.

I strongly believe that it all comes down to how we understand things and how we expand our knowledge. Typically, when we teach students new things, what we do is build upon their existing understanding. We hope that a student already has a foundation of knowledge in certain areas, such as basic mathematics, etc., so that we can use that to teach them about forces, motion, energy, and other fun stuff in intro physics. Then, after they understand the basic ideas, we show them the same thing, but with more complications added to it.

The same thing occurs when we try to help a student doing a homework problem. We always try to ask what the student know already, such as the basic principle being tested in that question. Does the student know where to start? What about the most general form of the equation that is relevant to the problem? Once we know a starting point, we then build on that to tackle that problem.

The common thread in both cases is that there exists a STARTING point as a reference foundation on which, other "new" stuff are built upon. We learn new and unknown subject based upon what we have already understood. This is something crucial to keep in mind because in the study of QM, this part is missing! I am certain that for most non-physicists, this is the most common reason why QM is puzzling, and why quacks and other people who are trying to use QM into other areas such as "metaphysics" or mysticism, are using it in a completely hilarious fashion.

There is a complete disconnect between our "existing" understanding of the universe based on classical understanding, and QM. There is nothing about our understanding of classical mechanics that we can build on to understand QM. We use the identical words such as particle, wave, spin, energy, position, momentum, etc... but in QM, they attain a very different nature. You can't explain these using existing classical concepts. The line between these two is not continuous, at least, not as of now. How does one use classical idea of a "spin" to explain a spin 1/2 particle in which one only regains the identical symmetry only upon two complete revolutions? We simply have to accept that we use the same word, but to ONLY mean that it produces a magnetic moment. It has nothing to do with anything that's spinning classically. We can't build the understanding of the QM spin using existing classical spin that we have already understood.

Now interestingly enough, the MATHEMATICAL FORMULATION of QM is quite familiar! The time-dependent Schrodinger equation has the same structure as a standard wave equation. We call the energy operator as the Hamiltonian not for nothing since it looks very familiar with the hamiltonian approach to classical mechanics. The matrix formulation also isn't anything new. What this means is that while the conceptual foundation of QM is completely disconnected with our traditional conceptual

understanding, the mathematical formulation of QM completely follows from our existing understanding! Mathematically, there is no discontinuity. We build the formalism of QM based on our existing understanding!

This is why, in a previous thread in PF, that I disagree that we should teach students the concepts of QM FIRST, rather than the mathematical formulation straightaway. There is nothing to "build on" in terms of conceptual understanding. We end up telling the students what they are out of thin air. The postulates of QM did not come out of our classical understanding of our world. Instead, the mathematical formalism is the only thing that saves us from dangling in mid air. It is the only thing in which our existing understanding can be built on.

What this implies clearly is that, if one lacks the understanding of the mathematical formalism of QM, one really hasn't understood QM at all! One ends up with all these weird, unexplained, unfamiliar, and frankly, rather strange ideas on how the world works. These conceptual description QM may even appear "mystical". It is not surprising that such connections are being made between QM and various forms of mysticism. One lacks any connection with the existing reality that one has understood. So somehow, since QM can do this, it seems as if it's a licence to simply invent stuff weely neely.

The mathematical formalism of QM is what defines the QM description. The "conceptual description" is secondary, and is only present because we desire some physical description based on what we already have classically. It is why people can disagree on the interpretation of QM, yet they all agree on the source, the mathematical formalism of QM.

This, however, does not mean that QM is nothing more than "just mathematics". This is no more true than saying the musical notes on a sheet of paper are just scribbles. The notes are not the important object. Rather, it is the sound that it represents that's the main point. The musical notes are simply a means to convey that point clearly and unambiguously. Similarly, the mathematics that is inherent in QM and in all of physics, is a means to convey an idea or principle. It is a form of communication, and so far it is the ONLY form of communication accurate and unambiguous enough to describe our universe. It reflects completely our understanding of a phenomena. So a mathematical formulation isn't "just math".

You cannot use your existing understanding of the universe to try to understand the various concepts of QM. There is a discontinuity between the two. It is only via the mathematical continuity of the description can there be a smooth transition to build upon. Without this, QM will not make "sense".

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Labels: Quantum mechanics