measure the particle going through one slit, there is another (with other conscious minds) where it goes through both. Such a view resolves a conflict between free will and God's omniscience and omnipotence--if God knows what our future actions will be, how can our will be free? And the answer would be a type of Molinism, God is aware of all possible counterfactuals, but they are only counterfactuals for our mind, our ego, not for God.

From a series of articles written by: Bob Kurland - a Catholic Scientist

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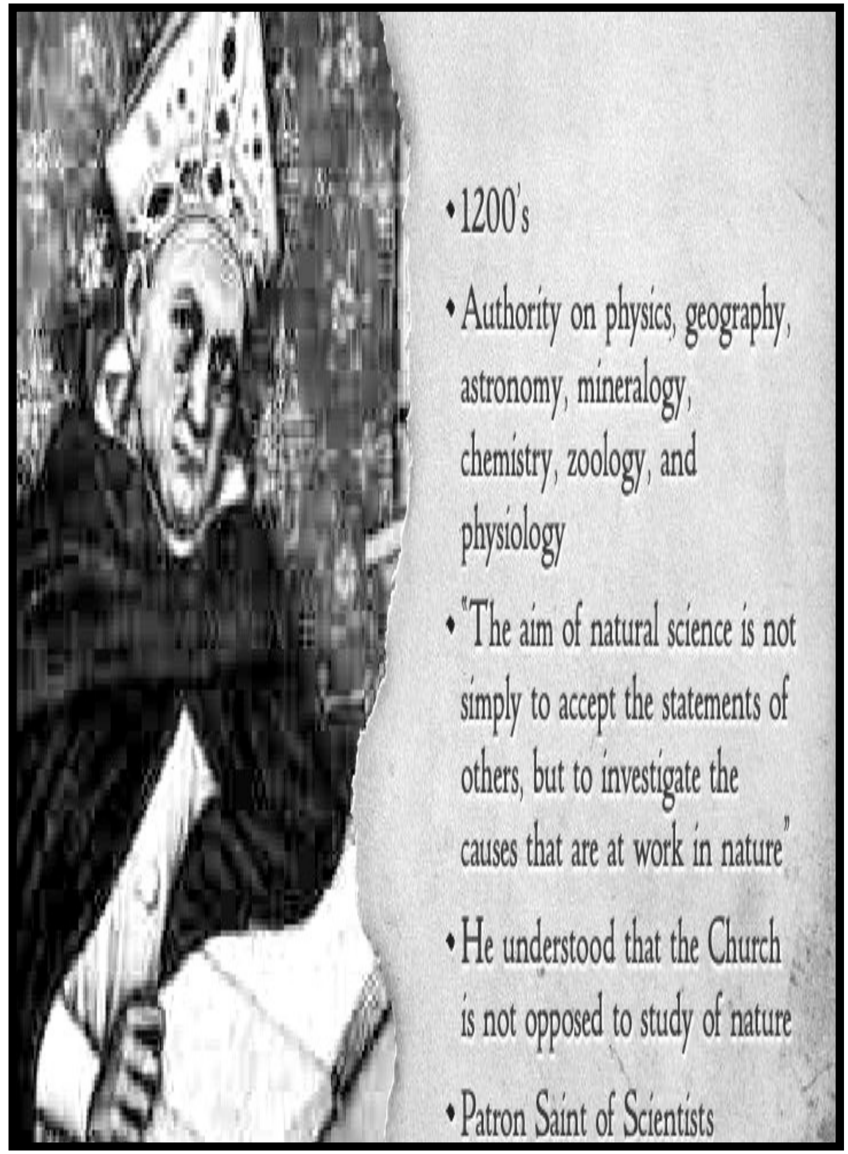
Catholic Physics - Reflections of a Catholic Scientist - Part 13

Do Quantum Entities Have Free Will? (And Do We?); Or, "Does it Matter if God Plays Dice?"



Catholic Physics - Reflections of a Catholic Scientist - Part 13

Do Quantum Entities Have Free Will? (And Do We?); Or, “Does it Matter if God Plays Dice?”

Of course I believe in free will. I have no choice.“ - The Salon Interview, 1987, Isaac Balshevis Singer,

"There is no evidence for determinism.” - Princeton Lectures, John H. Conway

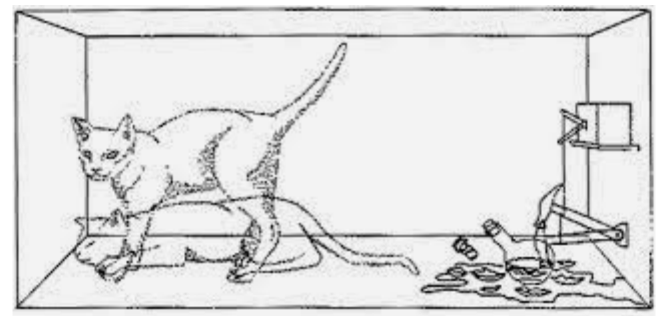
“Philosophy is too important to be left to philosophers” Unification beyond the Core , Frank Wilczek (also attributed to John Wheeler)

“…dearly beloved…be not disturbed by the obscurity of this question; I counsel you first to thank God for such things as you do understand; but for all which is beyond the reach of your mind, pray for understanding from the Lord, observing at the same time peace and love among yourselves…

"On Free Will and Grace , St. Augustine of Hippo

In one of the later Foundation novels, Isaac Asimov envisages a world, Gaia, in which a super conscious mind pervades the world, from the smallest virus or rock to the humans (and robots) in it. In such a world it would be natural that quantum entities have free will, and there would be nothing remarkable in the Conway-Kochen Free Will Theorem:

"Does it even matter if
God plays dice?"
Rachel Thomas' Plus-math Interview of John Conway



Schrodinger's Cat (U. Toronto, Physics)

If we turn to quantum mechanics, the state function, which most generally can be put as a superposition of basis states (“Schrodinger’s Cat”), evolves deterministically. The randomness comes at measurement, when the state function collapses, except for that basis state which gives the measured result. Chance/randomness for the measured result comes from the component nature of basis states, and should be distinguished from weighting in a mixture of states. (For links to basic web material on quantum mechanics, please refer to another post of mine, Quantum divine intervention..) Quantum Mechanics does not include this state function collapse on measurement as part of the general theory, and thus results the so-called Measurement Problem .

Amongst the various interpretations and alternative theories which attempt to resolve the measurement problem, I’d like to focus on two: 1) the relation between the observer, consciousness and measurement in quantum mechanics; 2) many worlds/many minds (relative state theory). From the earliest days of quantum mechanics, the great thinkers–Von Neumann, Wigner, Schrodinger–have posited that the final step in the measurement process was observation by a mind, a consciousness, and thus the mind and quantum mechanics were entwined. The delayed choice experiment adds weight to this belief, I believe. There are many physicists (not abashed by the popularization of this notion in quantum leap science fiction) who subscribe to the Many Worlds interpretation of quantum mechanics that at each measurement one option is made apparent and the rest branch (into alternative universes, alternative minds?).

Here finally is my take: as with John Wheeler, I believe there is a participatory universe created by the observer, conscious minds (ours? God's? both?). The free will of the quantum entity is our own free will. There is an infinitude of possible universes and our ego, our consciousness traverses these as it makes choices.   If there is a universe where we teams rotate from table to table, so that each team has played at each table with the same dealt hands. There is a predetermined initial lay of the cards, but the players are free to deal with the sets of hands as they will. (Is this an example of what philosophers call “compatibilism” in free will?) Conway strongly argues that the FWT forbids randomness as an agency, whether occurring at the event or predetermined:

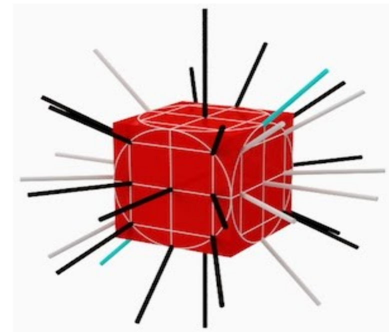
“That’s why it doesn’t matter if God plays dice with the Universe, or not. Even if we allowed random numbers into the Universe, which I’ll think of as God’s dice, that’s not sufficient to explain the lack of pre-determinism in quantum physics.” quoted in Rachel Thomas’s article.

Duplicate Bridge: Declarer's Hand (Wikipedia article)

I have a problem understanding this assertion. Granted that the FWT shows that the particle response cannot be predicted by a function involving past history, how exactly does that dispense with pseudo-randomness, predetermined before the world began? What can we learn from physics, in general, and quantum mechanics, in particular, to understand Conway’s argument?

Let’s consider first “random noise” in electronic devices, my old friend from nmr spectroscopy and MRI. Such noise can be characterized by mean square amplitude and correlation times, which in turn can be related to physical parameters. Molecular motion candidates for randomness also obey functional relationships. I’ve cited these as examples that don’t contradict Conroy’s argument about predetermined randomness. Can the reader cite others that might? I can’t.

"It asserts, roughly, that if indeed we humans have free will, then elementary particles already have their own small share of this valuable commodity. More precisely, if the experimenter can freely choose the directions in which to orient his apparatus in a certain measurement, then the particle’s response (to be pedantic – the universe’s response near the particle) is not determined by the entire previous history of the universe.” The Strong Free Will Theorem, John Conway and Simon Kochen.



The Proof of the Kochen-Specker Theorem
(from plus-maths discussion, by Rachel Thomas)

I won’t give an extended discussion of the proof (see the link in the caption for a very clear and detailed presentation by Rachel Thomas or the link for the quote for the rigorous mathematical proof). Nor will I give an extended discussion of what free will might be (a topic about which philosophers have contended over the past millennia). Halfway through writing this post, I discovered John Conway’s six Princeton lectures on his Free Will Theorem online. So really, rather than writing, I should just direct the reader to those lectures to see what the Free Will Theorem is all about. I should also note that Conway does not claim his Free Will Theorem dis-proves determinism; indeed, he says there is no way to disprove determinism, despite the fact that there is no evidence for it.

Nevertheless, I would like to use the Free Will Theorem (abbreviated as FWT) as a springboard to discuss several issues in interpreting quantum mechanics, namely how randomness and consciousness might enter into interpretations of quantum mechanics. (Fear not, gentle reader–this will not be a “What the Bleep” presentation, or a jump into Eastern mysticism.)

From "The Spin Family"
5 sculptures by Adrian Voss-Andreae

First, let's see how the three axioms are empirically justified by contemporary physics; I'll phrase the axioms to make the physics clear (I hope).

1. SPIN. There exist particles with intrinsic angular momentum (spin) with spin quantum number, S= 1, such that components of angular momentum along a preferred axis (as defined by, say, an electric/magnetic field or a polarizer) are 1, 0, and -1 (for angular momentum, I'm using units of hbar, where hbar = Planck's constant/(2pi)). The three components are shown in the illustration, "The Spin Family". The total angular momentum vector precesses about the defined direction. The upper cone shows the component with 1; the flat disc, the component with 0; the downward pointing cone, the component with -1. Then quantum mechanics shows that the squared components of spin in some arbitrary choice of three perpendicular directions must be either 0,1,1; 1,0,1; or 1,1,0 . Note that photons have S=1, which is handy, because laser experiments can be done with photons.

2. TWIN. It is possible to produce a pair of particles with combined total spin angular momentum 0, in what is called a "singlet" state. Thus, if particles a and b are so produced in a singlet state, then if particle a has angular momentum component (in units of hbar) +1 along the defined direction, particle b must have component -1; if particle a has component 0, so must particle b; if particle a has component -1, then particle b must have component +1. If the two particles should be separated after being created in a singlet state, their spin components will still be correlated: if a value of 1 or 0 for the squared component is measured in a certain direction for particle a, the same value must be measured in that direction for particle b. This "entanglement" of spin components for separated particles was used by David Bohm in his version of the EPR (Einstein-Podolsky-Rosen) paradox and entered into Bell's Theorem, to confirm (or disprove) hidden-variable theories for quantum mechanics. Such entanglement has been verified by many experiments (done to test Bell's Theorem) over separated distances of many miles.

3. MIN (the original third axiom was FIN, having to do with limitations of speeds of transmission because of special relativity). We'll take two investigators A and B who are separated in space. The spin system A studies is labeled a, and the spin system B studies is labeled b; a and b are separated parts of a singlet, and each has spin quantum number S=1. Then Conway/Kochen state in axiom 3 that the choices by A and B for studying direction of spin components are independent:

"Assume that the experiments performed by two investigators A and B are space-like separated. Then experimenter B can freely choose any one of the 33 particular directions w, and a's response is independent of this choice. Similarly and independently, A can freely choose any one of the 40 triples x, y, z, and b's response is independent of that choice."

This axiom was chosen to make the FWT stronger, and to overcome objections made to the use of the FIN axiom.

We can proceed now with a short summary of the Conway-Kochen theorem proof. First, it rests on the Kochen-Specker theorem (KST), which itself is quite important. KST shows that hidden-variable theories for quantum mechanics having functional relations amongst the variables, independent of measurement procedures, are not valid. Or, as Conway puts it, "the spin chooses its value on the fly." Accordingly, the measured value does not depend on the previous history of the world. Conway/Kochen's proof assumes that separated investigators (A-Alice and B-Bob) have free will in choosing the direction for measuring spin. Then by use of the Twin, Spin and Fin axioms, and the Kochen-Specker theorem, they show, in a proof by contradiction, that there is no functional relation for spin measurements by Bob, and therefore that the spin response is independent of the previous history of its worldline, i.e. the spin system's response is "free".

What do Conway/Kochen mean by "free will"? Both for the investigator and for particle system they mean that the choice–what is done–does not depend on previous history. A more conventional interpretation might be that free will is the ability to freely choose amongst several options. The term "freely" is understood, but susceptible to a number of definitions. (As with Justice Potter Stewart's definition of pornography, "I know it when I see it"). In his Princeton lectures and interviews for Rachel Thomas, Conway is quite emphatic that this freedom is not just "randomness". To show how randomness might enter, he sets a backgammon tournament as an example. The tournament director casts all the throws of the dice the night before the tournament, and then calls them out sequentially as each game is played, so that there is a level playing field for each contestant. An example more familiar to me is that of a duplicate bridge tournament. At each table the four hands are dealt out randomly to begin with and the