Quantum Mechanics

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1 Time for All Ages

This needs props. A toy cat, a box, a Geiger counter, something to go over the camera and make it black.

We start with a cat. We put the cat in a box. We take a Geiger counter, and we hook it in the box so if the Geiger counter detects a decay in five minutes, it opens a sleeping potion in the box. So, classically, there are two possibilities, either we open the box to find a very annoyed cat, or we open the box to find a sleeping cat. Of course, the box needs to be sound proof, and otherwise completely insulated from us, or we figure out if the cat is asleep or awake before we open the box.

What really happens, so far as we can tell with Quantum Mechanics? Well, since a nuclear decay is a quantum event that has two ways to go, it does both. So inside the box, the cat is both asleep and awake. If the box is completely insulated, then we on the outside are looking at a box with a cat that is both asleep and awake, at the same time.

Now, what happens when we look inside the box? At that point, our own quantum reality branches, and there are now two of us, one who is entangled on the branch where the cat is asleep, and one who is entangled on the branch where the cat is awake. So now there are two Joshes, who were more or less exactly the same, up until I open the box, and one sees an awake cat, and one sees an asleep cat.

2 Sermon

The world is not always as it seems. If we walk around outside, it mostly looks like the world is flat, not a sphere. It doesn't feel like we are traveling hundreds of miles per hour around the Earth when we are sitting still, but we are, as the Earth spins, and the Earth itself travels at about 67,000 miles per hour around the Sun.[1] It doesn't really feel like we are on a more or less spherical ball going 67,000 miles per hour, but we are.

There is another aspect to our world that is not easily observable. It's called quantum mechanics.[2] As it was originally understood, for some physics, what happened was random. If you set up the experiment exactly alike, it would give different results each time you ran it. An example would be that a uranium atom will randomly decay at some point, but whether that is

[1] `https://www.scientificamerican.com/article/how-fast-is-the-earth-mov/`

[2] One good introduction is The Feynman Lectures on Physics Volume III. Available as a book and online at: `https://www.feynmanlectures.caltech.edu/III_toc.html`

in one second or in a billion years, cannot be predicted. Einstein did not like this interpretation because it involved randomness and said that "God does not play dice with the universe."[3] Quantum mechanics, as originally understood, included randomness, unlike any other physics theory.

Before I continue, I will note that there is some controversy in how quantum mechanics is interpreted, and also that quantum mechanics and general relativity are in some cases contradictory,[4] and so there must be a better theory out there than what we have. We know that there is still more to learn about physics.

Einstein died in 1955 and so unfortunately did not live long enough to hear of a solution to the randomness. In 1957 Hugh Everett III published his Ph.D. thesis "On the Foundation of Quantum Mechanics". Everett showed that following the Schrodinger equation of the wavefunction, it will appear that the wave function has collapsed into a random value, but what actually happens is that all the possibilities continue and it only looks like some possibilities have vanished causing a random result.[5]

Quantum-gravity theorist Bryce DeWitt originally complained to Hugh Everett that he agreed with the math but that it didn't "*feel* like he was constantly splitting into parallel versions of himself." Physicist Max Tegmark wrote:

> Everett had responded with a question: "Do you feel like you're orbiting the Sun at thirty kilometers per second?" "Touché!" Bryce had exclaimed, and conceded defeat on the spot. Just as classical physics predicts both that we're zooming around the Sun and that we won't feel it, Everett showed that collapse-free quantum physics predicts both that we're splitting and that we won't feel it.[6]

Later on, Bryce DeWitt named this the many worlds interpretation of quantum mechanics. Basically, every time that quantum "randomness" would occur, instead, the world branches, and all the possibilities happen. So there is no randomness, the universe just splits into branches, one for each possibility.[7] It feels random to us, because, say, we watch if an atom decays in one half life 10 times. Most of the time we will end up on a branch where sometimes it did and sometimes it didn't, and so it looks random.

So, as an example, we have Casey at the bat. The pitcher throws the ball, the ball flies to home, and Casey swings. In some quantum branches, Casey hits the ball, and in others Casey misses. Where do the quantum branches happen? I haven't seen a rigorous calculation of Casey at the bat, and there are some unknowns that affect the result such as are protons eternal or do they have a half life? But from a Heisenberg uncertainty standpoint, we can predict where the ball will be with well under 1 mm of uncertainty in location and 1 millisecond in time, so to the accuracy needed to decide if the bat hits the ball, the ball is effectively deterministic. From when the ball is thrown to when

[3] In a letter to Max Born in 1926

[4] The problem is that gravity is not renormalizable. See Quantum Field Theory, 2003, by A. Zee, Chapter III.2 for the mathematical details

[5] The Theory of the Universal Wave Function `http://ucispace.lib.uci.edu/handle/10575/1302`

[6] Max Tegmark, Our Mathematical Universe, pg 190-191

[7] The formal name for this is decoherence. The mathematics of this can be found in multiple places, including The Emergent Multiverse by David Wallace, chapter 3

the ball gets to the plate, Newtonian physics is a quite accurate approximation and so both Quantum mechanics and Newtonian physics would predict the same path of the ball so far as hitting or missing the ball are concerned. Where does most of the uncertainty take place? In the two places where a small change gets amplified. Human brains are using chemistry, and at some point what happens in them comes down to did a certain neuron fire or not? This depends on the exact position of molecules in relation to other molecules, and so is very dependent on small changes in the positions, and can be different with high probability. So the quantum branches split depending on which signals are amplified and then are transmitted by the nerves to the pitcher's muscles and to Casey's muscles. Of course there is nothing magical about nerves, a photo multiplier tube would have the same effect of amplification.[8]

Note that if a robot was designed to hit the ball, it could be designed to be effectively perfect, to hit the ball in all the quantum branches or at least make a strike less than a one in a million event. Alternatively a robot could also be designed so in some quantum branches it hit the ball and in others it missed the ball. Of course, this robot would have a much lower batting average, compared to one designed to minimize quantum randomness in its decisions. Human brain design, to the extent that they are quantumly random, is sort of a design flaw since evolution is an imperfect designer. Good decisions should be dependent on the evidence and careful thought. Randomness in making a decision is a flaw. In baseball, the decision if and where to swing the bat needs to be done at nearly the limit of the human speed of thought, so there probably is some quantum randomness in it. As I see it, close decisions where it could have gone either way would have more chances of being different in different quantum branches.

What to does this all mean? Well, I suppose you can use a quantumly random number generator to run a lottery and then you can guarantee that everyone will win.[9] On a slightly more serious note, you can just pretend that Quantum Mechanics doesn't exist. Make decisions like there is only one result, and as long as you aren't doing something like transistor design you will never know the difference. However, it is interesting to know that there are lots of other you's out there. If you want to be sure to try both paths, you could make decisions with a Geiger counter, but unfortunately, each you only gets to remember the branch you are on since you very quickly becoming entangled with one branch, and we can't find out about the others.

This all comes out feeling very normal, just like walking on Earth doesn't feel like walking on a merry-go-round even tho' both are spinning.

I think it is a little comforting and a little scary that somewhere out there, there is a Josh who is living a life where everything physically possible has gone wrong, also a Josh who is living a life where everything physically possible has gone right, and every shade in between. The universe is vast, it contains multitudes. In one sense this is sort of a "ground hog day" movie reincarnation, you get to live your same life over and over with all the possible variations. In another sense this mirrors a heaven and hell view, except that everyone is in their own personal hell, and

[8] As Max Tegmark said: "a single photon bouncing off of an object had the same effect as if a person observed it. I realized that quantum observation isn't about consciousness, but simply about the transfer of information." (Our Mathematical Universe, by Max Tegmark, pg 199)

[9] Just not necessarily in the branch you end up in.

their own personal heaven, and all the span in between. However, unlike Buddhist or Christian concepts of reincarnation and heaven and hell, there is no underlying justice driving the result, just random-seeming physics.

Carl Sagan called living all these possible lives the Haldane consolation,[10] but I am not sure how much of a consolation this is. I suppose the most consoling thing I can say about it is that for any branch where a young person dies, there is almost certainly a branch where they live.[11]

In philosophy club, I mentioned that I think there are two different definitions of when someone dies. The first definition is someone dies when they die in a single branch. The second definition is that someone dies when they die in the last branch.

I suspect that there are many branches where humanity or the vast majority of people do not exist. For example, there have been multiple chances for the United States and the Soviet Union to have an all-out nuclear war. The fact that we do not remember it does not mean it hasn't happened, it just means that it hasn't happened on this branch.

This might result in people finding themselves luckier than would be physically expected for near death experiences,[12] since all the branches happen, so if there is a branch where you live, you will perceive it as just a near miss, even if it was only a one in a million chance that you could survive. Humanity as a whole will find ourselves luckier than we really are since we can look back and see that we have survived every single time, when in reality the past might be littered with multiple times where on other branches humanity went extinct.

I personally find it fascinating that all the quantum possibilities happen. This is both hopeful and terrifying. There are both branches where things are wonderful, and branches where things are horrible.

I was asked if I only believe in multiple worlds because I am afraid of death. I don't think so; I think that multiple worlds makes sense scientifically; I don't think multiple worlds is just wishful thinking. What it does do for me, is even when I am most pessimistic, and think that there is almost no chance that humanity survives, that anything I care about will survive, I can be pretty sure that there will be a few branches where humanity or their descendants survive. So it does give me some hope.

[10] The Demon-Haunted World, pg 206, by Carl Sagan

[11] Certainly for any normal accident or crime there would be branches where the tragedy did not happen.

[12] Such as a deadly car accident that nearly happens.