

## **Trixie playing with tiny bit of matter: The Young Double Slit Experiment.**

Before addressing the destiny, Trixie will face down the rabbit black hole, we need to take a deep breath and bring her to go back in time to the beginning of the XX century when the first deep discrepancies between classic and modern physics emerged. The time travel was feasible thank to special time where Trixie has set the exact date of the journey precisely to the year 1927 where two physicists Clinton Davisson and Lester Gremer will shown something that will revolutionize physics and the way we think for ever.

Certainly, there are multiple theorems and experiments that build the basis of quantum physics but among all of them the double slit experiment has emerged as perhaps the most meaningful due to the implications that smashed the basis of even the concept of measurement and observable. Indeed, according to Newtonian mechanics if Trixie claims up to a tree and while hanging there on a branch one of her candy felt down on the ground, surely due to gravity that pulled down the candy on the ground it would be possible to detect her landing point. The precise trajectory of the candy will be uniquely determined by measuring her momentum and her position.

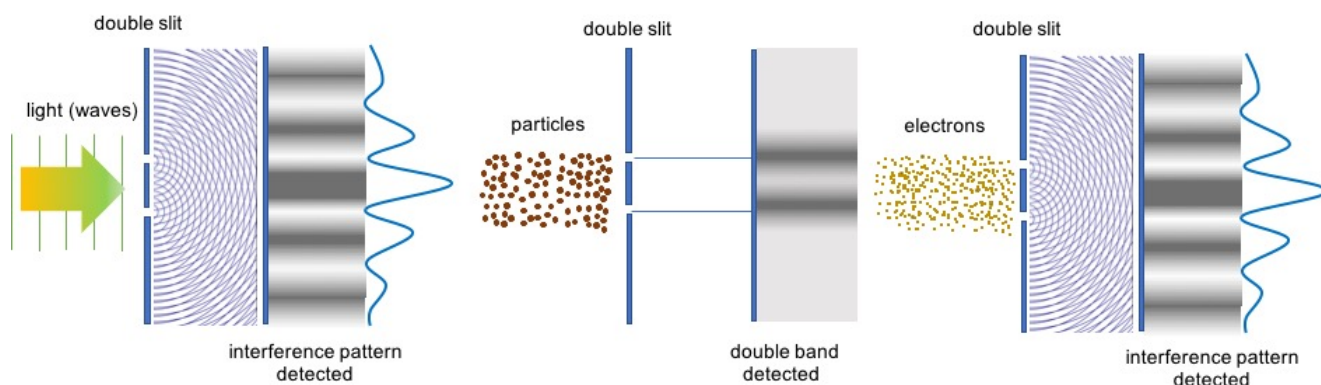
On the opposite side if we go to the quantum world the miniaturized Trixie will learn soon how the measurement of the tiny candy will no longer be so straightforward. When Trixie first met Davisson and Gremer in their laboratory, they explained her how the double slit experiment constitutes indeed the evidence for the apparently mystical nature of quantum physics and the way also this affected the universe unrevealing the mystical property of particles and waves unified under the concept of wave-particle duality. The 2 physicists have revisited the Young double slit experiment dated back on the 1801, where he first demonstrated within the classical physics the diffraction of light illuminating a screen pierced by two parallel slits and the interference patterns appeared on the detector behind. So, to let her Trixie fully understand this experiment and appreciate the deep implications related, they instructed her how she first needs to see how particles and waves behave in the macroscopic world (classical physics). At the beginning, she started very simply by shooting small marbles at the screen pierced first with only one single slit and she found

only one single band was produced on the back wall. Obviously, she wasn't particularly surprised when adding another slit on the screen, a double band was produced on the wall back. Everything was pretty clear concerning the marbles behavior and therefore the matter-related phenomena. To understand waves behavior instead she placed the pierced screens into a basin filled with water. By throwing pebbles into the basin she found how the waves produced by the pebbles and propagating through the pierced screen, behaves in effect very differently depending on the number of slits present on the pierced screen. Indeed, while with only one slit, the same single band observed for marbles and in line with the only slit was produced, when the screen was pierced with a double slit, multiple bands and more specifically an interference pattern appeared on the wall. Due to the intrinsic nature of waves and the diffraction they went through when hitting the slits, if the top of one wave meets the bottom of another wave they cancel each other out and where the two tops meet they combine leading to bands with higher intensity therefore explained the bright lines of the interference pattern on the back wall.

In summary for microscopic world and within the classic physics picture, when Trixie plays with marbles and pieces of matter, launching them through a double slit screen she found the double bands on the detector while when she plays with pebbles and the waves produced in water she found an interference pattern on the detector, the same as Young found for light proving her intrinsic wavelike nature. In areas where the light is brightly reflected along the screen the waves from both slits are arriving in phase and thus their peaks are added. In regions of darkness the waves arrive out of phase and cancel each other out.

At this stage Trixie was already relishing the time spent with Davisson and Gremer and she was already very excited by playing with marbles and pebbles enjoying the unexpected findings she experienced so far, but she was not conscious that the best part was yet to come. The further step implied going to microscopic size of quantum world, where the 2 physicists and Trixie found themselves miniaturized and instead of marbles and pebbles they were now playing with electrons and photons.

Electrons are indeed tiny bits of matter like tiny marbles and when Trixie starts shooting them through a single slit screen they behave just like the marble by producing a single band. On the other hand, when Trixie shoots electrons (the tiny bits of matter) through the double slit screen instead of getting two bands she finds an interference pattern like waves not like little marbles! Therefore while staring at the 2 physicists sitting next to her and smiling at each other's accomplices, she begins to wonder how pieces of matter could create an interference pattern, how that was even conceivable? Matter and particles could not explain fringes because such behavior is characteristic of the constructive and destructive interference only waves generate. But Trixie was a smart girl and she proved it by suggesting them how maybe those little balls were bouncing off each other creating in this way that pattern.



To verify this hypothesis Davisson and Gramer suggested her the trial of shooting electrons through one at a time, so that there is no way they could interfere with each other. And so, she started doing that and after one hour experiment of shooting one electron at the time, the same interference pattern has emerged behind the screen! The conclusion was inescapable: the pattern emerged in the distribution of final positions of many completely unrelated electrons. How this could have been even possible? Each electron has no idea where previous electrons landed or where future electron will land yet, it seems instead each electron is acting as pure propagating wave that passed through both slits equally and it chooses its landing point based on that. Or in other words, the single electron starting his journey as a particle and during the flight becomes a wave of potential going through both

slits and interferes with itself hitting the wall and producing the brightest and darkest line being the most and least likely landing points.

This mind-blowing experiment not only revealed the wave-particle duality also applicable for electrons and elementary particles, but also destroyed the fundamentals of classical mechanics and the measurements of a motion. Trixie could not even remotely understand the formalism behind but instead she was told that mathematically it was even stranger. The matrix formalism behind says that the electrons goes through both slits and it goes through neither and it goes through just one and it goes through just the other: all of the possibilities are in superposition with each other and they are all equivalent until the final particle land on a specific landing point where it is finally observed. It looks like a wave of possible undefined positions that at some point, for some reason, resolves itself into a single certain position.

Trixie was already completely shocked and delighted when she sawed also two new physicists joining the miniaturized world of the quantum lab, introducing themselves as Werner Heisenberg and Niels Bohr and appearing as little gnomes into that world. They began to elucidate Trixie by explaining her how even the XX century physicists and their community were completely baffled by these findings and by revealing how the necessity to revisit even the fundamentals of the scientific approach was at the end inevitable.

Within that mysterious span between the creation and the detection, was the particle anything more than a space of possibility? To answer this question, multiple interpretations came up trying to explain the paradox. Heisenberg and Bohr were pioneers of the quantum physics and according to their interpretation named “the Copenhagen interpretation” the wave function doesn't need to possess a physical nature. Instead, it's comprised of pure possibilities and it suggests that a particle traverse the double slit as a wave of possible locations that ultimately encompasses all possible paths. It's only when the particle is detected that a location and the path it took to get there are “decided”. The Copenhagen interpretation calls this transition from a possibility space to a defined set of properties “the collapse of the wave function”. It tells us that prior to the collapse, it's meaningless to even try to define a particle's properties. It's almost like the universe is allowing all possibilities

to exist simultaneously but holds off choosing which actually happened until the last instant. Weirder, those different possible paths, those different possible realities, interact with each other. That interaction increases the chance that some paths become real and decreases the chance of others. There's an interaction between possible realities that is seen in the distribution of final position in the interference pattern. That pattern is real, even though the vast majority of paths involved in producing the interference never attain reality. In the Copenhagen interpretation, that final choice of the experiment of the universe is fundamentally random within the constraints of the final wave function.

Within this interpretation, the potential objections Trixie might have had when first exposed to this experiment and its implications can be simply declined as just not being supported logically. However, the traditional world logic has no place in our Quantum Universe Dictionary.

We are living in a world where quantum level nature behaves in ways which require us to abandon our intuitive modes of thinking since we developed our brain only dealing with macroscopic phenomena. There is no reason that the fundamental nature of reality needs to be comprehensible to the mind of a human or of a girl like Trixie. There's no reason that visualization, normally associated with the concept of explanation, should be appropriate for describing objects at the most fundamental levels of reality. Nowadays we could accept our limits only by thinking the human brain is wired right now only to deal with classical mechanics and 3d dimensional space and by considering that our species is not YET evolved to the stage where concepts as multi-dimensional space and probability fluctuations are ordinary concepts for our mind. But if it is the case that nature is beyond human comprehension then how does it relieve our ignorance at all to try to fill the void with theories that also make no sense to us? Followers of Quantum Mechanics will always affirm that there is some sort of comprehension accomplished by playing around with the non-instinctive insights although the evidence that they are not really able to articulate substantively what sort of comprehension that is. The Quantum World is extraordinary and unusual and inexplicable and by utilizing analogies we just ought to acknowledge it.