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Philosophical Issues Arising from Dual Nature of Light in Young's Double-Slit Experiment

Young'ın Çift Yarık Deneyinde Işığın Düalist Davranışından Kaynaklı Açığa Çıkan Felsefi Sorunlar

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ABSTRACT

This study aims to present a perspective regarding the philosophical issues arising from the dual nature of light in Young's double-slit experiment. In this regard, a summary of Young's double-slit experiment was presented, the effect of the mathematical equations of the experiment on the existing philosophical was questioned, and the ontological and epistemological concerns arising from this experiment were discussed. To realize this discussion, the opinions of several philosophers of quantum mechanics were considered and an attempt made to establish a relationship between them.

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ÖZ

Bu makalenin amacı Young'ın çift yarık deneyinde ışığın düalist davranışından kaynaklı açığa çıkan felsefi sorunlara bir bakış sergilemektir. Bunun için Young'ın çift yarıklı deneyinin kısa bir özeti verilerek deneye ait matematiksel denklemlerin hâlihazırdaki mevcut felsefeye etkileri sorgulanırken diğer yandan bu deneyin yol açtığı ontolojik ve epistemolojik kaygılar tartışılmaktadır. Bu tartışmayı yapabilmek adına ise konu ile ilgili kuantum mekanikçilerin ve filozofların görüşleri dikkate alınıp aralarında bir ilişki kurulmaya çalışılmıştır.

1. Introduction

> *"I don't like it,*
> *and I'm sorry I ever had anything to do with it."*
> *Erwin Schrödinger*

Whether light is a particle, or a wave is one of the most paradoxical problems in quantum mechanics. In fact, this paradoxical structure, referred to as wave-particle duality, has been discussed for a very long time. Paul Davies (1984) says that this unsurprising and even Einstein who created essential changes in the space-time continuum and challenged the classic and deterministic argument agrees with him. Even if wave–particle duality reveals many data contrary to general assumptions makes it difficult to understand this theory, it makes it more essential to investigate the wave-particle duality from a philosophical perspective (Taslaman, 2008). Since this investigation entails duality dualistic principle of ontology, the problem emerges as a philosophical issue (Kamözüt, 2005). The

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paradoxical nature of the wave–particle duality has become so influential, in a philosophical sense, that the opinions of many famous philosophers who hold a mechanic-deterministic view have been shaken (Taslaman, 2008).

Among them is Galileo, one of the primary figureheads of modern science, who may even be considered the progenitor of the concept of nature as a quantifiable phenomenon. In other words, Galileo saw nature from a qualitative perspective and regarded any results derived from the qualitative values as real. Galileo's world was based on God, nevertheless it remained one of an essentially anthropocentric nature (Collingwood, 1960). Perspectives within Galileo's world limit modern science and the understanding of theology in nature (Işıklı, 2012). In the Galileo's world, where God and man are the primary concerns, the mechanistic view becomes dominant; however, the problem of a whole comprised of singularities becomes fuzzy over time. In the Galileo's worldview, wherein the mechanistic view is dominant, a 'structural problem' emerges regarding the system's holistic data while calculating the locations of particles within that system. This problematical structure shows itself as fuzzy and uncertain and, in quantum physics, emerges as Heisenberg's uncertainty principle; a principle claiming that conjugate properties cannot be simultaneously quantified (Işıklı, 2012). This situation is also apparent in Descartes's mind–body distinction. According to Descartes (1996), the mind and body order appears as two distinct objects that present themselves as space and time. While space presents itself as geometry, time arises as arithmetic. Descartes says that the reason for the single to be single is itself and advocates that the source of all occurs as itself. Descartes often evokes God in his discourse and bases the ontological reason of creature on the ontological reason of another creature. Einstein agrees with Descartes, advocating that mind and body cannot be comprehended equally. Within his special and general relativity theories, Einstein created his own duality by saying that space and time are two important, yet distinct, phenomena; nevertheless, both support one another. Similarly, Spinoza's thoughts that mind and body are two different reflections of a single essence (Warburton, 2004) and, in particular, that space and thought are two different appearances of the same creature can be considered as the first step towards conjugate properties (Işıklı, 2012). Newton (1998) thought that light, per its nature, should be considered as a particle, though he nevertheless encountered and experienced some contradictions regarding this opinion. Considering the zeitgeist, optical events such as diffraction and interference may have lead Newton to think that light should be considered to be a particle. The idea that light can be a particle was perpetuated by John Dalton (Sekmen, 2006), though opinion has since shifted toward perceiving light as a wave due to its wave-like characteristics unveiled in the work of Dutch physicist Christiaan Huygens Huygens. Maxwell's electromagnetism in particular, gave strength to the idea that light should be a wave (Sears, Zemansky, Young & Freedman, 2014). All these developments reveal that, within the light's particle–wave duality both sides seem to be irreconcilably opposed. However, when we consider that there are experimental results supporting both opposite claims, we notice that we fall into a mistake when using the word "seems like". Findings from quantum theory suggest that not only light, but also other subatomic particles, behave like a wave; this repeats the misconception caused by the aforementioned term "seem like". One of the most significant experiments on the dualist behavior of light was the double-slit experiment, considered to be the 'heart' of quantum physics by Richard Feynman (2001).

2. Young's Double-Slit Experiment

It has taken such a long time to replace Newton's theory with a new one because the interactions at the atomic level are so strange. Nevertheless, the formulation of a theory that can explain all these strange behaviors, and one that seems entirely contrary to common sense was developed in 1926. This skewed and maddening theory was called quantum mechanics. The meaning of the quantum word already pointed out nature's nonsensical behaviors; namely, its idiosyncratic characteristics.

The theory of quantum mechanics explains numerous details and, more specifically, successfully describes the whole of chemistry and the various characteristics of objects therein. However, it also presents a problem regarding the interactions of light and matter. We are unable to predict which slit a single photon pass will through. Probability is all we can propose. Hence the question arises: "Does physics, as a science with such a great certainty, turn out to be a science that can only speculate on probabilities without certainty?" The answer is, yes, unfortunately, this is the case; nature only allows us to calculate probabilities. Nonetheless, this does not mean the collapse of one of the three main sciences (Feynman, 1949). Young's double-slit experiment calls to mind Richard Feynman, as perhaps the one who suffered most from this and who was the best instructor on quantum mechanics in the final two decades. What made Feynman special in the quantum mechanical world was that he developed a quantum version of electromagnetism, quantum electrodynamics. While quantum physicists such as Heisenberg and Dirac were required to work within an unstable environment, wherein the logical relationship between concepts could not be easily revealed, physicists such as Feynman has all the pieces of the puzzle and the logic of sequencing those pieces was apparent to them (Gribbin, 2011). Feynman writes that Young's double-slit experiment is the cornerstone of quantum theory in the chapters related to quantum mechanics of his book titled Lectures, asserting: "Because this is not a phenomenon that can be explained by any classical prediction".

3. The Experiment Process and Probability Principles Emerged

Let us consider a kind of curtain, for example, a wall with two small holes in it and a further, second, wall on one side of the first wall that serves as a kind of a detector. The detector should have a background on which light and dark strips will form if we conduct the experiment using light. Alternatively, if we conduct the experiment with electrons, a wheeled detector can be used in order to understand how many electrons fall into a particular area of the curtain.

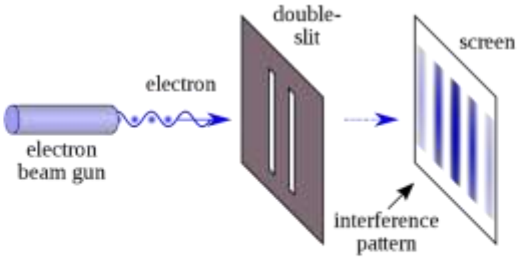

Figure 1. The double-slit experiment (from the wikipedia.com)

We should remember that there is a photon or electron source on the other side of the first wall; the wall with two holes in it. Now, let us consider the prosaic meaning of electrons and photons in daily life rather than per their quantum structures. Let us imagine that we place all the experiment equipment within a water vessel. Each wave developed by the wave source creates a regular pattern consisting of a peek and a trough on the background due to the interference created by passing through the hole. Now, if we cover one of the holes, it is obvious that there will be a change in the height of the waves on the background. The biggest waves will be those nearest to the hole, as one might expect. The intensity of a wave, the magnitude of the energy it carries is proportional to the square of the height, the amplitude (A^2). However, the situation becomes more complicated when both holes are open. When both holes are open, a great peak is formed between them with a lesser intensity on both sides of this peak. That is to say, the destructive interference of the two wave groups has resulted in them demolishing one another. Consequently, a low and high wave pattern is repeated on the background. Mathematically, when the two holes are open, the result given is the square of the sums of the two amplitudes, not the sum of their squares. The intensity of waves with amplitudes A and B are found to be $I = (A+B)^2$ rather than $I = A^2+B^2$ (Gribbin, 2011). When the waves are sent through both holes, the total energy is different from the sum of the energy for each wave, which increases fourfold by showing a tensor increase; this is found to be $I = A^2+B^2+2AB$. Here we can say that the extra term is due to the interference of the two waves. The term (A^2+B^2) is called a 'wave function' or 'amplitude' and consists of complex numbers. The wave function is denoted by Ψ. The Ψ function as a variable in Schrödinger's equation is related to the particular particle it describes. If Ψ is considered as a wave, the construction of its interference pattern is unsurprising; besides, it is an easy analysis to consider that Ψ behaves the amplitude of the wave and Ψ^2 behaves as the intensity. Since Ψ wave function contains more than one probability it concerns superimposition. However, the square of the absolute, $|\Psi|^2$ gives information about the system since Ψ does not make any sense by itself (Close, 2006).

Born, the progenitor, indicated that the wave function is nothing but a probability. Therefore, Born describes Ψ wave function as a probability amplitude Ψ (x, t) in the x dimension with t representing time and values ranging from 0–1. $|\Psi|^2$, described as the probability density, provides information regarding the current possibilities of the system in question. Such probabilities show themselves as breaking the principle of non-contradiction, one of the basic principles of logic. Niels Bohr puts this strange situation in the following words: "There is no quantum world. There are only abstract descriptions" (Pais, 2000). In this case, Ψ_1 and Ψ_2 represent the wave functions of the probability of electron interference through the 1st and 2nd slit. When one of the holes is covered, the counts obtained from the open hole within a minute, or the probability of electron interference are indicated by the square of the absolute value of these quantities. This result leads to the conclusion that electrons do not display classical particle behavior and furthermore, if they did, they would be unable to create an interference pattern in the double-slit experiment. The double-slit experiment falsifies the theory that the phenomena called electrons and photons pass through the first or second slit in such an experiment. As Feynman (2001) reported, "…it is not possible to design a device that can detect through which slit an electron will pass and that does not have a devastating effect on the electron's interference system. No one was able to figure out a way to prevent this".

If an experiment is conducted in a way that determines which option is to be used, the probability that the particular phenomenon will occur is different; indeed, the probability of the event is the sum of the probabilities within each option; there is no interference (Close, 2006). Young's double-slit experiment yields options that are difficult for us to accept as accepted electrons pass through both holes simultaneously. If we understand through which hole the electron passes, it seems like the electrons are mocking us by destroying the interference pattern, almost as if they understood what we were trying to observe. Within the double-slit experiment, electrons do not allow us to understand their nature, they merely indicate that we are only able to observe the boundaries they determine. In this regard, Young's double-slit experiment reveals a hard-to-believe result; it seems as if electrons have consciousness (Zohar & Marshall, 1990).

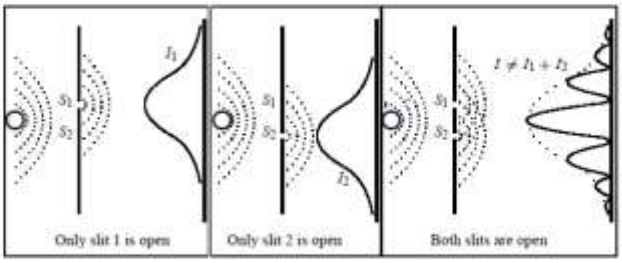

Figure 2. The probability density of interferences in single- and double-slit experiments. (from the physics.stackexchange.com)

Within a situation such as that of the aforementioned wave function, superimposition, and existence in two places at the same time emerge as exemplars of the strangeness of the quantum world and as philosophical problems that must be resolved.

4. Discussion

Those objects from which the sensory organs obtain their information are those objects that exist in the macro world; our perceptions measuring such objects had been a 'known fact' until the paradox of Young's double-slit experiment emerged. In other words, the classical physics had been built on a deterministic approach that is based on the mere perception of our sensory organs and prior to the discovery of the dualistic behavior of light as illuminated by Young's experiment. Thus, principles of classical logic were adopted without comparing virtual and actual values, in a way that does not account for the concept of probability (Öner, 2000). The double-slit experiment underlines the inevitable fact that our organs and more precise measuring instruments adapted to replace them are inadequate when it comes to measuring quantum systems. In fact, the most sensitive measuring instruments are incapable of measuring the quantum system through classic, deterministic logic (Öner, 2000). In this regard, one of the most problematic issues posed by the results of Young's double-slit experiment is the measurement problem. This situation emerges as a primitive theoretical situation that needs to be interpreted in terms of the quantum theory (Koç, 1983) because quantal measurements are quite different from daily measurements that our common sense can predict. In other words, measurements within a quantum system are quite different (Işıklı, 2012). Therefore, the interpretation of these measurements should be performed ontologically–epistemologically, in a way that one completes another. Through such an approach the ontic interpretation describes the location of measurement within the physical universe along with its empiric content, while the epistemic interpretation expresses the nature of information obtained by the measurement and the meaning of this information to the theory (Koç, 1983).

Young's double-slit experiment reveals that measurements need to be interpreted in the quantum theory and make it necessary to revise the probability density to evolve into a singular state according to the observation within the quantum philosophy. The Copenhagen interpretation, in particular, contains philosophical interpretations of quantum physics and it appears that quantum mechanics reduce or evolve to a singular case; this is difficult for nature to explain (Capra, 2010).

Furthermore, as what is expressed as a system is, axiomatically, there is no chance to return to the initial conditions through experiment or observation. Since the measurements take the system only to the initial point, it is therefore impossible for that system to reach the same results in a subsequent stage. Therefore, Young's experiment claims that a description should be made by in particular considering reversibility issue ontologically (Işıklı, 2012). Another significant result of Young's double-slit experiment is that the observation of phenomena turns them into ordinary objects. In fact, such an observation develops a different perspective in terms of describing ourselves within the natural world and finding our place within it. The relationship between Young's double-slit experiment and observations inevitably lead us to the entropy principle, the second law of thermodynamics. Although Young's double-slit experiment does not accept classic measurements, even when such a measurement is performed it seems impossible to return the system to its initial conditions that created the system itself, this is because the entropy change is at a linear level. Linear irregularity obviously rejects such a situation. Neumaier& Westra (2011) upholds that this situation stems from the mathematics used to describe both classic and quantal systems; that is, mathematical language causes a measurement problem.

There are many systems, such as mathematical, mechanical, and physical systems, all of which present themselves according to the user's aims and objectives. Of these systems, the atomic system differs from other classical systems due to the chaotic behavior of atoms. In this regard, an atomic system simultaneously emerges as a quantum system and, similarly, Young's double-slit experiment (which, in fact, is a serious quantum system establishing contextuality among an electron, a photon, a detector, and an observer) is an example of a quantum system. All the probabilities within such a system are expressed by a virtual or imaginary situation called a wave function. One of the strange and surprising lessons learned from Young's double-slit experiment was that an imaginary situation's realization in the used background in order to see the actualizations. A superposed quantum system, a system which contains multiple possibilities, transforms itself into a singular state in the background and presents itself to us as real (Gribbin, 1995).

Niels Bohr, a quantum philosopher who drew attention to this phenomenon, internalized wave function reduction so much that he was constantly mentioning it as a physical reality, and investigated it as a philosophical problem that could and needed to be resolved. He was especially concerned with the question of how human knowledge could contact this reality as opposed to deliberating over whether such a reality exists or not. From the results of Young's double-slit experiment and the philosophical expansions of Niels Bohr, the primary philosophical problems that we seem to face are: "Who is the observer?", "are there any interactions between the observed and observer?", and "are those devices used to make such observations a part of the quantal system? As Neumaier (2011) stated, starting points that are both defined and detected at the initial stage present a double phenomenon. A conscious act reduces the phenomenon to a single virtual phenomenon. According to, Neumaier's ideas, Young's double-slit experiment creates a mismatch between theory and practice the main reason for this mismatch was found to be the measurement problem. The reduction of those phenomena with multiple probabilities into a single case entitled with Young's double-slit experiment caused the following questions to become a topic of discussion (Işıklı, 2011):

"Who is the observer?"

"What is the actual nature of the observer?"

"Is direct observation possible?"

"What is the relationship dimension between the observer and observed?"

"What is the place of consciousness in this process?"

"Is the observable really observable?"

"What is reality?"

Principally, Young's double-slit experiment transforms the question "Who is the observer?" into: "Is it possible that other beings can also be observers apart from human with consciousness?" Furthermore, questions such as "Can we consider any counter used as a background or detector within Young's double-slit experiment to be an observer?" become particularly important in terms of enlightening the many quantum-mechanical mysteries. Additionally, an important reality emerges regarding following question: "Does Young's double-slit experiment about the inevitable relationship between the observed and observer set a limit to the possibility of describing the atomic objects' behaviors independent from human who is a conscious being or the observation devices?" Another paradoxical structure presenting a further question in Young's double-slit experiment is the impossibility of the observer to go behind the observation devices used and to see what is really there. The results of Young's double-slit experiment reveal a new epistemological problem in the philosophy of nature regarding absolute discrimination between the phenomenon of observation and the behavior of the object observed (Crease & Goldhaber, 2014). This problem becomes particularly significant within the positivist approach and in trying to explain reality through sensory experience; it forces scientists dealing with quantum phenomena to develop a new epistemology and ontology (Fischer, 1998).

Such paradoxical predictions about reality, as revealed by Young's double-slit experiment, were voiced by Sartre, one of the pioneers of existentialism. In particular, the definition of reality as two separate existence areas that are self-existence (the existence of phenomena) and being-for-itself (the existence of pre-reflection cogito) (Durğun, 2015) can be considered as exemplars of when positivism was interrupted. The electrons or photons used in Young's double-slit experiment simultaneously passing through double-slit or a single slit while forming an interference pattern have forced us to reconsider classical logic and its various principles; the law of "the excluded middle" in particular must be fully reconsidered (Omnes, 1994).

When we consider Newton's argument, especially regarding the formation of a single photon or electron, interference does not seem to be possible on its own terms, according to the arguments of classical logic; this is because an electron's or photon's splitting-up and subsequently interfering with itself appears to contradict this law.

One of the striking results of Young's double-slit experiment is that it changed the understanding of an "objective reality independent of the observation" described in the classical argument. Since the classical argument has an understanding that observation does not disturb the objects that belong to micro-universe, that the argument upholds that an object can only reach to reality by means of observation. Therefore, the result produced by any instrument that the subject uses to experience reality will itself be considered a reality. On the other hand, quantum predictions do not consider the relationship between subject and reality in the same way as the classical paradigm does. At least it suggests the conclusion that reaching such a reality is not as simple as stated. Additionally, any instrument used to describe the micro-universe will disturb any object belonging to that micro-universe; subsequently, the results collected by the subject collects with the help of instruments will be far from reality (Işıklı, 2012).

Another result that Young's double-slit experiment revealed is the fuzzy reality that exists during the reduction of a wave function. This reality is different from the classical ontology of positivism. Classical ontology states that the things it perceives as reality can be described using a mathematical language. However, the fuzzy reality cannot be transformed into a mathematical language. In this respect, the fuzzy reality seems to be more metaphysical in nature. Considering, in particular, the circumstances that cause the formation of this reality, we remember Derrida's philosophy that the circumstances that make metaphysics possible are metaphysics themselves (Kant, 2004). The fuzzy view revealed by Young's double-slit experiment seems to have simultaneously doubled those problems that need to be discussed in philosophy. Richard Feynman also supporting the philosophical problems revealed as saying "the heart of quantum uncertainties passes through Young's double-slit experiment" (Close, 2006).

Another philosophical problem revealed by Young's double-slit experiment is the fuzzy logic that revealed itself with fuzzy reality. Such fuzzy logic leads to the conclusion that the phenomena must be interpreted with a different point of view than usual; from this a new logical argument emerged from the many quantum arguments with the reinterpretation of the law of "the excluded middle" showing that more than one possibility can be possible at a single time (Omnes, 1994).

5. Conclusion

In this study, a step was taken to find out the philosophical arising from the dualistic nature of light according to Young's double-slit experiment. We do not believe that the steps taken herein will completely eliminate these philosophical concerns. Our study only aims to draw attention once again to quantum physics and Young's double-slit experiment that lies at the heart of quantum physics. In this regard; Young's double-slit experiment shows that light behaves as both as a wave and as a particle. In particular, experimental results show that light's dualistic behavior forms of the basic arguments of quantum theory. The double-slit experiment has given a new dimension to reality. The question "is there a relationship between dualism and reality" has become a current issue with the dualistic behavior of light in this experiment. The characteristics of waves and particles that comprise such dualistic behavior show themselves at the moment of measurement. An amplitude, and the statistical values based on this amplitude, are all we have before the observation itself; in other words, prior to the observation, the virtual data show themselves as doxa and are unimaginable. The measurement problem due to the dualistic behavior of light introduces several principles gleaned from Young's double-slit experiment; indeed, the fact that nothing could be drier and more barren than these principles (Omnes, 1994) has been evidenced by Young's double-slit experiment. The principles of Young's double-slit experiment infiltrated deep into our feelings, so much so it is as if they are controlling us. We, as the ones living in this world, cannot hold our worldview and the laws that we touch and express with ordinary words superior to the arrogant laws of the double-slit experiment. Such an arrogant experiment inevitably overturns the traditional epistemological assumptions. As a result of Young's double-slit experiment, a feeling has been created that the existence of the hidden variables governing objects we see in our environment, and what we use to make sense of them, has been proved. However, this does not mean that we can fully examine the philosophical consequences of Young's experiment. Young's double-slit experiment has interrupted usual thinking patterns which claim that common sense is only a consequence of nature's laws which possess their own logical structures. Young's double-slit experiment has demonstrated the difficulty of having necessary perspectives to get rid of the aforementioned logical structures by challenging our limits of toleration. With its many-faceted philosophical and epistemic-ontological consequences, Young's double-slit experiment has the greatest arrogance among all experiments; indeed, it almost screams at us:

"Come mortals, come and see the river in which nothing can be washed for a second time under the same conditions in the same place, look at the thing that creates and is changed infinitely and now attempt to reduce all of this in a simple annexure of mathematics where time is taken out from the mathematics in your hand and which was made sovereign by the fuzziness" (Omnes, 1994).

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