

Quantum Physics and the Boundaries of Human Perception

Ahmed Mabrouk*
asic4unwire@yahoo.com

Abstract

The experimental results of quantum physics were manipulated by empiricists to forward some philosophical notions, which are in conflict with common sense and religious convictions. Most seriously, the notion of observer-created reality questions the independent reality of subatomic particles and endows divine qualities on observers who presumably determine their status. Moreover, the seemingly spontaneous electronic transitions were used to shed light as to whether the universe has a stationary configuration. In this article, both notions are analysed in terms of the logical consistency of their arguments and the scientific approach they adopt. The same arguments are

* PhD in Electrical and Computer Engineering from Boston University, USA, in 1998. Dr. Mabrouk combines industrial experience at Lucent Technologies, USA, and Zarlink Semiconductors, Canada, with 35 years of academic experience teaching practical topics of Islamic law including at the International Islamic University Malaysia and University of Malaya, Malaysia. He is the author of a book *Islamic Worship: Fundamentals and Applications*. Currently, he is the Chief Executive Officer at Skilik Robo Advisory, for a company that is involved in the development of Islamic finance knowledge-based using artificial intelligence technology.

also examined in light of the Islamic conceptual framework pertinent to how the universe is like. The article starts by delineating the logical framework of classical physics through discussing three energy-related concepts. A more objective approach that emerges from the positions of rationalists, such as Faraday and Einstein, is proposed. It is argued that despite the peculiarities of quantum physics, drawing parallels between classical and quantum physics is possible, and following the same analytical approach in both is imperative.

Keywords

Quantum physics, conservation of energy, observer-created reality, double-slit experiment, randomness, Copenhagen interpretation, uncertainty principle, Copeniricism, limits of human knowledge.

Introduction

The interdependence of physics and philosophy has always been an intricate topic. On the one hand, mathematical formulas can be experimentally verified, which leaves a little room for discarding them. On the other hand, interpreting the implications of these formulas, which is the task of philosophy, could produce numerous dissenting views, each capturing a share of the truth. No field can demonstrate this concept better than quantum physics. Many useful and diverse applications have been developed based on the experimental results of quantum physics. However, various controversial concepts have been triggered by the same results. The scarcity of data about the quantum world deepened the disputes among adversaries and weakened the likelihood of a satisfactory resolution in the near future.

One particular point that made the controversy over the philosophical implications of quantum physics significant and relevant to many people, scientists and non-specialists alike, is that it questioned fundamental principles of common sense and accordingly the religious convictions founded on it. This article

focuses on two concepts that exhibit a great deal of disparity between quantum and classical physics, namely the notion of observer-created reality and the unexplained spontaneous transitions of subatomic particles.

Methodology and Outlines

This article is divided into two parts. The first part discusses three related laws and/or concepts of classical physics. The discussion reveals the main principles constituting the logical framework of classical physics. The second part discusses how quantum physics deviates from this framework. The views of Bohr, who primarily shaped the controversial issues, are presented as persuasively as possible, supported with quotes of their developer. Hereafter, these views are contrasted to those of the rational stream, led by Einstein. Whenever these conflicting views cross an Islamic concept, favourably or otherwise, the latter is elucidated and substantiated with logical evidence. Finally, the logical flaws in the views of Bohr and his team are highlighted, followed by a proposal aiming at a more objective explanation of the quantum enigma.

Due to the philosophical nature of this article, mathematical treatment is avoided. Instead, the logic driving the mathematical formulation is analysed. Furthermore, discussions are conducted in a heuristic, semi-formal style, for the sake of making the arguments accessible to the broadest possible base of readership, without sacrificing technical accuracy.

Mechanisms for Watching the Divine Actions in Classical Physics

To better understand how quantum physics questioned some of the accepted principles in classical physics, it is instructive to present the main mechanisms through which the divine actions can be watched. Discussing the metaphysical dimension of these mechanisms will put our later discussion about the philosophical foundations of quantum physics into perspective, as it will better

enable us to see the points at which quantum physics departs from the logical framework delineated by classical physics. Although the treatment of such classical mechanisms of physics in this article is not meant to be inclusive, leaving a room for more mechanisms to be identified, it should provide adequate grounds for contrasting the scientific logics of classical physics and quantum physics.

To conduct a thematically coherent discussion, the present article will address three mechanisms, all revolving around one aspect, namely energy as the most fundamental property in the universe. All the activities, conditions, and configurations assumed by all substances are expressions of energy-related terms in one way or another. Energy has been described quantitatively and qualitatively in several laws of physics. The first of these laws addresses the query regarding its conservation, and thereby raises questions such as whether the total amount of energy in the universe is constant, and whether the existent amount of energy is beginning-less or it was somehow injected into the universe at a certain point of time.

Is Energy Conserved Now and Indefinitely?

Heat energy, as a manifestation of the movements of the molecules of a substance, gravitational energy, and kinetic energy of a body all add up to a constant amount. This is the most common form of the first law of thermodynamics found in physics literature.¹ Accordingly, when a body loses some amount of one form of energy, it re-gains the same amount in another form of energy. For example, when a ball is thrown upward, it gradually loses its kinetic energy for a higher gravitational energy. The pendulum is another example of such an exchange.²

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1. This law was initially observed by the German physician, Julius Robert Mayer, in 1842. It was later rediscovered by several physicists such as Joule and Holtzmann. See Alan Lightman, *Great Ideas in Physics* (New York: McGraw-Hill, 2000), 7–8.
 2. For a more heuristic, and less mathematical, discussion, see Paul Hewitt, *Conceptual Physics* (Massachusetts: Addison-Wesley, 1987), 350–353.

The law of energy conservation, as stated above, is a clear demonstration of the law of cause and effect. As one form of energy can be converted into another, with direct proportionality to the amount of converted energy, the initial form of energy is indeed the cause of the final form of energy (the effect). In his semi-qualitative analysis of this phenomenon, Julius Robert Mayer concluded that, “Without the recognition of a causal connexion between motion and heat, it is just as difficult to explain the production of heat as it is to give any account of the motion that disappears.”³ The fact that energy changes its form, rather than its amount, accounts for the causal relationship. As reasoned by Mayer, “In a chain of causes and effects, a term or a part of a term can never, as plainly appears from the nature of an equation, become equals to nothing. The first property of all causes we call their indestructibility.”⁴

A few years later, James Joule, a British physicist, conducted experiments about the conservation of energy, which endowed the topic with the quantitative character we are familiar with nowadays, and further affirmed the law of cause and effect. Joule said that: “Experiment has shown that whenever living force is apparently destroyed or absorbed, heat is produced. The most frequent way in which living force is thus converted into heat is by means of friction.”⁵ In his conclusion, Joule commented saying that:

... and everything may appear complicated and involved in the apparent confusion and intricacy of an almost endless variety of causes, effects, conversions, and arrangements, yet is the most perfect regularity preserved—the whole being governed by the sovereign Will of God.⁶

3. Lightman, *Great Ideas*, 49.

4. *Ibid.*

5. Excerpt from a lecture entitled “On Matter, Living Force, and Heat” that Joule delivered at St. Ann’s Church in Manchester on 28 April 1847. Joule used the term “living force” in reference to kinetic energy. See Lightman, *Great Ideas*, 50–51.

6. Another excerpt from the same lecture mentioned in the previous footnote. See *Ibid.*, 51.

The above statement indicates that Joule, as a main contributor toward establishing the law of conservation of energy, did not believe in materialism, nor did he disacknowledge the divine act in physical phenomena. Actually, early originators of physical laws, including Joule, used mathematics as a suitable tool for describing the intricacy of interactions between causes and their respective effects. The inherent precision of mathematics points out the purposeful divine actions that drive things through their course.

Rethinking the implications of the law of conservation of energy, it is straightforward to realise that this law is nothing more than the premises commonly formulated in the literature of Islamic theology toward proving the existence of God. These premises usually read as follows: “Every changing being is a contingent being, rather than a necessary one. And every contingent being—by definition—must have a beginning, and thus needs a creator.”⁷ From the energy standpoint, the changes mentioned in the premises are the conversion from one form of energy to another, which in turn alters the system possessing this energy.

The law of conservation of energy has a common version, which is “Energy can neither be annihilated nor created out of nothing.” The second part of this law simply means that the currently existent energy has existed all the time. However, this claim contradicts the proof mentioned in the previous paragraph that every contingent being must have existed at a certain point of time. The error apparently resulted from limiting our consideration to creatures. Indeed, people cannot create energy out of nothing; they can only harness energy and manage it through conversion and utilization. However, as contingent beings need a creator, energy needs a creator too. The fact that it is beyond our capacity to create energy substantiates the fact that it is created by God. One of the main themes of the

7. ‘Abd al-Karīm Titān and Muḥammad al-Kilānī, *‘Awn al-Murīd li Sharḥ Jawharat al-Tawḥīd*, vol. 1 (Damascus: Dār al-Bashā’ir, 1999), 232–234.

Qur'an is to point out phenomena that can only be conducted by the divine. God says, "And Allah did create you from dust; then from a sperm-drop; then He made you in pairs."⁸ This verse mentions two transitions: the transition from inanimate dust to a living drop of sperm as a result of breathing the soul, and the transition from this minute drop to fully fashioned humans, each with his/her personal and mental characteristics. Both transitions are beyond human capabilities and can only be attributed to the divine power.

Does the Universe Age?

While the law of conservation of energy states the *constancy* of the total amount of energy, the second law of thermodynamics addresses how different types of energy tend to be redistributed over time. This law presents the direction of time by referring to irreversible processes in our terrestrial environment. To mention few examples, a vase may break into pieces but can never reform itself to its original shape; pigments on clothes and paints on walls tend to fade in color and do not get as vivid as before; and unattended rooms collect dust without having a mechanism to clean themselves. In virtue of these irreversible processes, systems tend to move to, and settle in, some favourable states, until some energy, associated with an action of an external agent, is pumped into them. These irreversible processes preclude physical phenomena from being cyclic, where the present states periodically replicate the states shown at some points of the past.⁹ The system transitions to more durable states indicate the *unidirectional* nature of time and motivate us to raise the question of whether the universe gets older and might suffer a death as humans do.

8. *Fātir* (35): 11.

9. It should be noted that the Newtonian physics and Galileo's observations do not capture such acyclic behaviour and thus assume that the world has a self-refreshing mechanism.

The familiar wording of the second law of thermodynamics was first formulated by William Thomson (1824–1907) during his study of heat and dissipation of energy.¹⁰ Thomson highlighted the tendency of heat to flow from hot areas to cold ones.¹¹ Thomson also stated that once heat transfer within a system ceases, i.e. heat has uniformly distributed throughout this system, no work can be derived out of this system.¹² In other words, heat transfer enables derivation of work. Knowing that heat is considered a lost energy in many processes,¹³ which cannot be converted into kinetic energy, the dissipation of heat marks the most common irreversible process. If the amount of energy in the universe is constant, as stated by Clausius and agreed by others,¹⁴ as heat loss continues, it could result in heat death where the whole universe freezes, causing all biological processes to stop.¹⁵

Among the laws of physics, the second law of thermodynamics is known for its numerous statements.¹⁶ All the statements, more or less, address the patterns of heat flow and the ability to derive work out of physical systems during their various states. For the purpose of this discussion, this article proposes an equivalent, yet more expressive, statement, which focuses on the loss factor of irreversible processes. The proposed statement is as follows: “All processes involve losses in substance and/or energy, precluding the full utilization of the resources made available to any process.” Our daily practical experience

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10. Thomson benefited greatly from the studies of Sadi Carnot (1796–1832) about the efficiency of steam engines.
 11. Due to this tendency, we feel hotter when we open the oven to take out a tray. Based on the same mechanism, we feel colder when we open the fridge because some of the hot air around us is attracted to it.
 12. Lightman, *Great Ideas*, 59.
 13. Think of light bulbs emitting light as a desired output and heat as a secondary, undesired output.
 14. Gerald Holton and Stephen Brush, *Physics, the Human Adventure* (New Brunswick: Rutgers University Press, 2006), 259.
 15. Some authors portrayed such a picture, see for example, “Carnot and the universal heat death,” in Holton and Brush, *Physics*, 261.
 16. See five of them in Lightman, *Great Ideas*, 63.

shows that all engines can never reach full efficiency. Likewise, our digestive systems always produce some waste regardless of the need and the condition of our bodies. Since losses are unavoidable in physical and biological processes, does that mean we are really running into a catastrophe of heat dissipation? To answer this question, we have to review the assumptions of this law. It is meant to address isolated systems, which do not lose or receive energy. It further states that the world carries a fixed amount of energy. But, how credible are these assumptions?

In fact, the assertion of a fixed amount of energy in the universe is based on the closed world assumption. It generalises some observations of terrestrial phenomena to the entire universe. Considering our extremely limited knowledge of the near space (few hundred light years from our solar system) and our full ignorance of the far space, this assertion is an unfounded conjecture. Whether the cosmos continually receives additional bursts of energy through divine actions or it has been originally created with enormous amount of latent energy within its spacious dimensions, an objective assessment indicates that we do not have sufficient, nor reliable evidence in support of such a claim.

More importantly, the second law of thermodynamics does not describe prevailing mechanisms that take place in *all* natural phenomena. As we see less-than-ideal efficiency in some processes, we also see the emergence of new lives in mankind and other creatures. Almost in every moment, our world witnesses new born babies that subsequently grow and gain strength, in a clear contradiction to the second law of thermodynamics. Moreover, our world witnesses the conversion of some waste by-products into active, life-support elements, such as the conversion of carbon dioxide into oxygen. The Quran describes how life emerges, bodies are shaped, and the weaker gets stronger, “It is Allah Who created you in a state of weakness, then gave (you) strength after weakness, then, after strength, gave (you) weakness and a hoary head.”¹⁷ It also points out reviving processes that

17. *Al-Rūm* (30): 54.

enable new cycles of life, leading to subsequent production of energy. God says, "... you see the earth barren and lifeless, but when We pour down rain on it, it is stirred (to life), it swells, and it puts forth every kind of beautiful growth (in pairs)."¹⁸ In sum, while some processes move toward extinction according to the second law of thermodynamics, others are associated with growth and revival.

Disorder or Nurture?

The quantitative figure describing heat transfer from hotter parts to colder parts is called the entropy.¹⁹ The mathematical formulation of entropy is set up in such a way that it can only increase upon heat redistribution in isolated systems. Since isolated systems move from low probable configurations to highly probable ones, the increase of entropy thus designates the transitions to configurations of high probability. Interestingly, highly probable configurations correspond to the most disordered states of systems. This leads one to realise that entropy can be regarded as a measure of disorder. To make sense of this statement, one can think of balls nicely aligned along a straight line. When a blow of wind drafts the balls, it is very unlikely they will maintain their alignment. In a similar token, one can think of the degree of control that has to be exercised on the driving wheel to keep the car going in a straight line. As such, order can only be achieved upon exercising control and diligent design.

The key point to recall is that in isolated systems, entropy, or disorder, can only increase. However, the universe obviously displays a high degree of order by which the flaming internal layers of the earth remain imprisoned inside it, fragile birds hatch, and day and night alternate in accordance to a precise schedule, leading to perfect regularity and cyclic planetary

18. *Al-Hajj* (22): 5.

19. This term was developed by the German physicist, Rudolph Clausius, in 1865 from Greek words meaning transformation.

motions. Therefore, the universe cannot be an isolated system. It must be subjected to constant maintenance by a transcendental Creator, Whose essence is dissimilar to the essence of the universe. Referring to the constant vigilance of the Creator, the Quran says, "..., no slumber can seize Him nor sleep."²⁰ In addition to the fact that the universe can only be maintained and kept in order by God, it says, "It is Allah Who sustains the heavens and the earth lest they move away from their places, and if they were to move away from their places, there is not one that could sustain them after Him."²¹

Fields and Action at a Distance

The Newtonian laws of motion portrayed force as a cause that acts upon contacting the affected body and thereby gets it to move. The idea of having the cause and effect in contact with each other, and thereby fulfilling spatial locality, seems natural and easy to accept. However, the discovery of electricity, whether in the forms of static charges or flowing electrons in a conductor, raised unfamiliar situations to physicists. William Gilbert (1544–1603) systematically investigated the phenomenon of magnetism. The magnetic force can be indirectly visualised through the alignment of iron filings along the assumed magnetic lines of force. In 1820, Oersted discovered that the flow of an electric current produced a magnetic field around the wire, making the first connection between electricity and magnetism.²² The most useful discovery related to magnetism was accidentally made by Michael Faraday (1791–1867) while conducting one of his lectures.²³ The discovery led Faraday to realise that when magnetic field lines sweep a wire back and forth, i.e. when they

20. *Al-Baqārah* (2): 255.

21. *Fātir* (35): 41; Muhammad al-Tāhir ibn ‘Āshūr, *al-Tahrīr wa al-Tamwīr*, vol. 22 (Tunis: al-Dār al-Tūnisiya li al-Nashr, 1984), 327–329.

22. Max Born, *Einstein's Theory of Relativity* (New York: Dover Publications Inc., 1965), 176.

23. Holton and Brush, *Physics*, 372.

vary in strength over time, they induce an electric current in the wire. Since the magnetic lines can be produced by a current flowing in a wire as discovered by Oersted, this means that an electric current in a wire induces a similar current in another. Such a situation thus may be interpreted as “action at a distance.”

How was the electric current induced in a wire that is not connected to a voltage source? The magnetic field produced in the insulating medium between the two wires seems to be the intermediate stimulus. But, what is the magnetic field? Is it real stuff flowing in the air or a mere calculational device used to describe action at a distance with more ease? The reality of fields, whether gravitational, electric, or magnetic, has been a controversial issue among earlier and contemporary physicists. The majority of earlier physicists, including Newton, Faraday, and Maxwell, affirmed in strong terms the reality of fields. In reference to gravitational force, Newton wrote:

That one body may act upon another at a distance through a vacuum, without the mediation of anything else, by and through which their action and force may be conveyed from one to another, is to me so great an absurdity, that I believe no man has in philosophical matters a competent faculty of thinking can ever fall into it.²⁴

Faraday also indicated that the existence of magnetic field is independent of whether there is some tool to detect such a field or not.²⁵ Faraday also added an important statement, which will be revisited in a later section, in reference to a ray of light, that: “And [this ray] is only made known through its effects.”²⁶ With the reality of fields, the spatial locality of cause and effect

24. I. Cohen, ed., *Isaac Newton's Papers and Letters on Natural Philosophy* (Cambridge: Harvard University Press, 1978), 302–3.

25. Marc Lange, *An Introduction to the Philosophy of Physics* (Cornwall: Blackwell Publishing, 2002), xi.

26. *Ibid.*

is fulfilled, as one thinks of the field as the actor that exerts force on its respective effect. Several contemporary physicists choose to think of fields as unreal, though.²⁷ Some physicists thought that the debates over the reality of fields delivered no scientific value. For example, Feynman said that:

The only sensible question is what is the most convenient way to look at electrical effects. Some people prefer to represent them as the interaction at a distance of charges, and to use a complicated law. Others love the field lines.²⁸

The Challenge of Modern Physics

Generally, the history of physics can be divided into three epochs. The first epoch extended for about eight centuries under the Islamic civilisation during which geometry and algebra matured and were used in developing optical and astronomical applications, accurate records of planetary motions were obtained associated with designing sophisticated astronomical devices, and mechanical machines and actuators utilising water circulation were invented. The second epoch extended for three centuries starting from the 17th century under the western civilisation during which calculus was established, electricity was discovered, and the electromagnetic theory was developed. During the first two epochs, physics *passively* described the inanimate world, while keeping a total separation between the observer and the observable, and thereby demonstrating the principle of causality in a perfect sense. For example, the law of the conservation of energy demonstrates the causal relationship in virtue of the fact that energy can only be converted from one form to another, keeping direct proportionality between the amounts

27. Views supporting their position are elaborated on in Lange, *Philosophy of Physics*, 53–61.

28. Richard Feynman et al., *The Feynman Lectures on Physics*, vol. II (Massachusetts: Addison-Wesley, 1963), 1–9.

of the initial and final energy. However, the beginning of the 20th century marked a sharp departure from that framework through an extraordinary revolutionary path of what is now termed as modern physics.

The Departure from Classical Physics

The following summarises some of the early discoveries that reshaped physics and made the transitions into its modern version.

1. In 1900, Max Plank discovered during his experiments on black body radiation, that light emitted from black bodies can only carry particular intensities, which are multiples of an extremely small constant that was later named after him.²⁹ Obviously, the concept of discretising the light intensity into steps does not fit within classical physics, which assumes continuous (analogue) changes. However, due to the high regard given to Maxwell theory and its unquestionable status at his time, Plank still assumed that discontinuity only takes place at the level of the hot body, after which light resumes its wave nature.
2. In 1905, Einstein, equipped with the courage that Plank apparently lacked, used the photoelectric effect phenomenon to demonstrate that in some situations, light acts as particles that deliver energy to a plate of metal and consequently releases electrons from it. In essence, Einstein generalised the quantum effect to the structure of light, as Plank was supposed to do.
3. In 1913, Niels Bohr developed a quantum model of the simplest atom, the hydrogen atom. The model is considered quantum because the energy levels of the atom can only exist in discrete series with *forbidden* energy gaps

29. Walter Heitler. “The Departure from Classical Thought in Modern Physics,” in *Albert Einstein: Philosopher-Scientist*, edited by Paul Schilpp (London: Cambridge University Press, 1970), 182.

in between. The significance of the Bohr model is that it translates the quantum effect in the light structure to the atomic structure.

4. Physicists used to think of light as a wave based on the early work of al-Hazen (965–1040) who demonstrated that light exhibited the phenomena of interference, diffraction, and reflection as sea waves did. The same results were re-stated by Maxwell in a mathematical form in the 19th century. However, as previously stated, the photoelectric effect showed that light also acts as particles. In a 1924 paper, de Broglie raised the brilliant idea that just as light has wave-like properties and particle-like properties, electrons may have the same combination of properties. Accordingly, de Broglie synthesised a wavelength for electrons in a similar manner to the way the wavelength of photons is calculated. In 1927, de Broglie's hypothesis was experimentally confirmed by Davisson and Germer, paving the way for de Broglie to win the Noble Prize of 1929. The de Broglie's wavelength provided an overarching framework that all particles, in fact, all bodies, may in principle act sometimes as waves and sometimes as particles. The wave-particle duality is perhaps the problem that has had the deepest implications, as well as complications, on modern physics, for which it will be revisited at later discussions in this article.

Real Complications with Reality

As quantum physics delineated a new framework for the subatomic phenomena, it also posed serious challenges to our common sense. In this section, the two most salient challenges will be discussed.³⁰ The first troubling notion that stirs philosophical discussions and sometimes tense confrontations among physicists

30. Cushing, *Philosophical Concepts*, Ch. 19, 282–284.

is the notion of observer-created reality.³¹ In daily life, realities of things are independent of one's observation. At times, one might perceive things as random, like the location of a missing item in a crowded room, even though one believes that the item is in a particular place before and after it is spotted. However, the notion under consideration denies such a stationary reality to quantum events. It claims that it is one's observation that fixes a particular status to the events observed. Prior to this, it is only the inherent randomness of the quantum world. Hence, the notion of observer-created reality can be described with relative simplicity using the following version of the double-slit experiment.³²

A plate with two micro-slits is exposed to a stream of electrons. In the first part of the experiment, the intensity of the electrons is high enough that many electrons pass through each slit at a time to fall on a screen behind the plate. As a result, a diffraction pattern, which extends for a few centimetres, forms on the screen and thereby exhibits the wave-like properties of electrons.³³ In the second part of the experiment, the intensity of the electron beam is reduced to the point that only one or two electrons pass through each slit at a time. Obviously, with this low number of electrons, the diffraction pattern cannot be visually observed.³⁴ Nonetheless, it can be observed that electrons arrive over time at specific, yet different, points on the screen. The arrival points of the electrons though, obey the same distribution of the diffraction pattern. Indeed, a few electrons arrive at the dark rings of the pattern while many arrive at the bright rings. In this part of the experiment, the particle nature of electrons is exhibited.

31. This notion was proposed by John Wheeler in an article entitled "Law without Law," in *Quantum Theory and Measurement*, ed. John Wheeler and Wojciech Hubert Zurek (New Jersey: Princeton University Press, 1983).

32. A similar experiment was conducted to prove the de Broglie wavelength.

33. Heider, "Departure from Classical Thought," 188–191.

34. This author interpreted some of the observations of the experiment differently from the version given in *ibid*.

The argument given by those who support the observer-reality notion is about the following third part of the experiment. Should the screen be made so thin that electrons can pass through it to fall on a second screen, where would the position of an electron on the first screen be relative to its position on the second screen? Indeed, as demonstrated, the two positions are exactly identical. Thus, capitalising on this fact, the supporters of the notion assert that while the positions of electrons on the first screen are random, they are fully predictable on the second screen. Their argument is that it is one's observation of the electrons on the first screen that created their reality and produced one's prior knowledge of their positions on the second screen.

Before analysing the above argument, which will be done in a later section, it is important to realise that the notion of observer-created reality does not obey principles of human sense and could demolish the entire platform of knowledge acquisition. The following fundamental questions are raised in response. First, how can an observer, who by definition lacks knowledge of the observable, make such unknown matters to him/her occur? Secondly, what determines the properties of the observable, is it the ignorance of the observer or the undetermined status of the observable? Thirdly, knowing that the observables in quantum physics are the constituents of the universe, how is our world run and maintained with elements that do not have a reality?

The second perplexing phenomenon is the unexplained electron transitions. Knowing that the move of an electron to a higher or a lower energy level is associated with the absorption or the emission of photons, respectively, the reader at this point may build a causal scenario in mind that upon exposing a matter to a light beam, electrons move up. In fact, such is *not* the case. The disturbing fact is that electrons move up and down *spontaneously*, i.e. without changing a single stimulus in the experimental setup. Moreover, the time an electron stays in an excited state, i.e. in an upper energy level, is not a fixed interval; it also changes

indeterministically.³⁵ Physicists describe such a situation as inherent randomness, as an alternative way of describing that the trigger behind the electron move is unknown to one. In other words, the causality relationship is hidden. Randomness can be said to be uncharacteristic to quantum physics as it also exists in many daily life scenarios. When high pressure gas is pushed into a container via a tiny hole, the gas molecules spread randomly all over the volume of the container. The term randomness is used in this case to describe one's lack of interest in the behaviour of every individual molecule. Rather, one is interested in the overall behaviour of the gas. However, in principle, one can determine how every molecule would move to its rest position in the container. On the other hand, one does not know what makes the electron jump up and down, and why the jumps occur at particular moments. The additional element in the quantum case is one's inability to figure out the underlying phenomenon that triggers the electron transitions.

Copenhagen Interpretation

The Copenhagen Interpretation was developed in Bohr's institute in Copenhagen, Denmark, primarily by Niels Bohr and his student Werner Heisenberg. The two developers attempted to explain the paradoxical results of quantum physics. At the outset of this section, this author has highlighted the fact that this interpretation does not constitute a philosophical theory. In fact, it is mainly concerned with the practical aspects of the measurements of quantum phenomena. This is the part of the interpretation that has gained wide acceptance among physicists. However, as these measurements unavoidably deal with the interaction of the macroscopic world, as represented by the measuring instruments, and the microscopic world that exhibits the quantum phenomena, the question of consciousness often arise. This is the part of the interpretation that this article

35. Heitler, "Departure from Classical Thought," 184.

is interested in, particularly as it relates to the observer-created reality assertion.

The Copenhagen interpretation can be summarised in the following three points:³⁶

1. Quantum physics is concerned with the probability of *finding* a particle at a particular region. The wave function developed by Schrodinger provides a mathematical formula for this probability.³⁷ Before the observation, the atom was not really at someplace.
2. The uncertainty principle of Heisenberg states that the more accurately one measures an object's position, the more uncertain one will be about its speed. This principle can be demonstrated through the double-slit experiment previously discussed. In order for the diffraction pattern to form, the electron beam has to be monochromatic, i.e. all electrons should have one sharp velocity. However, the diffraction pattern extends in space, making the position of an electron uncertain. On the other hand, to make the position of an electron sharp and thus certain, electrons with many frequencies have to be aggregated according to Fourier analysis, which makes the frequency component less certain.
3. Atomic particles have properties that cannot be measured simultaneously. Bohr called such a concept complementarity. In order to grasp a more complete knowledge of quantum phenomena, the two complementary properties have to be measured. Wave-like properties and particle-like properties are two complementary properties, according to the uncertainty principle, which can never be exhibited concurrently, and both are needed to understand the behaviour of light. Basically, complementarity is a neat

36. Bruce Rosenblum and Fred Kuttner, *Quantum Enigma* (New York: Oxford University Press, 2011), 128–137.

37. Raymond Serway and John Jewett, *Physics for Scientists and Engineers with Modern Physics* (Boston: Cengage Learning, 2014), 1267–1269.

frame for accommodating the contradictory phenomena encountered in quantum physics, which does not add scientific value to one's understanding of these phenomena.

Einstein versus Bohr

The claim that the microscopic objects lack reality before they are observed disturbed some western physicists. Most notably, Einstein and Schrodinger took a negative stance at the interpretation and described it in straightforward statements as nonsense. Einstein opined that: "...a particle must have a separate reality independent of the measurements I like to think the moon is there even if I am not looking at it."³⁸ Einstein and Bohr debated in conferences and over papers. To understand the theme of their debates, their contention needs to be specified. As known, light acts either as particles or as a wave, which extends in space. Both Einstein and Bohr agreed on the corpuscular nature of light. After all, it was Einstein who discovered that light consists of particles, carrying quanta of energy. However, the dispute was over the wave nature. Bohr thought that when an atom participates in a diffraction pattern, it loses its corpuscular reality, and becomes a rather fuzzy, indefinite matter. Bohr attempted to justify his view based on the uncertainty principle, which precludes detecting the atom that is involved in a wave because the energy needed for the detection would have to be high enough and would thus blur the diffraction pattern. On the other hand, Einstein thought that the corpuscular nature of the atom is maintained even when it participates in wave-related phenomena. In the Solvay conferences of 1927 and 1930, Einstein posed two challenges to Bohr.³⁹ However, Bohr evaded the challenges by arguing that the thought experiments proposed by Einstein assumed unrealistic

38. Rosenblum and Kuttner, *Quantum Enigma*, 155.

39. Dugald Murdoch, *Niels Bohr's Philosophy of Physics* (Cambridge: Cambridge University Press, 1990), 155–161.

situations that the uncertainty principle does not permit. The most serious challenge posed by Einstein was through the EPR paper, which is described in some detail below.

In 1935, Einstein, Podolsky, and Rosen wrote a paper, commonly entitled the EPR paper, describing a thought experiment aiming to affirm the physical reality of the quantum world. The authors attempted to show that a property of a particle could be known, without being observed. This means that the Copenhagen Interpretation is incomplete because it only considered one way of knowledge acquisition, namely observation.⁴⁰ This in turn demolishes the observer-created reality notion simply because a property can be maintained and predicted through a different channel than observation. The photon version of the EPR, which was later introduced by David Bohm, can be described as follows.⁴¹ A twin-state pair of photons have a particular polarisation. For such a pair, the polarisation of one photon can be predicted by knowing the polarisation of the other. Next, push the two photons apart from each other, one photon is moved to the right and the other to the left. Then, imagine two observers, one of whom, A, is closer to the starting point of the two photons than the other one, B. Accordingly, A would receive the photon travelling towards him before B does of the other one. Upon receiving the first photon, A will be able to know its polarisation, as well as the polarisation of the other photon. The polarisation of the latter photon, which is still on its way to B, is a property that could be predicted without causing any sort of disturbance to it. Such a property is physically real, rather than observer-created, and is *not* accounted for by the Copenhagen interpretation, making it incomplete. Note that A cannot communicate the polarisation of the other photon to B before it actually arrives to B since nothing can travel faster than light according to the theory of relativity.

40. The completeness of quantum mechanics is discussed in James Cushing, *Philosophical Concepts in Physics* (Cambridge: Cambridge University Press, 1998), 305–316.

41. Rosenblum and Kuttner, *Quantum Enigma*, 167–168.

Like what happened after every challenge from Einstein, Bohr and his team worked frantically to prepare an answer to the EPR. In a highly philosophical paper, Bohr claimed that the mere observation by A of the first photon could have caused a non-physical, i.e. semantic, disturbance of the other photon. Bohr did not address the type of mechanism by which this remote, or semantic, influence could have happened. Neither did he discuss the distance limit over which the influence could remain active. Can observing a photon in a galaxy *instantly* influence a photon in another galaxy, based on the semantic disturbance? It is also important to realise that Bohr's response to the EPR deviated from the framework of Copenhagen interpretation, and particularly the Heisenberg uncertainty principle, which only addresses physical disturbance. Emphatically, the three fundamental questions raised in an earlier section of this article⁴² strongly apply to Bohr's response.

EPR is by far the most cited scientific paper in the 20th century. Many scientists have analysed some aspects of it, and/or attempted to convert it into actual experiment by taking advantage of the technological advancements. In 1997, i.e. after 62 years of publishing the EPR, Nicolas Gisin and his team at the University of Geneva produced a pair of twin photons. They sent the two photons over two fibre cables going on opposite directions. One photon was sent to the city of Bernex (5km north of the lake of Geneva), while the other was sent to Bellevue (5km south of the lake of Geneva). While being 10km apart from each other, one photon was let to acquire some properties. The experimentalists reported that the other photon *instantly* acquired the opposite properties. The results of this experiment suggested that semantic influence might be possible, provided that other possible interpretations were adequately addressed and analysed. The results also question that the speed of light is indeed the highest speed by which bits of information can travel, based on the *instant* mutual influence

42. See the section on “Real Complications with Reality.”

reported in the experiment. It is beyond the scope of this paper to analyse all the technical updates as regards EPR and the nature of physical reality. The discussions thus far are merely confined to the scientific arguments forwarded by Einstein and Bohr. The contrast is discussed in the following section.

Where is the Flaw?

Indeed, the supporters of the Copenhagen Interpretation rose to its defence by claiming that it had worked very well. However, their claim was ambiguous as to which part had really succeeded. The Copenhagen Interpretation, and quantum physics in general, describe consistent behaviour of the atomic world, which has never been broken experimentally till today, thus enabling many important applications to be advanced. However, the problematic task in quantum physics is neither to figure out how to produce certain phenomena nor the mathematical derivation of its formulae, even though the tasks are hardly simple by any means. The problematic task is concerned with understanding the deep philosophical implications of the experimental results.⁴³ Due to the philosophical nature of Einstein and Bohr's debates, they were ignored by many physicists as they did not belong to physics. However, such philosophical aspects, especially as they intersect with religion, are the target of the present discussions.

Einstein and Bohr had dissenting views due to their different attitudes towards science and the way it relates to human knowledge. Einstein believed that science must be able to explain the reality of nature. He used robust reasoning that left little room for opponents to argue. Indeed, Einstein's experiments were, in fact, thought experiments, rather than actual ones. Nonetheless, none of his adversaries questioned them on that basis because of their concrete setup and the clarity of the points

43. It is interesting to recall that the interpretation of Schrodinger of his own wave function that he developed was not widely accepted. Max Born's statistical interpretation of the wave function was proven to be of higher merit.

they implied. In particular, Einstein relied heavily on inference, rather than tangible observations. Interestingly, the qualities of scientific research upheld by Einstein were the same ones that Francis Bacon attempted to obliterate centuries ago.⁴⁴

For Bohr, the goal of science in his view is rather limited. Bohr thought that the goal of science is not to explain nature, but only to describe what one can say about nature.⁴⁵ Moreover, the discovery tools for Bohr seem to be limited to physical observations, with no clear references to reasoning and inference. The world, according to Bohr, is the part one sees and science is the tool of inspection. Such remarks portray Bohr as an empiricist who relied solely on experimentation, without fitting the experimental results within a frame of reasoning. The notion of observer-created reality was driven by the perception that one cannot affirm the existence of quantum objects before conducting the observation. The notion gained more acceptance in the second half of the 20th century owing to the increasing number of empiricists. In this context, the conflict between Einstein and Bohr can be attributed to the disparity between rationalism and empiricism.

Since rationalists and empiricists both rely on experimentation and the difference between the two lies in adopting a robust reasoning framework through which the scientific investigation progresses, it is natural to ask what Bohr missed by neglecting a rational framework. Bohr issued inaccurate statements that reflect reckless use of ambiguous terms, making quantum physics a big puzzle and its concepts counter-intuitive. Following a rational line of thinking could have safeguarded against such spooky⁴⁶ thoughts by objectively stating the part one knows and the part one does not.

44. Lisa Jardine, *Francis Bacon Discovery and the Art of Discourse* (Cambridge: Cambridge University Press, 1974), 76–108.

45. Rosenblum and Kuttner, *Quantum Enigma*, 170.

46. Einstein used this term to describe the implications of the observer-created reality.

To shed some light on the above statement, what is meant by observation in classical physics will be elaborated. Measuring instruments should be able to detect some object/event without causing significant disturbance to the phenomenon under observation. In other words, the energy absorbed by the instruments should be negligible relative to the total amount of energy. The challenge in quantum physics is that one attempts to observe individual photons, for example, using a comparable number of photons for detection. This means disturbance-free observation is not possible in quantum physics. This limitation precluded physicists from gaining insight about the corpuscular nature of particles while acting as a wave. Einstein's response to such a dilemma was that electrons continue to act as concentrated particles even when they participate in a wave. On the other hand, Bohr and physicists with affinity to empiricism, said that when electrons behave as a wave, which intrinsically extends in space, an electron passes through the two slits at the same time. No satisfactory justification was given for this self-contradictory statement. Does an electron split into two while crossing the screen and then the two recombine afterwards? Indeed, a spread-in-space matter is no longer an electron. To compound matters even further, and based on the fact that electrons revert to the particle form upon being bombarded with other particles, empiricists said that it is one's observation that created the reality of the particles, before which no definite being existed. Not only are their statements unfounded and akin to fiction devoid of science, they confuse the mind and take away objective description of reality. What should have been stated is that electrons can exhibit waving characteristics when the setup renders the de Broglie wavelength within the range of observation of our instruments. However, one is incapable of watching individual electrons participating in a wave, as one watches water droplets involved in a sea wave, because of the dimension limitation inherent to the quantum world.

Due to the central role played by observation in empirical thinking, empiricists made reality conditional on observation.

Whatever observation indicates is considered real, and whatever observation fails to detect is considered unreal. This is the line of thinking through which the notion of observer-created reality was advanced. Accordingly, quantum objects were denied independent reality because observation changes their status. Notwithstanding the peculiarity of the quantum case, a similar case existed in classical physics. Fields are induced and give rise to undeniable effects while their nature is debated. Faraday and other rationalists objectively affirmed the reality of fields in virtue of their effects.⁴⁷ Faraday cleverly avoided being caught in the limitations of human observation by working within a solid frame of reasoning. A similar approach with quantum enigmas could have cleared many confusing aspects associated with them. Unfortunately, Bohr and Heisenberg handled philosophical issues with pure physical mentality. Indeed, the Copenhagen interpretation as far as it relates to physics did succeed, while its philosophical implications turned out troublesome. In the next section, the issue of indeterminism in the quantum world which was raised in an earlier section⁴⁸ will be discussed.

Can Randomness Generate Determinism?

Upon exploring the quantum world, one encounters the spontaneous and indeterministic behaviour of quantum events. While different types of matter display consistent and predictable behaviour in daily life and in laboratories of physics, their atoms do not show the same behaviour in the quantum world. This naturally leads one to wonder if randomness in the quantum world produces determinism in the classical world. For an adequate analysis of this point, it is instructive to define what randomness really means as this will turn out to be a key step towards the answer.

47. See the section on “Fields and Action at a Distance” of this article.

48. See the section titled “Real Complications with Reality” of this article.

An event is called random if its outcome cannot be predicted with certainty. Nonetheless, many random events can be predicted with varying degrees of confidence, such as the probability of having rain tomorrow, and the probability of a surgical operation to succeed. The more one knows about a system, the higher the confidence one can predict its behaviour with. This implies that pure randomness, in the sense that one has no clue whatsoever about how a system would behave, is only possible for systems one is totally unaware of. Mathematicians have formulated several probability distributions that describe the behaviour of important random systems. For example, the normal distribution (the bell-shaped distribution) is commonly used to describe the grades of a typical class, where most of the students get average grades, a few get excellent grades, and a few more get low grades. This suggests that one has *partial* knowledge of how a random process works. Such a partial knowledge enables us to predict the *range* within which the outcome will be. For deterministic processes, on the other hand, one can predict with full confidence the exact figure of the outcome. It is thus the transition from a range of predictions to a single exact figure that switches a random process to a deterministic one.

In the macroscopic world, there is a large number of coexisting agents. For example, many air molecules are around us and many nervous cells function concurrently. In this classical world, one basically observes the superposition, or the net effect, of many microscopic events. Thus, one is compelled to conclude that the randomness in the quantum world is *controlled* in such a way that produces determinism in the classical world. In other words, the seemingly spontaneous transitions of electrons between energy levels do generate deterministic behaviour for a large ensemble of atoms. Analogous cases can be found in daily life. For example, a specific direction can be assigned to a sea wave. However, the same cannot be done to all water drops forming the wave. The directions of the water drops would be considered random.

Limits of Human Knowledge

In a famous and much-quoted remark by Einstein that expressed his frustration of being unable to identify an underlying deterministic mechanism of quantum phenomena, he said that “God does not play dice.” Bohr’s reply was that “Perhaps Einstein should not tell God how to run the universe.” Actually, both statements may have captured different parts of the truth, based on the intents of their issuers.

If what Einstein meant by his statement is that it does not fit God’s supreme power and complete knowledge to let things happen randomly, this point is exactly correct. God says, “With Him are the keys of the unseen, none knows them but He. He knows whatever there is on the earth and in the sea; not a leaf does fall but He knows it. There is not a grain in the darkness of the earth, nor anything fresh or dry, but is (inscribed) in a Clear Record.”⁴⁹ This verse astonishingly addresses minute events, such as tree leaves falling down, that people classify as random, even though these events are fully known to God and recorded beforehand in a comprehensive and clear book.⁵⁰ The same fact is emphasised in another verse: “And there is nothing *hidden* in the heaven and the earth, but is in a Clear Book.”⁵¹ Many events skip human knowledge, either fully or partially, by knowing their occurrences but missing some of their properties. For example, humans have partial knowledge of electron transitions between energy levels, whereas we lack apprehension of their stimuli and thereby describe them as spontaneous. For God, however, the underlying mechanism is fully known and the time of every transition is indeed recorded.

On the other hand, if what Bohr meant by his statement is that it is God’s privilege to hide part of the reality of the quantum

49. *Al-An‘ām* (6): 59.

50. For a deep analysis of the verse, see Fakhr al-Dīn al-Rāzī, *Maḥāṭib al-Ghayb*, vol. 5 (Beirut: Dār al-Fikr, 2005), 9–11.

51. *Al-Naml* (27): 75.

world and makes it look like random to us, this point is exactly correct, too. The type and range of the human senses determine the sensual knowledge we can acquire. The common sense and cognitive abilities of humans are developed within the classical world, which provide meaningful data.⁵² However, there are other dimensions of the universe that are totally secluded from humans, and their principles of operation are likely to conflict with our common sense. Actually, the uncertainty principle of Heisenberg shows that human knowledge has an ultimate extent that can never exceed.⁵³ This extent is independent of the technology of the measuring instruments and the skills of the investigator; it is simply an inherent limitation of human knowledge. God said the truth that, “And of knowledge, you (mankind) have been given only a little.”⁵⁴

Conclusion

Indeed, the developments of Physics have walked men through increasingly subtle exposures to reality. The straightforward Newtonian laws of motion were followed with the discovery of invisible fields, yet capable of producing similar types of motion. This in turn sets the stage to the most serious challenge posed by quantum physics. This article has discussed three energy-related classical phenomena, which are in broad contrast to the framework of quantum physics. The law of the conservation of energy establishes the principle of causality, which is generalised in the literature of Islamic theology in the context of proving

52. This point holds true irrespective of whether these abilities are innate or the product of acquiring this data. John Locke and empiricists think that these abilities are the outcome of the learning process. Many Muslim thinkers, as well as Descartes, think that the basic forms of these abilities are innate and they get more developed during learning.

53. The mathematical formula of the uncertainty principle reads as follows: The multiplication of the uncertainty range of the position and the uncertainty range of the momentum of a particular particle is less than Planck's constant. See Serway and Jewett, *Physics for Scientists*, 1256–1258.

54. *Al-Isrā'* (17): 85.

that the universe is an effect that was originated by a capable Creator. Subsequently, the commonly quoted phrase that “energy cannot be created” was discredited as a result of classifying energy as a contingent being in need for a creator. The second law of thermodynamics was discussed and shown to be, despite its general statement, inapplicable to many natural processes involving growth and revival. Moreover, the possibility of running into heat catastrophe was questioned. It was argued that the universe cannot be a closed system in virtue of the high order it displays, which requires a constant maintenance by a transcendental (separate from the universe) Creator. The ability of remote charges to induce fields and thereby question the principle of the spatial locality of cause and effect, showed the importance of having a sound reasoning framework for interpreting scientific results. Lacking such a framework by the Copenhagen team added to the confusion in the philosophical aspects of quantum physics.

Due to the fact that the sensitivity of our senses is lower than that needed for detecting quantum events, we are isolated from the quantum world, except through measuring instruments, which disturb the events under observation and consequently shatter our hopes of grasping the reality of the quantum world. The philosophical aspects of the experimental outcomes of quantum physics were the victim of reckless interpretations by empiricists. Capitalising on the fact that individual electrons participating in wave-like behaviour cannot be observed and that when detected, the corpuscular nature is rather manifested, empiricists claimed that before the observation, electrons had no reality and that it is our observation that gave them their corpuscular reality. It was proposed that a reasoning framework that incorporates inference approaches, alongside observation, should be adopted for a more rational interpretation of quantum events. In particular, the position of Faraday in affirming the reality of fields based on their effects and the position of Einstein in affirming the corpuscular reality of electrons irrespective of the behaviour they exhibit, both positions represent a more

objective understanding of the quantum world. On another front, the seemingly random quantum events are controlled in such a way that gives rise to the deterministic phenomena in our classical world. Physicists should accept the fact that despite possible future advances in understanding the quantum world, the quantum enigma is likely to continue evading our comprehension as it originally emerged due to the inherent limitation imposed on our knowledge.

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