Acta Scientific Applied Physics

Volume 2 Issue 7 July 2022

Editorial

Three Paradigms in the World of Physics

Samir F Matar*

Lebanese German University, Jounieh, Lebanon

***Corresponding Author:** Samir F Matar, Lebanese German University, Jounieh, Lebanon, Emails: s.matar@lgu.edu.lb and sfm68@hotmail.com.

Received: May 28, 2022

Published: June 10, 2022

The science of knowledge defined as Epistemology, relies on observations, making statements regarding them. The statements are correct when, on the occurrence of these observations, science becomes interpretive and predictive of similar ones. Among the different classes of sciences, physics which relies strongly on mathematics -whence its rigor-, occupies an exceptional position. Physics is exact in the quantitative determinacy of its laws -we'll see that this aspect is questioned in quantum physics -vide infra-, while the other sciences are rather factual, such as biological sciences (biology and biochemistry). Such is the case of so-called "Classical Physics" devised by Isaac Newton (17^{th} - 18^{th} century). Newtonian physics is deterministic through laws implying continuity of physical phenomena present in every event that we observe: from the motion of bodies ruled by the laws of motion pertaining to speed and velocity, to friction and stress in materials and up to the structure and motion of planets. This involves an objective view of reality (without intervention of the observer; such a statement is relevant in the development of the second part of the paper). Newtonian understanding of physics remained dominant for two centuries. The principle upon which it is based is causality. According to Classical Physics, knowing the initial conditions for an event means that one could theoretically predict every event that would follow, thanks to the laws of motion and conservation of energy.

Nevertheless, despite the success of classical physics in explaining most phenomena in physics, it had drawbacks in addressing other ones like the black-body radiation caused by the thermal motion of particles in the solid. With increasing temperature, the emitted light of the heated material extends into the human visual range, from dark red, then to orange, yellow, green, and blue light. Ultimately after violet frequency, occurs the ultraviolet catastrophe at short wavelengths in violation of the Rayleigh-Jeans classical law for the energy emitted by an ideal black body. Such effects could not be explained with acquired knowledge of physics then.

A major step forward was done by the physicists of the early 20^{th} century who started the post-Newtonian era, treating the subatomic scale of matter. The Quantum Physics new era was initiated by the works of Max Planck who introduced the "h" (action) universal constant carrying his name ($h = 6.626\ 10^{-34}$ Joule.Seconds), that helped quantizing the energy $E = h\nu$ (ν: frequency) which now takes discrete values, otherwise continuous in Classical Physics. Physical phenomena that couldn't be understood by Newtonian physics as the black body radiation were finally explained.

Quantum physics shakes deeply the acquired 'beliefs' in physics, such as determinacy, embracing instead the idea that deterministic causality may be impossible at the atomic level. In 1927, the German physicist Werner Heisenberg expressed a fundamental limit of the laws of physics, which has become the famous Principle of Uncertainty –or Indeterminacy-. He provoked a seismic change in the vision of Physics by stating that the momentum and position of a particle could not be known together with accuracy at a given time t. Therefore, probabilistic physics of quantum mechanics, at the subatomic scale, marked the end of the determinism of classical physics: neither the past nor the future behavior of a particle could be determined with certainty. Such milestone is featured with "Copenhagen interpretation of Quantum Physics" of Bohr and Heisenberg. Based on the concept that Physics is the "Science of Measurement", a measurable quantity has no reality until it is measured. Developing further on this, the experiment involves simultaneously the measuring apparatus (classical physics) on one hand and the sub-atomic measured object (quantum physics) on the other hand. The subatomic particle remains in a wave with a superpositions of states until it is measured whereby the wavefunction collapses into one state. Mathematically, this is expressed with the Heisenberg Uncertainty Formula: $\Delta p \times \Delta x \geq h/4\pi$ where p and x are respectively the momentum and the position, and h the Planck's constant. The basic statement of the principle is that it is impossible to measure simultaneously the position (x) and the momentum (p) of a particle with absolute precision: the more precisely you know one of these values, the less precisely you know the other. For instance, to observe a sub-atomic particle as an electron, you need to irradiate it with light made of photons. Hitting elastically the electron at the position x, the photon delivers some energy, providing the electron with momentum p. The incident photons reporting back the electron position, would have already moved from there, thereby affecting the calculations about the position. The equation above means that the error of such measurement is larger or equal to $h/4\pi$. Quoting Heisenberg: "The conception of objective reality of the elementary particles has thus evaporated not into the cloud of some obscure new reality concept but into the transparent clarity of a mathematics that represents no longer the behavior of particles but rather our knowledge of this behavior". In such a novel conception of the World of Physics, the scientists abandoned the hope of Explaining the Nature of Reality (ontology), resigning to limiting ourselves to 'the knowledge of reality" (epistemology). Note that later, some physicists followed another school of thought implying the Many Worlds Interpretation, where there's no distinction between the measured, the apparatus and the experimenter-observer (Everett's theory). Oppositely to Copenhagen school, the evolution of the Schrödinger wave equation ($H\Psi = E\Psi$) becomes deterministic, and when applied to the entire universe, it 'governs' its quantum state. In other words, the superposition of the particle spreads to the apparatus, and to the experimenter-observer operating and looking at the apparatus, and ultimately to the entire universe. The components of the resulting superposition are like parallel universes: in one of them you see result A, in another you see result B, etc.

Lastly, in "every-day" quantum physics explorations computational methods relying on fast computers are there to assist researchers, not only in Physics but also the other disciplines as Chemistry, Biochemistry and more generally in Materials Sciences. See former opening paper by the author in ASAP January 2022. In 1965-66 the density functional theory DFT by Hohenberg, Kohn and Sham, was proposed to approach accurately the problem of the interelectron exchange-correlation and to use the electron density as variable to solve the Schrödinger-like wave equations, called KS-equations. The great success of DFT and the methods built around it with different sophistications and outcomes, is obvious from the enormous number of publications since its birth with not only interpretive results but also with predictions of novel properties and compounds, therefore becoming a force of proposition for the experimentalists. The reader is kindly referred to author's link to scientific works featuring original results using DFT-based quantum mechanics calculations: https://orcid.org/0000-0001-5419-358X.

To conclude, in so far that a "scientific school or discipline within which theories, laws, and generalizations, as well as the experiments performed in support of them" is shorthand-defined as a Paradigm, we may classify Physics into three paradigms: 1) Newtonian, 2) Quantum, and 3) Relativity. The Theory of Relativity of Albert Einstein describes the universe by combining the speed of light, simultaneity of events, geometry, and gravitating masses. On its own this paradigm deserves a development, and we'll get to it in a future work. But let me here cite Einstein's famous vision of reality when he was at Princeton University in the middle of the 20th century: Die Natur verbirgt ihr Geheimnis durch die Erhabenheit ihres Wesens, aber nicht durch List (German), meaning "Nature hides its secret through the grandeur of its essence, but not through malignancy". This is a lesson to learn from: Nature has no bad intention to hide anything of its secrets from us; we scientists have free unlimited access to explore and understand its laws. Consequently, "everything is knowable or can be known… eventually". The Physics World is an open one through the three paradigms and an invitation for researchers, each one in his domain of competence, to open the different doors of Nature at all scales.