**QUANTUM MECHANICS**

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Quantum Mechanics is the fundamental theory in Physics that provides a description of the physical properties of nature at the scale of the atoms and the subatomic particles. It is the foundation of all quantum physics including quantum chemistry, quantum field theory, quantum technology and quantum information science. Classical Physics, the description of Physics that existed before the theory of relativity and quantum mechanics – describes many aspects of nature at an ordinary (macroscopic) scale, while quantum mechanics explains the aspects of nature at small (atomic and subatomic) scales, for which Classical Mechanics is insufficient. Most theories in Classical Physics can be derived from Quantum Mechanics as an approximation, valid at large (macroscopic) scale. Formerly, scientists developed a consistent theory of the atom that explained its fundamental structure and its interactions. In 1926, ‘Laws of quantum mechanics’, also known as ‘Laws of wave mechanics’ was developed by the Physicist. Laws of quantum mechanics explain the atomic and subatomic phenomena. Quantum Mechanics is the Physics that explains how everything works : the best description we have of the nature of the particles that make up the matter and the forces with which they interact – it characterises the simple things, such as, how the position or momentum of a single particle or group of few particles change over time.

Quantum Mechanics differs from Classical Physics in that energy, momentum, angular momentum and other quantities of a bound system are restricted to discrete values (quantization), objects have characteristics of both particles and waves (wave-particle duality) and there are limits to how accurately the value of a physical quantity can be predicted prior to its measurement, given a complete set of initial conditions (the uncertainty principle). Quantum Mechanics arose gradually from theories to explain observations which could not be reconciled with Classical Physics, such as Max-Planck’s solution in 1900 to the black-body radiation problem and the correspondence between energy and frequency in Albert Einstein’s paper, published in 1905, which explained the photoelectric effect. These early attempts to understand microscopic phenomena, now known as the ‘old quantum theory’, led to the full development of quantum mechanics in mid-1920 by Niels Bohr, Erwin Schrodinger, Werner Heisenberg, max Born and many others. The modern theory is formulated in various specially developed mathematical formalisms. In one of them, a mathematical entity called the wave function provides information in the form of a probability amplitudes about what measurements of a particle’s energy, momentum and other physical properties may yield.

Quantum Mechanics is enormously successful in explaining many of the features of our universe, with regards to small-scale and discrete quantities and interactions which cannot be explained by classical methods. Quantum Mechanics is often the only theory that can reveal the individual behaviours of the subatomic particles that make up all forms of matter (electrons, protons, photons, neutrons and others). Solid-state Physics and Material Science are dependent upon Quantum Mechanics.

In many aspects, modern technology operates at a scale where the quantum effects are significant. Important applications of quantum theory include quantum chemistry, quantum optics, quantum computing, superconducting magnets, light emitting diodes, optical amplifier and the laser, the transistor and semiconductors such as microprocessor, medical and research imaging such as magnetic resonance imaging and electron microscopy. Explanations for many biological and physical phenomena are rooted in the nature of the chemical bond, most notably the macro-molecule DNA.

Albert Einstein himself being one of the founders of quantum theory was troubled by its apparent failure to respect some cherished metaphysical principles such as determinism and locality. Einstein’s long-running exchanges with Bohr about the meaning and status of quantum mechanics are known as the Bohr-Einstein debates. Einstein believed that underlying quantum mechanics must be a theory that explicitly forbids action at a distance. He argued that quantum mechanics was incomplete, a theory that was valid but not fundamental, analogous to how thermodynamics is valid but the fundamental theory behind it is the statistical mechanics. In 1935, Einstein and his collaborators Boris Podolsky and Nathan Rosen published an argument that the principle of locality implies the incompleteness of quantum mechanics, a thought experiment later termed as the Einstein-Podolsky-Rosen paradox. In 1964, John Bell showed that EPR’s principle of locality, together with determinism was actually incompatible with quantum mechanics : they implied constraints on the correlations produced by the distance systems now known as Bell inequalities, that can be violated by entangled particles. Since then several experiments have been performed to obtain these correlations with the result that they do in fact violates Bell inequalities and thus falsify the conjunction of locality with determinism.

Bohmian Mechanics shows that it is possible to reformulate quantum mechanics to make it deterministic at the price of making it explicitly nonlocal. It attributes not only the wave function to a physical system but in addition to a real position that evolves deterministically under a nonlocal guiding equation. The evolution of a physical system is given at all times by the Schrodinger equation together with the guiding equation; there is never a collapse of the wave function. This solves the measurement problem.

Everett’s many-world interpretation formulated in 1956, holds that all the possibilities described by quantum theory simultaneously occur in a multiverse composed of mostly independent parallel universes. This is a consequences of removing the axiom of the collapse of the wave-jacket. All possible states of the measured system and the measuring apparatus, together with the observer are present in a real physical quantum superposition. While the multiverse is deterministic, we perceive non-deterministic behaviour governed by the probabilities because we do not observe the multiverse as a whole but only one parallel universe at a time. Exactly how this is supposed to work has been the subject of much debate. Several attempts have been made to make sense of this and derive the Born rule, with no consensus on whether they have been successful. Relational Quantum Mechanics appeared in late 1990’s as a modern derivative of Copenhagen-type ideas and QBism was developed some years later.