

Quantum mechanics is the study of mechanical systems whose dimensions are close to or below the atomic scale, such as molecules, atoms, electrons, protons and other subatomic particles. Quantum mechanics is a fundamental branch of physics with wide applications. Quantum theory generalizes classical mechanics and provides accurate descriptions for many previously unexplained phenomena such as black body radiation and stable electron orbits. The effects of quantum mechanics are typically not observable on macroscopic scales, but become evident at the atomic and subatomic level. There are however exceptions to this rule such as superfluidity.

The word “quantum” came from the Latin word which means "unit of quantity". In quantum mechanics, it refers to a discrete unit that quantum theory assigns to certain physical quantities, such as the energy of an atom at rest . The discovery that waves have discrete energy packets (called quanta) that behave in a manner similar to particles led to the branch of physics that deals with atomic and subatomic systems which we today call quantum mechanics. It is the underlying mathematical framework of many fields of physics and chemistry, including condensed matter physics, solid-state physics, atomic physics, molecular physics, computational chemistry, quantum chemistry, particle physics, and nuclear physics. The foundations of quantum mechanics were established during the first half of the twentieth century by Werner Heisenberg, Max Planck, Louis de Broglie, Albert Einstein, Niels Bohr, Erwin Schrödinger, Max Born, John von Neumann, Paul Dirac, Wolfgang Pauli and others. Some fundamental aspects of the theory are still actively studied.

Quantum mechanics is essential to understand the behavior of systems at atomic length scales and smaller. For example, if Newtonian mechanics governed the workings of an atom, electrons would rapidly travel towards and collide with the nucleus, making stable atoms impossible. However, in the natural world the electrons normally remain in an unknown orbital path around the nucleus, defying classical electromagnetism.

In the formalism of quantum mechanics, the state of a system at a given time is described by a complex wave function (sometimes referred to as orbitals in the case of atomic electrons), and more generally, elements of a complex vector space. This abstract mathematical object allows for the calculation of probabilities of outcomes of concrete experiments. For example, it allows one to compute the probability of finding an electron in a particular region around the nucleus at a particular time. Contrary to classical mechanics, one can never make simultaneous predictions of conjugate variables, such as position and momentum, with arbitrary accuracy. For instance, electrons may be considered to be located somewhere within a region of space, but with their exact positions being unknown. Contours of constant probability, often referred to as “clouds” may be drawn around the nucleus of an atom to conceptualize where the electron might be located with the most probability. It should be stressed that the electron itself is not spread out over such cloud regions. It is either in a particular region of space, or it is not[citation needed]. Heisenberg's uncertainty principle quantifies the inability to precisely locate the particle.

The other exemplar that led to quantum mechanics was the study of electromagnetic waves such as light. When it was found in 1900 by Max Planck that the energy of waves could be described as consisting of small packets or quanta, Albert Einstein exploited this idea to show that an electromagnetic wave such as light could be described by a particle called the photon with a discrete energy dependent on its frequency. This led to a theory of unity between subatomic particles and electromagnetic waves called wave-particle duality in which particles and waves were neither one nor the other, but had certain properties of both. While quantum mechanics describes the world of the very small, it also is needed to explain certain “macroscopic quantum systems” such as superconductors and superfluids.

Broadly speaking, quantum mechanics incorporates four classes of phenomena that classical physics cannot account for: (i) the quantization (discretization) of certain physical quantities, (ii) wave-particle duality, (iii) the uncertainty principle, and (iv) quantum entanglement. Each of these phenomena is described in detail in subsequent sections. Predictions of quantum mechanics have been verified experimentally to a very high degree of accuracy. Thus, the current logic of correspondence principle between classical and quantum mechanics is that all objects obey laws of quantum mechanics, and classical mechanics is just a quantum mechanics of large systems (or a statistical quantum mechanics of a large collection of particles). Laws of classical mechanics thus follow from laws of quantum mechanics at the limit of large systems or large quantum numbers.