Selected Topics in Quantum Information Theory

Mohammad Alhyari
BME, Faculty of Natural Science, Math Department

The foundation of all quantum theory is based upon quantum mechanics. Towards the end of the 19th century, the framework of classical physics failed to account for numerous large- and small-scale phenomena, therefore there was a desire to rectify self-contradictions between theory and observed phenomena, which ultimately gave rise to a major revolution in the classical framework of physics that in turn led to the development of Quantum Mechanics.

In efforts to axiomatically construct quantum mechanics through the language of Mathematics, we need to acquaint ourselves with several mathematical notions. We start our discussion by establishing the necessary mathematical theory of finite-dimensional Hilbert spaces; the arena in which quantum mechanics takes place.

This proposed document seeks to present the mathematical and conceptual formalism for the development of a rigorous framework of quantum theory, where we start with introducing the necessary notions in matrix theory, followed by a detailed description of Quantum Mechanics Postulates, finishing off with a thought experiment whose resolution had important implications for the interpretation of quantum mechanics, namely: EPR Paradox.

We note that there are many mathematically equivalent formulations of quantum mechanics. Throughout this document we present the postulates as given by the book Quantum computation and quantum information by Nielsen, M. and Chuang, I., 2021.