PHY-903 Foundations of Quantum Mechanics

Credit Hours: 3-0

Prerequisite: Quantum Mechanics

Course Objectives: This course deals with the issues of the interpretation of quantum mechanics and addresses several important questions from a philosophical standpoint. This course is an excellent tool to better understand the cumbersome theory of quantum mechanics.

Core Contents: This course includes discussion of fundamental concepts of the foundation of quantum mechanics, especially focused on various interpretations of the quantum mechanics theory, deciding which interpretation fits better into the actual world is up to the reader. For instance, quantum mechanical description of measurement, the Copenhagen interpretation, the Einstein-Podolsky-Rosen problem, individual-particle and ensemble interpretations, generalized quantum mechanics, the Bell inequality and hidden-variables theories.

Detailed Course Contents: The detailed contents are given in the table below along with week-wise breakdown.

Textbooks: Willem M. de Muynck (WM), Foundations of Quantum Mechanics, an Emoiricist Approach, Springer (2002).

Reference Books:

1. Martin Plenio, Quantum Mechanics II, http://www.lsr.ph.ic.ac.uk/plenio/teaching.html

2. Chirs J. Isham, Lectures on Quantum Theory: Mathematical and Structural Foundations, Imperial College Press 1995.

Weekly Breakdown		
Week	***Section***	***Topics***
1	WM 1.1-1.7	Basic postulates of standard quantum mechanics, some elements of quantum field theory, Simultaneous and joint measurement of compatible observables, Mixtures, Coupled systems, Projection or reduction postulate, Uncertainty relations
2	WM 1.8-1.11	Proposition calculus of standard quantum mechanics, generalized quantum mechanical observables, Phase space representations, Wigner-Weyl representation, Wigner's theorem
3	WM 2.1-2.3	Empiricist interpretation of quantum mechanics, Logical positivism/empiricism and empiricist interpretation, Realist interpretation of quantum mechanics,
4	WM 2.4, 2.5	Empiricist or realist interpretation: which one to choose? Some consequences: Empiricist interpretation and generalized observables, Realist interpretation of quantum mechanics, and hidden variables Interpretations and the classical limit
5	WM 3.1,3.2, 3.3, 3.4	The (conventional) "measurement problem, Quantum mechanical description of the measurement process, Quantum mechanical description of the measurement process and POVMs, Decoherence
6	WM 4.1-4.4	Completeness of quantum mechanics, The correspondence principle (Realism versus empiricism, and correspondence), Complementarity in a wider and in a restricted sense
7	WM 4.5-4.8	Thought experiments (Diffraction of particles through a slit, The double-slit experiment), Meaning of the 'complementarity' concept, Critique of the complementarity principle, Complementarity, and empiricist interpretation
8	WM 5.1,	Formulation of the EPR problem in terms of physical quantities

	5.2	(The EPR reasoning and discussion of the EPR reasoning)
9	WM 5.3, 5.4	Bohr's answer to EPR (Criticisms of Bohr's answer to EPR), Formulation of the EPR problem in terms of state vectors
10	WM 6.1, 6.2, 6.3	Probabilistic and statistical interpretations of quantum statistics, Problems of an individual-particle interpretation (Spreading of the wave packet, Entanglement and Disentanglement by means of projection)
11	WM 6.4, 6.5, 6.6	To explain, or not to explain (Minimal interpretation Explanation by means of observables, Explanation by means of subensembles, Explanation by means of projection?), The EPR festival of confusions, Modal interpretations
12	WM 7.1-7.5	Introduction to generalized quantum mechanics, Inefficient photon detection, Quantum mechanical description of a double-slit experiment, Homodyne optical detection, Nonideal polarization measurement of a photon
13	WM 7.6-7.10	Theory of nonideal measurement, Partial ordering of nonideal measurements, Measures of nonideality or inaccuracy, Joint nonideal measurement of two observables, Complementarity in a joint nonideal measurement of two incompatible standard observables
14	WM 9.1-9.5	Introduction to the Bell inequality in quantum mechanics, Derivation of the Bell inequality from the existence of a quadrivariate probability distribution, The Bell inequality in an empiricist interpretation; relation to joint nonideal measurement of incompatible observables, The Bell inequality in realist interpretations, A Copenhagen-inspired empiricist approach
15		Revision