QM-06 Lecture Notes *

Postulate of Quantum Mechanics

Why begin with postulates?

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The inadequacy of classical theory and efforts to explain the observed physical phenomena led to a major revision of classical concepts and of the mathematical structure. Some of the earliest points of departure from the classical theory were discrete nature of physical processes, as in Plancks hypothesis and quantisation of dynamical variables, for example angular momentum in Bohrs theory. The wave particle duality had far reaching consequences and has changed the way we understand and do physics. Here we will briefly highlight the important points that are best seen to emerge from implications of wave particle duality on thought experiments. These are the indeterminacy, introduction of probabilities, uncertainty in simultaneous measurements of physical quantities. The principle of superposition has been known for the superposition of amplitude of waves and is responsible for the phenomenon of interference and polarisation. In order to correctly describe the particle nature of light, i.e., the behaviour of a single photon, in interference and polarisation experiments one is led to the principle of superposition of states. This superposition principle is not quite the same as in the classical theory of light. For example superposition of a quantum state with itself does not produce a new state.

In a double slit interference experiment for electrons we would expect to see an interference pattern as is the case for any wave. However, when the intensity of the incident beam is reduced and we seek the result of the experiment performed with a single electron, we are inclined to conclude that one would see a spot on the screen, and not an interference pattern, due to indivisibility of the particle nature. Still an interference pattern appears when the experiment is repeated with a large number of times. Within the commonly accepted interpretations of quantum mechanics, this is explained by associating a probability amplitude of electron reaching a point on the screen and accepting that the a prediction about exact location of the spot for in experiment with single electron is impossible and indeterminacy has entered in an essential way. It has to emphasised that the suggestion here is that indeterminacy is of fundamental nature of physical systems and not a limitation of the quantum theory.

An analysis of several thought experiments to measure position and momentum of particles simultaneously leads to the Heisenberg uncertainty principle which asserts that the

position and momentum of a particle cannot be measured simultaneously. This happens due to an uncontrollable disturbance, usually in momentum (position), when a measurement of position (momentum) is made.

We strongly recommend that the reader should go through a few pages of a terse but an illuminating discussion of superposition principle, indeterminacy, simultaneous measurement, and related issue from Landau Lifshitz. A 'teaser' from of this part of the book, reproduced below, should serve as an inducement for going to the original book.

Add a Teaser From Landau Lifshitz

Thus we are naturally led to ask the following, and many more, questions

- How are the states and dynamical variables are to described in quantum theory?
- How do we compute the allowed values of dynamical variables which may be quantised?
- What is the method to compute the probabilities of different possible outcomes of an experiment?
- Apart from position and momentum, for which other physical quantities a very accurate simultaneous measurement is ruled out.

The answers to these questions, and many more, will be obtained by an application of the postulates of quantum mechanics. Learning the postulates also keep allows us maintain a distinction between what is assumed and what is derived.

There are several different ways of formulating quantization applying to physical systems. In a different scheme the postulates and also technical details of any computation will ine general appear different. Remember that the postulates, to be described below, give us one scheme, Hilbert space approach of 'doing' quantum mechanics.