17 Probabilistic Determinism

It is often stated that, unlike classical physics, Quantum Physics is not deterministic. This statement is not really correct, but we need to define carefully what can and what cannot be determined. Very simply, this means that we can only determine the properties of a system that the system actually possesses (pretty obvious really!). In classical mechanics, given an initial condition, defined by the exact position and momentum of a particle at some time, Newton's laws of motion provide us with a set of equations, whose solution will determine the position and momentum of that particle at any subsequent time. The reason why this determination is not possible in Quantum Physics is simply because Heisenberg's Uncertainty relation prevents us from realizing the required initial condition. Remember that this uncertainty relation tells us that the particle does not possess well-defined position and momentum, so it is meaningless to ask whether we can determine them.

On the other hand, if a system is known to be in a certain quantum state, described by a wavefunction at time t_1, $\Psi(\mathbf{x}, t_1)$, then the solution to Schrödinger's equation gives us exactly the wavefunction, $\Psi(\mathbf{x}, t_2)$, at a later time t_2 – and therefore (provided we can solve Schrödinger's equation) we know the quantum state of the system at any later time.

From the wavefunction at any time, we can determine what is the probability that a measurement of the position of the particle will yield a value in a small range between x and $x+dx$. A well-defined mathematical procedure can be employed to determine the probability that a measurement of momentum will yield a value in a small range between p and $p+dp$. Since the wavefunction can be determined at any time, these probabilities can be determined at any time. So we see that we do get some information from the knowledge of a quantum state of a system. Although we are not able to determine the position and momentum of any particle in a quantum system, we can determine the probability that a measurement of its position will yield a result in a given range and similarly (by decomposing the wavepacket into its single frequency components) we can determine the probability that a measurement of momentum will yield a result in a given range - and the solution of Schrödinger's equation tells us that if these probabilities are known at some initial time they can be also calculated at any subsequent time. This means we do indeed have determinism, but only determinism of probability distributions of positions and momentum, as opposed to determinism of their exact values; these can be derived in classical mechanics, but clearly not in Quantum Physics since such exact values do not exist.

One of the reasons that we do not "understand" Quantum Physics is that we are uncomfortable with this probabilistic determination. However, we are quite used to this in other disciplines, such as the Social Sciences.

Suppose the Chancellor of the Exchequer (Minister of Finance) wishes to know what the extra revenue would result from an increase in tax on beer. (S)he would need to know how many people would reduce their beer intake as a result of the higher price and by how much. Civil Servants working in the treasury have models (theories) which enable them to calculate the probability that an individual would reduce his (her) beer consumption by a given amount (note that what is required here is a probability density $P(x)$ such that

$P(x)dx$ is the probability that an individual with reduce his (her) weekly consumption by an amount between x and $(x + dx)$. Provided the model used is correct, (i.e. that it is a faithful model of human behaviour) this is sufficient to predict the revenue gathered by the proposed increase in beer tax. However, no attempt is made to predict the behaviour of any one individual. Whether or not this might, even in principle, be possible, depends on whether it is the principle of pre-determination or the principle of free-will that correctly describes human behaviour. If pre-determination is correct, then the behaviour of any individual to an increase in beer tax is determined so that if we had a complete profile of the individual's biological and genetic structure together with a complete history of his/her past experiences, then a sufficiently sophisticated computer program could predict how (s)he would react to such an increase in tax on beer. In this sense the individual is being treated in a manner analogous to the "hidden variable" hypothesis. On the other hand, the free-will hypothesis argues that the decision of how to react is not pre-set and is only set by the person's free will when (s)he is actually confronted with the situation in which (s)he is required to make a choice. So far, we have not been able to devise an experiment which can unambiguously favour one or the other of the two viewpoints.

Probabilistic determinism in Quantum Physics is very much analogous to the above free-will example, (with the difference that it *has* been possible to devise and conduct an experiment which distinguishes between the predictions of Quantum Physics from those of the hidden variable hypothesis). If we go back to the double slit experiment, Quantum Physics (or simply wave physics) can be used to determine the probability that a particular photon will land at a particular position on the screen, but we cannot state exactly where it will land, since the photon does not possess the necessary properties that would enable us to make such a prediction. After this experiment has been conducted the fringe pattern which is observed will have dense regions such a probability density is high and sparse regions where it is low. Thus, although Quantum Physics does not allow us to determine where a particular photon will land, it does allow us to determine where we will find dense and sparse regions - and in this sense it is deterministic.

I regret to have to say that this limitation of determinism has theological implications. Most scientists will agree that Science and Religion can co-exist provided neither one encroaches on the domain of the other. Thus, for example, the theory of the creation of the Universe as expounded in the first chapter of the book of Genesis needs to be interpreted as, at best, symbolic. Likewise, one should not ask a scientist to determine at what point an admiration of the woman next door becomes an infringement of the tenth Commandment [38]. Theologians need to accept that the property of Omniscience assigned to the Supernatural has to be limited to knowledge of quantities that actually exist. In the Quantum world, we cannot determine when a particular cell will decay, since this is not a pre-determined quantity. All we can do is to determine the probability that a cell will decay after a certain period of time. This means that the time of death of any living organism (including us) is not pre-determined and cannot therefore be "known" to an Omniscient Supernatural being. On the other hand, it is perfectly possible that such an Omniscient Supernatural entity could be well aware of the fact that we covet our neighbour's wife, even if we have exercised sufficient self-control not to attempt to put our "secret" desire into practice.