Religion and the quantum world
Transcript

Date: Wednesday, 9 March 2005 - 12:00AM
Location: Barnard's Inn Hall
RELIGION AND THE QUANTUM WORLD

Professor Keith Ward

Richard Feynman has said that 'no one understands quantum mechanics'. He does not mean that the mathematics or the physics cannot be understood. There is no doubt that quantum mechanics is immensely successful at prediction. In practice it has been comprehensively confirmed, and is the basis for most of our computing and information technologies. It works. But what the theory might correspond to in objective reality is baffling, and there is no agreement among physicists on how to understand what it might be saying about the basic structure of physical reality. There is little doubt, however, that it undermines the theory that the physical world is made up of small particles that interact locally (by contact) in accordance with deterministic and completely knowable laws.

For quantum theory, there seems to be a complete difference between what the physical world is like when it is not being measured, and what it is like when observed. When not being observed, it is best described as a set of probability waves. To be specific, the square of their amplitude (the height of the wave from top to bottom) gives the probability that, if they were measured in a specific way, a particle would be found at a particular location. But the observer has a choice about what is to be measured, and waves can be described mathematically in a number of ways, depending on the sorts of measurements or observations that are of interest.

A measurement involves setting up an experimental situation in which the impact of particles is recorded on a phosphor screen or other recording device. The experimental apparatus constrains waves to ‘collapse’ into particles, the location of which can be predicted with a precise degree of probability. Waves themselves are never observed. We humans only see particles, or the evidence that particles have impacted on a screen or recording device in a specific way. We might therefore say that the apparatus selects for us out of wave-forms that we cannot perceive, particle impact patterns that we are able to perceive. At a specific point in time, the apparatus can freeze these patterns on some recording device, so that we can observe them later. The patterns that are chosen are precisely ones that we humans can perceive. So we might say that particles like photons or electrons are posited as frozen selections from wave-forms, selected because they are suitable for human perception.

WAVES AND PARTICLES

Which are real, waves or particles? On this opinions are divided, but what humans actually perceive in laboratory experiments are particles, or the impacts of particles. Waves are postulated to account for the patterns such impacts make. So while some theorists affirm that probability waves really exist, most physicists have a preference for particles, which at least are actualities, not just probabilities.

But that preference carries with it some unusual implications, very different from those of classical physics. For it seems that particles only really exist when they are observed. John Wheeler says, ‘No elementary phenomenon is a real phenomenon until it is an observed phenomenon’. Philosophers will recall the eighteenth century Anglican Bishop Berkeley's dictum that 'to be is to be perceived'. Nothing is real, the Bishop held, unless it exists in the mind of some observer, whether it is some finite spirit or the mind of God.

Known as Idealism, this philosophical view has been unpopular in recent times, partly because science seemed to suggest that nothing exists except material particles, and that the mind is no more than an accidental by-product of the material brain. In a totally surprising way, quantum physics is taken by some to show that Berkeley was more or less right, after all. Nobel Laureate Eugene Wigner writes: ‘The very study of the external world led to the conclusion that the content of the consciousness is an ultimate reality’. Particles only exist when observed, he suggests, and so the reality of particles entails that consciousness is a fundamental element of reality, not just a by-product of some ‘real’ material world.

Some, like Von Neumann, even suggest that nothing would be real unless consciousness exists, that all real things are
constituents of consciousness - which is a complete reversal of materialism. Most quantum physicists, however, suppose that there is some non-conscious reality underlying the phenomena we see. Particles are real, but only as phenomena observed by human consciousness. Particles do not exist when not being observed. They are how reality appears to us under specific conditions, from a specifically human point of view. Something may underlie them, but what it is, the true reality, is forever hidden, a ‘veiled reality’, as Bernard d’Espagnat puts it. This is a more moderate form of Idealism, sometimes associated with the philosopher Immanuel Kant. Niels Bohr admitted the influence of Kant's philosophy on his interpretation of quantum theory. What we know and experience of the material world is largely a product of our consciousness. But there is a 'hidden' reality underlying theseAppearances.

Many quantum physicists, perhaps even a majority, agree with this view. For this group of physicists – and they are some of the leading quantum theorists in the world - consciousness becomes of fundamental importance, as what gives form to reality as it appears to us. The world in itself, almost completely unknown to us in its essential character, must be distinguished from the world as it appears, as phenomenon. Consciousness, and its specific form, makes a difference to how things are perceived to be, and so consciousness is a constitutive element of reality, not just some by-product of a solid material world of real elementary particles.

An analogy is with perceived colour. Objects have no colour when they are not being observed, for colour arises when wavelengths of light refracted from objects impinge on the eye and coded information is transmitted to the brain. Objects have properties that give rise to sensations of colour when observed, but colour is not an intrinsic property of objects. So in the quantum world particles have no precise position or momentum. But probability waves, whatever exactly they are, generate such particles when they are observed in a specific way, or when they are fixed in time by an experimental apparatus that will give a precise position or momentum when observed.

**THE WORLD AS APPEARANCE**

Von Neumann suggests that the observer creates phenomenal reality. A less extreme view would be to say that the observer, and the nature of the observer's consciousness, creates the reality we perceive out of an underlying reality whose true nature must be forever hidden from us. Either way, it looks as if consciousness has a fundamental and ineliminable place in our conception of what the physical world is like. In other words, the physical is not simply there, apart from consciousness. Consciousness has to exist for physical reality to exist in the way it does, in relation to us – and we cannot get beyond that to a deeper reality, except in a purely mathematical sense. It is not just 'secondary qualities' like colour and smell that only exist in relation to a human observer. Now the very electrons and atoms out of which physical reality appears to be constituted only exist in relation to a human observer.

If we do get a hint of a deeper and more objective reality, it is by way of the pure mathematics of wave - functions and conceptual spaces that cannot be mapped onto any imaginable real world. Perhaps the underlying reality is purely mathematical, or more conceptual than material in any imaginable sense. Perhaps the very idea of brute matter, and therefore of materialism, must be given up, and replaced by the idea of a deep mathematical or intelligible world, which appears to us as a physical and phenomenal world - though that is only an appearance, partly constituted by our forms of perception.

There is an objective reality, but it is forever hidden, and it is deeply mathematical in character. It is remarkably like what Plato called the world of 'Forms' or 'Ideas'. The Forms are non-material, and they function as patterns or ideals to which things in the physical world approximate. Whatever this reality is, it is not material, in any ordinary sense. It might seem that, if consciousness is necessary for the world of Appearances to exist, so consciousness might also be necessary for the intelligible world of Forms to exist.

Physical things dissolve into Appearances, which exist in minds. So intelligible Forms, in the 'hidden' world of quantum physics, might also be realities that exist in some form of consciousness. Some mathematicians hold that mathematics is a construct of human minds. If that is so, and if mathematical truths are objective, if they exist apart from any human mind, perhaps they are constructs of a non-human, objective mind, the mind of God.

Such a hypothesis will appeal to anyone who thinks that, on the one hand, the truths of mathematics are constructed by mental activity, and on the other hand, that we discover mathematical truths, and do not simply invent them.

Disputes about whether mathematics is objective, whether mathematical truths are invented or discovered, and whether the
real world is more mathematical than material, cannot be decisively resolved just by appeal to quantum physics. That physics needs to be interpreted, and there are varying ways of interpreting it. But some major quantum physicists think the best interpretation is one which sees ultimate reality as non-material, as an intelligible or mathematical realm, and therefore as one which can be seen as pointing to an objective mind or consciousness which 'constructs' such mathematical truths.

As Heisenberg put it, ‘Atoms and elementary particles...form a world of potentialities or possibilities, rather than one of things or facts...atoms are not things’. Atoms are slices of probability waves, selected because they are observer-compatible. And probability waves, like mathematical entities, are more like mentally envisaged realities than like spatially localised and solid independently existing elements. In that sense, quantum theory makes respectable a reconstructed Berkeleyan view that all things ultimately exist in the mind of God.

**A PROBABILISTIC UNIVERSE**

Not only is the real world revealed by quantum physics not discrete and atomistic. It appears to show forms of causality that are non-deterministic. The standard interpretation of quantum mechanics - the Copenhagen interpretation, named after Niels Bohr of Copenhagen - is that there are genuine indeterminacies in nature. It is not just that we cannot predict the future. Some events happen, at the sub-atomic level, that are not completely determined by any previous physical state or by any physical law.

A probability-wave is exactly that. It cannot predict the position of an electron exactly, but only with a mathematically assignable probability. Such a probability, according to Bohr, is objective. That is, it is not just a limitation on human knowledge. An electron will probably be observed at a specific location, but there is a finite probability that it will not. The reason we cannot predict exactly where it will be is that there is nothing to determine where it will be. The future is open - within very precisely definable limits - and the electron may take one of several possible paths at random.

The Schrödinger equations, which predict the probable outcomes of particle experiments, are deterministic in mathematical form, but they assign only probabilities to patterns of observable particles. For quantum mechanics, the same cause can give rise to different effects. This was a great shock for those who thought that science must assume as a basic axiom that the same cause always produces the same effect. It is, however, welcome to believers in radical freedom, whose view of freedom is that the same initial situation can open up a number of different tracks into the future.

A paradigm of a morally relevant decision is when one alternative realises an objectively good state, and another realises the egoistic satisfaction of the agent. Believers in radical freedom, among whom I count myself, think that the ascription of praise and blame to humans depends upon agents being undetermined by anything other than themselves, their knowledge of possibilities open to them, their awareness of right and wrong, and their capacity to choose without compulsion, in crucial moments of moral choice.

Determinism is the view that every physical state is the only possible effect of preceding physical states plus the laws of nature. It depends on the axiom that the same cause always produces the same effect. If this axiom is undermined by quantum physics, the postulate of radical freedom becomes much more plausible.

**THE PRINCIPLE OF INDETERMINACY**

We should not, however, confine human freedom to the realm of quantum indeterminacy. Quantum indeterminacies occur at minute dimensions, and normally cancel out over millions of cases, so as to give rise to the orderly world we see around us. The importance of quantum theory is not that it proves that radical freedom really exists. It might seem much too restrictive to make morally responsible free acts depend on tiny random events in the sub-atomic realm, which mostly cancel each other out. It is not even that the principle of indeterminacy proves the world is not deterministic – since as I will mention in the next section, it may yet be possible to provide deterministic accounts of quantum theory. What quantum theory shows is that determinism is not necessary to good scientific procedure and explanation. Indeterminism within specifiable limits of probability does not undermine scientific explanations. In fact the majority interpretation of quantum physics is actually indeterministic, so that much available scientific evidence counts against determinism. What the principle of indeterminacy shows is that radical freedom is in principle possible, though I think the indeterminism involved would have to be at the level of ordinary life, not at the sub-atomic
Science can work very well with indeterminism, so the existence of radical free will at the supra-atomic level would not contradict scientific methodology, which already accepts that the same situation can generate different effects at the quantum level. There is thus no scientific barrier to indeterminism at the everyday level. No scientific laws will be broken if humans can on some occasions determine by an act of will, not itself scientifically observable, that one future rather than another should become actual.

This thought is reinforced by the fact that there is no hope of proving that, on every occasion, one and only one future outcome is possible. It is, after all, an extremely ambitious statement to say that there is only one possible future at any stage of the existence of the universe. How could we possibly establish that no other track into the future was even possible? As the philosopher David Hume put it, what strange sort of necessity would it be that ensured that every causal situation could have one and only one effect?

It does not look as if we could ever establish such a thing scientifically. We simply cannot know that we have exhaustively specified every causal feature in any real life situation. We do not have the resources to measure all real life situations in a rigorous experimental way. The sciences rely on experiments made in controlled conditions that consider only a selected group of data. Generalisations from such carefully controlled conditions to everyday life should only be made with caution - as any practical engineer can testify.

In any case, quantum physics shows that it is impossible to gather exhaustively all possible information about any given state. Heisenberg’s uncertainty principle prevents us being able to measure precisely both the position and momentum of a fundamental particle, and so it prohibits complete knowledge of any physical state. Thus we cannot know the precise causal conditions at any stage of the universe’s existence. That means that we can never be in a position to say precisely what effect is bound to follow from such causal conditions.

We can never conclusively test whether physical determinism is true - whether one and only one precise effect is bound to occur, given any causal state and the laws of physics. That is because we can never establish exactly and exhaustively what any specific causal state is, and therefore we can never predict exactly what effect is bound to follow. That does not mean physical determinism is false. But it does mean that its truth cannot be scientifically established. Physical indeterminism is thus fully consistent with present science, it is accepted by most quantum physicists, and it cannot be scientifically disproved. That is a fairly strong position for a theory that common sense and morality presuppose when they assume that at least some physical organisms - namely, human persons - are sometimes free to choose which track into the future they will take.

Whatever the truth or otherwise of determinism, it is certain that many causal outcomes can only be predicted in a probabilistic or statistical way. The development of chaos theory shows that dynamic systems far from equilibrium have the property that minute fluctuations can, in the right circumstances, have large-scale effects. We have all heard the story of how the flap of a butterfly’s wing can cause a hurricane on the other side of the world. The point is that we cannot predict many ordinary states (like the weather) if they depend on fluctuations in minute sub-atomic conditions. Quantum theory shows that there are such fluctuations, which are themselves unpredictable in detail. Therefore deterministic prediction, of the sort hoped for by LaPlace, is in principle impossible.

All this does not prove that freedom and creative spontaneity are objective features of the universe. What it shows is that determinism cannot be proved, that it is not needed for good science, and that most scientists these days do not accept it. All the standard interpretations of quantum theory posit that the cosmos changes in accordance with causal principles that are stochastic or probabilistic. To most modern scientists, it looks as if the universe continually moves into an open future by probabilistic processes. It is a plausible generalisation from this that similar processes may occur at the atomic and molecular levels. Suitably complex organisms may give rise to acts of creative spontaneity and responsible freedom in a world that lays down a number of alternative tracks into an open and undetermined future. That is a very different picture than that of the heirs of Newton and classical, largely deterministic, physics.

**THE QUANTUM WORLD**

It must be stressed that this whole area of physics is still a realm of deep disputes. Einstein never accepted that a statistical theory could be complete, and so maintained to the last that ‘hidden variables’ could one day be found that would eliminate
probability. The physical world, he believed, did consist of objective events that could in principle be modelled by a complete physical theory that would not be indeterministic, and would not speak of such strange objective realities as probability waves, superimposed realities, collapses of wave functions and non-physical interactions between fundamental particles.

This does not entail the sort of ‘universal physical determinism’ that was inspired, however oddly, by Newtonian mechanics. It affirms that there are real physical particles and real non-probabilistic causal laws, and so restores a generally Newtonian view of the physical world. But it need not deny, any more than Newton did, that there are also non-physical causal factors in reality with which the physical sciences do not deal.

In any case such a theory is not within sight, and even the most ardent Einsteinian would have to agree that the hope to find a ‘realist’ view of fundamental particles that are more or less ordinary physical entities is a matter of faith. God may not play dice with the universe, but it looks as if God does!

David Bohm developed a theory that would restore determinism to fundamental particles, but only at the cost of postulating a mysterious ‘pilot wave’, without energy, probably unobservable, conveying information faster than light. His precise theory has not convinced many physicists, but it shows that quantum physics does not necessarily rule determinism out. It also shows that physicists are nowhere near having a complete knowledge of the bases of matter. They are as yet unable to reconcile relativity and quantum theory in one coherent explanatory theory. Perhaps determinism is not, after all, dead. But it is absolutely not established by the sciences, and remains little more than a philosophical dogma.

Furthermore it looks as though any adequate account of both determinism and matter will be very different from any simple picturing theory of intuitively clear realities. The quantum world is one of virtual particles continually fluctuating in and out of existence, even in a vacuum, of superstrings vibrating and twisting in ten or eleven dimensions, most of which are ‘rolled up’ and invisible, of a reality in which gravitation, spacetime and matter are or were merged in one ‘instanton’ (a postulate of Hawking and Turek). This is not anything like the classical materialist world of small massy particles bumping into each other forever.

Determinist or indeterminist, the reality with which modern physics deals is one in which imaginary time (using the square root of minus one as a constant) seems more real than real time (which flows from past to future), in which spacetime can be finite, unbounded and expanding without expanding in anything, and in which new spacetimes can possibly be generated inside ‘black holes’. This is a world far beyond common sense and visualisation. So even if the Copenhagen interpretation of quantum physics turns out to be wrong, modern physics still shows the world to be a deeply intelligible, mathematically beautiful reality that is very different from anything the senses perceive. An important part of Platonism is the view that says the senses provide only Appearances, whereas Reality is purely intelligible and knowable, if at all, only by mind. In this sense Platonism, it seems, has returned in triumph, now guided and tested by observation and measurement, but erected on a foundation of intellectual beauty, perceptible only by mind, a world of concepts and numbers appearing to us as a world of material objects constructed by our senses.

ENTANGLEMENT

Another major feature of quantum theory, which seems to be very well established but is also astonishing, is quantum entanglement. It seems that change is not always brought about by objects bumping into one another in space, but can be effected instantaneously in non-local ways (that is, between entities widely separated in space). There are apparently non-local, superluminal (faster than light) connections between particles that have once interacted. The Bell Theorem, constructed by CERN physicist John Bell in 1964, states that elementary particles are ‘entangled’, that once waveforms meet, they continue to influence each other even at vast distances. Niels Bohr writes, ‘The inseparable quantum interconnectedness of the whole universe is the fundamental reality’.

It has been known since 1864, when Maxwell invented field theory, that the waves that constitute physical reality are infinite in extent. Gravity extends as far as space extends, though it is so weak at great distances that its effects are not discernible. Quantum theory goes further. Not only are its waves probability-waves, so that they are only physical in a very strange sense. They are also connected in what must be a non-physical way, since nothing can travel faster than light, yet particles instantaneously correlate with one another over vast distances.

Everything in the universe is connected to everything else in the universe in a non-physical way, yet a way which produces real
and observable physical effects. So Bohr says, ‘Isolated material particles are abstractions’, and Einstein wrote, ‘A human being...experiences himself as something separated from the rest – a kind of optical delusion of his consciousness’. We seem to be independent beings, but in fact we are parts of an interconnected unitary universe, each part of which has effects on every other part. It is our private consciousness that gives rise to the universe of solid physical objects that we perceive, and it is, says Einstein, ‘a delusion’.

The word ‘delusion’ is rather strong, but the word ‘appearance’ seems appropriate. In this phenomenal world, we seem to be separate independent beings, but in reality all beings are strongly interconnected or entangled. That does not mean, as Einstein’s words may suggest, that we are not autonomous individuals, with our own distinctive sense of self. But it does mean that we are not as easily disconnected from our environment as we might think. We are internally, not just contingently, connected to it after all.

If we could see reality as it is, we would see that we could not have come to exist in any universe other than this, and that even small changes in our small part of the universe may have effects at immense distances and in quite unforeseen ways. It may seem as though we could just make some changes that would make this world better – remove pain, for instance. But it may be that the changes this would produce in the complex waveform that is the universe would be absolutely devastating. The possibilities for changing the universe radically may be much narrower than we imagine. The dream that sometimes occurs to each of us, that we, just as we are, could have existed in a much better universe, could never become real.

THE VEILED WORLD

The quantum world is extremely strange, and it may be that some new theory awaits that will change our view of basic physical reality in an unforeseeable way. But it is vastly unlikely that physics will ever return to the sort of simple materialism that some (wrongly) thought to be an implication of Newtonian mechanics. Reality is not the world it appears to be to common-sense observation. It is a world in which every part is connected to every other, so that discrete entities are slices out of overlapping and dynamic fields of potentiality. Particles are what appear to us, with our form of consciousness. Complete knowledge of the underlying reality is forever hidden from us, yet the structures we can know have an elegance and beauty that is astonishing.

In the face of this theory, I think we have to renounce the possibility of complete understanding of physical reality, and yet celebrate its immense intelligibility and complexity. A veiled, interconnected, probabilistic, and yet wholly intelligible reality underlies the physical reality in which we live and move and have our being. Quantum theory is, of course, neutral as to the existence of God. There are quantum theorists who deny the existence of any personal creator of the universe. But they would accept that the ultimate nature of physical reality is not the world of discrete and solid atoms circling in the absolute space and time of Newtonian mechanics. It is a literally unimaginable world of elegant beauty, which is more mathematical or intelligible than material (i.e. solid and precisely located in space). It is a quasi-Platonic world, exhibiting a complex interplay of chance, intelligibility and necessity. We discern a minute part of the phenomenal appearance of it, as its internal dynamic structures of possibility creatively actualise into the diverse observed forms of space - time and into us. It is a natural, though not forced, step from here to make the move that Augustine made in the fifth century CE, and set this veiled reality within the mind of God. Such a God would not be a person external to the universe, interfering with it from time to time. It would be more like the mind of the universe itself, the ultimate reality within which all things, intelligible and physical, exist, and part of the infinite reality of which all things express. For many quantum physics, this is a rational and plausible interpretation of how the cosmos ultimately is. It moves God much closer to the centre of the scientific view of the world, and makes belief in God, if not compelling, at least highly plausible.