

Why the Quantum?

Quantum Theory appears to many as strange, unwelcome, and forced on physics as it were from outside against its will. In contrast, if the essential point could be grasped in a single phrase, we can well believe that the quantum would seem so natural that we would recognize at once that the universe could not even have come into being without it.¹

- John A. Wheeler: physicist

Perhaps, in some sense, this is 'why' we, as sentient beings, must live in a quantum world, rather than an entirely classical one, despite all the richness, and indeed mystery, that is already present in the classical universe. Might a quantum world be *required* so that thinking perceiving creatures, such as ourselves, can be constructed from its substance?²

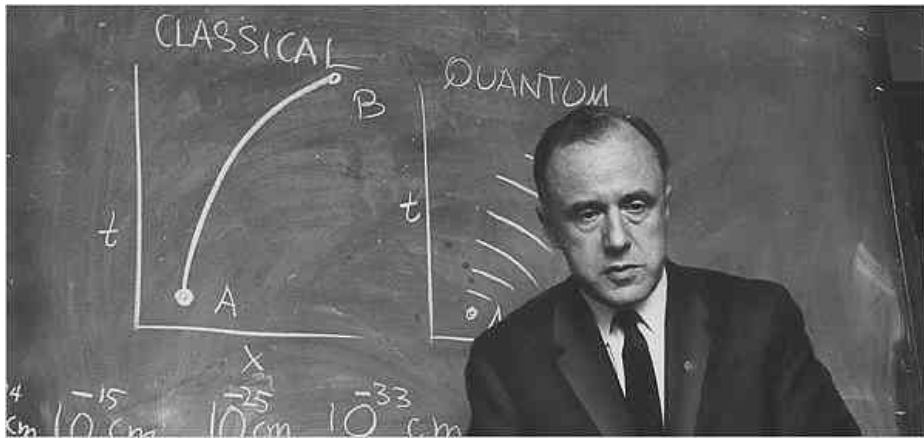
- Roger Penrose: physicist

Whatever is dependently arisen
Does not arise, does not cease,
Is not permanent, is not extinct,
Does not come, does not go
And is neither one thing nor different things.³

-Nagarjuna: Madhyamika philosopher

It's character is neither existent, nor non-existent,
Nor both existent and non-existent, nor neither.
...true reality ...is free from these four possibilities.⁴

- Bhavaviveka: Madhyamika philosopher



John Wheeler

John Wheeler, one of the great physicists of the twentieth century, indicated that the solution to the question ‘why the quantum?’ might contain the solution to the question of existence itself:

...eventually we will have an answer to the question ‘How come the quantum?’
And to the companion question, ‘How come existence?’⁵

According to Wheeler, then, the answer to the question concerning the quantum nature of reality might contain the answer to the question which the philosopher Heidegger considered to be the most important question for philosophy; ‘why is there something rather than nothing?’ The confrontation between the everyday world and the quantum world leads us to the very limits of what we can know about reality. And according to Wheeler the solution to the question regarding why the world has a quantum basis will provide an insight into the nature of existence itself. This is, indeed, an extraordinary possibility which should be sought at all cost.

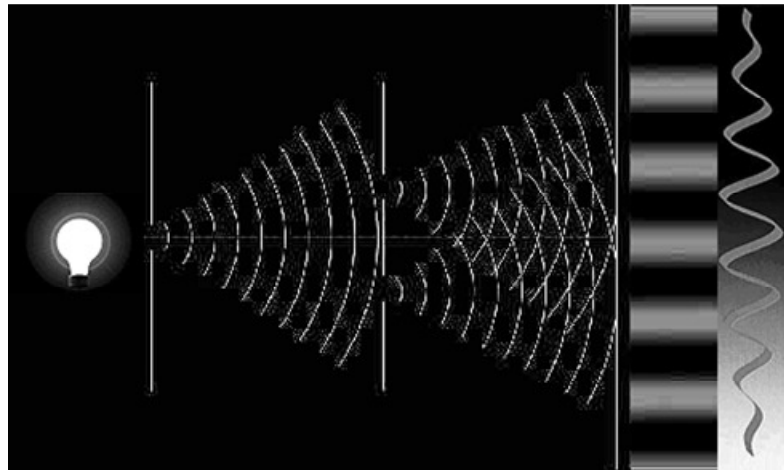


Fig 3.1

For those not acquainted with the bizarre world of quantum reality the following example, which is the modern version of the eighteenth century Thomas Young experiment referred to in the second chapter, will serve as an introduction. According to Richard Feynman this experiment is ‘designed to contain all of the mystery of quantum mechanics.’⁶ Jim Al-Khalili refers to the behavior displayed in this experiment as ‘nature’s conjuring trick’⁷, a very apt rubric. When light is shone through two narrow slits onto a screen beyond the slits (Fig 3.1) the light rays, which were originally thought to be continuous electromagnetic waves, interact with each other to produce a pattern of light and dark strips. This happens because the light waves which meet from the different slits are either in phase, in which case they reinforce each other, or they are out of phase, in which case they cancel each other out; areas where the light waves are in phase are bright, and where they cancel dark areas are produced (fig 3.2).

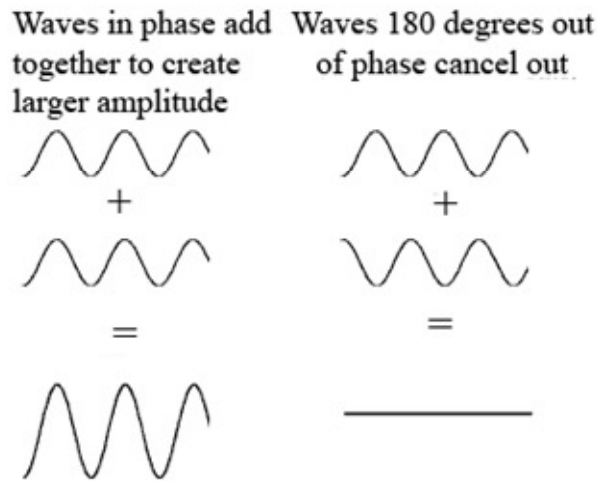


Fig 3.2

So far the situation may not seem at all outlandish. There are waves going through the top slit and waves going through the bottom slit. The waves go through one or other of the slits and interfere on the other side. But this picture is not quite correct. Light is actually made up of ‘particles’ of electromagnetic waves called photons; which are little pieces of electromagnetic vibration which should be indivisible. Even now there is no problem, we can think that some of the particles go through the top slit, others through the bottom, and then they interact to produce the light and dark pattern on the other side.

Now we introduce the conjuring trick; we send the particles, each one of which should be an indivisible wave-particle, through the slits one at a time. Because we are sending light particles through the apparatus one at a time it would seem reasonable to suppose that they would go through either the top slit or the bottom slit. It also seems reasonable to suppose that there will be no other wave-particles on the other side to interact with, so we would not expect to get the light and dark stripes, which should only occur because of the interaction of many waves going through top and bottom slits at the same time. There should be just two stripes, one for each slit.

This, however, does not happen. The light and dark interference pattern still remains just as it was when a lot of wave-particles were going through the slits. How can this be? What is the wave-particle doing? Although the wave-particle does have a wave aspect it is also supposed to be an indivisible particle which should travel like a particle, which means it should go through just one of the slits. It should not, according to common sense, go through both slits.

Now suppose we decide to really find out what is going on; we change the experiment so that we place detectors at each slit to see through which slit the wave-particles travel. As soon as we do this the interference stripes disappear. It seems as if just looking at the slits to see what is happening changes the way that the wave-particles behave. It actually appears that if we do not look the wave-particle divides itself up, in a way that it should not be able to, in order to go through both slits. As soon as we look, however, it changes its behavior so that it goes through just one of the slits. It appears to ‘know’ when we are looking. When we look, then, we find that it is a particle. But when we do not look, it becomes something else. And this something else seems to be able to do the impossible. It divides itself up, whilst still remaining one indivisible thing, and then comes back together on the other side. Jim Al-Khalili likens this to a skier going around a tree on both sides (fig 3.3).

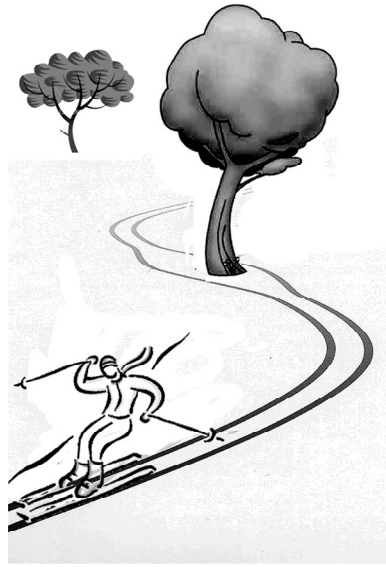


Fig 3.3

This not only happens with light wave-particles, it also happens with electrons, protons, atoms, and molecules, all of which have a quantum wave aspect. When there is no way of knowing which path the ‘particles’ take the interference pattern appears, which seems to suggest that they take both paths, even though this should be impossible because the particle aspect should be indivisible. When we know which path is taken, however, the interference pattern disappears. The remarkable implication of this evidence is that conscious interference in the experiment has a direct effect at the quantum level. As Rosenblum and Kuttner say:

Physics had encountered consciousness and but did not yet realize it.⁸

It looks as if the nature of the quantum realm is surprisingly mutable and is able to respond to the entire configuration of the experimental apparatus, including the observers and the nature of the observation.

This kind of quantum behavior is often presented as being totally in-comprehensible. However, the first opening quote from John Wheeler suggests the necessity for grasping the ‘essential point’ concerning quantum reality which can ‘be grasped in a single phrase’ that reveals that the quantum world is ‘so natural that we would recognize at once that the universe could not even have come into being without it’. The experimental physicist Anton Zeilinger, who has carried out some of the most precise and subtle quantum experiments currently possible, has written in appreciation of Wheeler’s work of his:

...realization that the implications of quantum physics are so far-reaching that they require a completely novel approach in our view of reality and in the way we see our role in the universe. This distinguishes him from many others who in one way or another tried to save pre-quantum viewpoints, particularly the obviously wrong notion of a reality independent of us.⁹

Can we find an ‘essential point’ which can ‘be grasped in a single phrase’ which supplies ‘a completely novel approach in our view of reality and in the way we see our role in the universe’ which rectifies ‘the obviously wrong notion of a reality independent of us’ and is

also ‘so natural that we would recognize at once that the universe could not even have come into being without it?’

As we shall see, the concept of Emptiness, or dependent co-origination, one of the core concepts of the Madhyamaka, the central philosophical foundation of Mahayana Buddhism, is certainly a good candidate. It is vital to understand at the outset that Emptiness does not mean the same as nothingness. The concept of Emptiness refers to the fact that the Madhyamaka analysis of the process of reality has uncovered the lack of ‘inherent existence’ in all phenomena; so the Madhyamaka describes all phenomena as being *empty* of inherent existence; phenomena have no inner independent essence which cuts them off from the rest of reality, and it because of this that all phenomena are responsive to all other phenomena.

The concept of emptiness is introduced in the third opening quote, from the great second century Madhyamika¹⁰ master Nagarjuna. It illuminates what the Madhyamaka asserted, roughly two thousand years ago, about the inner nature of reality. All phenomena are illusion-like, interdependent appearances which, contrary to the nature of their appearance, lack any independent self-substantiality:

Since these phenomena without existence are devoid of a core ...
If those who assert true existence were indeed correct,
How could these phenomena fit into space?
...sever the ropes of grasping conceptions this instant;
...illusions that project appearances but do not exist.¹¹

Truly existent phenomena could not fit into space because to do so they would have to have a relationship with the phenomenon of space, in which case they would not be completely independent of all other phenomena. ‘True existence’ is a synonym for ‘inherently existent.’ Our natural manner of relating to the objects that surround us in everyday life is to believe that they are truly or inherently existent, which means they are completely self-enclosed and independent entities. It is this picture of ‘things’ that the Madhyamaka seeks to undermine. Although the world appears to truly exist, this picture is deceptive; when we come to grasp the significance of emptiness it will become apparent that ‘true existence’ is, like a ‘horn of a rabbit’¹², non-existent.

An important difference between ‘true existence’ and the notion of a ‘rabbit’s horn’, however, is that everyone knows that rabbits do not have horns. There is no need to construct sophisticated philosophical techniques of analysis to prove the lack of rabbit’s horns in reality. ‘True existence’, however, is a different kettle of fish. According to the Madhyamaka the perception of true existence is virtually a universal mode of perceiving the world. It is an innate mode of perception which has been ‘hard wired’ into the perceptual apparatus of all unenlightened sentient beings. The natural way to apprehend the numerous objects that we interact with in everyday life is simply to treat them as if they existed from ‘their own side’, completely independent of our, and everyone else’s, mind. We also assume that each object is self enclosed, so to speak, and cut off from all other objects. This is an innate mode of understanding the world, and it was the mode which underpinned the pre-quantum ‘classical’ understanding of the physical world:

...the world is regarded as constituted of entities which are outside of each other, in the sense that they exist independently in different regions of space (and time) and interact through forces that do not bring about any changes in their essential natures.¹³

The point is that such ultimate ‘things’ must be self-enclosed and independent of all other things.

The concept of emptiness actually has several levels of understanding, each succeeding level more subtle than the previous. However it may be considered as beginning from an analysis of ‘thinghood.’ This is an example of how the Madhyamaka gets to the heart of reality from very humble beginnings. Very few people, West or East, stop to think about the

way in which they conceive reality down at a basic level, or the implications of this unexamined assumption. According to the Madhyamaka the untrained mind invariably conceives of ‘things’ as being ultimately unchanging, self-enclosed and independent. We may pay lip service to the obvious fact that ‘things always change’, but deep down the mind thinks of ‘things’ as things which do not change. And the point that the Madhyamaka succinctly makes is that such self enclosed and independent entities could not exist. According to the *Sagaramatinirdesha-sutra*:

Everything arising by dependence,
No ‘thingness’ does it have in any sense.
All that is devoid of entity
Does not arise in any way.¹⁴

And from the *Hastikakshya-sutra*:

A thing that in itself is truly born
Is utterly beyond our observation.¹⁵

And from the *Ratnakara-sutra*:

All things are devoid of entity.¹⁶

When a ‘thing’ is conceived of as being inherently existent it must be un-changeable, it must have inner core of reality which is immutable. If some-thing is inherently existent its thinghood requires an inner unchanging essence which makes it what it is. The Madhyamaka has always denied the possibility of this kind of ‘thing’ actually existing in reality. A point of view which, when fully comprehended, has deep and remarkable ramifications.

The significance of the Madhyamika rejection of thinghood may not be immediately obvious, and may seem irrelevant, because we are so used to thinking about ‘things’ relating and interacting with each other all the time. But the Madhyamaka is relentless and draws attention to the fact that it is a basic requirement of an *ultimately* real ‘thing’, so to speak, to be unchangeable. This is the conception of thinghood which seems inherent to the human mind; even if we let the boundaries of the conception slip and become fuzzy for everyday convenience. But during any interaction ‘things’ change to accommodate the interaction and therefore do not remain in their state of self enclosed thinghood. When we speak of ‘things’ in everyday life we are employing the term loosely for convenience. But in actuality something which changes into some ‘thing’ else can’t be the ‘thing’ we thought it was because it has ceased to be that ‘thing’ so has lost its thinghood. Ultimate things actually must for ever maintain an unchanging self-enclosed aloofness from all other things in order to maintain their thinghood.

According to the Madhyamaka this notion of things is not a merely surface phenomenon. The idea that things exist as independent self-enclosed and self-powered entities is a very deep assumption within the minds of all sentient beings. It is like one of Kant’s categories of thought, or perception, which resides deep within the human psyche; because of this the notion of inherent entities creeps into all corners of human thought. It was certainly a fundamental aspect of pre-quantum physics and it still undermines a full appreciation of the full implications of quantum physics, leading to the fragmentation of views described in the first chapter.

The second opening quote, from Nagarjuna, is a pithy summing up of the implications of the view that all things are ‘empty’ of ‘inherent existence’. To comprehend the unsettling and counter intuitive play on concepts it is vital to hold in mind that the following paradoxical analysis applies to some ‘thing’ which is considered as ‘arising’ as an inherently existing thing, which is a changeless entity that is independent of all other entities:

Whatever is dependently arisen

Does not arise, does not cease,

An inherently existing entity would have to be changeless and therefore, by definition, could not 'arise' simply because it cannot come into or go out of existence! Here we find the notion of dependent origination, which is the hallmark of emptiness, what is being asserted here is that if something arises dependently then it does not arise as an inherently existent entity and neither can it cease as an inherently existent entity because it has not arisen in the first place! Furthermore, inherently existent entities cannot cease by definition. Something which arises on the basis of something else cannot be given credence as being a 'real' thing because it has arisen in dependence on something else, so it is not self-powered, it depends on something else. It follows that this illusory 'thing', which means an inherently existent 'thing', that we might think has come into inherent being has not actually arisen because it's not actually there as an inherently existent entity! It cannot, inherently, cease because there is nothing inherently existent to cease.

The next line is:

Is not permanent, is not extinct,

It cannot be permanent because it appeared to arise in the first place and because of this it cannot become extinct because there was never anything inherently existent to become extinct!

Does not come, does not go

Something which has not come into existence (as an inherently existent thing) can not come or go!

And is neither one thing nor different things.

It cannot be one inherently existent thing because it has arisen and so is not an inherently existent thing in the first place. It cannot be different things because the analysis would apply to each of those things in turn and, anyway, it has appeared as being in the guise of one thing. The Madhya-maka begins, then, with a complete demolition of the notion of ultimate things and ultimate thinghood, which it denotes by the term 'inherent existence', 'intrinsic existence' or own-nature (*svabhava*).

It might be thought that such a paradoxical deconstruction could not be of much relevance to the problems of quantum physics. However, the problems of quantum interpretation can be traced, in part, back to the disappearance of the 'things' of classical physics. As Lee Smolin says:

Quantum physics tells us, no it screams at us, that reality is not composed of things.
It is made up of processes...¹⁷

So the disappearance of 'things' from the conceptual armory of physics is obviously important to the quantum revolution. But things (!) are not quite as simple as that. What is a quantum entity? The simplest answer might be that it was a wave packet of energy. But if a quantum 'wave-packet' is not a 'thing', what is it?

A deep problem that faces quantum physicists is this: although they have developed mathematical tools to describe and predict the functioning of the quantum world, they do not have ordinary concepts, so to speak, because none of our ordinary concepts apply to what seems to be going on. And, make no mistake, the difference between the way 'objects' behave at the quantum level and the everyday level is dramatically different. The constituents of the quantum realm behave in such a bizarre manner from the point of view of our ordinary reality that it seems almost impossible to explain how our everyday world can

possibly develop out of the quantum world. In the quantum world ‘things’, using this term very loosely, do not have definite boundaries the way that they seem to do in everyday life. They partially exist in many different states at the same time whilst waiting to be discovered in one of their possible states. And, it seems, that the only time that these nebulous partially existent entities at the quantum level decide to ‘get real’ is, like the wave-particle going through a slit, when someone looks at them.

The extraordinary nature of the quantum experimental results indicating that the attributes of reality are created by consciousness cannot be over-emphasized. In their book *Quantum Enigma* Rosenblum and Kuttner refer to the fact that at the quantum level physics has run up against the issue of the nature of consciousness as physics’ ‘skeleton in the closet.’ Most physicists have been, and still are, uncomfortable with this conclusion because of the far reaching implications. Rosenblum and Kuttner, however, are adamant about their conclusion:

Consciousness and the quantum enigma are not just two mysteries; they are *the* two mysteries; first, our physical demonstration of the quantum enigma, faces us with the fundamental mystery of the objective world ‘out there;’ the second, conscious awareness, faces us with the fundamental mystery of the subjective, mental world ‘in here.’ Quantum mechanics seems to connect the two.¹⁸

In the West the nature of consciousness is generally considered to be problematic and difficult. ‘Consciousness remains a mystery,’ as one leading light in the field of consciousness studies, paradoxically, pronounces¹⁹. Within Buddhist philosophy however, the nature of consciousness is deeply understood both through direct experience and rigorous philosophical analysis; and this understanding can shed light on many of the problems of understanding how the quantum realm and consciousness interconnect. As we shall see later the Yogacara²⁰ perspective gives a remarkable account of the functioning of reality which may be conceived of as embracing the ground quantum field of reality which can only be of the nature of consciousness.

There is an enormous gulf between quantum entities and everyday objects, the two spheres of reality, so to speak, appear to be so different that it seems impossible that the everyday world appears from the quantum; and yet it does. The confrontation between the everyday world and the quantum world leads us to the very limits of what we can know about reality. So, if Wheeler is correct about the enormous philosophical import of understanding the nature of quantum reality, the possibility of a deep knowledge of the essence of reality lies at the boundary between the quantum realm and the everyday world. We know that the quantum realm cannot be a figment of the imagination of a group of mad scientists; we have cd-players, camcorders, mobile phones, and computers and so on. The technology of the last one hundred years depends upon our knowledge of quantum physics. We also know that there is a very different realm of our direct experience of our everyday world. And, if Wheeler is right, the solution to the question of existence is to be found in understanding the nature of the boundary between the two.

It is here that the Madhyamaka can offer significant insight. There is a very deep reason why the world must be quantum in nature; and this reason is connected to understanding the deep nature of existence. Furthermore this understanding is illuminated by an appreciation of the remarkable Madhya-maka exposition of the concept of Emptiness according to which the apparent ‘things’ of the everyday world function as if they were real ‘things’ because they actually do not fully exist! They appear to exist as independent entities but in actuality in their ‘ultimate’ nature they hover between existence and non-existence. As the Madhyamika Bhavaviveka (1st-2nd century) indicated the character of reality is

Neither existent, nor nonexistent
Nor both existent and nonexistent, nor neither.
...true reality
...is free from these four possibilities.²¹

This assertion indicates that Emptiness can be considered to be fundamental level of reality which somehow 'hovers' between existence and nonexistence. The reader might at this point think that this must be pushing the limits of comparison between abstruse and impenetrable Buddhist mystical musings and the modern science of quantum physics to breaking point. But this is not so. The Madhyamika analysis was meant to be, and is, a precise analysis of the inner nature of reality, and it corresponds to discoveries of quantum theory in a remarkable fashion.

The paradox of Schrödinger's cat is a famous quantum conundrum by which Schrödinger indicated to Einstein that quantum weirdness must have everyday implications. A cat which is sealed inside a container in such a way that its life or death depends upon a probabilistic quantum event must actually hover between existence and nonexistence. The following is from science writer Marcus Chown's book *The Never-Ending Days of Being Dead*, which contains entertaining elucidations of cutting edge physics:

So, what of a water droplet that hovers half in existence and half out of existence? It goes without saying that nobody has actually seen such a schizophrenic water droplet ... Where does the quantum weirdness go.²²

Here Chown clearly indicates that the condition of hovering between existence and non-existence is precisely the nature of 'quantum weirdness'. So it is somewhat remarkable that the Madhyamaka asserts that the empty nature of reality, which is indicated by the fact that the ultimate nature of reality is a hovering between existence and non-existence, is essential for the universe to function:

If things were not empty of inherent existence, nothing could function...It is their emptiness of inherent existence that allows everything to operate satisfactorily.²³

The term 'things' here refers, of course, to the 'things' of 'seeming' reality, the way that reality appears within the minds of everyday sentient beings.

In the light of this assertion that emptiness is essential for the manifestation of the world of experience we might ask whether there is anything within quantum physics that corresponds to this claim. In a recent work the science writer Michio Kaku tells us that:

The reason why molecules are stable and the universe does not disintegrate is that electrons can be in many places at the same time.electrons can exist in parallel states hovering between existence and non-existence.²⁴

The ability of a quantum particle to be in two places at the same time, whilst still maintaining an identity as a single entity, is a feature of quantum behavior that is absolutely crucial for the functioning of reality. It is a primary feature of the quantum world that from a classical perspective should be completely impossible. The fact that quantum entities are fundamentally wave-like, however, makes this magical trick, which is given the name 'delocality', inevitable.

Quantum delocality is the mechanism which accounts for alpha decay of a radioactive nucleus. The radioactive elements are those that have heavy nuclei, with many protons and neutrons; Uranium 238, for instance, has 92 protons and 146 neutrons. Such large atoms have unstable nuclei and on occasion a very stable combination of 2 protons and 2 neutrons, an alpha particle, forms internally as a single unit. If the alpha particle were completely 'localized' inside the nucleus it would not be able to escape. But the alpha particle is actually, when not observed, not a particle. It only displays its particle-like face when it is observed. In the absence of detection there is only a wavefunction of probabilities and:

Schrödinger's equation predicts that ... the alpha particle's wavefunction may be sizable at very large distances outside the nucleus. This is because

wavefunctions have wave-like properties and therefore are not confined by the same rules as particles.²⁵

The alpha particle, then, is able to jump the boundary which contains it within the atom.

This mechanism, which is a consequence of the fundamental wave nature of the unobserved quantum realm, is called 'quantum tunneling'. For instance when an electron is confined inside a box it has a probability wave as shown in figure 3.4

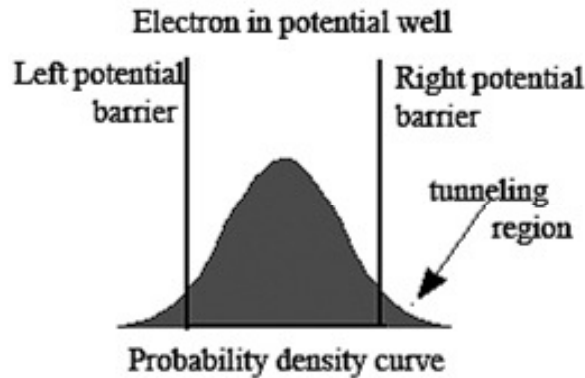


Fig 3.4

There is a non-zero probability that the electron can be found outside the box. Because of this an electron which is supposedly trapped inside a container will sometimes 'tunnel' to the outside of the box. Because the electron is a 'smeared out' probability wave, part of this wave will actually already be on the right hand side, so sometimes an electron can 'tunnel' through the barrier (fig 3.5).

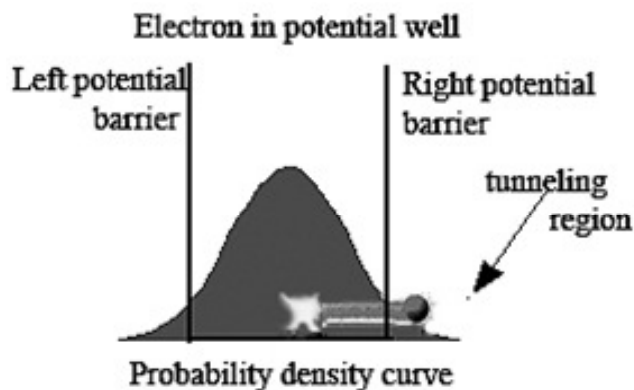


Fig 3.5

The electron does not literally tunnel through, but, because it has a fundamental wave nature it already has a quantum probability of being over on the right hand side, and because it has this probability of being on the other side of the barrier, it has to sometimes appear on the other side of the barrier in accordance with the probability. So on a proportion of

occasions, determined by the wavefunction, the quantum particle will jump the barrier because its wave nature makes it able to be in two places, either side of the barrier. So when it is observed it will sometimes magically appear to have performed an impossible feat of jumping an insurmountable obstacle. In actuality it only appears to 'tunnel' because there is a probability wavefunction which straddles the energy barrier in the middle.

This quantum marvel is a result of the fact that quantum entities are partially in many places at the same time; and this functioning underlies all the significant processes that maintain the universe and the life within it. Until quantum entities are observed they actually are not here, not there, not here and there, and not neither here or there. As Michio Kaku says it is this remarkable hovering between existence and non-existence which forms the ground for the functioning of reality.

This incredible mechanism of quantum delocalization is the 'glue' which holds molecules together. The behavior of electrons is of paramount importance in the way that the atoms combine to produce the fabric of the material world. Elements are able to form molecules by combining together by sharing of electrons between atoms. An atom consists of a central nucleus comprised of protons and neutrons around which electrons are supposed to orbit in shells. The word 'supposed' is slipped in here to remind us that in actuality the atom is not inherently like this; this is a picture used for analysis.

According to Pauli's exclusion principle the number of electrons allowed in each shell is strictly determined by various parameters. An atomic energy shell cannot contain two electrons with the same parameters. The first and lowest energy shell can only contain a maximum of two electrons, one with spin up and the other with spin down. As we move to orbits further away from the nucleus the greater the number of electrons that are allowed. The chemical properties of any element are determined by the electron configuration of the outermost shell. Chemically active elements like lithium, sodium and potassium have gaps in their outer electron shells whereas inert elements, like helium and neon, have full outer shells. Because of the gaps in the outer shells atoms of the active elements are able to share electrons with other atoms, and in so doing they make molecules.

Oxygen, for instance, has two electron gaps in its outer shell and a hydrogen atom has one electron and one gap. This means that one oxygen atom can combine with two hydrogen atoms to form H_2O – water. The hydrogen electrons are shared with the oxygen atom so that the outer shell of the oxygen has a full complement of electrons. On their own hydrogen and oxygen are incomplete, so to speak, their incomplete outer shells are 'looking' to get filled in; the water molecule, on the other hand, is stable because by sharing electrons the outer shells of both the oxygen and hydrogen atoms are completed (fig 3.6, fig 3.7).

The conventional picture of bonding electrons (fig 3.7) is that they sit between the two nuclei that they bond. This picture, however, does not take into account the wave properties of quantum entities and does not really give a full account of the phenomenon. A more adequate account can be given by considering an electron's potential energy curve and its wave properties. From this point of view electrons are not so much 'particles' but are much more like clouds of 'probability fluid.' Fig 3.8 shows the configurations of this electronic probability fluid for various sets of parameters for a hydrogen atom. The actual title for these images is 'probability density plots' for the hydrogen wavefunction. It is a staggering truth about the make up of the

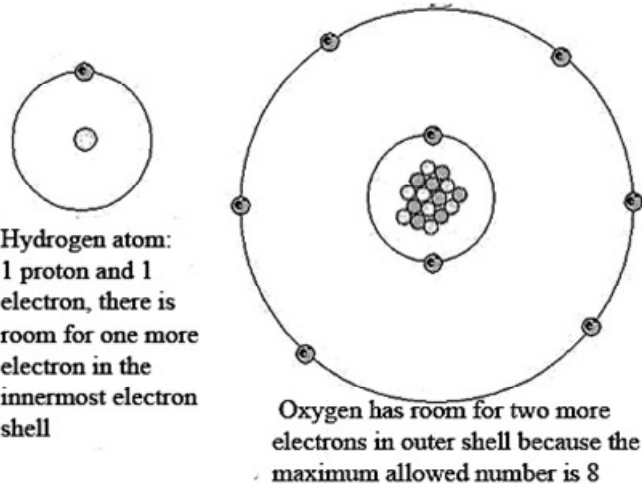


Fig 3.6

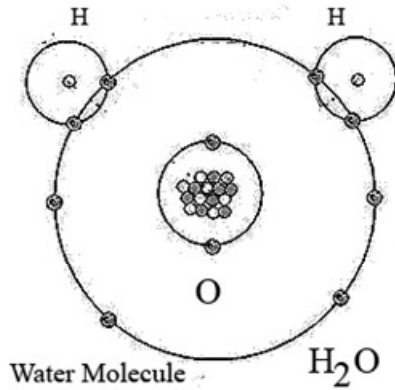


Fig 3.7

apparently solid material world that it is actually held together precisely by such nebulous clouds of probable existence! As Nick Herbert says:

...something seems smeared out to fill the atom, an indescribable something we call a 'probability cloud,' 'realm of positional possibilities,' 'electron wavefunction,' or 'quantum stuff,' without really being sure what we are talking about. Whatever it is, though, the whole world is made of it.²⁶

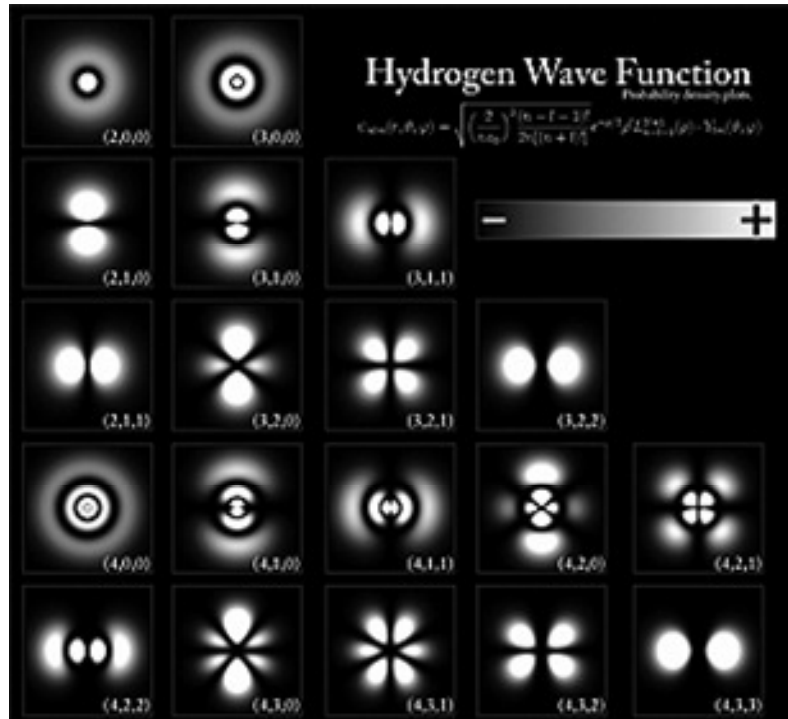


Fig 3.8

Fig 3.9 shows the electron potential/kinetic energy curve against distance from a nucleus, in this case a hydrogen nucleus which is a single proton. The shaded region shows the range of distances and energies that an electron can have when it occupies the lowest shell in a hydrogen atom, which has just one electron. The electron can be viewed as a 'probability fluid' which occupies the shaded region²⁷.

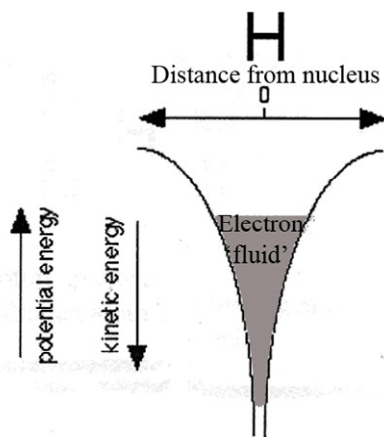


Fig 3.9

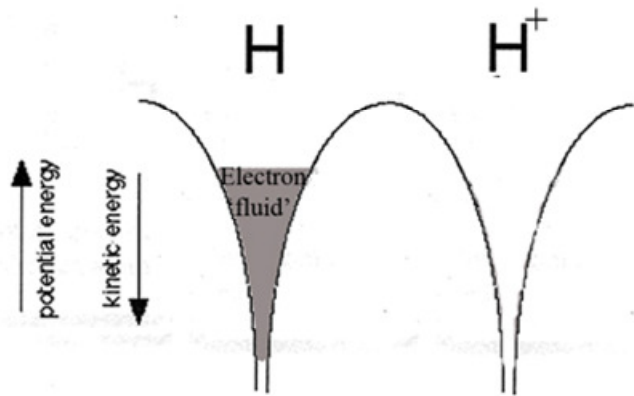


Fig 3.10

Now suppose we bring a bare hydrogen nucleus (H^+), a single positively charged proton without an accompanying electron up to the electron probability haze which surrounds the first hydrogen atom (fig 3.10). The single proton provides a potential well which is waiting to be filled with what we can think of as electron probability fluid. But, as the diagram shows there is an energy barrier which, in the classical world, would be insurmountable. The electron probability 'fluid' however can 'tunnel' through the barrier to occupy both potential wells, although never being located in between them, whilst keeping its identity as a single electron (fig 3.11). This is how electrons, by being in two places at the same time whilst keeping a single identity, act as the glue which holds molecules, and hence the universe, together.

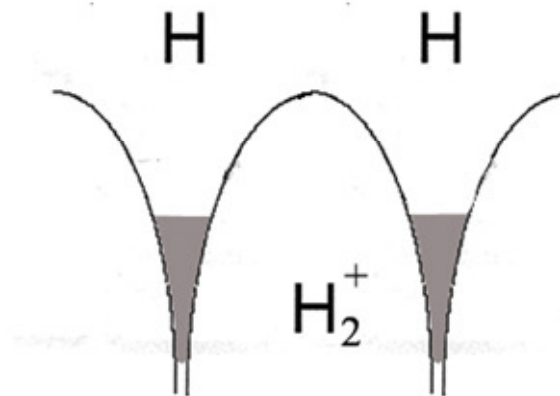


Fig 3.11

Electrons are able to perform the role of connecting atoms together because, as Kaku says, they hover between existence and non-existence. It is because they do not exist as definitely locatable entities that they are able to function as molecular glue. If they existed in the way we conceive of every-day objects to exist, which is to say inherently and determinately 'real', then there would be no way that they could perform this remarkable feat and so perform the task of molecular coupling. It is the wave-like aspect of electrons that is crucial for the functioning of reality.

What a remarkable state of affairs; the manifestation of the solidity of the everyday world requires an essential lack of solidity at the quantum level, a lack of solidity which bears the hallmark of neither existence or non-existence nor both nor neither; how remarkable it also is that two thousand five hundred years ago:

The one who knows all things and all absences of things,
The Transcendent Conqueror,
Refuted both existence and non-existence²⁸

And:

From certain single perspectives
[The Buddha] taught them as either 'nonexistent' or 'existent.'
From both perspectives,
He expressed them as 'neither existent nor nonexistent.'
Since they do not exist as they appear,
He talked about their 'nonexistence.'
Since they appear in such ways,
He spoke about their 'existence.'²⁹

The Madhyamaka is precise about the fact that emptiness is essential for cause and effect to function. Emptiness is the essence of the cause and effect; it is the ungraspable glue that holds cause and effect together. At the quantum level phenomena balance on the edge of existence, which is to say they hover between existence and non-existence. In his book *Entanglement: The Greatest Mystery In Physics* Amir D Aczel describes the situation:

I'm at the bank, and there are two lines in front of the teller windows. They're both equally long, and there's no one behind me. I want to be in the line which moves the fastest, but I don't know which one that will be. I stand between the two lines, or I keep jumping from one line to the other as one or the other becomes shorter. I am in 'both lines at once'³⁰

It is this hovering between the two extremes, the dance of almost existing which is the dance of emptiness, which allows causality, and the universe, or multiverse, to function. This observation is not an obscure piece of oriental vagueness, it is actually completely precise. If the fundamental nature of reality were other than emptiness, the fundamental quality of reality which allows electrons to function as the 'glue' which supports the manifestation of an experienced world, then there would be no experienced world.

The Madhyamika philosophers obviously did not know the theory of quantum interactions in the form that physicists today do. They were, however, aware of 'subtle particles' which flicker in and out of 'existence' within the void from which the universe is manifested; and it is extraordinary that they performed a remarkable razor sharp analysis of the nature of causality and reality which led them to say that the universe functioned only because of its essential 'emptiness' which is described as the ability to hover between the four 'extremes' of existence, nonexistence, not both, nor neither, but maintain a state beyond them all, until, that is they are observed.

This state of hovering between extremes of existence – neither existent, nor non-existent, nor both existent and non-existent, nor neither – but not fully occupying any is both the hallmark of the unobserved quantum realm and of Emptiness. For instance Jeffrey Alan Barrett in his book *The Quantum Mechanics of Minds and Worlds* cites this paradoxical quantum configuration of existence:

...a neutral K meson is typically not a K^0 meson, not a $-K^0$ meson, not both and not neither.³¹

And J. Robert Oppenheimer made this observation when discussing the Heisenberg Uncertainty Principle:

If we ask, for instance, whether the position of the electron remains the same, we must say 'no;' if we ask whether the electron's position changes with time, we must say 'no;' if we ask whether the electron is at rest, we must say 'no;' if we ask whether it is in motion, we must say 'no.' The Buddha has given such answers when interrogated as to the conditions of man's self after his death; but they are not familiar answers for the tradition of seventeenth and eighteenth-century science.³²

(The Buddha said that the self after death neither exists, nor does not exist, nor both nor neither).

The Heisenberg Uncertainty Principle, which accounts for the fact that quantum entities can 'hover' between existence and nonexistence, is certainly, but counter-intuitively, the aspect of quantum functioning which allows the phenomena of the universe to function coherently. And, as we have seen, the Buddhist concept of Emptiness, which describes the ultimate metaphysical nature at the heart of the process of reality, maps precisely onto the ontological structure of the Heisenberg Uncertainty Principle. It seems, then, that we can answer Wheeler's question 'Why the Quantum?' with Nagarjuna's answer:

For those for whom emptiness is possible,
Everything is possible,
For those for whom emptiness is not possible,
Nothing is possible.³³

¹ Tests of Times p491

² New Mind p292

³ Mulamadhyamakakarika – opening praise

⁴ Center of Sunlight Sky p84s

⁵ Science and Ultimate Reality pxi

⁶ Quantum electrodynamics p130

⁷ Jim Al-Khalili – Quantum – Guide for the Perplexed

⁸ Quantum Enigma p67

⁹ Science and Ultimate Reality p201

¹⁰ There has been some disagreement in Western scholarship on the use of the terms Madhyamaka and Madhyamika. Great Sanskritists such as T. R. V. Murti, a member of the Sanskrit Commission set up by the Indian government in 1959, advocated the use of "Madhyamika" on all occasions. Others use Madhyamaka for the system and the texts, and Madhyamika for its advocates.

¹¹ Book of Kadma p50

¹² A 'rabbits horn' and the 'son of a barren woman' are Madhyamaka indicators of impossible entities.

¹³ Wholeness p219

¹⁴ Adornment of the Middle Way p295

¹⁵ ibid

¹⁶ ibid

¹⁷ Three Roads p

¹⁸ Enigma p179

¹⁹ Susan Blackmore

²⁰ Explain Yogacara

²¹ Center Sunlit p228

²² Neverending p93

²³ How Karma Works – Geshe Sonam Rinchen p19

²⁴ Parallel Worlds – Kaku p148

²⁵ Perplexed p77-78

²⁶ Quantum Reality p124

²⁷ The following discussion and diagrams are based on

www.chem1.com/acad/webtut/bonding/TunnelBond.html

²⁸ Sun of Wisdom p95

²⁹ Center of Sunlight Sky p507

³⁰ Entanglement p85

³¹ QMMW

³² J. R. Oppenheimer, Science and the Common Understanding, (Oxford University Press, 1954) pp 8-9

³³ Center of Sunlit Sky p214