<u>Quantum Mechanics: Dead Cats And Things Like That</u>

by Hilary E. Roberts,1985

<u>WHO CARES AND WHY</u>

Quantum mechanics - yeeck! Why should anyone need to know anything about QM other than us befuddled physicists? Because it has become increasingly popular to use quantum theories of physics to flail away at the Christian's faith. Although this attack generally goes unnoticed outside the halls of intellectualism, it is as predictable as sin that in the near future such attacks will make inroads through the more popular media. Atheists such as Carl Sagan will be preaching to us about billions and billions of more reasons that enlightened people should know better than to trust in God. The problem this time is clearly in the Christian's favor who can say " I know whom I have believed in". We poor physicists are at a point in the theories where fundamental physical "laws" appear to have vanished into the worm holes of uncertainty.

This is not some sudden development. Such a challenge has been imminent for the 60 years since the birth of modern quantum physics in Heisenberg's uncertainty principle. This principle is not some ambivalent philosophy of Heisenberg, but rather a mathematical statement that says certain physical properties such as velocity and position when measured always yield uncertain values. Such is not a flaw in the measurement process, but rather ambivalence on the part of nature. If one asks a scientist to measure the velocity of an electron, such can be done to great precision. However if the scientist is then asked to point out where the electron was when it had such a velocity, he can not do it. Not because he is a poor scientist but because nature lets the electron be anywhere it wants. Turned around one could measure the position of the electron precisely but then nature lets the velocity be anything at all. This is the uncertainty principle that Heisenberg discovered.

So how come this doesn't keep me from getting speeding tickets? The policeman measures my speed and claims I was doing 60 in a 35mph zone with absolute certainty. True. Another aspect of nature is that the uncertainty is only noticeable for very small things like atoms and electrons which aren't noticeable themselves in the way that a car is to the policeman. But then recall that we think cars are made of atoms. What if the scientist tried to measure the velocity and position of all the atoms in the car and average the speeds to get the speed of the car? Common sense tells us that should be just as good as the policeman measuring them all at once. *But the physics tells us that common sense is wrong!* Atoms aren't at all common in the way of cars, even though cars are made of atoms (we think).

In the language of physics what is at stake here is determinancy - the principle of physical cause and effect. The atom does not have velocity unless velocity is measured. The atom does not have position unless position is measured. In fact, the "atom" may not exist independently unless it is being measured in some way and then only the property being measured has any meaning - all other properties are uncertain.

In the past with the physics developed by Newton, it was believed that once all the laws of physics were known then it would be possible in principle to determine, what effect any cause would have or to know the cause of any effect. Said in another way, given any initial condition at some time, then all other conditions before or after could be calculated. This implied that the whole course of nature was rigidly determined. Of course this was taken to mean that there was not really any such thing as free will. Everything must happen as it does. Such thinking led many to believe in a clockwork universe. Maybe a god wound it up but since he has left it alone to run in its own predetermined way. Some believed that when all the laws of nature were discovered then there would no longer be any need for a god to account for misunderstood whims of nature. This determinism even found its way into theories of the evolution of life. In response to charges that life as a product of pure chance was unbelieveable, the evolutionist observed that it was no such thing but only the natural result of what *had* to happen according to the deterministic laws of physics. The uncertainty principle flies in the face of all this because it says that *even in principle* the initial conditions cannot be known because – *they don't exist!*

<u>IT GETS WORSE</u>

Many other aspects of nature have been postulated to behave in weird ways like this when observed on the very small scale of an atom. Recent experiments in physics have verified some of the most weird behavior that grows out of the uncertainty principle - what Einstein disdainfully called "spooky actions at a distance." It is the results of these experiments which have caused the latest flurry of media coverage. Sometimes these are referrred to as a paradox in local and non-local systems.

When the uncertainty principle is applied to certain types of atomic systems which have two particles instead of just one, very weird behavior results. Suppose that the two particle system is split up and the two pieces carried far away from each other. Then experiments are independently carried out on the two pieces. Now further suppose that these two pieces have a sort of agreement - when you are “up” I’ll be “down”,. This is similar to an atomic action/reaction principle. Now as long as the particles were together this was fine, when one was measured and found to be “up” sure enough the other was found to be “down”. So that's why the particles were separated. Furthermore suppose that we take hold of the particles after they have been separated and flip them all around. Now when the two are measured clearly they can no longer collaborate and sometimes they are different and sometimes they are --- Oops, they're always different! But how can this be? Its like they are still in the same place whenever we measure up or down-ness no matter how far apart we put them or how much we twist them around. It’s almost like telepathy. How? Its the uncertainty principle again. Whenever we measure for “up” or “down”, nature is so uncertain about the particles’ position that they can still behave as if they were together no matter how far apart the measurements are taken.

You see it is spooky! This experiment has now been performed in many ways to test for various explanations more in line with common sense, but alas nature is always weird and the uncertainty principle holds firm . In fact quantum theory has never been shown to give any incorrect results!

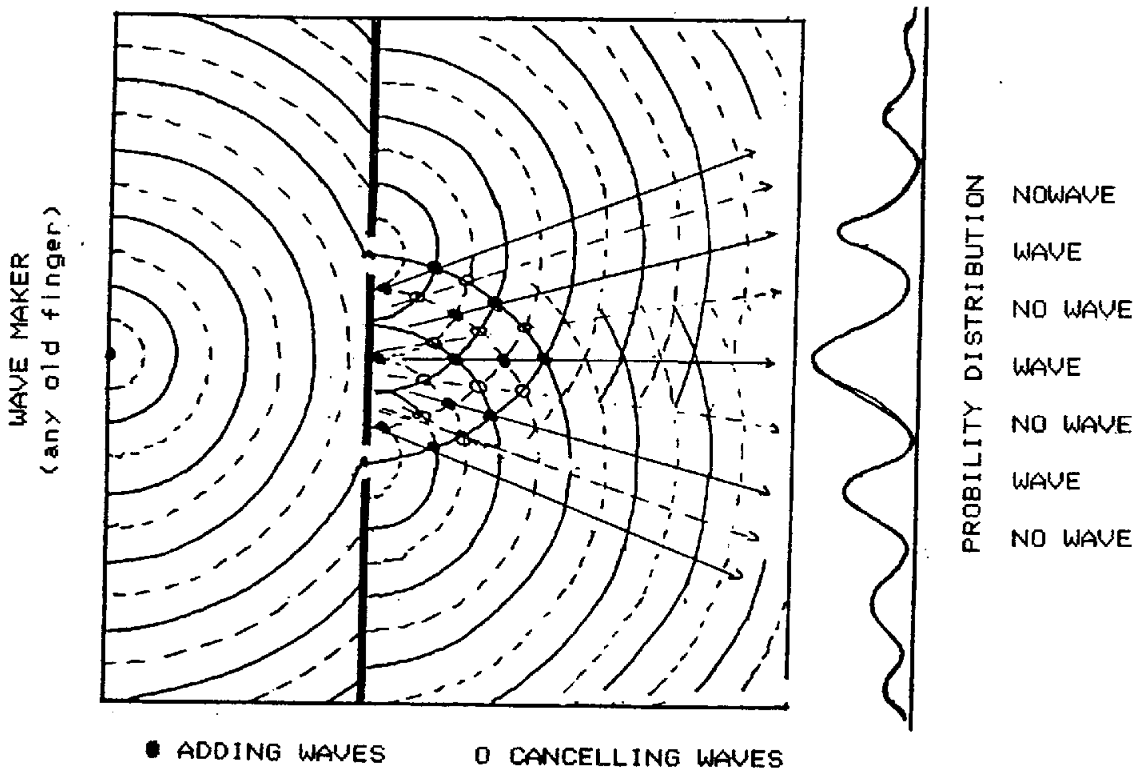
<u>HOW LONG HALT YE BETWEEN TWO OPINIONS</u>

This theory and experimental verification may seem like something so foreign as to have no practical application so that really we don't have to worry about it. But alas, this same uncertainly principle also gives us lasers, TV's, computers, genetic engineering, CAT and NMR scanners, chemistry and nuclear power just to name a few. It can't be dismissed as the misguided delusions of a few academians. It is in fact THE fundamental theory of science. As such it has far reaching philosophical (religious) implications. In the world of physics there are basically two philosophical views for these implications. These two views are termed the Coppenhagen Interpretation and the Many Worlds view.

The Coppenhagen Interpretation was fathered by Neils Bohr who is responsible for the image many have of the atom as a little solar system. It isn't any such thing but such an image helped Bohr to develop some of the early theories of quantum theory. The Coppenhagen Interpretation holds that nothing on the atomic scale exist in the usual sense between observations, there are only observations. Between observations atoms (and maybe things comprised of atoms) only have probabilities for the various alternatives that can result in any observation. The reason our common sense has a problem with this is that we like to think that a state B in a physical system was determined by the unobserved events that transformed state A into state B.

We see dials wiggle a certain way in an atom experiment. We imagine a concept called atoms to explain why the dials wiggled the way they did. This concept is governed by complex mathematical expressions to state exactly how the dials wiggle. Hence we assume that these atoms exist. In the Coppenhagen Interpretation only the observations exist. The atoms are only a figment of our imagination! Remember - we also think everything is made of these little figments.

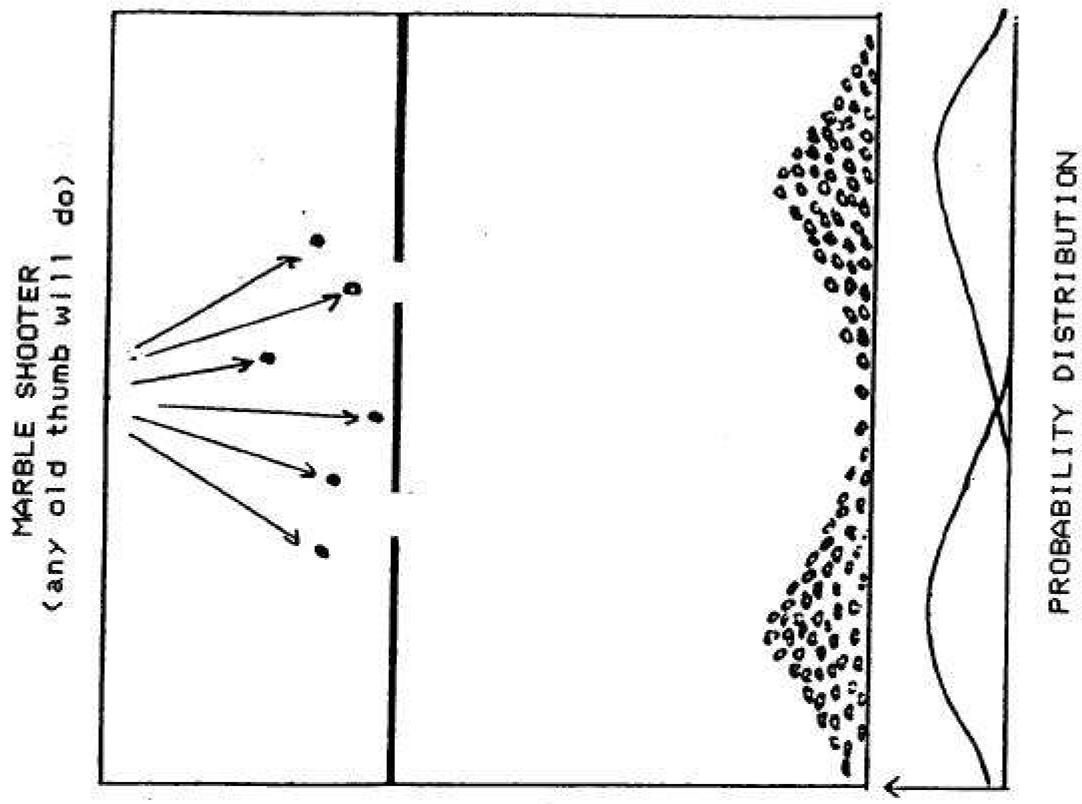
Consider a real experiment which illustrates why physicists are so uncertain. It is called the double slit experiment. First, some background. Light and atoms both appear to have properties similar to water waves and other properties similar to marbles or "particles." One property of waves is called interference. This occurs when two waves run together. Where-ever the crests of the waves line up the result is a wave twice as big and where-ever the troughs line up the valley is twice as deep. Also if a crest lines up with a trough then the waves cancel each other out and the "wave" is flat – i.e., no wave. This can be demonstrated in a tray of water as shown below.



Notice that the waves produce a regular pattern of big waves and no waves all along the wall, not just behind the two slits. That is called an interference pattern.

Now imagine doing the experiment by draining the water out of the tray and randomly shooting marbles through the two holes, (see next figure). Any child would know where to put his hand along the back wall to catch the marbles – directly behind either of the two slits. No-one would expect to catch marbles directly between the two double slits – waves, yes; marbles, no.

Another way of saying this in physics terms is that the child will put his hand where he believes the probability of catching a marble is the highest – behind either of the two slits. There is some probability that marbles will ricochet of the sides of the holes and land between the two slits or slightly off to the sides but the chances seem to be less for that happening. The child would correctly assume it impossible to catch a marble very far off to either side. All of this is illustrated by the "probability curve" drawn beside the marble experiment. What a child can do in his head requires some fancy physics equations to do mathematically. But in the end both the child and the physicist will catch marbles according to this probability curve.



In the same way physicists can calculate a probability curve for the case when waves are used (this is not a childish computation). The resulting curve was shown beside the water tray experiment, (see first figure). There the curve shows the places where the water will wiggle the most (peaks of the curve) and where the waves will cancel out (valleys of the curve). Quantum theory allows the physicist to calculate similar probability curves for quantum widgets like electrons or photons.

Now if the experiment is performed using electrons (or photons), an interesting thing happens. The electrons will produce a pattern on the back wall like the water waves did. Is it then reasonable to assume the electrons are waves? Is it as easy to understand the pattern for electrons as it was with the water? Does the electron spread out and actually go through both holes to create the interference pattern. A particle clearly cannot go through both holes at the same time. Suppose the problem is just that the electrons are coming too fast and we miss some of what's happening. Let's slow down the electron gun so that only one electron is in flight at any given time. Now we record where each electron lands by putting a mark on the wall one at time. Oh no! After charting the impact of many electrons the interference pattern still shows up.

Somehow the electrons know what all the other electrons before and after were going to do so that the result is the same as if they had all done it together. Each electron behaved according to the interference rules for double slits even though there were no other electrons to interfere with. Maybe the electrons aren't particles after all.

Suppose that we close one of the slits and shoot the electrons. Sure enough we catch whole electrons behind the open slit just as if they were marbles. We now close that slit and open the other. Just the same we catch electrons just like they are marbles behind the open slit. So now we open both slits which shouldn't make any difference for something which is acting like marbles going through only one slit at a time. One more time just to be sure we shoot and catch electrons one at a time with both slits open. But now the electrons are no longer acting like marbles but like waves. We can catch them at all the peaks in the interference pattern, even the places which are completely blocked between the slits but we are still catching them whole and one at a time like marbles. To get the interference with the waves, the wave went through both slits at the same time - marbles can't do that. Common sense tells us that what we are observing with electrons can't be happening, but it is. The electron (a particle?) appears to go through both slits at the same time to produce a wavelike interference pattern.

Now we get creative. Lets leave both slits open but put an electron detector at each slit to see the electron when it comes through. Then we should be able to tell if its going through both slits at the same time to make the interference pattern. So we do it. What we find is that sure enough never do both detectors indicate an electron at the same time. We feel much better. But wait, when we look at the back wall we notice that the interference pattern has gone away. We turn off the electron detectors at the slits and the interference pattern comes back. Nature is being its usual quantum mechanical weirdo.

When we look at the slits the electrons behave like respectable particles, but when we stop looking they act like waves. The only thing changed is only how we observed them. *This is a real experiment.* What an electron is depends on how it is observed, not on what it is intrinsically.

Now lets get really creative. Okay, lets get downright devious! We'll get lots of different physics laboratories to do the double slit experiment with only one single electron each - any time they want. Then we'll collect all the results. With that we can plot on one chart where the single electron landed in each laboratory. Once again nature has outsmarted us for there in all its glory is that marvelous interference pattern. Its impossible but its there! This goes right to the heart of quantum theory. The interference pattern that is calculated by quantum theory and observed with the electrons is not a pattern of waves or particles, as it was for water or marbles. The idea of an *actual* electron in *actual* unobserved flight has no meaning. The pattern just gives the probability that an electron's position will be measured at any given location. The probability that any single electron will be measured at a point on any given peak of the pattern is about the same for all the peaks in the pattern. So in any given laboratory no-one could predict exactly where the single electron was going to be measured. (There goes determinancy!) But when a large number of electrons are measured, even in separate laboratories, the total results reflect the interference pattern, which is just the distribution of probabilities for where any given electron will be measured in a double slit experiment. Physics cannot predict what any single electron will do but can very accurately predict what a large group will do.

Think of a crowd of people in a theater in which someone yells "FIRE!" The crowd behavior is predictable but the individual behavior is not. Yet what is acceptable for people feels strangely uncomfortable when applied to an atom.

The same experiment can be performed with photons (light) and the results are identical: light waves are just as weird electron particles.

In quantum mechanical terms the electron only exists as a set of probabilities until it is observed. At which point the electron assumes one of the multiple states allowed by the probability function. In the double slit experiment if no observation is made at the slits then the electron continues to exist only as a probability. There is an even probability of being found at either one or the other slits if we do look. Unless we look, the two probability states -not the electron both exist and can "go through" both slits and interfere to produce the observable pattern of interference. If observed at the slits, then the probability must actualize at one of the slits which then does away with any probability of existence at the other slit. Therefore no interference between the probability states can occur and the electrons are secondarily observed to land as particles would be expected to land.

The Coppenhagen Interpretation says, "Yes that is a correct view of the double slit experiment. The electron doesn't exist materially until it is observed. When it **was** observed, it exists in a manner consistent with the observation rather than some inherent deterministic property of the electron."

I DON'T UNDERSTAND IT EITHER

If all this seems like gibberish don't worry. Its not your problem but the poor physicist's. In some respects the physicist suffers the same problems trying to understand and explain quantum theory as God must have in trying to explain concepts such as heaven, His abundant greatness, divine peace, or vicarious atonement. The experience and words of humanity simply cannot grasp the essence of these things divine. Hence the Lord describes them with phrases like streets of gold; exceeding abundantly beyond all; passeth understanding. Yet we still have essentially no real understanding - such will come when we are changed and can by experience know these things. The situation with quantum physics is similar in that the audience has no direct experiences with the atomic world of quantum events. No-one has ever seen an atom or an electron or a muon or any of the subatomic fermions. (The dark adapted eye *can* detect a single photon .) However the situation is also distinctly different. Whereas God does understand what heaven is like, even the physicist is not sure what an atom is much less how to explain it! The one thing he knows is that quantum concepts of events and things are not like *anything* we've ever encountered before. An atom is not like a solar system or a billiard ball or a wave and yet it is often pictured as such even by physicists trying to identify a strange concept with something familiar. Many of the quantum concepts are best illustrated by thought experiments such as one Schrodinger postulated for his cat. *Don't ever give your cat to a quantum physicist!*

IS THE CAT DEAD YET

The experiment consist of a sealed box that contains the following stuff: a cat, a vial of poison, a radioactive particle, and a radiation detector that will break the vial if a radioactive decay event occurs. The radioactive particle can decay or split up to produce a flash of radiation. However for any given particle the exact time at which such will occur is completely uncertain - even if everything there is to know about the particle is known. The mathematics shows two states for the particle all the time: one for the decayed state and another for the original state. It is only when the particle is observed that one or the other state dominates. In fact, until the observation, quantum theory says that everything inside the sealed box is in two states; the particle, the detector, the vial and schizophrenic kitty. The cat is both alive and dead and neither alive nor dead according to the mathematics. You don't buy it, I can tell. Rightly so, for this paradox has been strongly debated since it was proposed in 1935. (If anyone ever says scientist don't decide things on the basis of debate they are wrong.) It is one of the few paradoxes of QM still under discussion. The problem comes in knowing what can constitute an observer. Is it those outside the box? Some physicists would so contend. Can the cat be the observer? What about the detector? Suppose we put a sealed box around ourselves, do we then also exist in two states until someone observes us? Moving to one limit leads to a form of lockstep super-determinism where all action is locked to all other action past, present, and future. Moving to the other limit leads to the question, "Who observes the observers?" The real question is, "Before the box was opened was kitty alive or dead?" Quantum theory indicates that we are asking a question for which nature has no answer.

One physicist has explained the predicament of Schrodinger's cat as if there were two "ghost" probability-particles in the box: one decayed and one not. Then of necessity there are also two ghost kittys: one dead to go with the decayed particle, and one alive to go with the original particle. When the box was opened one pair of ghosts materialized and one vanished.

As you might imagine physicists who act as if things exist whether they are observed or not are not overly enthusiastic about this interpretation - even though the Coppenhagen Interpretation is the most widely held view. This is where the Many Worlds view comes in. Don't get your hopes up, you won't like this any better!

HELP! I'M COMING APART AT THE SEAMS

The Many Worlds view would explain the double slit experiment this way. The electron really exist all along. However when the electron must 'decide' which slit to go through, it doesn't – decide that is. What really happens is that the universe splits into two copies. (Wow!) In the world where we watch slits, the electron acts like a particle, goes through one of the slits and lands like a particle. In the other world where we do not watch slits, the electron acts like any well behaved wave making interference patterns. The two worlds are completely isolated from one another and can never interact. Every time a quantum particle interacts with any other the universe splits into as many versions as necessary to accommodate all the possible outcomes and then each universe proceeds from there splitting and splitting again as necessary.

In the Many Worlds view there are no ghost kittys. In one world the particle didn't decay while the detector was on and so when the box was opened, out jumped kitty. In another world the particle did decay and when the box was opened the Humane Society was very upset! As you can see the "many" in Many Worlds must be the most drastic understatement ever if such were correct. Still this view has something going for it: it is the least contrived in a mathematical sense. As the ghosts indicate, the Coppenhagen view is highly contrived.

At this point it must be reemphasized that modern physics does not even entertain the possibility that *the* kitty exist inside *the* box in the usual sense. The data from experiments like the double slit just cannot be made to fit common sense. There are other speculative outgrowths of this theory such as anti-matter, vacuum fluctuations, inflationary universe and super-space concepts. But in the end they all trace back to the perplexing uncertainty of the double slit enigma.

SO WHAT?

What has all this got to do with religion? One popular book, "The Dancing Wu Li Masters," attempts to show that the modern view of physics is much more closely aligned with the existential concepts of eastern religions where nothing exists except the consciousness of being. This results from what I term "deterministic shock." It comes as a real blow to most people to discover that not only can science not answer all the questions but worse that science itself is saying that some things are unknowable. In response to this, some have leaped all the way to concepts as far from cause and effect laboratory science as possible. Concepts such as Buddhism, Hinduism, or Zen are quite in vogue among the titles of popular science. Is science really ready to pronounce God the father of Christ as dead *in favor of some fat statue?* Incredible as it seems, some are doing just that.

It has been popular to argue against a spiritual God since such is a non-testable hypothesis (cannot be falsified). A theory is said to be non-falsifiable when it cannot be tested in a way which in principle could show it to be false if it were false. It is a postulate of logic that non-falsifiable theories cannot be true. It is further claimed that any true view of the universe must be based on the firmer footing of modern science and its testable predictions. Yet look where this firmer footing has led. Science has discovered a limit to its ability to predict the outcome of the most fundamental aspects of nature. Apparently nature itself doesn't always know what to do until placed in the context of interaction with observers. In the Coppenhagen Interpretation it seems that the whole of nature must be bound by an endless regression of observers. As one physicist put it, who observes the observers? If the answer is not obvious (as it isn't to most atheists), then the Many Worlds view is about all that is left. But look – by definition the Many Worlds view is non-falsiflable. One world can never be aware of any other world. So then even the atheist is forced to admit that philosophically Many Worlds suffers the same predicament that religion is charged with: requiring faith in something which cannot be known to be either true or false directly. Actually the Coppenhagen view is also non-falsifiable.

In the general sense religion as it is practiced by the eastern religions and some western religions **is** entirely non-falsifiable. That is, such religions rest on inner experiences which are not subject to outward investigations. However, non-falsibility is a false accusation against the religion of Christ. The primary documents themselves (the Bible) put forth the test: if Christ be not raised then our preaching is false and our faith is vain, 1 Cor. 15:14. This then places this religion in a class by itself. It can be outwardly tested by the same means any historical event is validated. Was the historical Jesus resurrected from the dead? The Bible can either be found to contradict other historical data or to fully corroborate with historical data. So then a world view based on the resurrected Christ rest on a firmer footing than either the Coppenhagen or Many Worlds views. At least there is a test, history. But still history may not seem to carry the same strength as physical law. Interestingly enough another implication of quantum theory is that there is very little distinction between the records of history, current laboratory observations and predictions of theory. Reality always depends on the observer regardless of when the observation occurs. Of course one who uses common sense knows that Jesus couldn't have been really resurrected from the dead and ascended into heaven so the historical data must be wrong. If quantum theory and the double slit experiment teach us anything it certainly teaches that common sense is a particularly poor measure of reality. Especially when the events under question clearly lie beyond common experience. Of all the disciplines of science, the quantum physicist should be the most willing to accept the possibility of a resurrected body. Few do.

It seems that even in quantum theory God does not compel one by incontrovertible means to accept or deny Him. More and more it is being recognized that one choice (Many Worlds) is consistent with atheistic faiths of cosmic and organic evolution. On the other hand, the holistic world view required by the Coppenhagen Interpretation melds well with the view that the supreme observer is one and the same as the God revealed in the Bible; the one of whom scripture claims "in Him all things consist".

"But God hath chosen the foolish things of the world to confound the wise."
1 Corinthians 1:27

FOR FURTHER READING: (in order of expected usefulness)

Richard Feynman, "The Character of Physical Law," M.I.T. Press, 1965.
(best popular review of modern physics that I've found)

John Gribbin, "In Search of Schrodinger's Cat," Bantam New Age Books, 1984.
(good popular review of modern physics)

Allen Emmerson, "A Disorienting View of God's Creation," Christianity Today, Feb 1, 1985.
(good short summary of the physics but seems to miss some very basic points)

N. David Mermin , “Is the Moon Really There When Nobody Looks? Reality and the quantum theory”, Physics Today / April 1985.
(describes some of the recent two particle 'up or down' type experiments)

Gary Zukav, "The Dancing Wu Li Masters," Bantam New Age Books, 1979.
(typical eastern religion view, easy reading, not much content)

Paul Davies, "Other Worlds," Simon and Schuster, 1980.
(many worlds jabberwocky, now abandoned by Davies himself)

Frita Capra, "The Tao of Physics," Bantam, 1980.
(more eastern religion claptrap)

B. d'Espagnet, “Quantum Theory and Reality,” Sci Am., March, 1980.
(advanced summary of QM)

P.A.M. Dirac, “The Principles of Quantum Mechanics,” Oxford University Press, 1982.
(*THE* definitive text for modern physics combining QM and relativity
- not for the mathematically weak)

About the author: Hilary E. Roberts, BS, MS solid state physics. Mr. Roberts' career has revolved around quantum mechanics. His graduate work, in conjunction with colleagues, is published in Applied Physics Journal as well as industry journals. Mr. Roberts has worked to develop quantum solid state devices called Charge Coupled Devices, investigated thermoluminescent and electron spin resonant behavior in organic crystals and developed testing programs for safety electronics and other equipment used in nuclear power stations. His current work (1988) includes UV and IR spectroscopic research in conjunction with NASA. Mr. Roberts is a Christian worshipping with the Weatherly Heights church of Christ in Huntsville, Alabama.