"We cannot know, as a matter of principle, the present in all its details" — Heisenberg. This frees us from the determinism of classical ideas. For Newton, if we knew the position + momentum of every particle of every particle in the universe it would be possible to predict the entire course of the future. The modern physicist sees this as meaningless, because we cannot know precisely the position and momentum of even one particle.

Heisenberg used the basic equation of quantum mechanics $pq - qp = \hbar/i$. The product of the uncertainties in position (Δq) and momentum (Δp) must always be bigger than $\hbar$. The same uncertainty rule applies to any pair of conjugate variables, variables that multiply out to have the units of action

"We can know, in principle, the past in all its details" — Heisenberg. Here the future is seen uncertain,

There is a feature of the quantum world at its base. Both wave + particle concepts are needed as complementary: Bohr lectured in Como, Italy in 1927 and introduced the complementarity idea (the "Copenhagen interpretation"). Neither position nor momentum alone can explain the quantum; both complement each other. Classical physics has interesting particles whether observed or not; like clockwork. But in Quantum Physics the observer interacts with the observed system, so there is not an independent existence. If we precisely measure position of a particle, we have not measured its momentum. If its momentum then not its position. If we measure a particle, we have not measured a wave, if a wave, then not a particle. Classical physics claimed to measure particles' position precisely in space-time, and to be able to predict their behaviour.

Quantum theory leaves the classical view, even "relativity" is here 'classical'

Large objects may not appear to change when we observe them, but subatomic particles are affected by our mode of observing them. Observer & observed are parts of an experiment. There are not particle systems (clockworks) which are unaffected by observation & experiments. We know only results of experiments. From experiments & quantum theory equations we see that if we observe a system once, we get answer A, and if we look again we get answer B. We cannot say what is happening when we are not observing. If we see an electron jump orbit, and look again to see where it is, we cannot know even it is the same electron. Things found in State A, and in State B are known, but not what happens between

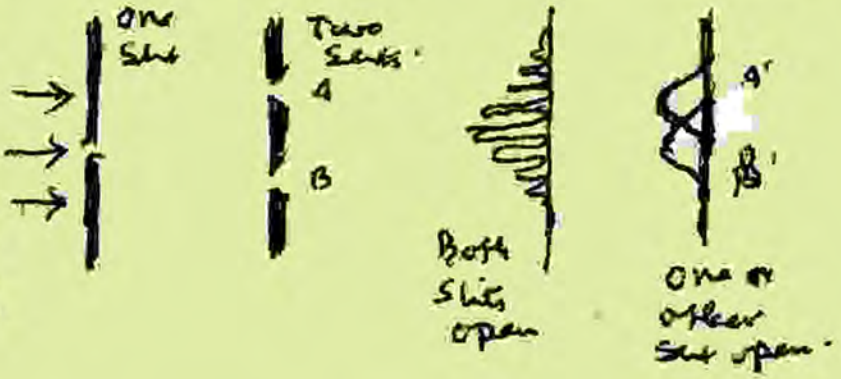
we do not know how things get from one observed state to another observed state. This is because to quantum physics our knowledge of an electron is limited if we observe it, and we have no idea whatever of what it is doing when not observed. "Expectation colours what we learn from experiment" – Eddington. As a sculptor may be said to 'see' a statue in a block of marble, and work to release it, so Rutherford may have 'seen' a nucleus in an atom. No-one has actually seen an atom's nucleus. We see results of experiments, and interpret these in terms of the concept "nucleus". "Neutrinos" were needed to explain subtle differences in some radioactive decays. Eddington said, "Dare I say that experimental physicists will not have

different regularity to make neutrinos? If we follow Quantum Theory, we may perform experiments that give pointer readings & interpret these as indicating the existence of a certain kind of particle. And the interpretation may become a persistent delusion. Before Rutherford nobody looked at a nucleus. Before Dirac no-one imagined the existence of a positron. In the quantum world, what you see is what you get. Nothing is real. The best we can hope is that we can get a set of delusions that agree with each other. But even such hopes are dashed by a simple experiment. Double-slit experiments were used to have proved the wave-nature of light. What of photons?

If we use a tank of water and a device to jiggle the water to make regular waves we find that the pattern differs if

Electron or photon beam

we have barriers with one and with two slits



The intensity of the wave is a measure of the amount of energy carried by the wave, + is proportional to the square of the height or amplitude H^2, → shows a similar pattern for each separate hole. If both holes are open the pattern is much more complex and there is a large peak intensity in line with the two holes, and a low intensity at either side of the peak, where the two sets of waves cancel out.

The intensity of both holes together is not the sum of their two separate intensities (sum of the squares) but the square of the sum of the two amplitudes. Large particles do not show this interference pattern, only waves + very small particles show interference patterns.

An experimental observation is valid only in the context of the experiment, and cannot tell what we do not observe. Apparatus, electrons & observer are all parts of the experiment. The quantum world is holistic. The parts are in touch with the whole. The act of observing a System forces it to select one of its options, which then becomes real. (This is the Copenhagen interpretation of the quantum world.)

The observation that crystallises one of an array of potential electrons is equivalent, in terms of wave mechanics, to the disappearance of all the array of probability waves except for one packet of waves that describes one real electron. This is the "collapse of the wave function" the heart of the Copenhagen interpretation. Myriads of ghost particles interfere all the time, and collapse into a single real particle only when the wave function collapses during an observation". As soon as observation stops the particle at once splits into a new array of ghost particles, each pursuing its own path of probabilities in the quantum world.

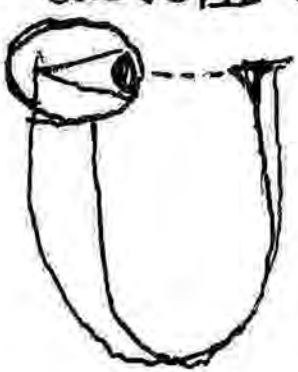
It is possible that the infinite regression of cause & effect means that the whole universe may owe its "real" existence to its being observed by intelligent beings. (E. Wigner & J. Wheeler considered this.)

The EPR Paradox (of Einstein, Podolsky & Rosen) considered the Copenhagen interpretation as not complete. They thought that there really is some underlying clockwork that runs the universe and that it gives only an appearance of uncertainty & unpredictability at quantum level through statistical variations. EPR say that there is an objective reality, a world of particles, real, with momentum & position, both precisely defined even when not observed.

John Wheeler played 20 questions with a group. They kept him out for a long time. To each of his questions they had to answer yes or ~~No~~ but truthfully & consistent with what the others had said. With only one question left, Wheeler said, 'Is it a cloud?' The others had agreed not to agree about an object, but to give a truthful answer about some object in his mind, & consistent with the answers already given. Wheeler had thought a real object had been chosen, but there was not. All the answers to his questions were real. The cloud was created by the questioning process. So also might the electron be created by modes of experiment. This stresses what quantum theory says, that no elementary phenomenon is such until it is recorded. The recording process may play tricks with man's everyday concept of reality. History may depend on how we choose to make an experiment.

Has history a meaning? The past does not exist except as a record in the present.

Wheeler considered that the whole universe may be a participatory self-excited circuit. It starts with the Big Bang, expands, cools, & produces after billions of years beings able to observe it; i.e. participate in it as observers. The echo of delayed-experiment it can give reality to the universe now and in its past. By observing the Big Bang's echo (photons of cosmic background radiation), we may be creating the Big Bang and the universe.



The whole universe must be thought of as a delayed choice experiment in which the existence of observers who notice what is going on gives tangible reality to the origin of everything.

what was wanted was Schrödinger's cat, and then this was supplied by the early 1980's Aspect Experiment. Quantum weirdness is not only real but observable and measurable.

Particle spin defines a direction in space as the earth's spin defines its north-south axis. Compared with a uniform magnetic field, an electron can line up in one of two possible states, parallel or antiparallel to the field. If we know the spin of one particle of a pair, we know the spin of the other, for the two add up to zero. In the classical world the measurement is simple for we deal with particles in a 3D world and must measure 3 directions of spin. The three add together (by rules of vector arithmetic). But in the quantum world if we measure one component of spin we change the other component. The spin vector one

Complementary and cannot be measured simultaneously.
Particle Spin (of electron or photon) is quantised
To measure the Spin in any direction, we
can get the answer only up or down (+1 or −1).
If we measure on the I-axis + get answer +1
then along the Y-axis, we get only a 50/50 chance
of result. Measuring complementary spin vectors
restores quantum uncertainty of the state previously
measured. Einstein thought "non-Locality" absurd.

SPIN PARADOX

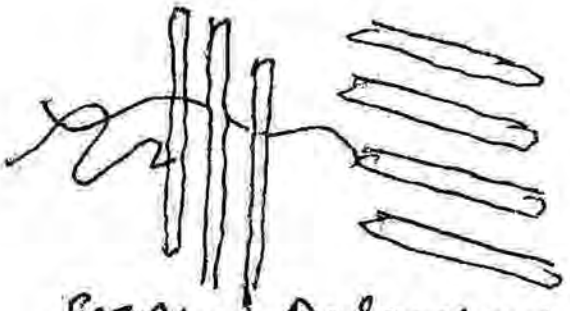
Dirac established that the unit of Spin is $\frac{1}{2}\hbar$.
Hence +1 unit of Spin. The difference between +1 unit
and −1 unit is the difference between plus + minus
$\frac{1}{2}\hbar$, which is $\hbar$.

POLARISATION

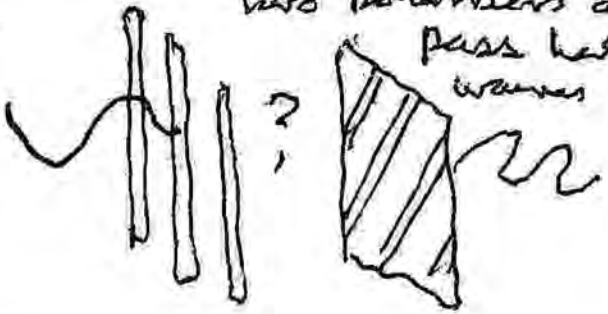
Polarisation is a property that defines a direction in space associated with a photon. or photon-beam. just as spin defines a direction in space associated with a material particle.

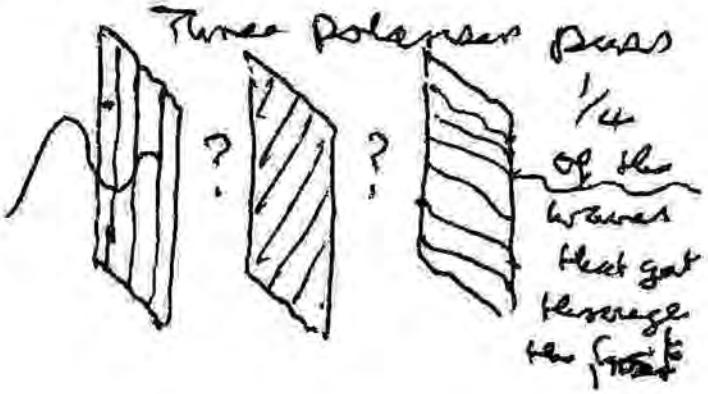
Vertically polarised waves pass through a fence of vertical slats.

Horizontal waves are blocked



Crossed polarisers stop all waves.





Using polarisers at different angles we measure different vector components of polarisation + each new measurement destroys the validity of the information we got out of all previous measurement.

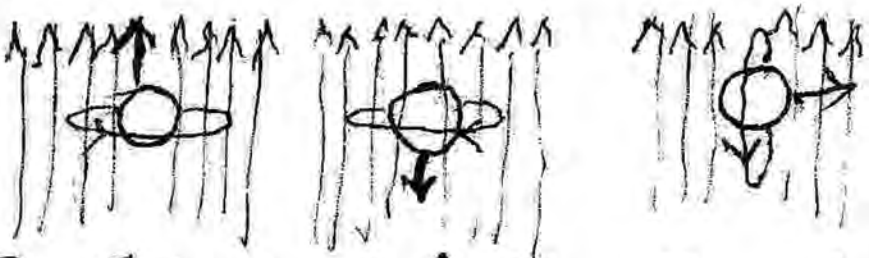
If we measure the polarisation of one photon of a pair we collapse the wave function not just of one but of both, even if far from each other-as in "ghostly" action at a distance.

Bernard d'Espagnat of Paris-South University says that our everyday view of reality is based on these basic assumptions: (1) there are real things existing whether we observe them or not; (2) it is legitimate to draw general conclusions from consistent observations or experiments; (3) no influence can propagate faster than light-speed;

which he calls "locality". Together these three are the bases of "local realistic" views of the world.

The Bell test starts out from a local realistic view of the world. In the proton spin experiment we cannot know the three components of spin for the same particle, but we can measure any one of them. If we record a value +1 for the X spin of one proton, we find a value −1 for the X spin of its counterpart, and so on.

D'Espagnat says that our everyday view of reality rests on three assumptions: (1) That there are real things that exist whether observed or not. (2) That it is legitimate to draw general conclusions from consistent observations or experiments. (3) That no influence can propagate faster than light.



Particles with half-integer spin can line up only parallel or antiparallel to a magnetic field. Particle with integer spin can align also across the field.

Photons have zero rest mass, move at light's speed and have no means of distinguishing time. It is not clear what locality means for a photon.

Local realistic views of the world are false. This was proved by the Fourier experiment on Bell's inequality.

The only reals are the results of experiments, & the way we measure influences what we measure

Despagnat + Bohm say that everything is connected with everything else, + only a holistic approach to the Universe is likely to explain phenomena such as human consciousness.

A great puzzle of physics is inertia, resistance to change. Newton said that in free space any object moves in a straight line at constant speed until pushed by an outer force. Amount of push needed depends on amount of material contained in the object. If there were only one particle in an otherwise empty universe, there would be nothing to measure its resistance to change of its motion.

If all things are interconnected, change in one thing's motion affects that of all others.

Hugh Everett at Princeton University in the 1950's thinks that the overlapping wave functions of the whole universe, the alternative realities interacting to produce measurable interference at quantum level, do not collapse. All are equally real and exist in

their own parts of superspace and superime.
If we make a measurement at quantum level
we are forced by the observation process to select
one of these alternatives, which becomes part
of what we see as the "real" world. The act of
observation cuts the ties that bind alternative
realities together and lets them go their own separate
ways through superspacetime. Each alternative
reality has its own observer, who has made the
same observation but got a different quantum
'answer' and thinks that he has 'collapsed the wave-
function' into one single quantum alternative.

Schrödinger's Cat experiment has two cats,
one dead, one alive, but located in different worlds.