

Consummate correlation - *How to entangle two objects*

Entanglement is one of the strangest properties of quantum mechanics and describes a kind of correlation, which goes far beyond any classical analogue. In order to explain it, we consider a simple example. Imagine there is a machine, that produces two dice and places them in two dice cups, so that one has to lift a cup in order to see a die. That machine further has the property, that the combined value of the two dice is always eight. So if you see one cup and see that that die has a value of 2 for example, you automatically know that the other one must have the value 6 and don't even need to lift the second cup. So far this is a normal correlation, but it gets special in the context of quantum mechanics. Quantum mechanics says, that only a measurement forces an object to take a discrete result. Until there it is assumed to be in a superposition of the possible results. This may sound odd and is indeed absolutely non trivial. The famous physicist Niels Bohr remarked, that "who is not shocked hasn't understand this".

In case of the die this behaviour would mean, that the die only takes a concrete value, if one actually lifts the cup. But because the combined value *always* has the value 8, the other die's value must *immediately* also be chosen regardless of whether someone lifts its cup or not. This must even hold if the two cups are billions of kilometers apart, so this happens faster than light could travel. There are many applications of this effect, for example in order to send secret messages.

The dice machine is of course only a thought experiment, but how can you actually build a machine that entangles two objects? To do so we have to look at the double slit experiment, which may be familiar to many from school. Light particles can pass to one of two slits and get then detected at a screen. Since one didn't measure which slit the particle went through, it exists in a superposition until it gets detected. It can actually interfere with itself and creates therefore a so called interference pattern, so one can observe alternately bright and dark spots on the screen. It looks just like two waves had intermingled, which is why that behaviour is called 'wave-like'.

The set up to create entanglement is very similar. A particle that travels to a so called beam splitter, which may transmit or reflect the particle with a respective probability. So one doesn't know which path the particle is on. On its way, it can interact with an object on each path and thereby change one object. After that, a second beam splitter leads the particle to an upper or a lower detector. If the particle gets detected at the upper detector one cannot distinguish whether the particle came from the lower path and got transmitted or from the upper path and got reflected. It can be shown that the 'wave-like' behaviour can be used to single out the cases, where one can be absolutely sure that the particle interacted with one of the objects. One can't know which one though, which is why the objects are entangled. It is the same situation as with the dice. One knows the combined situation perfectly well, but can't say anything about the single objects without looking at them.