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Newton's Cradle and Quantum Observation

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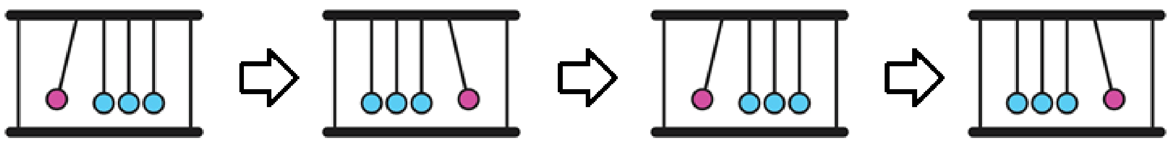
Includes new figures and minor edits. Original text-only Backreaction version is at:
http://backreaction.blogspot.com/2019/10/what-is-quantum-measurement-problem.html?showComment=1572213322428#c6028159424345209571

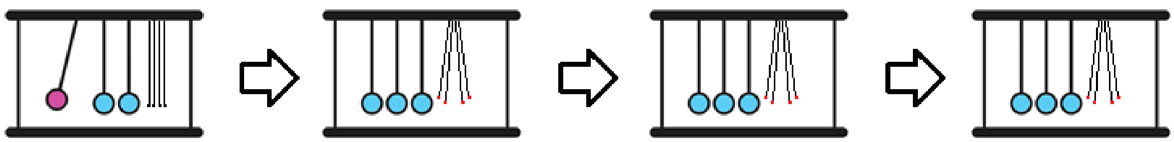
Most folks have seen a Newton's Cradle. It is a chain of barely touching steel balls, each held by two strings to keep their motions aligned.

If you drop a ball at one end of a Cradle, its impact transmits a momentum impulse to the other end of the chain, launching the end ball into motion. The end ball then reverses direction and begins the process over:



The Cradle is a great demo of momentum transfer, but it is also an excellent example of a time-reversible oscillatory process, since a video of a Cradle in action looks the same whether it is played forward or backward.

Now, let's change things up a bit by replacing the final ball with a cluster of much smaller balls, each suspended from one string instead of two. What happens?



The momentum is transferred as before into the final unit, but then everything falls apart, literally. When the momentum impulse hits, the less constrained tiny balls scatter like billiard balls after a hard cue ball break. The original sharp momentum pulse is blurred and diffused over time, making its reconstruction extremely unlikely. Time symmetry is lost, since the process can no longer repeat itself.

Another way to describe this loss of time symmetry is to say the Cradle is 'observed' by the chaotic transformation that takes place within its more complex end unit. It's an observation in the sense that the end unit keeps an energy 'record' of the initial ball impact, the one that took place at the other end of the chain. Furthermore, since time-reversibility has been lost, that now-singular impact takes on a temporal uniqueness that makes it more like a classical event.

Much like the chain of balls in Newton's Cradle, a photon also carries momentum across space. And also like Newton's Cradle, a photon remains 'simple' and time-reversible *only* if both ends of its momentum transmission path remain simple and quantum. While that sounds unlikely, it actually happens all the time. We call it 'transparency', which is a rather amazing bit of physics in its own right.

Now, let's take another look at the two-hole electron diffraction experiment.

A photon that bounces off of an electron does not immediately become 'classical', since both the electron and photon are simple and thus capable of time-reversal. However, if the photon next hits a bit of thermal matter that not only absorbs but shreds and purees its momentum across a large ensemble of jiggling atoms, its time-reversal become statistically

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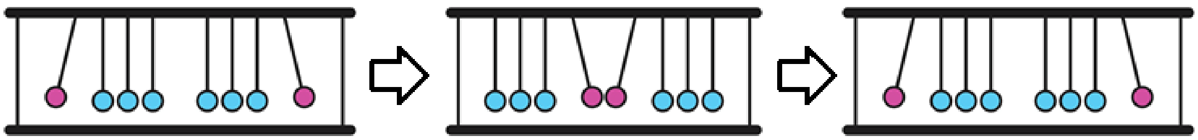
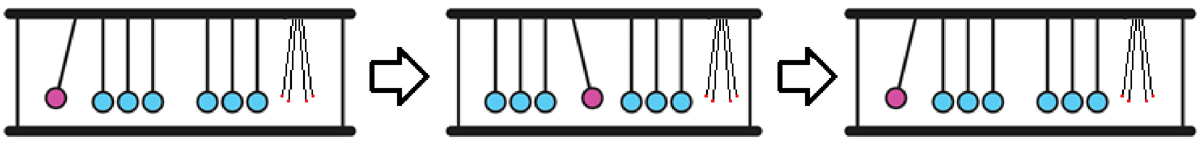
unlikely, and thus the photon becomes part of classical physics. Notice, however — and this is important — that this simplicity is lost *at both ends* of the photon chain, not just at the absorption or detection end. The original electron emission event *also* loses its ability to be oscillatory, which means that it too must become classical.

This situation of an initially reversible electron-photon interaction becoming statistically irreversible through chaotic shredding of the (possibly very remote) photon end of a momentum pair can also be modeled by with Newton's Cradle. This time two end-to-end clusters are used to represent a reversible momentum pair:



The left-hand cradle cluster represents electron momentum, while the right-hand cluster represents photon momentum.

The photon end of the momentum pair can be "shredded" (made statistically irreversible) if it encounters, for example, a rhodopsin molecule in a human eye:



Even if this photon shredding occurs at a distant location, what was potentially a time-reversible situation becomes insurmountably unlikely to reverse after the shredding event. This statistically insurmountable break in time symmetry effectively localizes the left-side wave function of the electron, forcing the electron to move forward in history with fewer options. The electron has been *observed.*

Stated a bit differently: Chaotic absorption of a photon forces its *entire* momentum history to become classical. Thus the absorption also makes the entangled emitting electron classical, since the simple oscillatory (quantum) behavior of that electron is disrupted just as much as that of the photon. It is as if the observer 'donates' a bit of their own classical reality to the electron via momentum entanglement, no matter how distant the electron may be.

Decoherence has it mostly right in asserting that interactions with larger objects degrade quantum behavior. However, the deeper message is that there is a statistical continuum in all forms of quantum observation. Even a dust speck can 'observe' quantum events, provided only that it is complex enough to provide statistically irreversible shredding of one end of a previously simple wave function.

The bottom line is this: For matters quantum, it's not the consciousness of the observer that matters. It's the thermal chaos in the rhodopsin of her eyes. And yes, there probably should be a song about that… :)