Dancing to the Same Score

One of the most famous experiments in physics is a simple yet profound example of the dual nature of light. It is called the “two-slit experiment.” It was first conducted by English polymath, Thomas Yong around 1800 and validated the wave theory of light, overturning Newton’s corpuscular ideas. Neils Bohr used it to develop the Principle of Complementarity showing that light was both a particle and a wave and no description of light was complete without referencing both. It was also at the heart of Einstein’s famous thought experiment called the EPR Paradox, designed to show the incompleteness of quantum theory. One of the most intriguing aspects of the experiment is that you find exactly what you expect to find. It validates light as both a particle and a wave. How can this be? Well, that is the very question physicists have been trying to answer for over 200 years.

The experiment is very simple. A steady laser beam of light is aimed at a target. Two devices with slits which can be individually opened or closed are placed side by side in the path of the light beam. When only one slit is open, all of the light travels through it and hits a target on the other side of the slit in a bullet fashion. This demonstrates the particle nature of light. When both slits are open, the pattern on the target looks exactly like waves which are interfering with one another. The most puzzling thing is that these same patterns emerge when the light is sent in a steady stream or when one photon is released at a time.

There are two main conclusions which physicists have drawn from this experiment. The first is that you find what you are seeking. If you set up the experiment with one slit to detect particles, that’s what is produced on the target. If you set up the experiment to detect waves, that will be the pattern produced regardless if it is a steady stream of light or one photon at a time.

As physicists attempted to come to grips with these results, some exotic theories arose. Some called into play the hidden variables found in entanglement experiments. Others suggested that each particle somehow “knows” beforehand which path to take so that it mysteriously cooperated with all of the other particles yet to be fired. Einstein even suggested a pilot wave ahead of the particle that served to guide it.

Physicist David Bohm developed a most intriguing theory. He described the two-slit experiment as photons dancing to a musical score. The score came from what he called the Seamless Whole which acted as a pool of information. This Whole included the physicist, the laser, the photons within the laser beam, the slits and the target, or measuring device. After the experiment was set up by the physicist, all elements of it became known to the Whole. For example, the conditions under which the experiment would be conducted was one element in the overall pool of information in the entire system. If the experiment were set up with one slit open to detect particles, that condition became a “known” element in the entire system. The photons then, simply went along with that information. In other words, they danced to that music. When the experimental conditions were changed, i.e., when the music changed, the photons simply did another dance in accordance. The photons didn’t have to have prior knowledge of anything nor was an observer necessary.

Prior to the introduction of Bohm’s theory, all of quantum physics had been absorbed in determining the state of a system in the present and the prediction of how that system would be in the future. This description was muddled in murky probabilities. Bohm’s theory described the genuine motion of particles over time, not just the probability of where any one would be at any one time. This solidified the idea that the universe must be seen as a whole system and that anything which can be said of its individual elements at any one instance is only a partial description at best. Bohm’s theories eventually came to be referred to as Bohmian Mechanics.

One of the interesting features of the two-slit experiment is that it allows a thing to be realized in two different ways. But, our daily experience would lead us to believe the words of Gertrude Stein in that “A rose, is a rose, is a rose.” We can accumulate different sensations of it by looking at it, smelling it and even touching it, but alas, it remains a rose. But, the two-slit experiment demonstrates a thing becoming a wave. That's like a door knob turning into a sound depending on how you observe it. The entire concept is mind-boggling. Of such things, Heisenberg said, "What we learn about is not nature itself, but nature exposed to our methods of questioning." Perhaps someday we will have a broader concept of nature that will give the two-slit experiment a fitting context so that we can better understand the question we are asking of it.