What I Know Nothing About

--- or ---

Some Paradoxes We Choose To Ignore In Everyday Life

J. Terry Fuqua, October 2017

Members of this society usually write about something they know and understand thoroughly. Tonight I've chosen to write about things I don't know about, things I don't understand..

In the sixth grade we had to define words for the first time. I soon discovered that those hardest to define were often simple little words so evident in meaning we fail to examine them critically: words like paradox or enigma are easy, but what about "time", "space", "light"? See what I mean? So tonight I choose to look at some obvious phenomena and see how indefinable, how paradoxical they are. Let's start with a light task.

In the 17th century Christiaan Huygens and Isaac Newton proposed competing theories of light: light was thought either to consist of waves (Huygens) or of particles (Newton).

In 1801 an English physicist, Thomas Young, decided to test his theory that light travelled in waves. [1] He knew that, in water-borne waves for example, each point on a wavefront could start a new series of wavelets and that waves timed so that peak met peak were reinforced while waves timed so that peak met trough resulted in cancellation of the wave. Using that idea he cut a very narrow slit into a sheet of thin material and let sunlight strike that slit. Then he cut into a second piece of thin material two parallel slits very close together. Now if he positioned the second sheet (the one with the double slit) so that sunlight from the first struck the double slits and went through to a sheet of paper behind, sure enough interference bands were seen on the paper. The closer together the slits were the brighter the bands appeared, just the effect one would expect from waves in water.

So light is a wave, right?

Well, a second phenomenon seemed to show that light was composed of particles. If one shone a light onto the surface of certain metals, a current would flow. According to classical electromagnetic theory, this effect can be attributed to the transfer of energy from the light to an electron. If light were a wave, one expect the stronger the light source the more current would flow. But that didn't happen. Instead, if one used a faint blue light, one got current that was stronger than one got from using a bright red light. Frequency (therefore wavelength) of the incident light and not intensity (brightness) controlled this current, which was soon called the photoelectric effect. In 1905 Einstein came up with an explanation and viewed light as both wave-like and particular. Indeed electrons and other forms of "particles" can produce diffraction fringes in the double-slit experiment.[2] Did you get that? Particles, like electrons, reinforce and cancel just as waves do when they go through those slits!

NOW ----- are you ready for a rather different subject? Picture a space rocket in orbit around the sun. Gravity is pulling it toward the sun while its thrusters urge it away from the sun. At any point in its orbit we can calculate just how much energy those thrusters must expend to keep the rocket from crashing into the sun. So electrons in orbit around a nucleus should behave the same way, right? Hmmmmm.

What would you say if I told you that electrons cannot exist except in certain, predetermined orbits. They can't orbit the nucleus just any distance out. There are certain packets or quanta of energy that are associated with these orbits, and the amoiunt of energy varies in steps, not continuously. So that little electron can be on step one or step two or whichever step of the atomic stairway you choose, but it cannot exist between two steps. So how can the electron move from one orbit to another without at least briefly occupying some intermediate position. It's rather like saying I can be in New York, Chicago, or Los Angeles but can never be somewhere in between. How does that grab you?

May we look at paradox #3?

in 1927, Werner Heisenberg decided that one could not determine momentum and position of a subatomic particle simultaneously, that the more accurately one determined the momentum the less accurately one could know its position and vice versa. Although his formulas were off a bit, the validity of the Heisenberg Uncertainty Principle, as it came to be called, is still valid. This phenomenon is easily confused with a somewhat similar effect in physics, called the observer effect, which notes that measurements of certain systems cannot be made without affecting the systems. We'll look at that effect in a minute.

This uncertainty principle is, however, inherent in the properties of all wave-like systems and arises on account of the matter wave nature of all quantum objects. Thus, the uncertainty principle actually states a fundamental property of quantum systems, and is not a statement about the observational success or "accuracy" of current technology.

So what? What does all this have to do with how the universe works?

Well, one example is alpha decay. Alpha particles are a little cluster of two protons and two neutrons that can be emitted by some heavy atomic nuclei, such as uranium-238. Usually these are bound inside the heavy nucleus and would need lots of energy to break the bonds keeping them in place. But, because an alpha particle inside a nucleus has a very well-defined velocity, its position is not so well-defined. That means there is a small, but non-zero, chance that the alpha particle could, at some point, find itself outside the nucleus, even though it technically does not have enough energy to escape. Such an event is known as "quantum tunneling", as though the escaping particle can somehow dig its way through an energy barrier that it cannot leap over, the alpha particle escapes fom the nucleus, and we see radioactivity, alpha emission.[5]

Shall we have a go at another of Nature's paradoxes? . . . . the Observer Effect. I told you a minute ago that the Uncertainty Principle is different from the Observor Effect. Do you remember the double slit experiment we first discussed? We saw light acted like a wave with fringe diffraction. This was our evidence that light travelled as waves, and the photoelectric effect was our evidence it travelled as particles. Only if light goes through both slits should you get an interference pattern. Guess what, if you repeat the double slit experiment but this time insert an observing device that will tell you which slit the little photon is passing through[3], you will see the images of the two slits, not an interference pattern. So observing the experiment alters the outcome, the way light travels!

Does this mean the little photon "knows" someone is watching?

In 2002 scientists set up an apparatus that emits one single photon at a time and either inserts or does not insert an interferometer to "observe" which slit the photon transits. The insertion or removal of the observing interferometer took only 40 nanoseconds, while the interferometer to photon distance was 160 nanoseconds. Thus the photon would not be able to know in advance whether it was being observed.

How did the experiment come out? The photons acted like particles 93% of the time that they were observed. They acted like waves if unobserved.

So one can prove the **observer effect** for subatomic scale events. What about larger ones, "real-life" objects? Well, the double slit experiment works for larger atoms. Would it work, albeit with fainter interference bands, for bullets or cars or people?

In 1924 a physicist named Louis de Broglie showed that wavelength = Planck's Constant/momentum.[4] So all matter has wave properties when moving.

Well, tonight we've taken a short trip through Alice In Wonderland, the usually-ignored paradoxes of the universe. Light is a wave. Light is particles. The spacecraft Cassini could have any orbit around Saturn the research team desired, but a lonely electron circling its nucleus has to reside on a finite number of orbital shells and cannot occupy an orbit between these, although orbital transitions of electrons are the way we get different colors of light. And observing a phenomenon, even without directly "touching" the experiment, changes the outcome.

And beyond the topics I've covered lie other paradoxes: Is time constant, or do "seconds" vary not just with motion as Einstein showed but with your locus in the universe. Is space constant? Why should triangles moved through space remain congruent with those never translocated? And how does all of this fit in with the theory of entanglement?

So I challenge you, what DO we really know?

References:
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