Quantum discussions

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The discussion topics come from *The Modern Revolution in Physics* by B. Crowell.

1. Uncertainty vs. random in Quantum Mechanics.

   (From Encyclopedia Britannica)
   A fundamental concept in quantum mechanics is that of randomness, or indeterminacy. In general, the theory predicts only the probability of a certain result. Consider the case of radioactivity. Imagine a box of atoms with identical nuclei that can undergo decay with the emission of an alpha particle. In a given time interval, a certain fraction will decay. The theory may tell precisely what that fraction will be, but it cannot predict which particular nuclei will decay. The theory asserts that, at the beginning of the time interval, all the nuclei are in an identical state and that the decay is a completely random process. A particular atom has no idea how old it is, and can decay at any time. The probability of decay at any particular interval is the same as the probability of decay during any other interval. Radioactive decay is entirely random... In quantum mechanics, the randomness is asserted to be absolutely fundamental. The theory says that, though one nucleus decayed and the other did not, they were previously in the identical state.

   (From the book by Crowell)
   The sequence of digits 121212121212121212 seems clearly nonrandom, and 41592653589793 seems random. The latter sequence, however, is the decimal form of pi, starting with the third digit. There is a story about the Indian mathematician Ramanujan, a self-taught prodigy, that a friend came to visit him in a cab, and remarked that the number of the cab, 1729, seemed relatively uninteresting. Ramanujan replied that on the contrary, it was very interesting because it was the smallest number that could be represented in two different ways as the sum of two cubes. The Argentine author Jorge Luis Borges wrote a short story called "The Library of Babel," in which he imagined a library containing every book that could possibly be written using the letters of the alphabet. It would include a book containing only the repeated letter "a;" all the ancient Greek tragedies known today, all the lost Greek tragedies, and millions of Greek tragedies that were never actually written; your own life story, and various incorrect versions of your own life story; and countless anthologies containing a short story called "The Library of Babel." Of course, if you picked a book from the shelves of the library, it would almost certainly look like a nonsensical sequence of letters and punctuation, but it's always possible that the seemingly meaningless book would be a science-fiction screenplay written in the language of a Neanderthal tribe, or the lyrics to a set of incomparably beautiful love songs written in a language that never existed. In view of these examples, what does it really mean to say that something is random?

2. Changes in light when passing from a given material into another with a different index of refraction.

   Does $E = h\nu$ imply that a photon changes its energy when it passes from one transparent material into another substance with a different index of refraction?

3. Colored photons.

   Can a red photon exist? ... Can a white photon exist?

4. Quantum behavior in small boxes.

   Neutrons attract each other via the strong nuclear force, so according to classical physics it should be possible to form nuclei out of clusters of two or more neutrons, with no protons at all. Experimental searches, however, have failed to turn up evidence of a stable two-neutron system (dineutron) or larger stable clusters. Explain based on quantum physics why a dineutron might spontaneously fly apart.

   Note: Strong nuclear forces are negligible beyond a few fm (1 fm = 10^{-5} Å)