

The Meaning of Time in the Quantum Realms

In an atom, the distances involved in the electromagnetic interactions between electrons and nuclei are on the order of 0.1 nanometers, i.e., 1×10^{-10} m. The interactions are mediated by photons (quantized perturbations in the electromagnetic field) traveling at the speed of light, so interactions occur at least every 3.33×10^{-19} sec within the diameter of the atom, and the frequency of interactions is the inverse of that and is at least 3×10^{18} interactions per second if one ignores the interactions occurring within the atomic nucleus. In an atomic nucleus, the distances of the strong and weak nuclear interactions (quantized perturbations in the bosonic fields) are on the order of 1×10^{-15} m. The interactions are mediated by gluons traveling at the speed of light and other mass containing bosons traveling at less than the speed of light, and the frequency of interactions is at least 3×10^{23} interactions per second.

The Heisenberg Uncertainty Principle may be expressed as:

$$\Delta E \Delta t \geq h / (4 \pi)$$

where h is Planck's constant, ΔE is the uncertainty in the energy and Δt is the uncertainty in the time. Uncertainty in the energy manifests itself as an uncertainty in the frequency through the relationship $\Delta E = h \Delta \nu$, so it follows that

$$(h \Delta \nu) \Delta t \geq h / (4 \pi)$$

And the *minimum* uncertainty in the frequency of interactions $\Delta \nu$ is :

$$\Delta \nu \geq 1 / (4 \pi \Delta t)$$

Assuming a *maximum* time of Δt of 3.33×10^{-19} sec between interactions in an atom, the *minimum* uncertainty in the frequency $\Delta \nu \geq 2.4 \times 10^{17} \text{ sec}^{-1}$.

Due to the uncertainties, it follows that we humans have ***no clue*** about the interactions that occur in time periods of less than about 3.33×10^{-19} sec within atoms and nuclei at even shorter time scales. The behavior may be very complicated but manifest itself to our observations in relatively simple physical laws. This lack of knowledge does not prove that intelligence and consciousness exist in the atomic and nuclear quantum realms, but it allows it.