Note on the Uncertainty Principle

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We describe a hypothetical apparatus for making arbitrarily accurate simultaneous successive measurements of a particle's positions, momenta, energies and times.

In order to clarify our understanding of the implications of the Uncertainty Principle we will describe a Gedanken experiment involving an apparatus for making certain arbitrarily precise measurements.

The apparatus consists of a hollow evacuated space (we can assume for now that it is spherical) where the entire inside surface is very densely coated with microscopic detectors that measure, with arbitrarily high precision, the time and location of impact of a particle, such as a Helium 3 (^{3}He) atom. We will assume that the interior of the sphere is a perfect vacuum aside from containing one single ^{3}He atom. Whenever the atom impacts the surface of the sphere, an accurate measurement is made of the time of impact and the coordinates on the inside surface of the sphere. The location is determined by means of knowing the location of every detector. The detector system reports to a computer the times and locations of every event where the single ^{3}He atom bounces off of the interior surface of the sphere.

Whenever the ^{3}He atom is detected and its position and the time are measured with arbitrarily high accuracy, the result is to introduce an uncertainty in both the future momentum and the future energy of the ^{3}He atom after each impact. However, we can again measure the time and position of the next impact. We can then calculate, taking into account the effects of the Earth's gravitational attraction on the ^{3}He atom, both the prior momentum and the prior energy of the ^{3}He atom prior to that next impact. Thus we can compute a lengthy, arbitrarily precise history of interaction events with simultaneous measurements of positions, momenta, times and energies. It would also be possible to have a program that, as a function of time, yields a complete and arbitrarily accurate time stamp history of the particle's positions, momenta and energies; again with arbitrary precision.

What the Uncertainty Principle implies is that we cannot, with arbitrary precision, simultaneously measure the position of a particle while also determining the future momentum. We cannot, with arbitrary precision simultaneously measure the time of a particle event while also determining the future energy of the particle.

It is a simple misunderstanding of the uncertainty principle to state that one cannot make measurements, with arbitrary precision, that yeild arbitrarily accurate measures of both position and momentum at prior instants of time or both energy and time at prior events.