Virtual Probability Fluctuations (VPF)

Monday, September 26, 2011
9:23 AM

In physics, a virtual particle is a particle that exists for a limited time and space. The energy and momentum of a virtual particle are uncertain according to the uncertainty principle. The degree of uncertainty of each is inversely proportional to time duration (for energy) or to position span (for momentum).

Virtual particles exhibit some of the phenomena that real particles do, such as obedience to the conservation laws. If a single particle is detected, then the consequences of its existence are prolonged to such a degree that it cannot be virtual. Virtual particles are viewed as the quanta that describe fields of the basic force interactions, which cannot be described in terms of real particles. Examples of these are static force fields, such as a simple electric or magnetic field, or any field that exists without excitations that result in its carrying information from place to place. Virtual photons are also a major component of antenna near field phenomena and induction fields, which have shorter-range effects, and do not radiate through space with the same range-properties as do electromagnetic wave photons. For example, the energy carried from one winding of a transformer to another, in quantum terms, is carried by virtual photons, not real photons.

The virtual particle forms of massless particles, such as photons, do have mass (which may be either positive or negative) and are said to be off mass shell. They are allowed to have mass (which consists of "borrowed energy") because they exist for only a temporary time, which in turn gives them a limited "range". This is in accordance with the uncertainty principle which allows existence of such particles of borrowed energy, so long as their energy, multiplied by the time they exist, is a fraction of Planck's constant.

The concept of virtual particles is closely related to the idea of quantum fluctuations. Virtual particles can be thought of as coming into existence as quantities, such as the electric field, which fluctuate around their expectation values as required by quantum mechanics.

In probability theory, a probability density function (pdf), or density of a continuous random variable is a function that describes the relative likelihood for this random variable to occur at a given point. The probability for the random variable to fall within a particular region is given by the integral of this variable's density over the region. The probability density function is nonnegative everywhere, and its integral over the entire space is equal to one.

The terms "probability distribution function" and "probability function" have also sometimes been used to denote the probability density function. However, this use is not standard among probabilists and statisticians. In other sources, "probability distribution function" may be used when the probability distribution is defined as a function over general sets of values, or it may refer to the cumulative distribution function, or it may be a probability mass function rather than the density. Further confusion of terminology exists because density function has also been used for what is here called the "probability mass function".

The fluctuation-dissipation theorem (FDT) is a powerful tool in statistical physics for predicting the behavior of non-equilibrium thermodynamical systems. These systems involve the irreversible dissipation of energy into heat from their reversible thermal fluctuations at thermodynamic equilibrium. The fluctuation-dissipation theorem applies both to classical and quantum mechanical systems.

The fluctuation-dissipation theorem relies on the assumption that the response of a system in thermodynamic equilibrium to a small applied force is the same as its response to a spontaneous fluctuation. Therefore, the theorem connects the linear response relaxation of a system from a prepared non-equilibrium state to its statistical fluctuation properties in equilibrium. Often the linear response takes the form of one or more exponential decays.

The fluctuation-dissipation theorem was originally formulated by Harry Nyquist in 1928, and later proven by Herbert Callen and Theodore A. Welton in 1951.