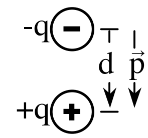
Electric Dipole Moment

The electric dipole moment for a pair of opposite charges of magnitude q is defined as:

- the magnitude of the charge multiplied by the distance between them and
- the defined direction is toward the positive charge.

It is a useful concept in atoms and molecules where the effects of charge separation are measurable, but the distances between the charges are too small to be easily measurable.



$\vec{p} = q\vec{d}$

The EDM (both electron and neutron) has important implications for understanding CP violation. In particle physics, CP violation is the violation of the combined conservation laws associated with charge conjugation (C) and parity (P) by the weak nuclear force, which is responsible for reactions such as the decay of atomic nuclei. Charge conjugation is a mathematical operation that transforms a particle into an antiparticle, for example, changing the sign of the charge. Charge conjugation implies that every charged particle has an oppositely charged antimatter counterpart, or antiparticle.

For years it was assumed that C and P were exact symmetries of elementary processes, namely those involving electromagnetic, strong, and weak interactions. The same was held true for a third operation, time reversal (T), which corresponds to reversal of motion. Invariance under time implies that whenever a motion is allowed by the laws of physics, the reversed motion is also an allowed one. A series of discoveries from the mid-1950s caused physicists to alter significantly their assumptions about the invariance of C, P, and T.

No completely satisfactory explanation of CP violation has yet been devised. The size of the effect, only about two parts per thousand, has prompted a theory that invokes a new force, called the “superweak” force, to explain the phenomenon. This force, much weaker than the nuclear weak force. This force would operate only between some quarks and would produce no other observable effects. Another theory, named the Kobayashi-Maskawa model after its inventors, posits certain quantum mechanical effects in the weak force between quarks as the cause of CP violation.

CP violation has important theoretical consequences. The violation of CP symmetry, taken as a kind of proof of the CPT theorem, enables physicists to make an absolute distinction between matter and antimatter. The distinction between matter and antimatter may have profound implications for cosmology. One of the unsolved theoretical questions in physics is why the universe is made chiefly of matter. With a series of debatable but plausible assumptions, it can be demonstrated that the observed matter-antimatter ratio may have been produced by the violation of CP in the first seconds after the “big bang,” the violent explosion that is thought to have resulted in the formation of the universe.

So, our search for the electric dipole moment of the electron (and neutron, for we are searching for the nEDM as well) is part of physicists larger effort to define elements of the Standard Model of elementary particle physics— the means by which we understand and predict the physical phenomena we observe in the universe around us.

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