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Refining the fine-structure constant

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Physicists have made the most accurate measurement to date of the fine-structure constant, alpha -- the dimensionless number that is a measure of the strength of the electromagnetic force. The new value, based on the most precise measurements ever of the magnetic moment of the electron, has an uncertainty of 0.7 parts per billion. The new value is ten times better than the next most accurate way to measure alpha.

Alpha -- one of the fundamental constants of physics -- determines the strength of interactions between charged particles and electromagnetic fields. It equals e^2/c *h-bar* -- where *e* is the charge on the electron, *h-bar* is the Planck constant divided by 2π, and *c* is the speed of light -- and is about 1/137. As a dimensionless number, it is even more fundamental than other constants such as the strength of gravity, the speed of light or *e* itself.

Most attempts to calculate alpha involve measuring the magnetic moment of the electron, *g*, which relates the size of the electron's magnetism to its intrinsic spin. A value for alpha can then be obtained by inserting this value of *g* into equations from quantum electrodynamics (QED) -- the theory that describes the electromagnetic interactions between electrically charged particles and the virtual particles of empty space. If such interactions did not exist, *g* should be 2, but precise measurements over the years have shown that it differs slightly from this value, as predicted by QED itself.

Until now, the best measurement of *g* had an uncertainty of 4 parts per trillion. Now, Gerald Gabrielse and colleagues at Harvard University have increased this precision by a factor of almost six to 0.76 parts per trillion (*Phys. Rev. Lett.* **97** 030801). By inserting this new value of *g* into new and improved QED equations, the Harvard physicists, with colleagues from Cornell University and RIKEN in Japan have determined a new value for alpha that is ten times more accurate than the next most accurate value (*Phys. Rev. Lett.* **97** 030802).

Gabrielse and colleagues measured *g* by studying the motion of a single electron held inside a trap made of charged electrodes and magnetic coils. The combined electric and magnetic forces keep the electron moving in a circular "cyclotron" orbit. On top of this planar motion, the electron also wobbles vertically up and down in the direction of the magnetic field. This set-up allowed the researchers to cleverly tweak the electron's motion and measure its energy levels with great precision. The value of *g* was determined by observing transitions between the lowest spin and cyclotron energy levels of the electron.

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Gabrielse thinks a better value of alpha could help in plans to redefine the kilogram that do not rely on using an actual weight kept in a vault in Paris.

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