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Study of Electron G-2 From 1947 To Present[1]

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In 1947 Kusch and Foley discovered in the study of Zeeman splitting of Ga atom that the electron g-factor was about 0.2% larger than the value 2 predicted by the Dirac equation. Soon afterwards Schwinger showed that it can be explained as the effect of radiative correction. His calculation, in the second order perturbation theory of the Lorentz invariant formulation of renormalized quantum electrodynamics, showed that the electron has an excess magnetic moment $a_e \equiv (g-2)/2 = \alpha/(2\pi)$, where α is the fine structure constant, in agreement with the measurement within 3%. Thus began a long series of friendly competition between experimentalists and theorists to improve the precision of a_e. Over the period of more than 60 years measurement precision of a_e was improved by more than 10^4 by the spin precession technique, and further 10^3 by the Penning trap experiments. In step with the progress of measurement, the theory of a_e, expressed as a power series in α, has been pushed to the fifth power of α. Including small contributions from hadronic effects and weak interaction effect and using the best non-QED value of α: $\alpha^{-1} = 137.035999049(90)$, one finds $a_e(theory) = 1159652181.72(77) \times 10^{-12}$. The uncertainty is about 0.66 *ppb*, where 1 $ppb = 10^{-9}$. The intrinsic uncertainty of theory itself is less than 0.1 *ppb*. The over all uncertainty comes mostly from the uncertainty of non-QED α mentioned above, which is about 0.66 *ppb*. This is in good agreement with the latest measurement: $a_e(experiment) = 1159652180.73(28) \times 10^{-12}$. The uncertainty of measurement is 0.24 *ppb*. An alternate approach to test QED is to assume the validity of QED (and the Standard Model of particle physics) and obtain α by solving the equation $a_e(experiment) = a_e(theory)$. This yields $\alpha^{-1}(a_e) = 137.0359991727(342)$, whose uncertainty is 0.25 *ppb*, better than α obtained by any other means. Although comparison of theory and experiment of a_e began historically as a test of the validity of QED, it has now evolved into a precision test of fine structure constant at the level exceeding 1 *ppb*, which may be regarded as a test of internal consistency of quantum mechanics as a whole.

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