

# Lamb Shift Encyclopedia Article

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# Lamb Shift

The Lamb shift describes a small but measurable difference in **electron energy** levels within the hydrogen **atom** that is accounted for by quantum electrodynamic theory. Specifically, the difference involves a shift between the 2s and the 2p states of the **hydrogen atom**. The 2s state has a **frequency** value 1,057.8 megahertz larger than the 2p state.

In early quantum mechanical theory of the hydrogen atom, these two atomic states for hydrogen were predicted to have the same energy, even when relativistic effects and coupling between the electron's spin and orbital **angular momentum** were taken into account. However, prior to World War II techniques were unavailable to verify the truth of this prediction regarding identical energy states. **Work** on microwave techniques during the war finally allowed for precision tests on hydrogen energy levels. In 1947 American physicists, Willis Lamb and Robert Retherford, first measured a frequency difference between the two energy levels of about 1,060 megahertz. Soon afterward, **Hans Bethe** calculated the energy splitting nonrelativistically to be 1,040 megahertz, and a later relativistic treatment by Victor F. Weisskopf (1908-) resulted in a theoretical prediction of 1,057.7 megahertz, in extremely good agreement with the experimental value.

In **quantum electrodynamics (QED)**, one can write down the self-energy of an electron, that is, the energy coming from an electron acting on itself. This self-energy leads to an **energy level** shift for atomic wavefunctions that are nonzero at the center of the atom; this explains why the 2s and 2p states are split, because the s-state wavefunctions are nonzero at the center of the atom while the p-state wavefunctions are zero there.

A problem with the first predictions of the level shift was that it was infinite. This problem was overcome in one of the first applications of **renormalization** theory. Following renormalization infinite values cancel each other out to leave a finite level shift. The accuracy of the theoretical prediction of the Lamb shift verifies that renormalization theory is a valid way to treat infinities in **quantum theory**.