discussed above, the preliminary data indicate a general increase in the magnetic field strength throughout most of the inner zone (see Fig. 1) as well as irregular deviations. Although a longitudinal drift of the total plasma field should exist and provide a current, the resultant field depression, seen by a magnetometer presumed to be interior to such a region, is difficult to evaluate and requires knowledge of the velocity distribution function for the charged particles. It does appear from the data, however, that the commonly postulated condition, $\nabla \times \vec{H} = 0$, is inadmissible in the outer atmosphere.[7]

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MEASUREMENT OF THE GRAVITATIONAL RED SHIFT USING THE MÖSSBAUER EFFECT IN Fe^{57}

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The change in the frequency of spectral lines with gravitational potential, generally referred to as the gravitational red shift, was first predicted by A. Einstein in 1907.[1] The effect can be calculated from the time dilatation in a gravitational potential which follows from the principle of equivalence. From the point of view of a single coordinate system two atomic systems at different gravitational potentials will have different total energies. The spacings of their energy levels, both atomic and nuclear, will be different in proportion to their total energies. The photons are then regarded as not changing their energy and the expected red shift results only from the difference in the gravitational potential energies of the emitting and absorbing systems. Astronomical observations, though somewhat ambiguous, have tended to confirm this effect.[2] The recent discovery by Mössbauer[3] of recoilless nuclear resonance absorption of gamma rays as a precise resonance process has suggested to several groups[4-6] the possibility of using this effect to measure the gravitational red shift. More specifically the discovery that Fe^{57} could absorb 14.4-kev gamma rays in a resonance whose width is approximately 6.4×10^{-13} of the gamma-ray energy[4,6,7] has made this experiment a practical possibility.

We have performed this experiment using a total difference in height of 12.5 meters. A source of Co^{57} of approximately 30 millicuries was electrodeposited on the surface of an iron disk which was then heated for five hours at 700°C in a hydrogen atmosphere, then for an equal length of time in a vacuum. This disk was mounted on a transducer device which consisted of a coil mounted between the poles of an electromagnet and supported on an elastic spider. The gamma rays passed through an evacuated tube with 0.005-in. Mylar windows on both ends. Antiscattering baffles were mounted inside the tube. The detector consisted of a proportional counter with a five-inch diameter window also covered by 0.005-in. Mylar. The counter was filled with krypton gas to approximately $\frac{1}{4}$ atmosphere pressure. Krypton is especially favorable because its absorption edge is just below the energy of the 14-kev gamma rays.[8] A five-inch diameter foil containing 4 mg/cm² of Fe enriched in Fe^{57} to 24.1% was directly above the counter.

The transducer was driven sinusoidally at 50 cps and counts were recorded in two scalers for alternate halves of the cycle. Two other scalers were switched simultaneously and recorded timing pulses in order that small inequalities in the counting times would be corrected. The phasing of the switching pulses with respect to the motion was carefully checked and then switched through 180° at 200-minute intervals in order to cancel out systematic errors. The fluctuations in the averages of these sets of runs were subjected to a χ^2 test. For 29 data points χ^2 was 34.4, indicating that fluctuations were almost entirely due to counting statistics.

Ideally one would move the source with a constant velocity up and down, with the precise optimum value of the velocity determined by the measured width of the absorption curve and the amount of absorption. Sinusoidal motion can be easily obtained and it can be shown that such motion will be only about ~20% less sensitive to a shift in the energy of the resonance peak. In our experiment we determined that the width of the peak was 0.40 mm/sec at half maximum, considerably broader than the expected width of 0.14 mm/sec, and the maximum absorption was 18.5% in the gross counting rate. The fractional shift expected in the total energy for this height is $gh/c^2 = 1.36\times10^{-15}$. With these parameters the expected shift in the ratio of the two counting rates is 3.9×10^{-4} when the amplitude of the oscillation was 0.51 micron. The effect of the broadened peak not having a Lorentz shape was assumed to be negligible.

The amplitude of the motion on the transducer was calibrated by measurement on a microscope under stroboscopic illumination. It was monitored by a phonograph crystal pickup and is believed to be accurate to better than 10%. A total of 250 hours of counting yielded a ratio which differed from unity by 3.75×10^{-4} with an uncertainty from counting statistics of 1.76×10^{-4}. Other sources of error are believed to be negligible in comparison with this. Thus we observed 0.96 ± 0.45 times the expected shift in the energy of the gamma rays. This implies that the probability of the gravitational red shift being zero is 0.017.

The measurement was also repeated at a height of three meters to look for possible asymmetries with improved counting statistics. The result was $(0.5\pm1.0)\times10^{-4}$ where 0.9×10^{-4} was expected. The error quoted was due to counting statistics alone. Here the fluctuations in the individual runs were appreciably larger than expected from statistics. This can be largely attributed to the improved statistics of the individual runs which would emphasize short-term fluctuations, but the results indicate that these cancel out when many runs are averaged together. The statistics on this null measurement were not included in the final result.

A repetition of the experiment is intended under more favorable conditions. The accuracy in the present measurement was limited mostly by the unexpectedly great width of the peak and by the smallness of the total absorption. We hope to be able to alleviate this condition by repurifying the source and replating it under carefully controlled conditions. The source was considerably weaker than expected and contained a relatively large Co^{56} contaminant. This also contributed to the difficulties and it did not seem practical to continue the experiment under the present conditions to improve the statistical accuracy of the result.

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