Null Result for the Weight Change of a Spinning Gyroscope

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A null result was obtained for the weight change of a right-spinning gyroscope, contradicting the results recently reported by Hayasaka and Takeuchi. No weight change could be observed under a variety of spin directions for rotational frequencies between 0 and 2.2×10^4 rpm. Our limit of -0.025 ± 0.07 mg is more than 2 orders of magnitude smaller than the effect reported by Hayasaka and Takeuchi.

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In a recent Letter[1] the anomalous weight reduction of several gyroscopes is reported. The authors conclude from their experiments that the weight changes for rotations around the vertical axis are completely asymmetrical: No weight change is observed for left rotations, while right rotations cause weight reductions of up to 10 mg for rotational frequencies on the order of 10^4 rpm. Subsequently, two experiments[2,3] have found *no* evidence for weight reductions. These two experiments were similar and differed from those described in Ref. 1 in several ways: (i) The masses of the gyroscope rotors were substantially larger; (ii) the gyroscopes were spun in closed, but not evacuated, containers; (iii) the maximum rotational frequencies were somewhat lower; and (iv) the rotors were air driven rather than electrically driven. We have carried out experiments under more similar conditions to those reported in Ref. 1 and have also found *no* such weight changes.

Our gyroscope assembly (rotor, housing, and drive motor circuit board) was obtained from an aircraft directional gyroscope, model No. RCA 15BK, manufactured by R. C. Allen Instruments, Wichita, KS. The brass rotor had a radius of 1.92 cm and a mass of 142.4 g; it was enclosed together with its frame in an evacuated container (at a pressure of 1–3 Pa) and operated at a maximum rotational frequency of 2.2×10^4 rpm. The weight of the entire assembly was 242.4 g.

For a rotating body of arbitrary shape, it is possible to define a radius of gyration or effective radius $r_{\rm eff}=\sqrt{I/M}$ from the moment of inertia I and mass M of the spinning object. We determined the moment of inertia of our rotor from the relationship

$$\mathbf{F}\times\mathbf{R}=Mr_{\rm eff}^2\,d\boldsymbol{\omega}/dt$$

by measuring the reactive torque $\mathbf{F}\times\mathbf{R}$ exerted on the vacuum container while a uniform angular deceleration $d\boldsymbol{\omega}/dt$ was affected on the gyroscope via an electromagnetic brake. The effective radius of our rotor was 1.52 cm. In Ref. 1, an equivalent radius $r_{\rm eq}$ was defined by the formula

$$Mr_{\rm eq}=\int\int\rho(r,z)2\pi r^2\,dr\,dz\ ,$$

where $\rho(r,z)$ is the density of the rotor material(s); $r_{\rm eq}$ is slightly different from $r_{\rm eff}$. For example, a cylinder of uniform composition with radius R has $r_{\rm eff}=(1/\sqrt{2})R$ whereas $r_{\rm eq}=\frac{2}{3}R$, a difference of 6%. For our gyroscope, we could not evaluate $r_{\rm eq}$ since $\rho(r,z)$ is unknown and we have assumed in the following that $r_{\rm eq}\approx r_{\rm eff}$.

All weights were determined using a Mettler HE20 balance with a BA28/BE20 electronic readout and tare system. The balance capacity was increased from 160 to 260 g and had an electronic range of ±1 g with 0.1-mg readability. The balance was calibrated with standard weights prior to the measurements. The balance was partially isolated from the gyroscope vibrations by placing a 1.8-cm-thick polyurethane foam pad under the gyroscope. No magnetic shielding was applied.

Measurements were carried out with the gyroscope

TABLE I. Measured and expected weight changes ΔW of our gyroscope for a change in the rotational frequency from 2.2×10^4 to 0 rpm.

Direction of spin vector	Orientation of gyroscope axis	Expected[a] ΔW (mg)	Observed ΔW (mg)
Up	Vertical normal	0.0	$+0.08\pm0.5$ [b]
Down	Vertical normal	-10.2	$+0.12\pm0.5$ [b]
Up	Vertical inverted	0.0	$+0.16\pm0.5$ [b]
Down	Vertical inverted	-10.2	$+0.07\pm0.5$ [b]
South	Horizontal	n.a.	-0.49 ± 0.5 [c]
North	Horizontal	n.a.	$+0.12\pm0.5$ [c]
Down-up [d]	Vertical normal	-10.2	$+0.04\pm0.10$ [e]
Down-up [d]	Vertical inverted	-10.2	-0.09 ± 0.10 [e]

[a]Assuming $r_{\rm eq}=r_{\rm eff}$ (from Ref. 1).
[b]Average of three separate experiments.
[c]Result of single experiment.
[d]See text for details.
[e]Reduced uncertainty since weight drifts due to convection currents cancel.

axis in the normal vertical, inverted vertical, and horizontal positions under left and right rotations. Through fine copper wires of 50 μm diam, a three-phase, 414-Hz power supply was connected to the gyroscope for 1 min to spin it up to $(2.2\pm0.03)\times10^4$ rpm. After disconnecting the power source, several weight measurements were made until the rotor stopped after ~5 min. Balance readings were taken at 0, 10, 20, 30, 45, 60, 90, 120, 150, 180, 240, and 300 s after switching off the power supply. The uncertainty in the time at which the readings were taken is estimated to be ±2 s. The relationship between rotational frequency and elapsed spin-down time was measured for the normal vertical orientation in a separate experiment using a photocell and an electronic counter. Convection currents inside the balance, due to the slight warming of the gyroscope housing, caused an apparent weight change of -0.19 ± 0.08 mg/min for *all* orientations and directions of the spin vector, even when the rotor was prevented from spinning by a wedge.

The measured weight changes (rotating weight minus stationary weight) of our gyroscope for the largest change in rotational frequency (from 2.2×10^4 to 0 rpm) are given in Table I, together with the expected weight changes $\Delta W(\omega)$ calculated according to the expression given in Ref. 1 (assuming $r_{eq}=r_{eff}$):

$$\Delta W(\omega) = -2\times10^{-5} M r_{eq}\omega \text{ (cgs units)}.$$

Three sets of measurements were carried out for both directions of the spin vector with the vertical axis of the gyroscope in the normal and inverted orientations. Two experiments were made with the spin vector in the horizontal plane. The results in Table I have been corrected for the temperature drift; the quoted errors of the weight measurements are, however, almost entirely due to this effect. The most accurate results, shown in rows 7 and 8 of Table I, were obtained by taking the differences between the weight changes for the up and down directions of the spin vector since the weight drift due to convection currents cancels. We have assumed that the uncertainty for these two values is due to the uncertainties in the balance readings only. The weight changes as a function of rotational frequency could be determined for the normal vertical orientation only (as mentioned previously) and Fig. 1 shows the differences in weight changes for left and right rotations versus rotational frequency. It is apparent that there is no observable weight change for our gyroscope in the rotational frequency range of 0 to 2.2×10^4 rpm. Taking the results of the normal (Table I, row 7) and the inverted (row 8) orientations together, our observed average weight difference for the two spin directions is -0.025 ± 0.07 mg while, according to Ref. 1, we would have expected a difference of -10.2 mg.

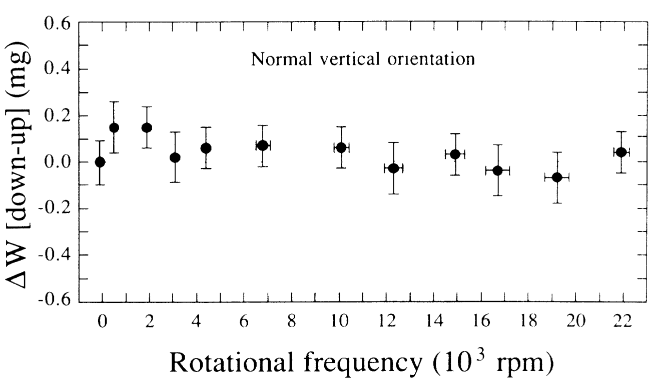

FIG. 1. Differences in the weight changes (expressed in mg) for the up- and down-spin vector directions as a function of rotational frequency for the normal vertical gyroscope orientation. Estimated uncertainties in the rotational frequency are shown if larger than the plotting symbol. The error bars in the difference in weight changes reflect the uncertainties in the balance readings only, since the systematic uncertainty due to the temperature drift cancels.

TABLE II. Summary of experiments attempting to confirm the results reported in Ref. 1.

Experiment	Limit for ΔW (mg)	Predicted ΔW (mg)
Ref. 2	< 0.4	−10.2 [a]
Ref. 3	< 0.06	−8.0 [a]
This work	< 0.07	−10.2 [b]

[a]Result from Ref. 1 scaled by both mass and equivalent radius.
[b]Assuming $r_{eff}=r_{eq}$ (see text).

The results of our experiment and the results from Refs. 2 and 3 are summarized in Table II. There is no apparent weight reduction within experimental limits for right-rotating gyroscopes in any of these experiments. We, therefore, conclude that the difference in the weight change of a right- versus left-rotating gyroscope is at least 2 orders of magnitude smaller than reported in Ref. 1 and, hence, there is—within the error limits—no reflection asymmetry.

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