Alternative Experimental Procedures for the TeachSpin MT-1A

Jake Fontana and Jamie Romnes

Physics Department
California Polytechnic State University
San Luis Obispo, CA 93407

I. Introduction

The Cal Poly Physics Department incorporated the TeachSpin MT-1A apparatus into the junior-level, Quantum Physics Laboratory course beginning in the 2002-2003 school year. The course comprises three full quarters of modern physics experiments and is known as the most challenging experience that physics students encounter during the pursuit of their degree at Cal Poly. While Magnetic Torque has become a very valuable addition to Q-Lab we found it difficult to get the cue ball spinning consistently by the method presented in the TeachSpin, i.e., holding the post at the top of the ball with the fingertips and "snapping" the ball into spinning. Our attempts to get the ball spinning at high frequencies resulted in noticeable wobble (nutation).

Here we present a simple method to spin the ball consistently without wobble and offer an alternative method to determine the magnitude of the magnetic dipole moment of the cue ball.

II. The String-Pull Method

Our alternative spinning method, which is reminiscent of old-fashioned tops, uses a string that is wrapped around the post at the top of the ball. A piece of masking tape wrapped on the post under the string helps keep the string from slipping. A pencil point or a thin, straight, metal rod is placed in the hole in the post. The hand holding the pencil or rod rests on the top of the magnetic coil form for stability. Then the string on the ball is pulled with constant force. The hand with the pencil applies light pressure to the ball, just enough to keep the ball from wobbling. Once the string is completely pulled off the post, the pencil point is removed from the post. This procedure produces very uniform and consistent spins, with the initial angular velocity depending on the length of the string and the magnitude of the pulling force. The setup is shown in figure 1.

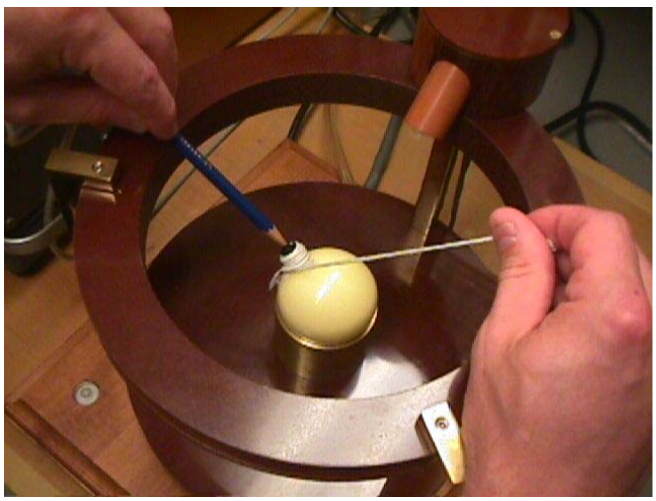

Figure 1: String-Pull Method

Using the string-pull method, it is possible to get the ball spinning at frequencies as high as 20 Hz with very little nutation. Because the spin frequencies could be higher than the frequency range of the strobe in the MT1-A, we initially used an external strobe with a higher frequency range to detect the spin frequency. However, we also found that it is possible to use the internal strobe if one remembers that the white dot on the post will appear to be standing still for spin frequencies f_s which are an integer multiple of the strobe frequency f_{st} (i.e., $f_s=nf_{st}$, where n =1, 2, 3...). However, if the ball is spinning at a multiple of

f_{st}, the white dot will appear to go out of and then back into coherence with the strobe as ball spin slows down.

Figure 2: Experimental Setup with Secondary Strobe Light

III. Experimental Application

The String-Pull Method is especially effective when used with the magnetic precession experiment. As stated in the manual, the objectives of this experiment are to measure the dipole moment of the cue ball while also observing the motion of a spinning sphere when it is subject to an external torque. We decided to use the String-Pull method to measure the relationship between the precession frequency and spin frequency at constant magnetic field. The theoretical relationship between these quantities is given by Equation (1):

$$\Omega_p = \mu B\,(1/L), \tag{1}$$

where Ω_p is the angular frequency of precession, and L is the spin angular momentum. L is equal to the product of the moment of inertia of the ball I and the spin angular frequency ω_s.

Measurements of the precession period were made for spin frequencies from 6.0 Hz to 20 Hz, incrementing by 1 Hz (see Table 1). The coil current was held constant at 2 Amps. Three runs were performed at each frequency and averaged. A plot of the precession angular frequency versus the inverse of the spin angular frequency is shown in Figure 3. A linear fit of the data with Microsoft Excel yielded an experimental relationship between the two quantities as shown in Figure 3. Using this data, we measured the magnitude of the dipole moment μ = 0.39 A-m^2 with an uncertainty of approximately 0.02 A-m^2.

$f_{[spin]}$* (Hz)	$1/\omega_{[spin]}$ (1/Hz)	**Avg. $\Omega_{[precession]}$*** (s/cycle)	Avg. $\Omega_{[precession]}$ (rad/s)
6.0	0.027	7.46	0.84
7.0	0.023	8.45	0.74
8.0	0.020	10.25	0.61
9.0	0.018	11.53	0.54
10.0	0.016	12.65	0.50
11.0	0.014	13.83	0.45
12.0	0.013	15.34	0.41
13.0	0.012	16.65	0.38
14.0	0.011	17.69	0.35
15.0	0.011	18.68	0.34
16.0	0.010	19.78	0.32
17.0	0.009	20.83	0.30
18.0	0.009	21.59	0.29
20.0	0.008	23.59	0.27

Table 1: Experimental data obtained using the String-Pull Method
* (Note: Bold letters indicate actual measured values)

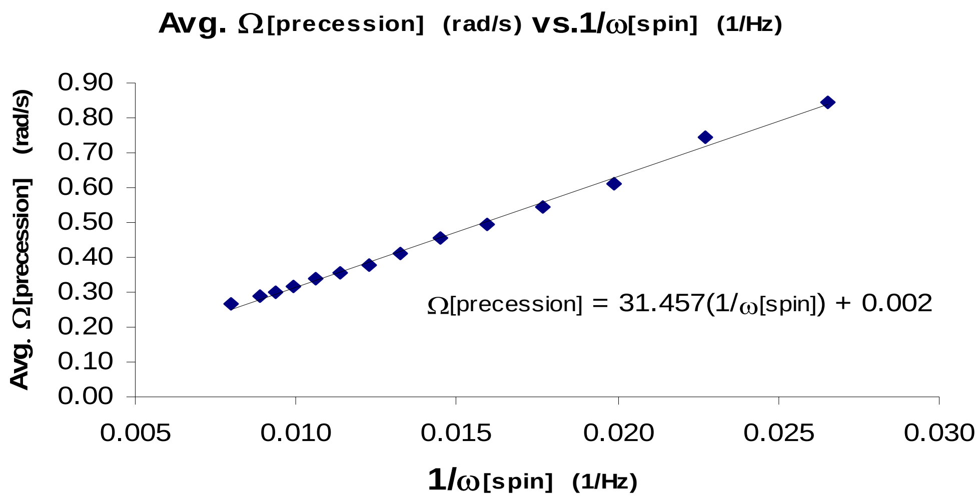

Figure 3: Plot of experimental data obtained using the String-Pull Method

A variation of the String-Pull method can also be used to facilitate the rotation of the transverse magnetic field accessory, as shown in Figure 4.

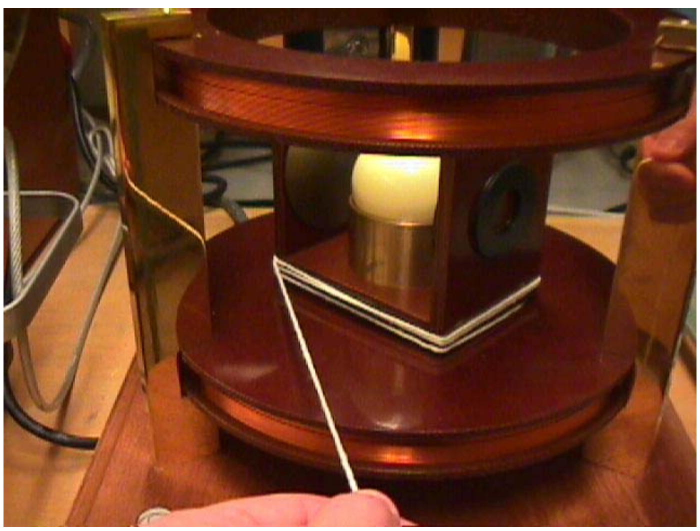

Figure 4: The String-Pull Method and the rotating, transverse-field, device.

IV. Conclusions

The advantages of the String-Pull method over the finger-snapping technique include the greater consistency and ease of spinning the cue ball and obtaining higher spin frequencies. This allows a better determination of the effect of spin frequency on the precession of the spinning sphere. Because this apparatus is a teaching tool, this advantage is of great benefit to students that are trying to understand the interaction of a magnetic moment with an external magnetic field.

We acknowledge Professor Richard B. Frankel for supervising this study and for critical reading of the manuscript.