**Measuring a Magnetic Dipole via Harmonic Oscillation**

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**Introduction:**

Oscillations are among the most important motions to understand when dealing with physics on both a macro and micro scale; the oscillation of an object can be used to determine specific properties of said object, especially in the case of magnets and magnetic fields[[1]](#endnote-1). In this case, we placed a cue ball containing a magnetic dipole in a constant magnetic field generated by a near[[2]](#endnote-2) Helmholtz coil (so as to create a consistent magnetic field in the area that the cue ball was placed) and allowed it to oscillate. By changing the current through the coil[[3]](#endnote-3) and measuring the change in the frequency of oscillations, we were able to calculate the strength of the magnetic dipole. Given the input of the current (our independent variable) and the output of the frequency (our dependent variable), a simple way to draw a comparison between the two was to find a method by which we could linearize the graph of the values such that the slope of the line would be our value for the magnetic dipole. To linearize this graph, we could not have just placed the raw values on the axes, rather we needed to calculate values that depended on these raw values. Based on the idea that the sum of the torques on a system will be equal to the moment of inertia times the angular acceleration, the latter of which is the second derivative of angular position, meaning that

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| --- | --- |
|  | (1) |

where is the angular position and is the angular acceleration. Given the equation for the magnetic torque being

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| --- | --- |
|  | (2) |

where is the torque, is the magnetic dipole moment, and B is the magnitude of the magnetic t, we were able to set this formula equal to , a more general equation for torque. As this was a harmonic oscillator and a differential equation, we were able to assume the equation for to be

|  |  |
| --- | --- |
|  | (3) |

where is the frequency of oscillation. We also assumed a small angle for the magnetic torque, allowing us to simplify that equation to just

|  |  |
| --- | --- |
|  | (4) |

which led to a slightly simpler equation than we would have gotten otherwise, that being

|  |  |
| --- | --- |
|  | (5) |

after substituting in for . From there we simplified along the following steps:

|  |  |
| --- | --- |
|  | (6a) |
|  | (6b) |
|  | (6c) |

While our goal was to find , we did not simply solve this equation for , we wanted to create an equation for some function to which we would be able to fit our data (including any uncertainty bars). We found that the simplest route by which this could be done would be to create an equation for a line, i.e. , wherein the slope we found was to be . With this in mind, we rearranged the equation to find

|  |  |
| --- | --- |
|  | (7) |

**Experimental Methods:**

The primary apparatus used for this experiment was the TeachSpin M1-A,[[4]](#endnote-4) which comprises of the aforementioned near Helmholtz coils, an air pump, and a power supply. The oscillator was built out of a cue ball, with a magnetic dipole at the center and a hole in which a metal bar was placed (this acted as a weight, which would allow the moment of inertia to be altered). Once the cue ball was placed in the center, it was pushed upwards by the air pump, this would remove nearly all the friction that would otherwise have been caused by the material from which the structure of the apparatus was built. When the current from the power supply was applied to the coils, a magnetic field was generated. The weight at the end of the pole from the cue ball acted as a pendulum, moving with an oscillation. To find the frequency of this oscillation, all three members of our lab group measured the time with their own stop watch, and these times were then averaged so as to attain the most accurate measurement of time.

1. . A.H. Morrish, The Physical Principles of Magnetism (IEEE Press, New York, 2001). [↑](#endnote-ref-1)
2. . A proper Helmholtz coil would have an equal distance between the two coils as the radius of the coil, our coils had an effective radius of 0.109m and a separation of 0.138m. [↑](#endnote-ref-2)
3. . H.D. Brewster, Electromagnetism (Oxford Book Co., Jaipur, India, 2010). [↑](#endnote-ref-3)
4. . D. LaFountain and J. Reichert, Magnetic Torque (Teachspin, Inc., Buffalo, NY, 1998). [↑](#endnote-ref-4)