Experiment 33: Electromotive Response to Moving Magnetic Sources

Avi Patel
Physics 326
University of Victoria

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Abstract

The final results for the dipole moments were $0.44525Am^2 \pm 0.01679Am^2$ *and* $3.8535Am^2 \pm 0.231Am^2$*, for the small and large magnets, respectively. This was determined from direct measurement of the magnets. The experimental dipole moments from the drop of the magnets and the signals collected were* $0.41 \pm 0.02Am^2$ *and* $0.7 \pm 0.04Am^2$

1 Introduction

The purpose of this experiment is to use two magnets of different sizes to fall through four stationary conductive coils and analyze the graphs that would be created due to the motion. This analysis will be compared to the theoretical answers. The magnetic field of the two magnets will be measured using a gaussmeter manually using a ruler to determine the decrease in field strength with distance from the source. This can be used to form a linear relationship to get the result for the dipole moment using equation 2. Using loggerpro connected to a labpro unit to measure the potentials, an experiment value of the dipole moment can be determined and then compared to the theoretical obtained from equation 1. The flux can also be obtained from the potential curves for each of the stationary coils by integrating over the positive and negative phases to get the flux for each phase. For a given curve, the fluxes from the positive and negative phases can be compared to see if there's a difference in values between individual flux values for both positive and negative phases.

1.1 Equations

$$\epsilon = -\frac{3}{2} N \mu_0 p_m r_0^2 \frac{z}{(r_0^2 + z^2)^{\frac{5}{2}}} \tag{1}$$

The equation for emf using the position and velocity equations in 3 and 4, respectively. N is the number of turns (20). μ_0 is $4\pi \times 10^{-7}$. p_m is the is the dipole moment. r_0 is radius of the ring.

$$B_Z = p_m \frac{\mu_0}{2\pi} \frac{1}{z^3} \tag{2}$$

The magnetic field for a large axial distance z. This will be used in part 1 of the experiment explained later to determine the dipole moment.

$$z = \frac{1}{2} a t^2 + v_0 t + z_0 \tag{3}$$

The equation for position depending on time. Where v_0 and z_0 are the initial velocity and position, respectively.

$$z = at + v_0 \tag{4}$$

The equation for velocity depending on time, obtained by differentiating equation 3.

2 Sample Calculation and Equations

$$\begin{aligned} p_m &= \frac{2\pi(slope)}{_0} \\ &= \frac{2\pi(8.905 \times 10^{-8} \pm 3.36 \times 10^{-9}) T m^3}{4\pi \times 10^{-7} N/A^2} \\ &= 0.44525 T m^3 A^2/N \end{aligned} \tag{5}$$

Sample calculation for the dipole moment for the small magnet using the slope of the graph in figure 4.

$$\begin{aligned} z &= \frac{1}{2}(9.508 m/s^2 \pm 0.004 m/s^2) t^2 + (3.448 m/s \pm 0.000641 m/s) t + 4.733 \times 10^{-5} m \pm 4.173 \times 10^{-5} m \\ z &= \frac{1}{2}(9.538 m/s^2 \pm 0.00248 m/s^2) t^2 + (3.520 m/s \pm 0.000378 m/s) t + 2.727 \times 10^{-5} m \pm 2.433 \times 10^{-5} m \end{aligned} \tag{6}$$

The z distance equations for the small and large magnets, respectively are shown. The experimental value for gravity can be noted in the first term of each equation.

$$\begin{aligned} v &= (9.508 m/s^2 \pm 0.004 m/s^2) t + (3.448 m/s \pm 0.000641 m/s) \\ v &= (9.538 m/s^2 \pm 0.00248 m/s^2) t + (3.520 m/s \pm 0.000378 m/s) \end{aligned} \tag{7}$$

The equations for the velocity obtained from differentiating the z equations above.

3 Experimental Procedure and Design

There are two magnets used for this experiment, a short and long magnet. The magnets will be used to get the magnetic field strength and also the dipole moment of of the two magnets. The two magnets will then fall through the stationary conductive coils and eventually get the dipole moments from the signals collected from the drop. There are two parts of the experiment, the first one is to measure the magnetic field at increasing distances from the source to see the relationship of the strength vs. the distance. The second part is to drop the two magnets through the stationary coils to get readings in loggerpro that the motion the two magnets produced.

A point by point procedure can be outlined via:

3.1 Part 1: The B-Field measurement

1. For the first part the smaller magnet was placed on a ruler such that the ruler now acts as an axis parallel to the magnet direction.
2. Next, a gaussmeter was used to measure the magnetic field from the center of the magnet in increments of 1cm until the gaussmeter had a reading of zero Gauss.
3. The same steps as above were taken for the larger magnet.
4. The graph of the inverse distance cubed vs the magnetic field strength was plotted to get a linear relationship for both magnets.
5. The dipole moment could then be obtained from this relationship.

3.2 Part 2: The Fall

1. The second part of the experiment involves dropping the magnets from a fixed height through four stationary conductive coils. First, the loggerpro software was set up such that so that the duration was 1 second and sampling rate was 2500 samples/sec, which was the highest possible. The triggering was set to a small decreasing negative voltage that exceeds the signal noise. 1000 samples before trigger were collected so that all the signals from the coils are recorded.
2. The small magnet was set up for the fall. The potentials from all four of the labpro channels connected to the coils will be recorded after triggering.
3. The potentials that were recorded were divided by the gain (300) of the amplifier since it was amplified by it.
4. The zero-crossing time for each emf and the position are measured relative to coil B. The distances from the coil to the other coils were measured using a ruler.
5. The position vs time graph of was plotted for the four points at which the

magnet passes through a coil. These points are part of a parabola, so using logger pro's curve fitting tool an equation for the position was interpolated.

6. The equation for the velocity could also be obtained from the position equation by differentiating.

7. From these two equations, the emf was obtained using equation 1.

3.3 Part 3: Analysis

1. From the drop, the emf was calculated and graphed with time using equation 1.

2. This emf was compared to the experimental curve from coil B and the dipole moment was varied through trial and error to find the theoretical curve that would fit the experimental curve as precisely as possible.

3. The fluxes for the positive and negative phases of the small magnet were determined by integration and compared.

4 Results

The results for part 1 of the experiment produced a linear graph, which produced dipole moments of $0.44525Am^2 \pm 0.01679Am^2$ and $3.8535Am^2 \pm 0.231Am^2$, for the small and large magnets, respectively. The dipole moments obtained through trial and error from the emf curves were $0.41Am^2 \pm 0.02$ and $0.7Am^2 \pm 0.04$, for the small and large magnets, respectively. The fluxes are seen for the positive and negative phases in from figure 12 to 19.

5 Discussion

From the results the experiment seems to have produced better results for the small magnet than the larger one. From the graphs of the positive phase flux values, it should be noted that the flux does not change significantly from the other fluxes, the same is the case for the negative phases. The positive phases are typically larger than their negative counterparts. The reason for these could be due to the velocity of the magnet being faster below the coil and slower above it. The acceleration due to gravity can be seen in the first term of the z-distance equations. Both of the values are close, but not exact with the accepted value of $9.8m/s^2$. The reason these values are lower than the accepted values might be because the magnet is dropping very slightly slower than it would in free-fall. This could be because of the friction between the wire and magnet or the coils themselves are having an effect on the magnet which slows it down slightly. To increase the net flux, it would be better to increase the diameter of the coils. This is because the radius is directly proportional to the flux, so if you increase the radius then it can intercept more flux. However, there is a limit to how big the radius can be because at some point in increasing the radius, the flux will not increase as it's already captured all the flux there is to be captured.

6 Conclusion

The overall experiment was successful in that it accomplished its purpose of analysing the graphs created by the motion of two magnets of different sizes through the stationary coils. The useful quantities such as dipole moments and flux were verified using the signals collected.

A Data and Graphs

	A	B	C	D	E	F
1		Slope(Tm^3	Uncertainty	p_m exp	uncertainty	p_m theo
2	Small_Mag	8.91E-08	3.36E-09	0.44525	0.01679	0.41
3	Large_Mag	7.71E-07	4.62E-08	3.8535	0.231	0.7
4						
5	Gain:	300	3			
6	r_0:	0.0442m				
7	N:	20 turns				

Figure 1: Basic data acquired from the experiment. The slope of the linear graph plotted in the first part of the experiment. The experimental dipole moment is acquired from the slope of the graph in part 1. The theoretical is obtained from trial and error when comparing the curve from equation 1 and the potential from coil B.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	1/z^3	z (cm)	gauss			length of small magnet			length of large magnet			z (cm)	gauss	1/z^3
2	0.082189529	2.3	117.5			2.6cm			8.5cm			5.25	133	0.006910701
3	0.027826474	3.3	28.5									6.25	35	0.004096
4	0.012577509	4.3	10.2									7.25	14.9	0.002624134
5	0.006716954	5.3	5.2									8.25	7.9	0.001780894
6	0.003999248	6.3	2.5									9.25	4.5	0.001263499
7	0.002570582	7.3	1.3									10.25	2.5	0.000928599
8	0.001748903	8.3	0.7									11.25	1.5	0.000702332
9	0.001243229	9.3	0.5									12.25	0.7	0.000543991
10	0.000915142	10.3	0									13.25	0.3	0.000429885
11		small mag										14.25	0	0.000345585
12													Large mag	

Figure 2: This is data collected from part 1 of the experiment. It shows the distance from the center of the magnet to the place of measurement of the Gauss reading.

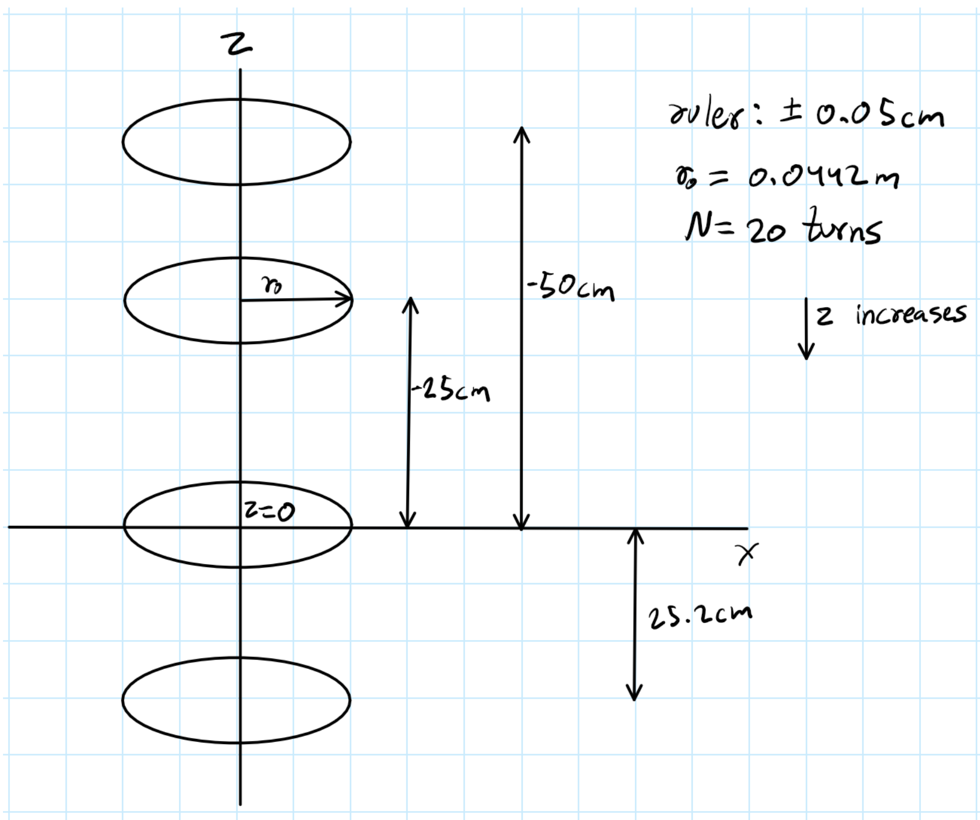

Figure 3: A simple representation of the apparatus used for the second part of the experiment. The distances are measured with a ruler and are shown with respect to the z=0.

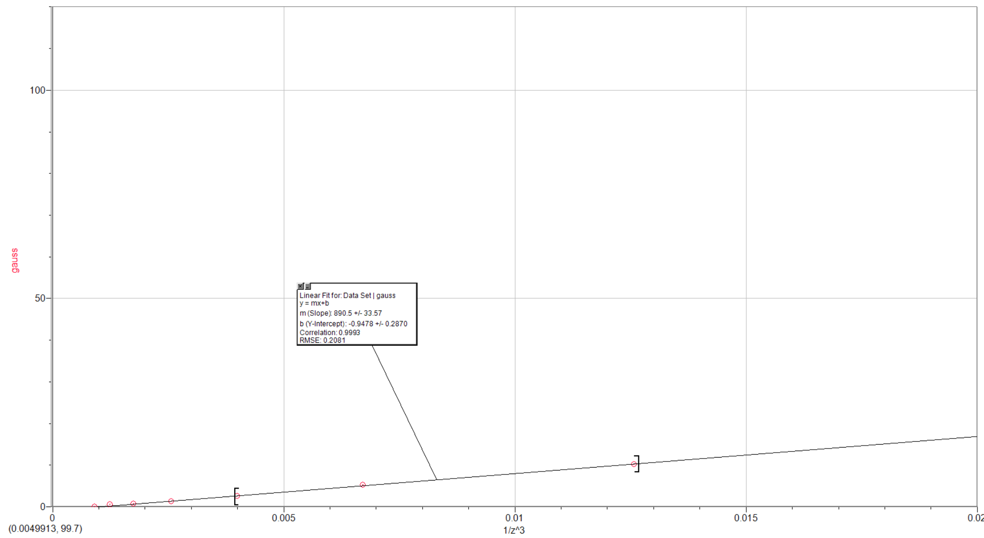

Figure 4: For the small magnet, this is a plot of the inverse distance cubed vs magnetic field strength, which produces a linear relationship. The slope is obtained from loggerpro and by choosing the middle points of the graph such that the very close and very far magnetic field values will not effect the slope. This will make sure that the close and far readings of the magnet are not taken into account as they can give an inaccurate representation of the relationship.

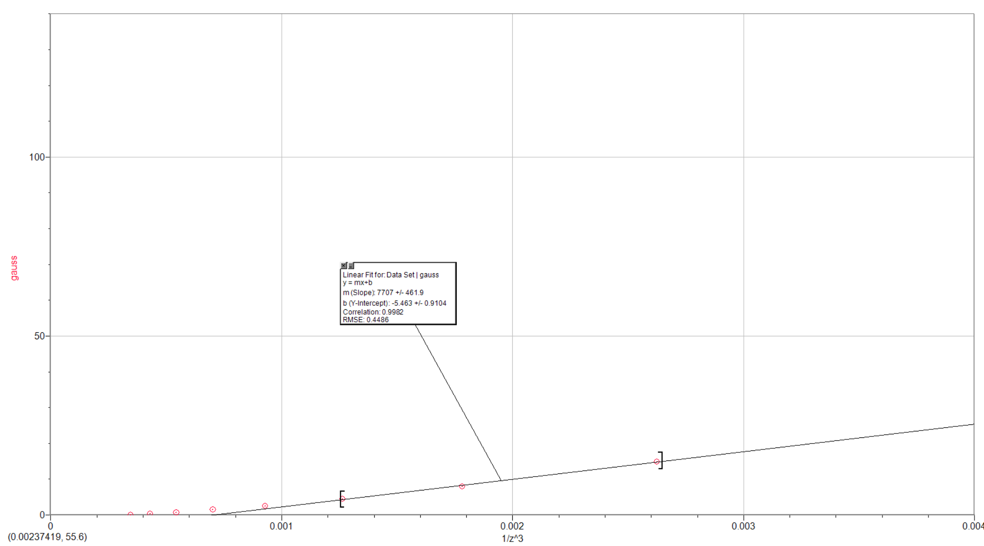

Figure 5: For the small magnet, this is a plot of the inverse distance cubed vs magnetic field strength, which produces a linear relationship. The slope is obtained similarly as that of figure 4.

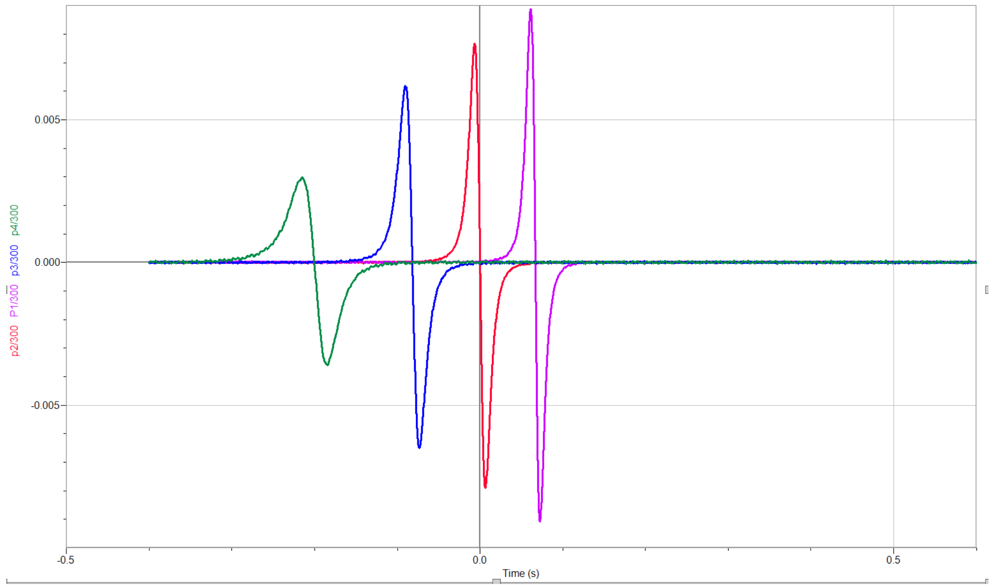

Figure 6: The small magnet potentials for the four conductive stationary coils divided by the gain to get rid of its amplification is plotted with time such that potential of coil B crosses zero on the time axis.

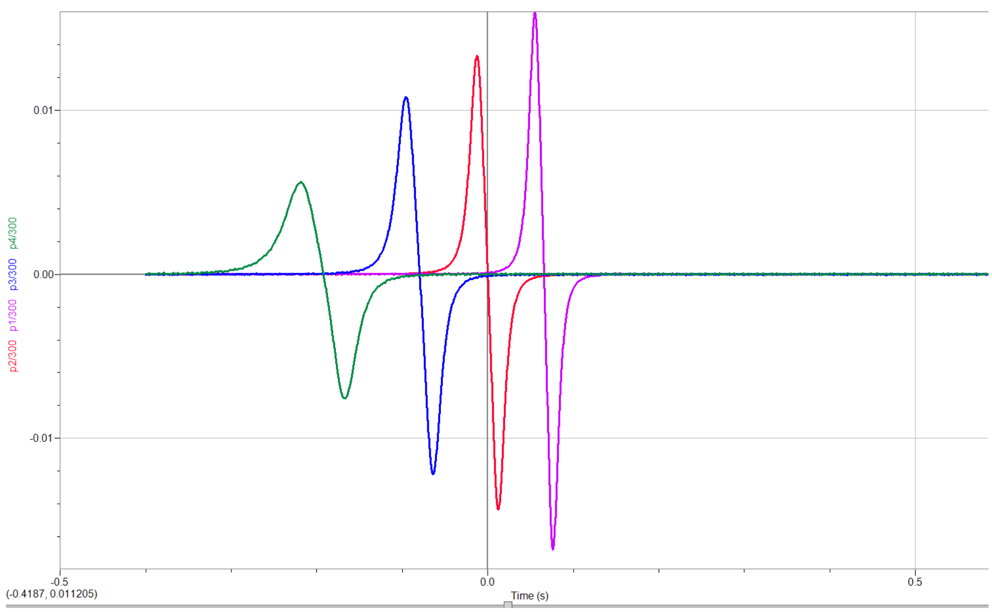

Figure 7: The large magnet potentials for the four conductive stationary coils divided by the gain to get rid of its amplification is plotted with time such that potential of coil B crosses zero on the time axis.

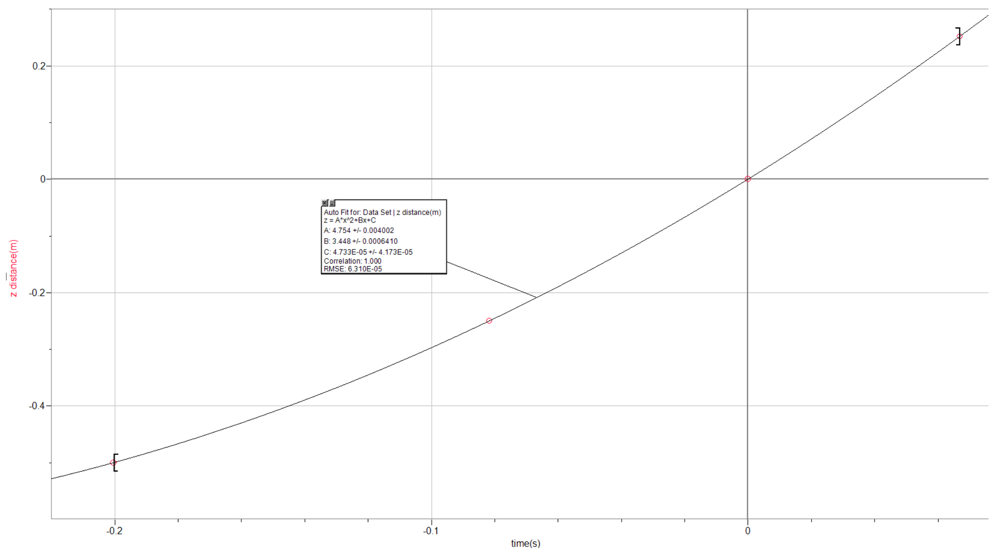

Figure 8: By zooming into the zero-crossing times in figure 6, the time when the potentials cross from positive to negative could be found. Using these times along with the distances as seen in figure 3 these points were plotted, which are part of a larger parabola. Logger-pro can fit a parabolic curve to these points and provide an equation that's of the form seen in equation 3.

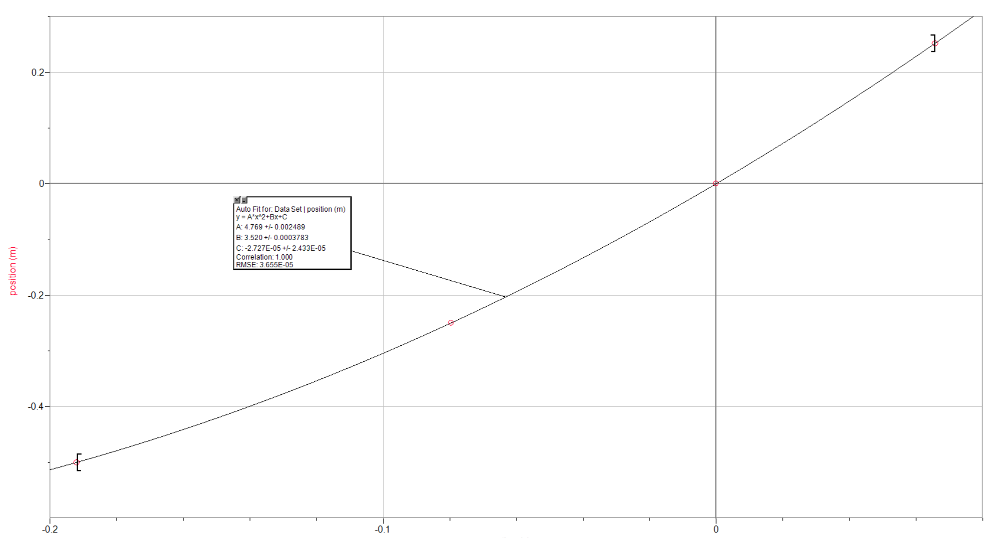

Figure 9: By zooming into the zero-crossing times in figure 7, the time when the potentials cross from positive to negative could be found. Using these times along with the distances as seen in figure 3 these points were plotted, which are part of a larger parabola. Logger-pro can fit a parabolic curve to these points and provide an equation that's of the form seen in equation 3.

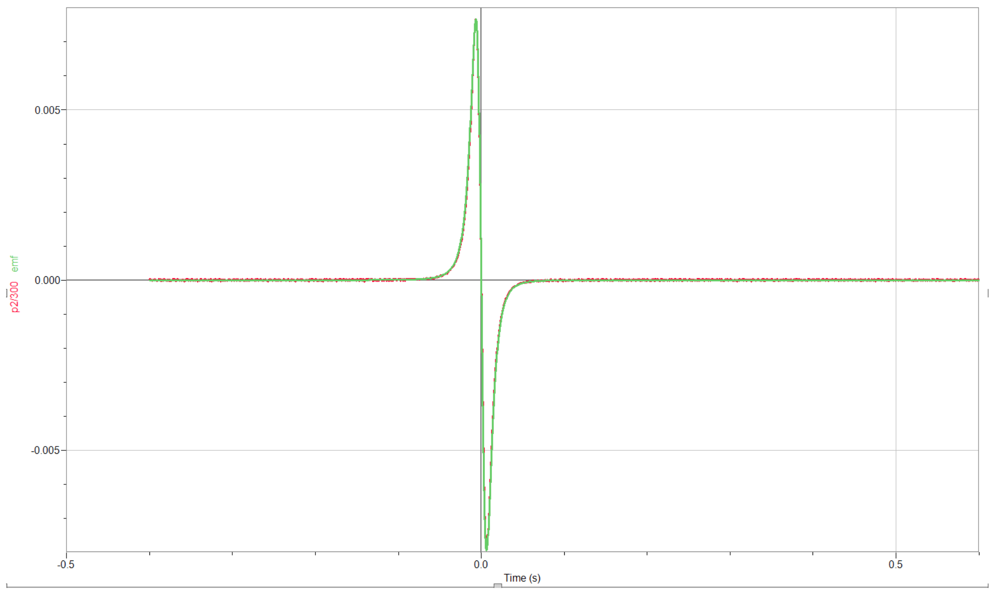

Figure 10: The emf is plotted using equation 1 and plotted along side the potential for coil B potential de-amplified. The theoretical graph originally didn't match the experimental graph, but had to be adjusted by changing the dipole moment in equation 1. The dipole moment (p_m) was changed and through trial and error a value of 0.41.

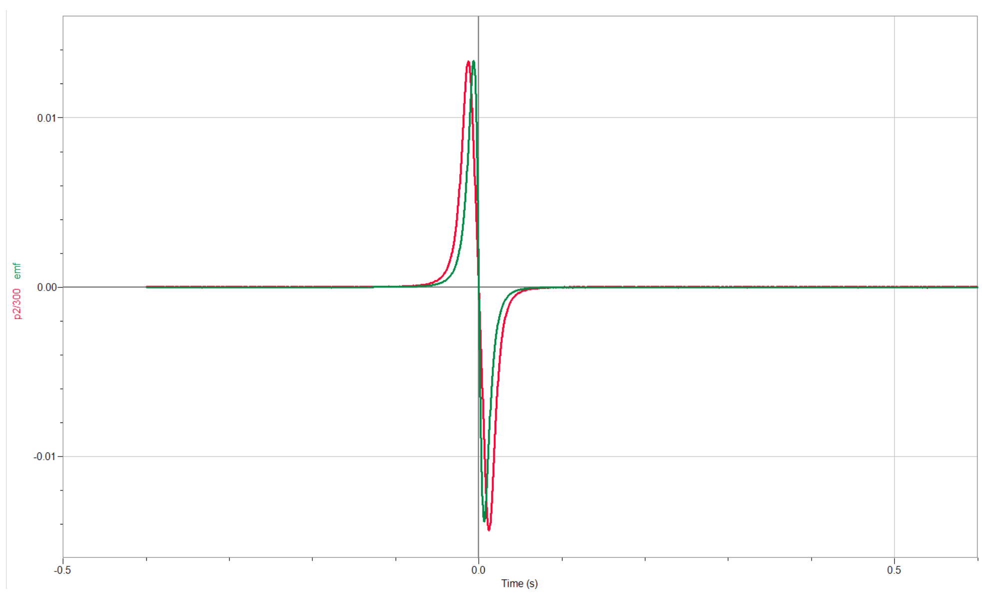

Figure 11: The emf is plotted using equation 1 and plotted along side the potential for coil B potential de-amplified. The theoretical graph originally didn't match the experimental graph, but had to be adjusted by changing the dipole moment in equation 1. The dipole moment (p_m) was changed and through trial and error a value of 0.7.

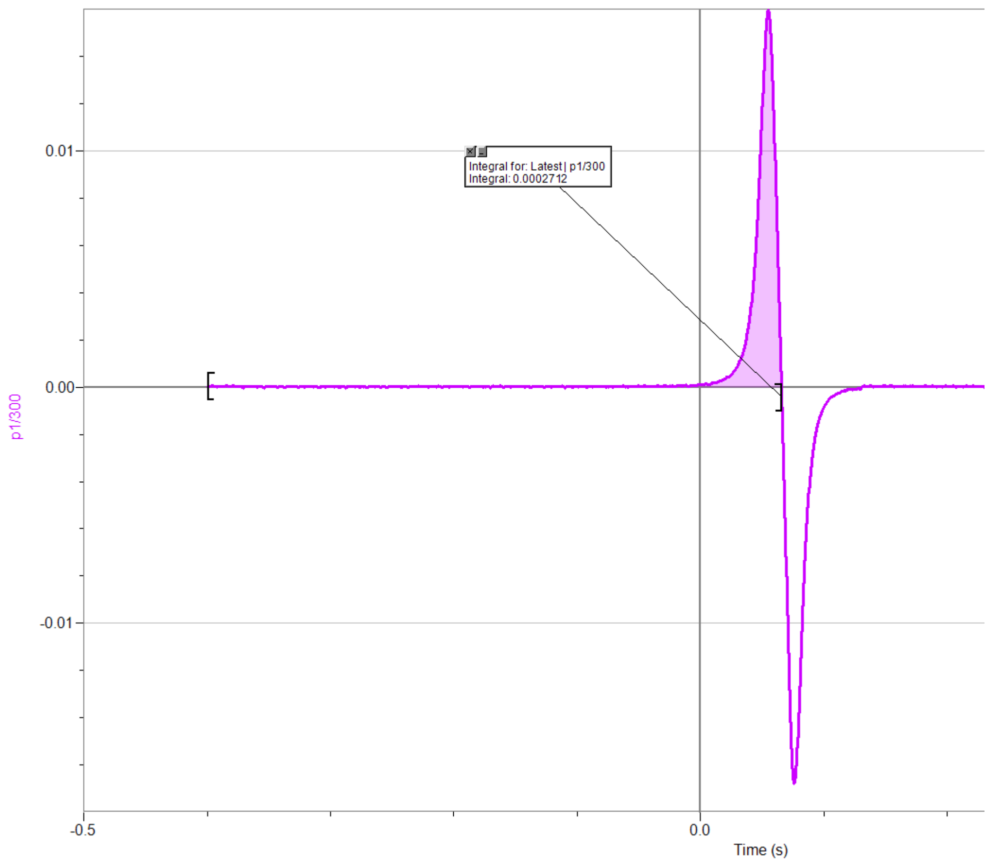

Figure 12: Positive phase of potential 1 integrated to get the flux.

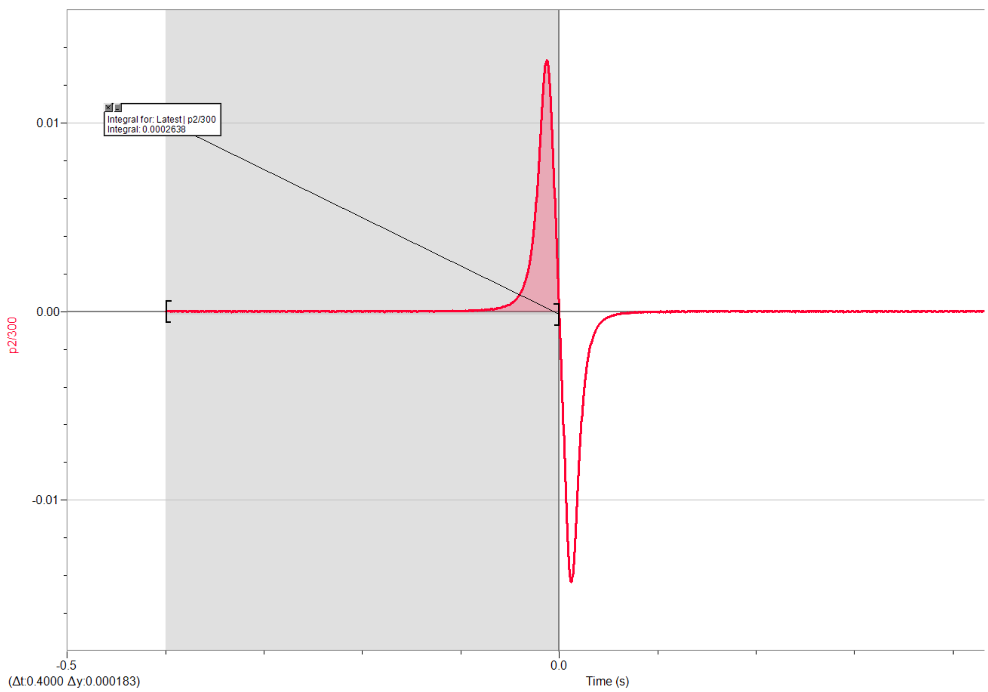

Figure 13: Positive phase of potential 2 integrated to get the flux.

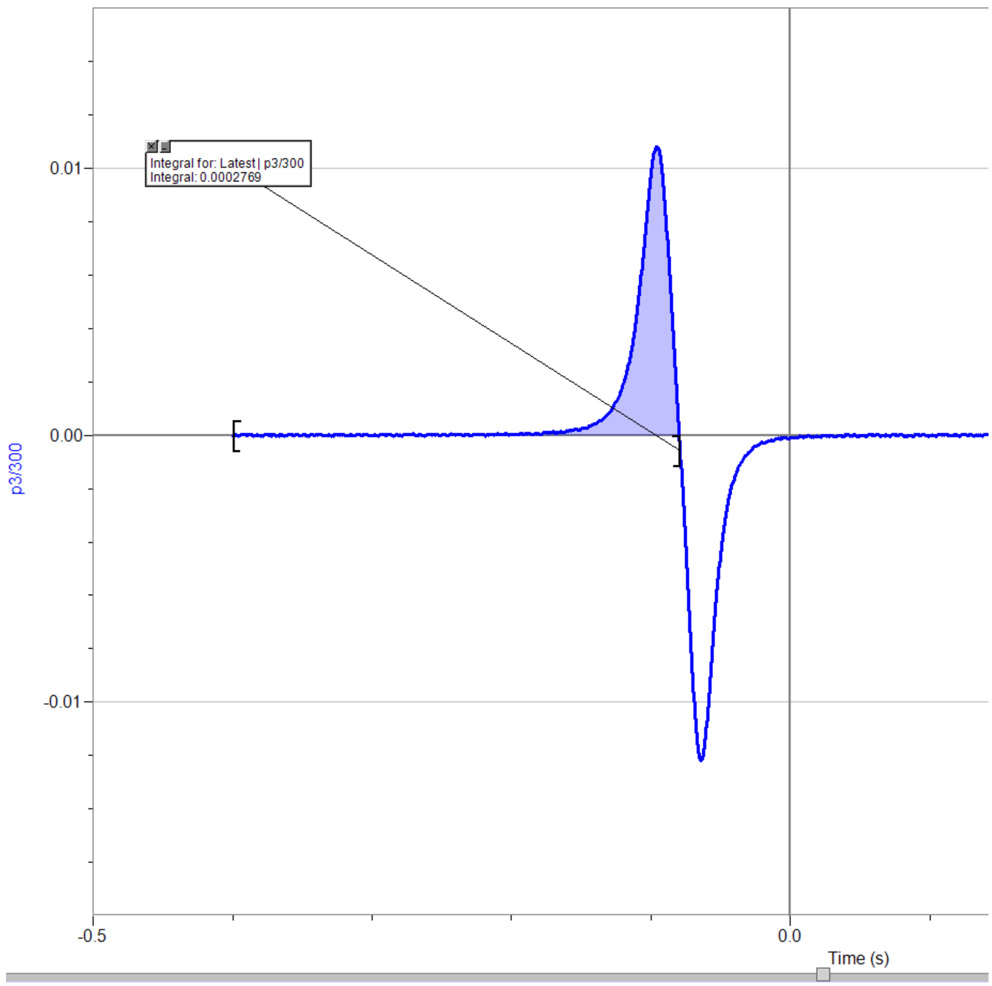

Figure 14: Positive phase of potential 3 integrated to get the flux.

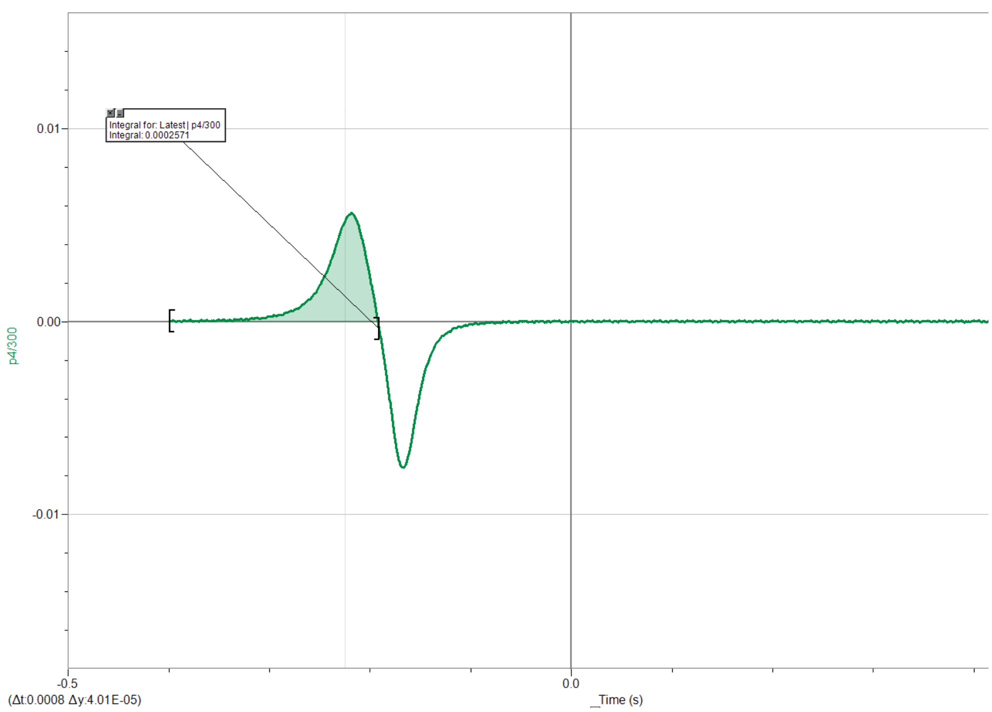

Figure 15: Positive phase of potential 4 integrated to get the flux.

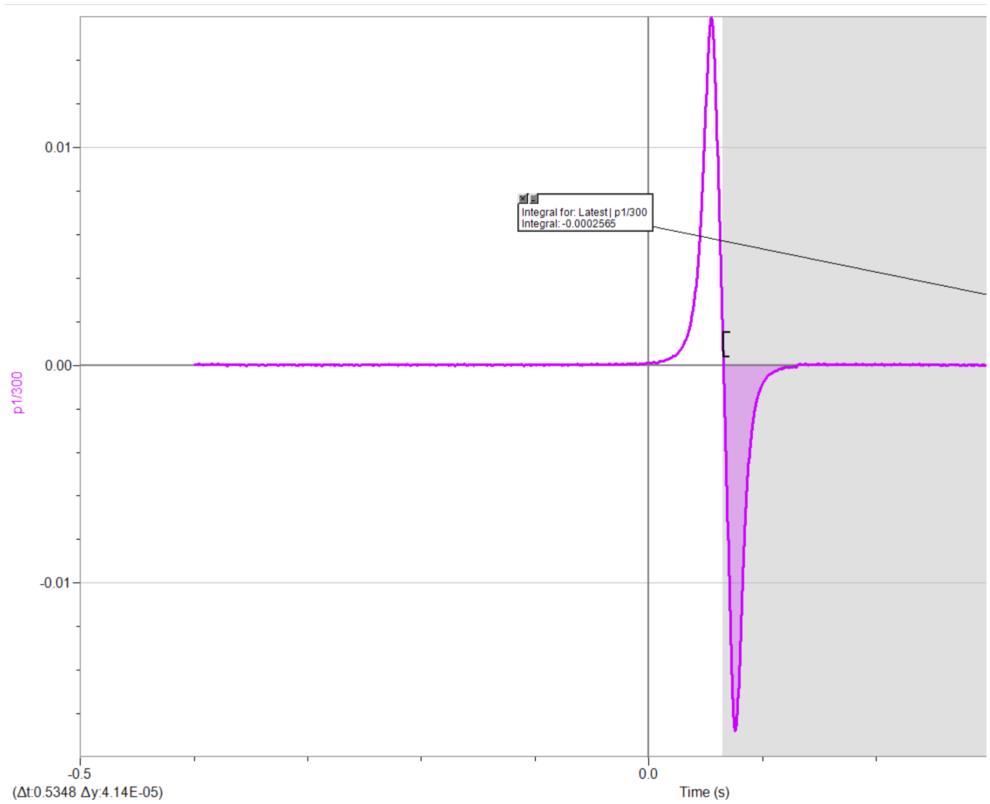

Figure 16: Negative phase of potential 1 integrated to get the flux.

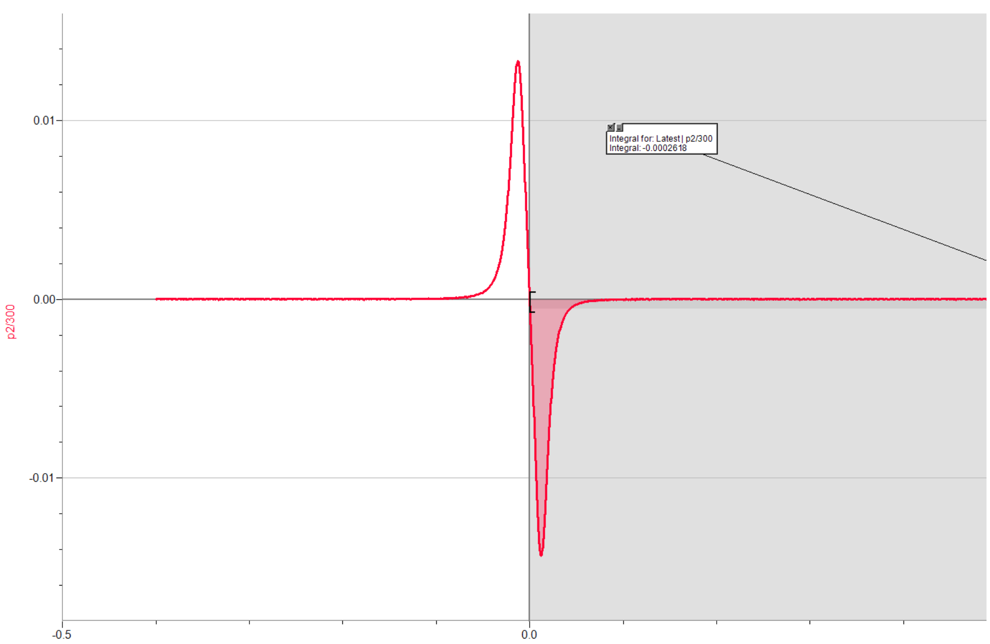

Figure 17: Negative phase of potential 2 integrated to get the flux.

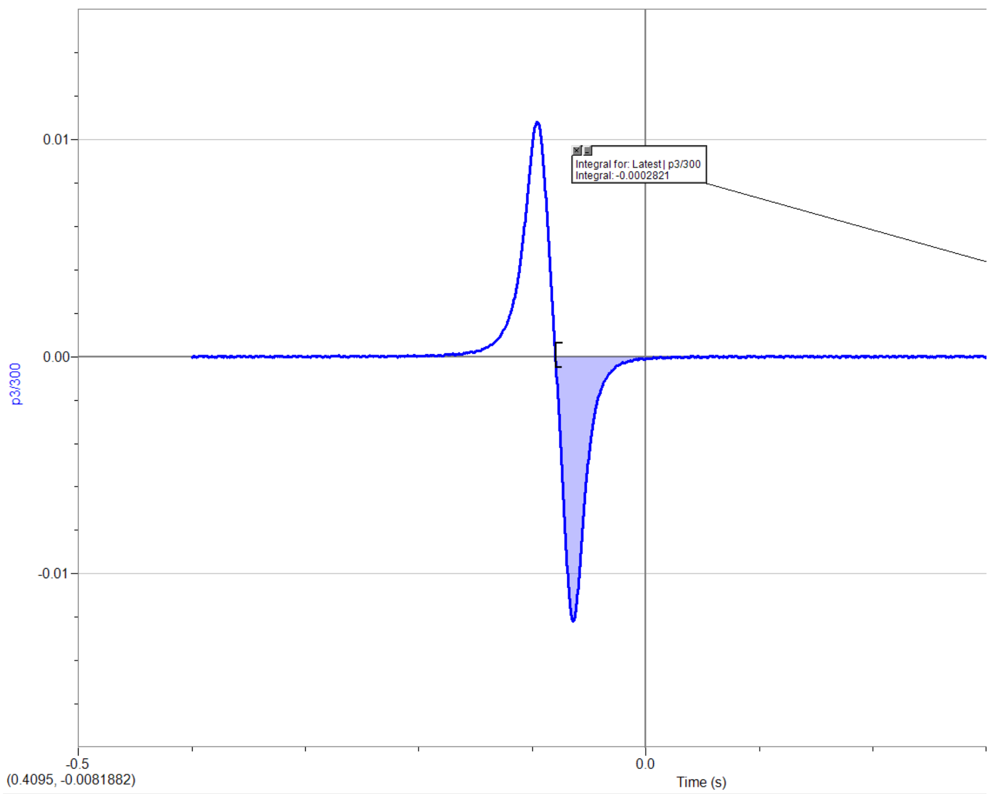

Figure 18: Negative phase of potential 3 integrated to get the flux.

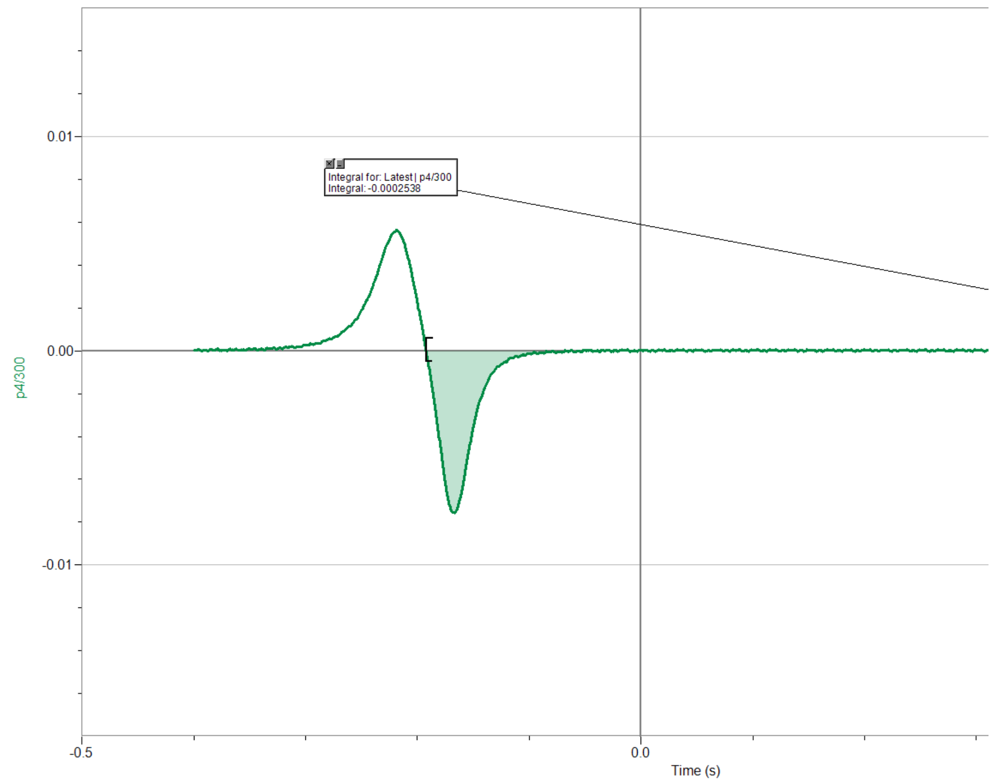

Figure 19: Negative phase of potential 4 integrated to get the flux.