**Experiment 5: Harmonic Oscillator Part 1: Spring Oscillator**

Kubilay Agi

UID: 304784519

Lab Date: 27 August 2018

Lab Section 8 – Monday/Wednesday 11:30am

TA: Jordan Runco

Partner: Shannon Largman

**(2) Full Lab Report**

**Abstract**

**Analysis of a Spring’s Damped and Undamped Oscillations**

K. Y. Agi1

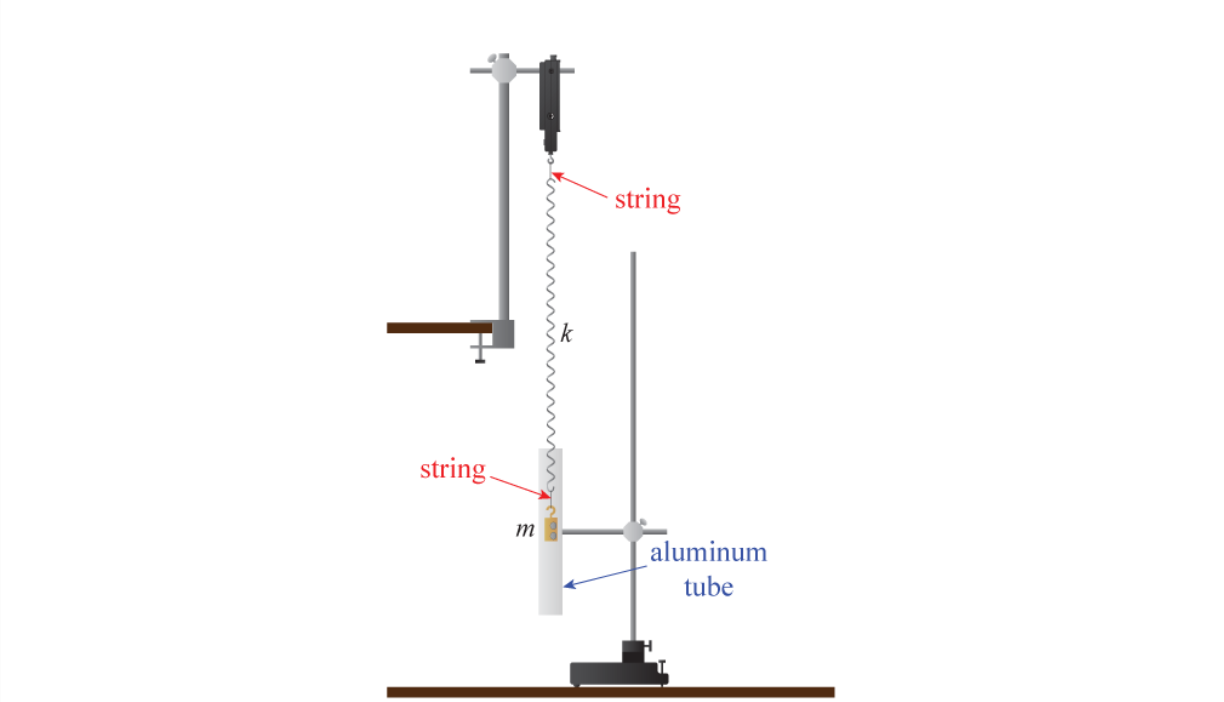
This is my abstract! It’s really great. What’s the difference between an abstract and an indtroduction you ask? Absolutely nothing!

1Department of Engineering and Applied Sciences, University of California, Los Angeles

**Introduction**

This is my introduction! It’s exactly the same thing as my abstract!

**Method**



**Figure X**1**:** This image illustrates how our apparatus is set up for this experiment. The aluminum tube is not present in the first part when we measure the distance between the bottom of the spring and the floor.

The first step in this experiment is to calculate the string constant. We attach five masses of different mass to one end of our spring. The other end is attached to the force sensor. On both sides of the spring, the masses and force sensor are attached to the spring via a string. The string is used to reduce rotational motion during the experiment. The force sensor is oriented downward to be parallel with the hanging spring. For each mass that we hung on the spring, we measured the distance of the bottom of the string from the ground. We measured from the bottom of the spring because each mass had a different length. The data would be inconsistent, and it would not provide us with an accurate spring constant.

After calculating the spring constant, we begin our oscillation trials. We start with undamped oscillation. Since the mass with magnets attached to it is used in the damped oscillation trial, we use the same one for the undamped oscillation trial. We keep the same set up as we had when we were measuring distance between the bottom of the spring and the floor. The mass should not hit the floor when it is oscillating. The data acquisition system (DAQ) is set up to record timestamps and the voltage signal produced from the force sensor in units of Volts. To record values in volts from the sensor, we choose to read it as a User Defined Sensor instead of a Force Sensor. We pull the mass down and release it and press ‘Record’ on the DAQ interface. We record one minute of data, although only about 25 seconds worth of data was used in the analysis.

Next, we record the data for the damped oscillation trial. The setup for this trial is the same as the previous part, except that the mass needs to oscillate inside of a aluminum tube. We place the tube around the mass and spring, and we line it up so that the middle of the tube, both horizontally and vertically. We do this to make sure that the mass does not scrape against the insides of the tube, and also to keep the mass inside of the tube throughout the trial. If the mass were to come out of the tube in either direction during the mass’ oscillation, the movement would be damped less. This would lead to inconsistent data because the mass would only be outside of the tube on a couple of cycles, but not for all of them. The damping factor would be higher in the cycles that the mass was completely surrounded by the tube, and lower in the cycles where the mass was not. Again, we record the timestamps and the voltage produced by the force sensor when reading it as a User Defined Sensor.

**Analysis**

\*\* Derive some equations for f, Q, tau \*\*

The hanging mass had a mass of (173.9 ± 0.3) g. The scale only measures up to 110 g, so we counterbalanced the scale with a mass of (99.3 ± 0.2) g. Our uncertainty measurement for each mass was 0.2 g. The hanging mass we used for our experiment has a higher uncertainty because we need to account for the uncertainty of the mass used to counterbalance the scale.

**Figure X, Title:** This plot shows how the distance from the spring to the floor varies depending on how much mass is attached to the spring. Hooke’s Law tells us that this relationship should be linear. We see from the plot that this is true. The slope of the trendline is equivalent to the spring coefficient, and they have a value of (-3.328 ± 0.009) N/m. However, because we are measuring the distance between the string and the floor instead of the length of the spring itself, our value becomes negative. Therefore, our true spring constant has a value of (3.328 ± 0.009) N/m.

The data points in our graph should be almost perfectly linear. However, it’s possible that the oscillations of the spring made it difficult to place exactly where the equilibrium point for the spring. The second through fifth point on the graph are completely linear, but the value

*Calculations for Frequency with Uncertainty in Undamped Trial*

To calculate the experimental oscillation frequency, we look at the number of extrema that occur within a certain time span. We do not necessarily need to look at extrema; as long as we pick the same point in each oscillation cycle the result will be the same. It is just easier to look at the extrema because they are easily identifiable in the data points. Consider the case where we look at two adjacent maxima in the graph. There is one oscillation cycle that happens between these two points. In the case where we have three consecutive maxima, we have two cycles. A pattern emerges from this: for every *n* maxima, there are *n* – 1 cycles that happen inbetween them. Frequency is measured in units of Hertz, so we are looking for the number of cycles per second that happen. We can take the time values of the leftmost and rightmost extrema point. We also find the time difference between these two to get the time range that we are considering. From our data, we will look at *n* = 9 extrema. We use the following method:

Our equation of uncertainty for the experimental frequency is determined through the propagation of uncertainties. Here, is the standard deviation of each time difference between adjacent maxima, and *n* is the number of cycles that we look at (it is the same as it is in the calculation for frequency above)

Now we need to find the equation for the predicted oscillation frequency. The mass we used for this experiment has mass *m* = (0.1739 ± 0.0003) kg, and our spring constant *k* = (3.328 ± 0.009) N/m.

From this equation, we find that our frequency *f0* = 0.696 Hz. We also need to find the equation for the uncertainty.

|  |  |
| --- | --- |
| Predicted Frequency (Hz) | Experimental Frequency (Hz) |
| 0.696 ± 0.002 | 0.691 ± 0.005 |

**Figure X, Title:** This table shows predicted oscillation frequency of the system versus the actual observed frequency in our experiment. An analysis of the results is present below Figure X\*\*\*.

We also know that the period, *T*, is equivalent to 1/*f*. With this, we can find the predicted and experimental period of oscillation.

Propagation of uncertainties for 1/*f* tells us that the uncertainty has a value of:

|  |  |
| --- | --- |
| Predicted Period of Oscillation (s) | Experimental Period of Oscillation (s) |
| 1.436 ± 0.004 | 1.447 ± 0.01 |

**Figure X:** This table shows the period of oscillation that we expect in an ideal environment, and the period of oscillation that we observe in our undamped.

Our results for frequency and period are close to the predicted value, although slightly off. These small discrepancies can be attributed to environmental factors. One place where some of the mechanical energy could be lost is from friction between our oscillating mass and the air. Also, we kept our aluminum tube on the floor, nearby the oscillating mass during the undamped trial. It is possible that the magnets and the tube interacted during the experiment, causing unintended damping.

**Figure X, Undamped Oscillation Trial:** This plot shows the voltage readings from the force sensor at each instance of time. The relationship between them is sinusoidal, which is expected because the spring oscillates. The data points had an offset of (-0.258 ± 0.001) V, so this value was added to each voltage reading so that the data is centered around zero.

Although it is not entirely clear in Figure X\*\*\*, there is a slight decrease in amplitude of the oscillations as time goes on. Between time *t* = 0.62 s and time *t* = 4.94 s, there is a 0.001 V difference in the amplitudes. As mentioned previously, this slight difference can be attributed to environmental factors

*Calculations for Frequency and Uncertainty in Undamped Trial*

We can use the same calculations that were used to calculate oscillation frequency and period for the undamped trial for the damped trial. With these equations, the experimental frequency is (0.690 ± 0.014) Hz. The period of oscillation is (1.449 ± 0.029) s. However, these methods do not account for the noise in the recorded values. These methods work better when they are applied to undamped oscillations. For damped oscillations, it is more appropriate to use equations that involve damping time or damping term with the quality factor.

**Figure X, Damped Oscillation Trial:** This plot shows the voltage readings from the force sensor at each point in time during the damped oscillation trial. The damping was created by placing a mass with magnets attached to it inside of an aluminum tube. The damping is what caused the exponential decay in the data. The offset for this data set was (-0.256 ± 0.001) V, so this value was added to every value of voltage to center the data around zero.

There is more noise in the readings as the amplitude decreases. This is likely the reason why the data points begin to deviate from their trend as time goes on (and each new maximum is reached).

\*\*\* Calculate damping time \*\*\*

Oscillating masses can be modeled with the following equation:

This is a linear homogeneous differential equation, so it has a solution of the form , where *A* is some nonzero constant.

Because *R* is nonzero, and the *e* term will always be nonzero, we have:

We plug this value back into our solution for *x*(*t*):

Our second term does not contain any oscillating terms, so we can substitute in damping time into the second term. Damping time is defined as:

Substituting, we get the result:

We will run into issues here when trying to solve for damping time, because we do not know the value of *b*. Instead, we can look at the ratio of adjacent amplitude measurements *V*(*t*) and *V*(*t*+*T*). We are allowed to do this because our decay is exponential.

**Figure X, Title:** This plot shows the ratio of decay in adjacent maxima for eight pairs of maxima. There are nine maxima total that were used to generate this plot. We expect that the ratio between each extremum is constant because we have constant damping. The linear trendline that fits our data has a slope of (-0.0097 ± 0.004). This value is close to zero, so the downward trend could be because of environmental factors or because of the noise picked up by the sensor. The values range from 0.64 to 0.74, and the average is 0.71.

Solving for the damping time, we get:

From Figure X\*\*\*, we know that the average value of the ratio between the extrema amplitudes was 0.71. We can substitute this value into our equation for damping time.

The uncertainty for the damping time is calculated using the propagation of uncertainties method shown in equation ii.23 of the lab manual.

We find that the amount of time that it takes for the amplitude to decay by a factor of 1/*e* is (4.22 ± 0.03) s.

*Calculation for Quality Factor*

We are given the definition of the frequency of damped oscillation in two forms

We notice that the second term under the radical in both equations should be equivalent. We set these two values equal to each other and solve for the quality factor *Q.*

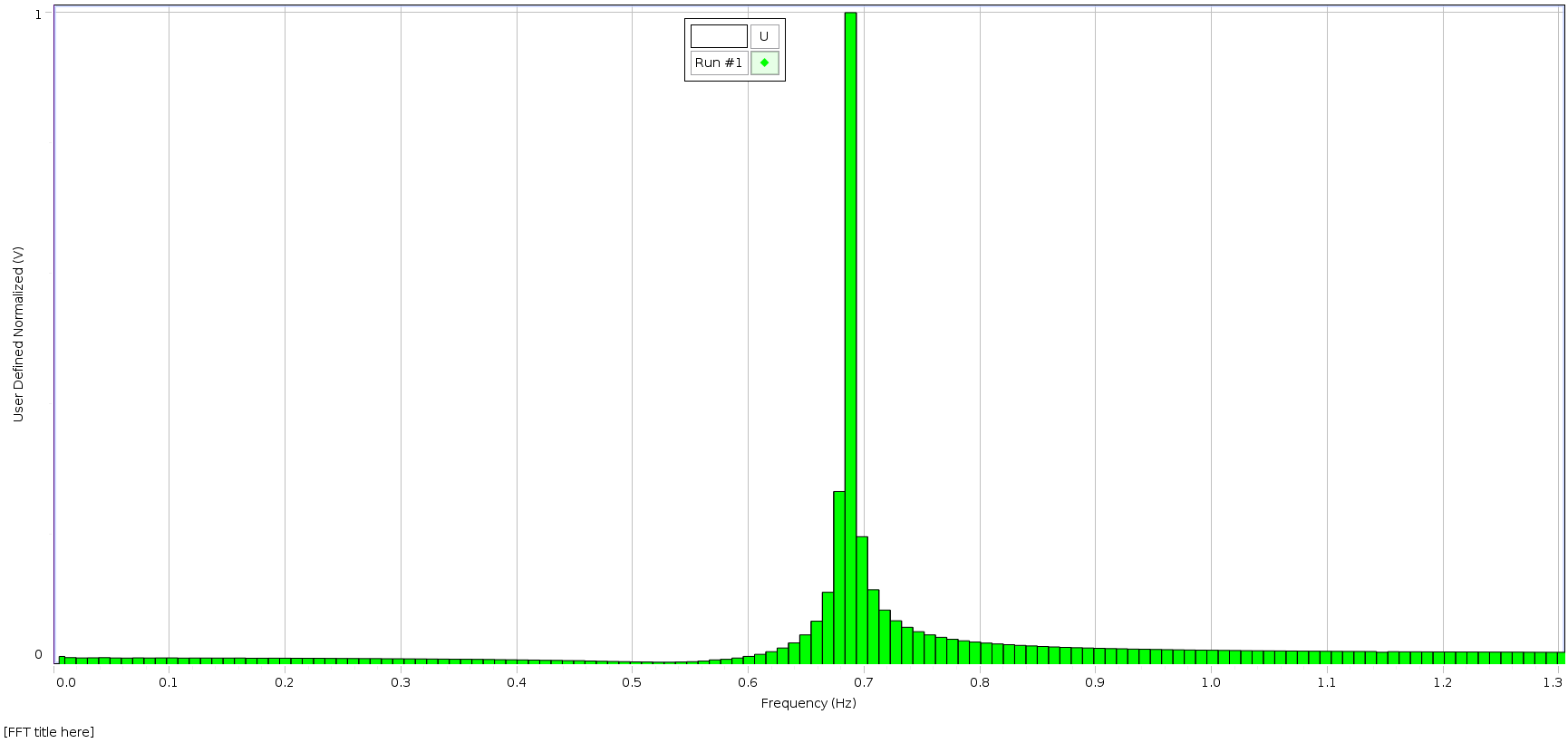
We also have a definition for *b* that we can substitute into the equation for *Q*.

To determine the uncertainty of *Q*, we use the following equation:

Our value for the quality factor is (9.23 ± 0.01). We can now plug this value back into our definition of damped oscillation frequency that is dependent on *Q*:

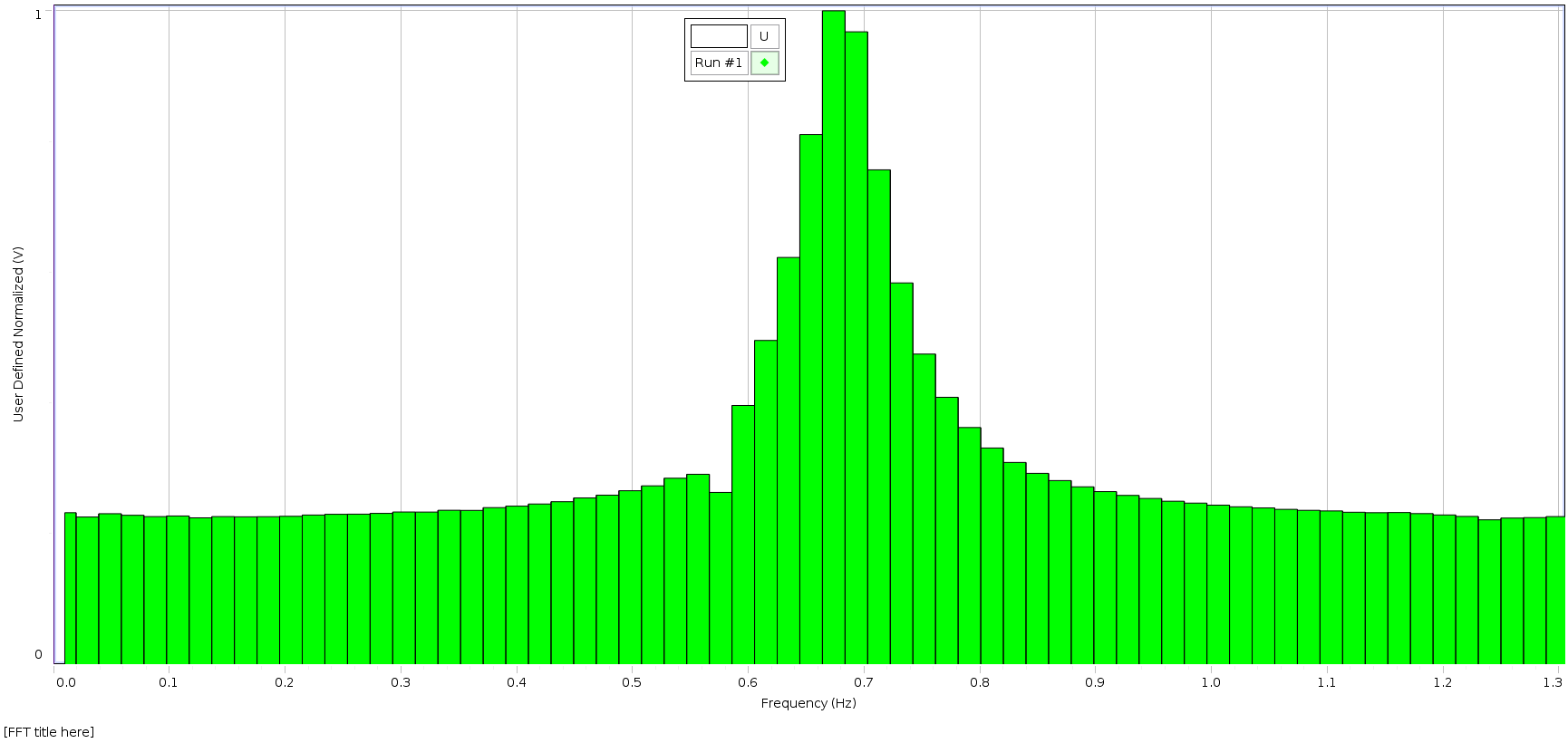
With uncertainty, our value for damped oscillation frequency is (0.695 ± 0.002) Hz. HERE IS SOME ANALYSIS ABOUT WHY THIS METHOD IS BETTER\*\*\*\*

**(3) Extra Credit**



**Figure X, Title:** this is a fft (expand) for undamped oscillation

Agrees with its experimental frequency. Our calculated value was (0.691 ± 0.014) Hz and the plot also shows that the data is centered around 0.69



**Figure X, Title:** this is a fft (expand) for damped oscillation

This also agrees with the calculated value of experimental frequency, which was (0.691 ± 0.02) Hz. The plot is also centered around this point.

**Conclusion**

**Bibliography**

1. Campbell, W. C. et al. Physics 4AL: Mechanics Lab Manual (ver. June 27, 2018). (Univ. California Los Angeles, Los Angeles, California).