PHYSICS 4AL

EXPERIMENT 5: HARMONIC OSCILLATOR PART I: SPRING OSCILLATOR

Terrence Ho | ID: 804793446
Date of Lab: May 16th, 2017
Lab Section: Tuesday, 5 P.M.
T.A.: David Bauer
Lab Partners: Robathan Harries

Contents

INVESTIGATING DAMPED AND UNDAMPED OSCILLATIONS

T. Ho[1]

In Newtonian mechanics, a mass suspended on a spring undergoes harmonic motions. The objective of the experiment was to investigate the motion of damped and undamped oscillations. Specifically, we wanted to find whether resonant frequencies in both types of oscillations would be equivalent, as well as any other observations we could make. A mass was hung from a vertical force sensor, and measured both voltage and time, with magnets providing a damping force. Graphs of voltage vs time were plotted to find the relationship between these values. Through this, we confirmed the experimental resonant frequency closely matched calculated predicted values, which was 0.6799 1/s. We observed the amplitude of an undamped oscillation being near constant, while an undamped oscillation's amplitude decreased very quickly. Lastly, values of damping term and Q-factor were also derived from the experiment.

[1] Henry Samueli School of Engineering and Applied Science, University of California, Los Angeles

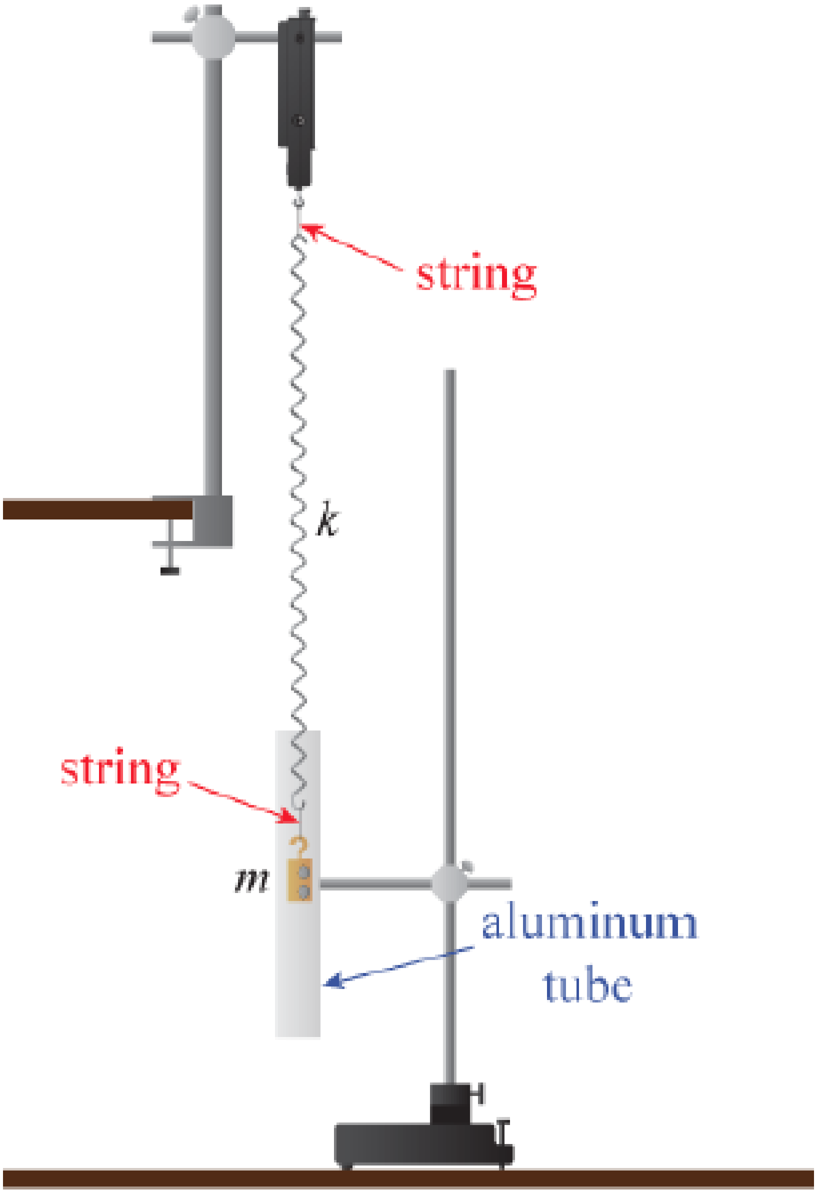

Figure 5.1 Setup for Oscillation Experiment. The sensor provides the readout of voltage during oscillation motion. The weight has magnets that can provide a damping force if passed through the aluminum tube. Be sure to decouple the spring from the mass and the force sensor to produce the most accurate data. Figure reproduced (with permission) from Fig. 5.1 by Campbell, W. C. et al.[1]

INTRODUCTION

Oscillations are caused by an acting force and a restoring force exerted by a spring. If an object is oscillating and there is no other force acting on it, it is in simple harmonic motion and has a constant amplitude and frequency. This frequency is also known as the resonant frequency, where it's amplitude will be greatest.

In our experiment, we sought to observe both undamped and damped oscillations, with the ultimate goal of finding the resonant frequency. By hanging a mass onto a force sensor and measuring voltage produced by the mass over time, we can determine the amplitudes, frequencies, and periods by which the mass on the spring oscillated at. We can also determine if the resonant frequency is the same for both undamped and damped oscillations.

METHODS

The first step of the experiment is to determine the spring constant of the spring we will hang our masses from. A series of masses were hung from the spring and the distance from the mass to the floor was measured and plotted. The slope of the best fit line gives our spring constant k (**Figure 5.2**).

Figure 5.1 shows the layout of our experiment. With the force sensor (measuring voltage) attached to the computer, set a high sample rate for the sensor so voltage data is accurate. Attach a small string to the bottom of the hook, then attach the mass to the string (this is done to avoid uncertainty that occurs when the spring rotates and turns as it stretches and compresses). The mass should have magnets on it's side so an aluminnum tube can be used for the damped oscillation trial and slow the mass. A small force was given to the spring mass system and let to oscillate for 40 seconds, during which voltage and time are recorded.

Any data recorded should be transferred over to Excel for analysis. Other data important to collect would be an offset voltage(to account for the fact the voltage data may not be centered at zero) and mass of the weight used.

ANALYSIS

We first determined the spring constant of the spring by hanging masses of 0 g, 50 g, 100 g, 150 g, and 200 g, and plotting these masses against the distance remaining from the ground to the spring when placed onto the spring. This is illustrated in **Figure 5.2**. The spring constant is determined to be 3.2 ± 0.2 N/m.

The mass m on the spring we used for our experiment was 175 ± 0.5 g.

To predict out resonant frequency, we used the equation $f_0 = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$, where k is the spring constant found on **Figure 5.2** and m is the mass of the weight on spring. Using the propagation of uncertainty, $\frac{\delta f_0}{f_0} = \sqrt{\left(\frac{\delta k}{2k}\right)^2 + \left(\frac{\delta m}{2m}\right)^2}$, to find the uncertainty for f_0, we find that $f_{0,predict} = 0.67 \pm 0.2$ Hz.

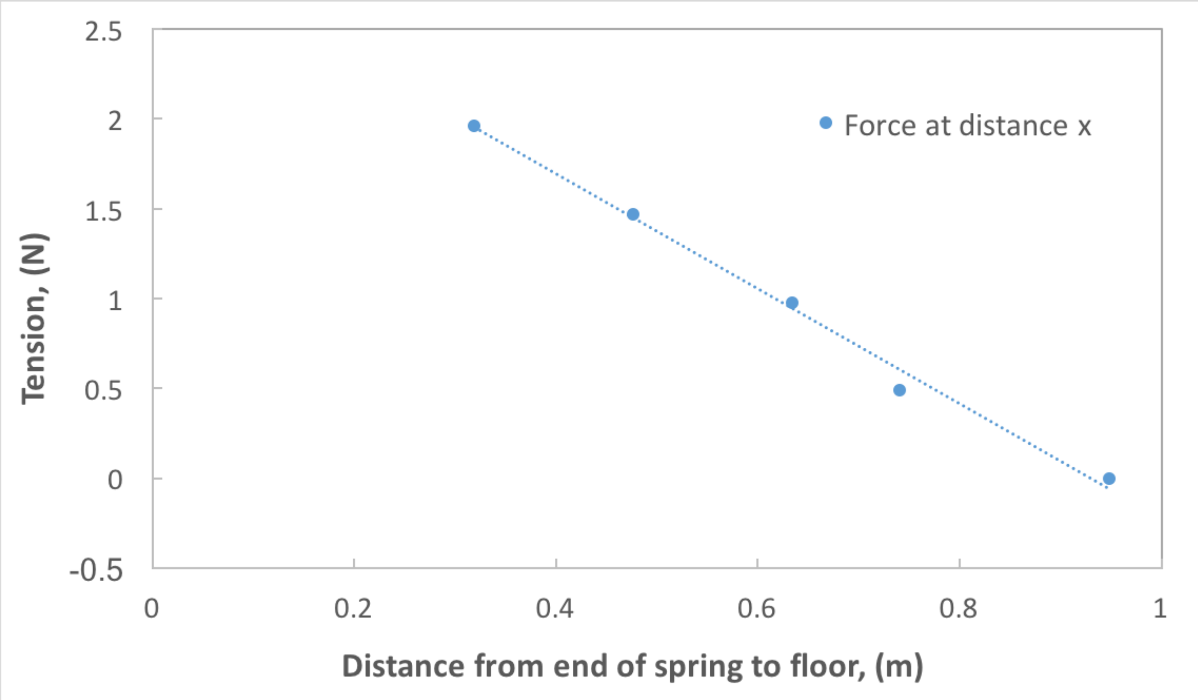

Figure 5.2 Measuring Spring Constant of a Spring. Masses used were 0 g, 50 g, 100 g, 150 g, and 200 g. The best fit line has the equation $F = -3.1945x + 2.9174$ The spring constant was found to be 3.2 ± 0.2.

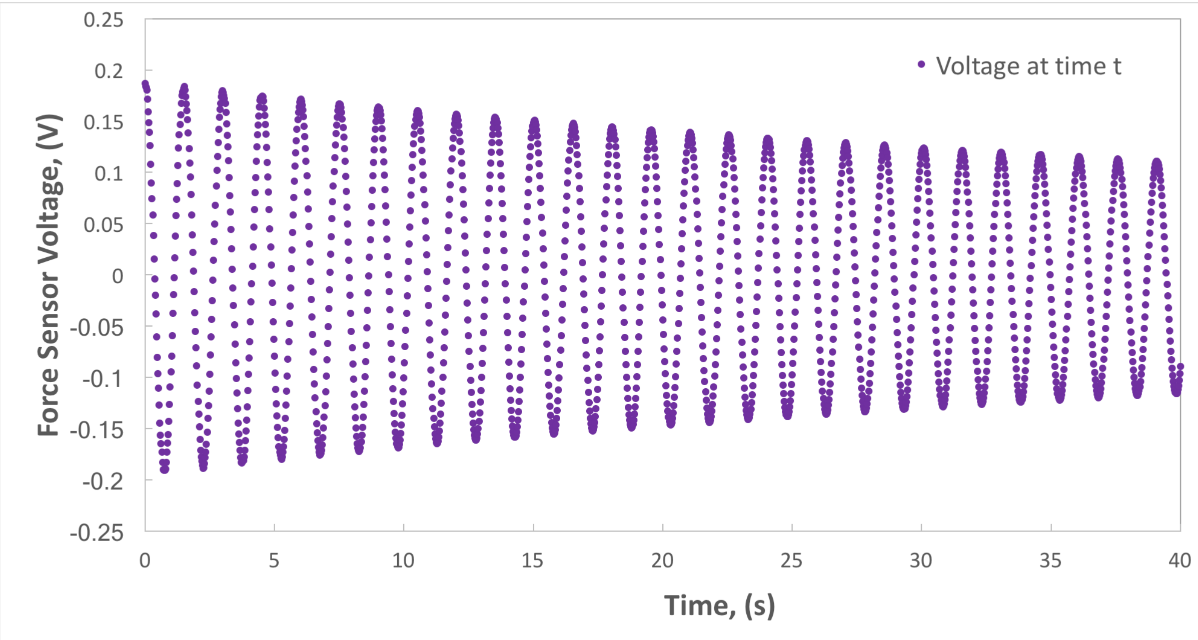

Figure 5.3 Simple Harmonic Motion of Spring. The x-axis shows time of reading and the y-axis shows the voltage measured by the force sensor at that time. An offset of 0.0327 V was added to each voltage to center our readings at V = 0.

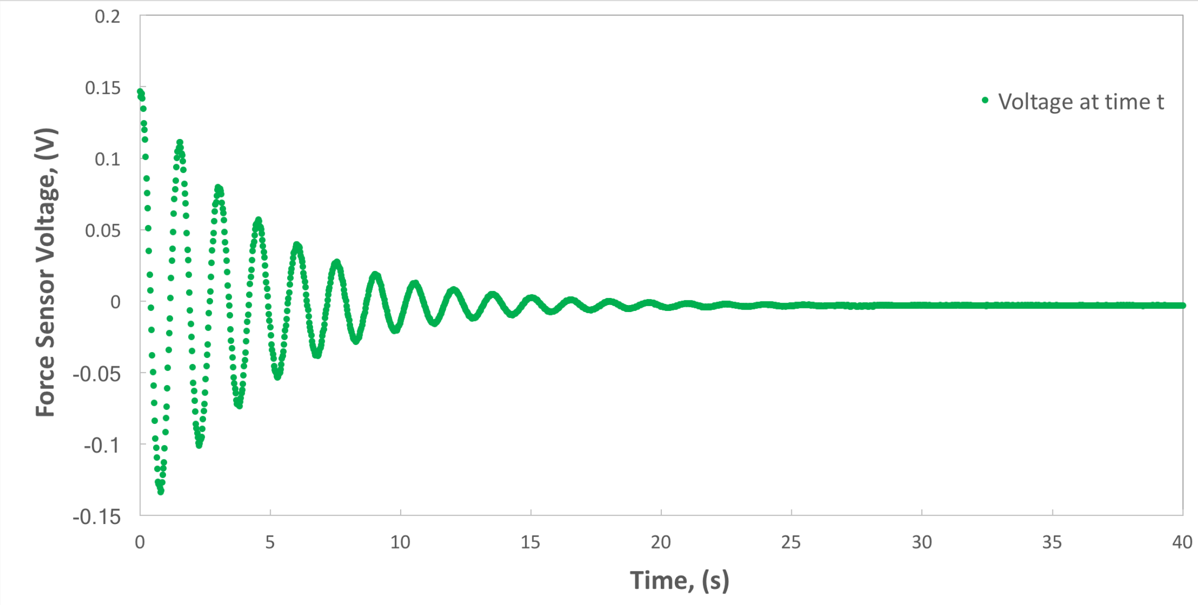

Figure 5.4 Damped Oscillation of a Spring. The x-axis shows the time of reading and the y-axis shows the voltage measured by the force sensor at that time. The offset was 0.0327 V, which was added to each voltage value to center our readings.

In both **Figure 5.3** and **Figure 5.4**, we plotted our measured voltage values at each time. The data is presented with an offset to the voltage, which accounts for the fact the equilibrium voltage was not 0 V and to avoid drifting in our data for the damping oscillation in **Figure 5.4**. The offset value is 0.0327 V.

Figure 5.3 shows our plotted values of voltage V at time t for the undamped oscillation. We derived our experimental value of $f_{0,undamped}$ by taking the maxima at several different points, zooming in and finding the maximum value and time of each peak. The resonant frequency $f_{0,undamped}$ is then equal to $\frac{n-1}{t_n-t_1}$, where n is the peak number and t is the time when that peak occured. We took several trials of this data to find an uncertainty range (standard deviation of the data divided by the number of trials), and the resulting frequency was $f_{0,undamped} = 0.661 \pm 0.002$ Hz.

Similarly, we plotted the measured voltage values at each time for the damped oscillation in **Figure 5.4**. We derived our experimental value of f_{damped} by taking the maxima at several different points, zooming in and finding the maximum value and time of each peak. The resonant frequency is then equal to $\frac{n-1}{t_n-t_1}$, where n is the peak number and t is the time when that peak occured. We took several trials of this data to find an uncertainty range (standard deviation of the data divided by the number of trials), and the resulting frequency was $f_{damped} = 0.660 \pm 0.003$ Hz.

We can see that in both the damped and undamped oscillations, the resonant frequencies f_0 calculated from our experiment were within the uncertainty range of our predicted resonant frequency $f_{0,predict}$, which was 0.67 ± 0.02 Hz. Thus our calculated values are accurate relative to our predicted value.

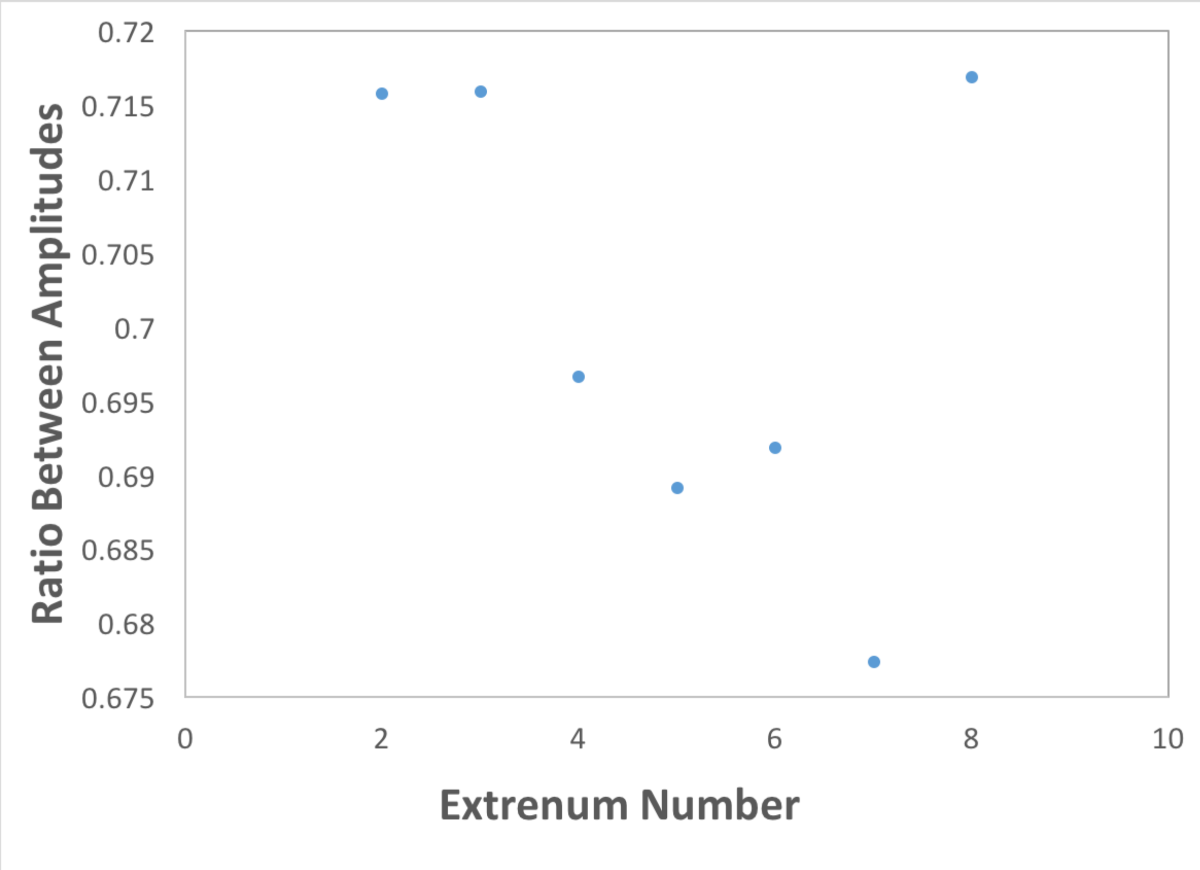

Figure 5.5 Ratios of Peak Amplitudes

We can also determine damping time from our graph. Damping time is

CONCLUSION

We performed our experiment to study simple harmonic motion and damped oscillations.

References

1. Campbell, W. C. et al. Physics 4AL: Mechanics Lab Manual (ver. April 3, 2017). (Univ. California Los Angeles, Los Angeles, California).