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Quantitative Engineering Analysis 3
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Project 1: Characterization of a Harmonic Oscillator

I. Introduction and Requirements:

In this project, you will work with a partner to build and characterize a single degree-of-freedom (DOF) harmonic oscillator. This will involve using differential equations with real measurements.

Our final report includes the following:

- [x] Table of estimated values
    - [x] Moving mass (m), in kg
    - [x] Spring constant (K), in N/m
    - [x] Damping coefficient (b), in N*s/m = kg/s
    - [x] Natural frequency (omega_n), in Hz
    - [x] Damping ratio (zeta), unitless
- [x] Photo of your experimental setup
- [x] Plots of Experimental Data
    - [x] Experimental data from phone: Acceleration on vertical axis, time on horizontal axis
    - [x] Experimental data from spring characterization: Force on vertical axis, displacement on horizontal axis
- [x] Your raw data (experimental data from phone, acceleration in m/s^2, time in s)
- [x] Abstract (1-3 paragraphs summarizing your experimental approach and findings)

II. Data Tables

A. Spring 1 spring constant measurements

Force (N)	Distance (m)	Spring Constant
.135	0.60	0.225
.195	0.80	0.24375
.25	1	0.25
0.11	.5	0.22
.165	.7	0.235714
.22	.9	0.244

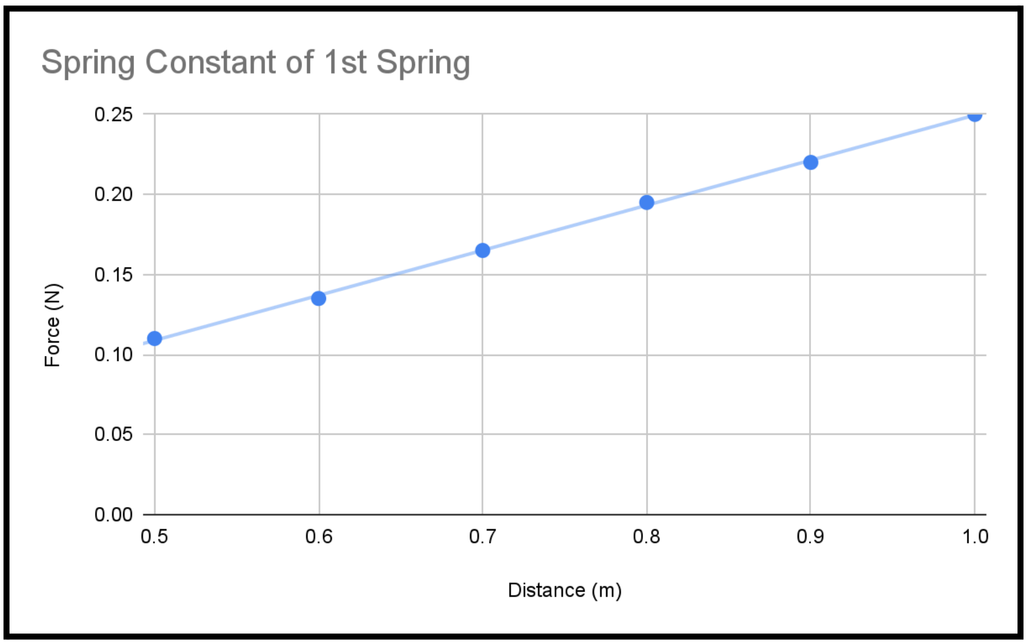

Figure 2.1: Measurement of Spring 1 Spring Constant, Avg Spring Constant: 0.23641

B. Spring 2 spring constant measurements

Force (N)	Distance (m)	Spring constant
.17	.70	0.2428
.208	.8	0.26
.085	.4	0.2125

Force (N)	Distance (m)	Spring constant
.17	.70	0.2428
.110	.5	0.22

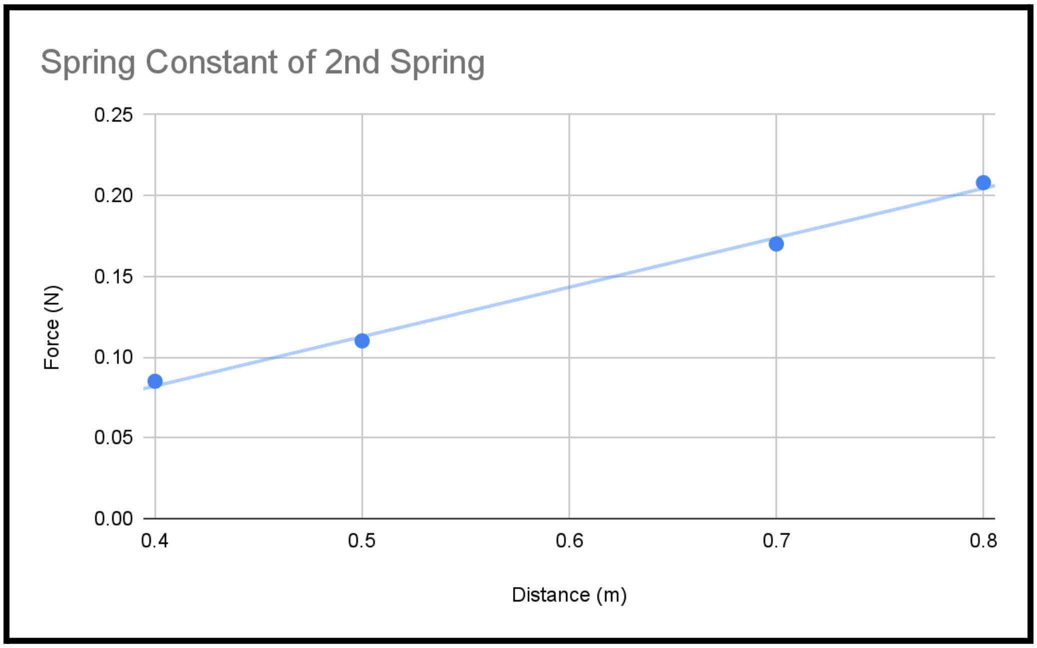

Figure 2.2: Measurement of Spring 1 Spring Constant, Avg Spring Constant: 0.233825

C. Table of Estimated Values

Cart Displacement from Equilibrium	Moving mass (m), in kg	Spring constant 1 (K), in N/m– by using the force scale	Spring constant 2 (K), in N/m– by using the force scale	Effective spring constant (K)	Damping coefficient (b), in N*s/m = kg/s	Natural frequency (omega_n), in Hz	Damping ratio (zeta), unitless
30cm	0.757	0.23641	0.233825	0.470235	-0.7825	2.7872	0.0338
15cm	0.757	0.23641	0.233825	0.470235	-0.1363	2.7711	0.0250
Average	0.757	0.23641	0.233825	0.470235	-0.4594	2.77915	0.0294

Figure 2.3: Table of Estimated Value. Note that the difference in damping coefficient comes from the increase of velocity from the 30 cm displacement to the 15 cm displacement. This occurs since we are using a linear equation to map a system that is parabolic to velocity.

III. Experimental Setup

A. Photo of Setup

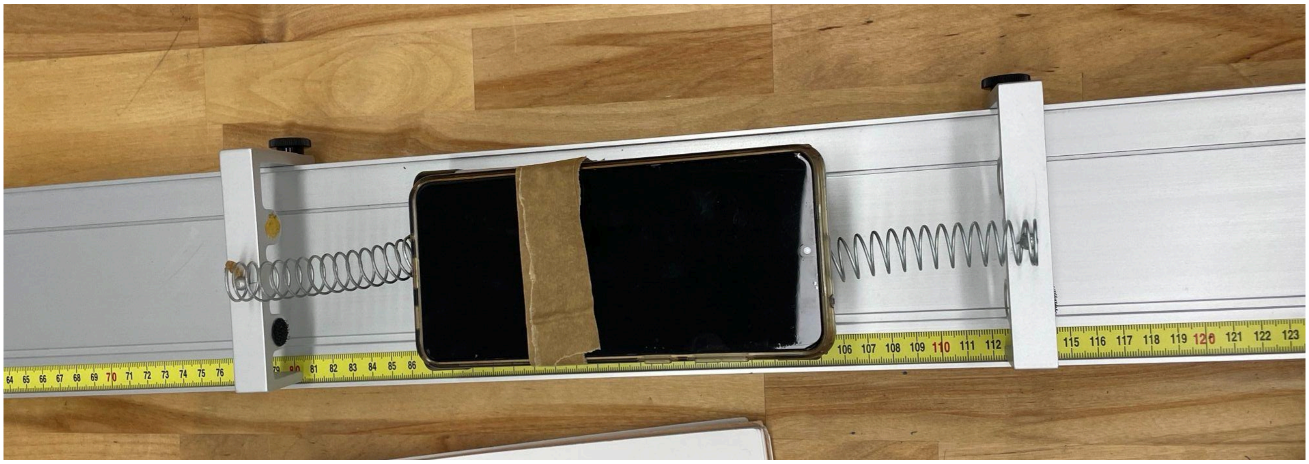

Figure 3.1: Above is our experimental setup that has a cart, two springs, and a phone to collect data.

B. Experimental Data: Time vs. Acceleration

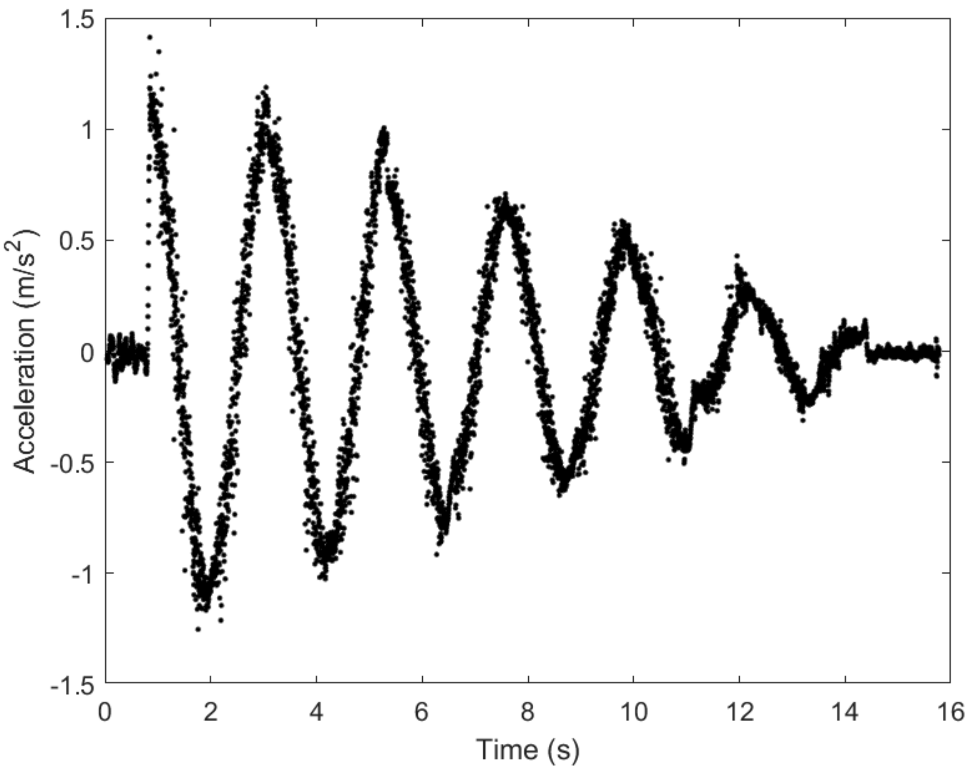

Figure 3.2: Experimental data collected from phone of acceleration over time

15 cm displacement experimental data:
https://docs.google.com/spreadsheets/d/1BG9CPki5G-VO_PWUwPjdCRT56MwAGDNL4_h1msTJEK8/edit?gid=1254956290#gid=1254956290

30 cm displacement experimental data:
https://docs.google.com/spreadsheets/d/1pT2zJzku73D4f8FM38f1gSzLGUm8DfoVWVN1L3pcYEI/edit?gid=1147698283#gid=1147698283

IV. Abstract

We first started our experimental process by determining the spring constant (K) and effective spring constant in our system. We determined the spring constant using each spring and a digital spring scale. The spring constant is the slope of Force over meters. Thus, we connected the spring scale to each spring and pulled it back incrementally, collecting the force the scale was reported as we went. From there we graph each of the springs and find the slope of the line of best fit, giving us each spring constant. In order to determine the effective spring constant in the entire system we modeled the system in a free body diagram. From there we applied Newton's Second Law of Motion to see that the effective spring constant equals the sum of the individual spring constants.

Once we determined our spring constant we collected our oscillation data. Each side of the cart was attached to a spring and placed on rails. A phone with an app that collects acceleration data was taped to the cart as pictured in Figure 1. We first displaced the cart by 15 cm in one direction and collected the oscillation data, then we displaced it by 30 cm and re-collected the data. Finally, we took this acceleration data and used a Matlab script to plot our data across time. The force of friction served as our forcing function in our second-order derivative. We arrived at the plots with the calculated analytical solutions using the provided MATLAB script.

Our results proved that our experimental results matched the theoretical results, proving a linear harmonic second-order equation matches the motion of an underdamped spring system. The only mismatch between the physical and theoretical systems was the damping coefficient, which changed significantly between our tests of 15 cm displacement and 30 cm displacement. This was calculated as damping_force = damping_coeffecient*velocity, assuming the damping force is linearly correlated with velocity; however, it is more accurately correlated with velocity squared (as seen in standard aerodynamic equations). As such, the damping coefficient for a 30 cm displacement was higher due to the increased velocity.