Lab Report 13-A: Real vs Ideal Oscillations

PHY121

November, 23rd, 2024

Professor R. Lathrop — Professor M. Petralia

Abereni Opuiyo

Table of Contents

Purpose

To study how mass distribution affects the period of a spring and a pendulum.

Theory

Springs when stretched or compressed a certain distance tend to return to their original state. The force required for a spring to return to its original state is called the *restoring force*. The force required for a spring to return to its original position is directly proportional to the displacement of the spring. A greater stretch andor compression results in a greater restoring force. The restoring force also changes based on the stiffness of a spring, also known as the *spring constant*, k. This relationship between a spring's stiffness, displacement, and restoring force is referred to as *Hooke's Law*, and is represented by the following equation:

$$\mathbf{F} = -kx \tag{1}$$

If you were to hang a mass to a frictionless, massless spring, the time it takes for the spring to oscillate between its original and new positions is called the *period*.

The period of a spring with a hanging mass attached to it can be determined with the following equation:

$$\mathrm{T} = 2\pi\sqrt{\frac{m}{k}}$$

$$\begin{aligned} \mathrm{T} &: \text{period} \\ m &: \text{mass of object} \\ k &: \text{spring constant} \end{aligned}$$

A pendulum, where all mass is located at the bottom, experiences a similar periodic motion to that of a spring. The period of a pendulum can be determined with the following equation:

$$\mathrm{T} = 2\pi\sqrt{\frac{l}{g}}$$

$$\begin{aligned} \mathrm{T} &: \text{period} \\ l &: \text{length of pendulum} \\ g &: \text{acceleration due to gravity} \end{aligned}$$

Procedure

Part 1: Measuring Spring Constant

1. Mounted **spring** to **clamp**.
2. Attached **hanging mass** with 50 g of mass to bottom of **spring**.
3. Added mass in 50 g increments up to 400 g, recording the *equilibrium position* for each mass using a **meter stick**.

Part 2: Measuring The Period

4. Setup **motion detector** right beneath **spring**, with 0.5 me of distance between them.
5. Removed all masses from **spring** except **mass hanger**.
6. Slowly set 150 g onto **mass hanger** and recorded oscillations using **logger pro**.
7. Repeated step 6 for increasing increments of 100 g up to 450 g.

Part 3: Pendulum

8. Attached 100 g mass to end of **meter stick** using **tape**.
9. Set **pendulum** into oscillation and measured time it took for 5 cycles to complete.
10. Repeated step 2, two more times.
11. Removed mass from end of **meter stick** and repeated steps 2-3.

Calculations & Graphs

Period of a Spring with A Hanging Mass

$$\mathrm{T} = 2\pi\sqrt{\frac{m}{k}} \tag{2}$$

$$\begin{aligned} \mathrm{T} &: \text{period} \\ m &: \text{mass of hanging weight and spring} \\ k &: \text{spring constant} \end{aligned}$$

Sample Calculation

part 2, expected period for mass of 15 g

$$\begin{aligned} \mathrm{T} &= 2\pi\sqrt{\frac{m}{k}} \\ &= 2\pi\sqrt{\frac{0.31\ \text{kg}}{8.0051}} \\ \mathrm{T} &= \boxed{1.236\,\text{s}} \end{aligned}$$

Period of a Pendulum

$$\mathrm{T} = 2\pi\sqrt{\frac{l}{g}} \tag{3}$$

$$\begin{aligned} \mathrm{T} &: \text{period} \\ l &: \text{length of pendulum} \\ g &: \text{acceleration due to gravity} \end{aligned}$$

Sample Calculation

part 2, expected period for ideal pendulum

$$\begin{aligned} \mathrm{T} &= 2\pi\sqrt{\frac{l}{g}} \\ &= 2\pi\sqrt{\frac{1\ \text{m}}{9.8\ \text{m/s}^2}} \\ \mathrm{T} &= \boxed{2\ \text{s}} \end{aligned}$$

Fractional Discrepancy

$$\text{FD} = \left| \frac{\text{measured - actual}}{\text{actual}} \right| \tag{4}$$

Sample Calculation

percent error between ideal period and measured period using values from part 3

$$\text{FD} = \left| \frac{\text{measured - actual}}{\text{actual}} \right|$$

$$\text{FD} = \left| \frac{1.986 \text{ s - } 2 \text{ s}}{2 \text{ s}} \right|$$

$$\text{FD} = \boxed{0.007}$$

Percent Error

$$\text{PD} = \left| \frac{\text{measured - actual}}{\text{actual}} \right| \text{ x } 100\% \tag{5}$$

Sample Calculation

percent error between ideal period and measured period using values from part 3

$$\text{PD} = \left| \frac{\text{measured - actual}}{\text{actual}} \right| \text{ x } 100\%$$

$$\text{PD} = \left| \frac{1.986 \text{ s - } 2 \text{ s}}{2 \text{ s}} \right| \text{ x } 100\%$$

$$\text{PD} = \boxed{0.7\%}$$

Tables

Table 1: Part 1 - Spring Constant Table

Mass (kg)	0.05	0.1	0.15	0.2	0.25	0.3	0.35	0.4
Weight (N)	0.49	0.98	1.47	1.96	2.45	2.94	3.43	3.92
Position (m)	0.555	0.615	0.675	0.735	0.795	0.855	0.915	0.989
Mass of Spring (kg)	0.16							

Table 2: Part 2 - Periods of Different Hanging Masses

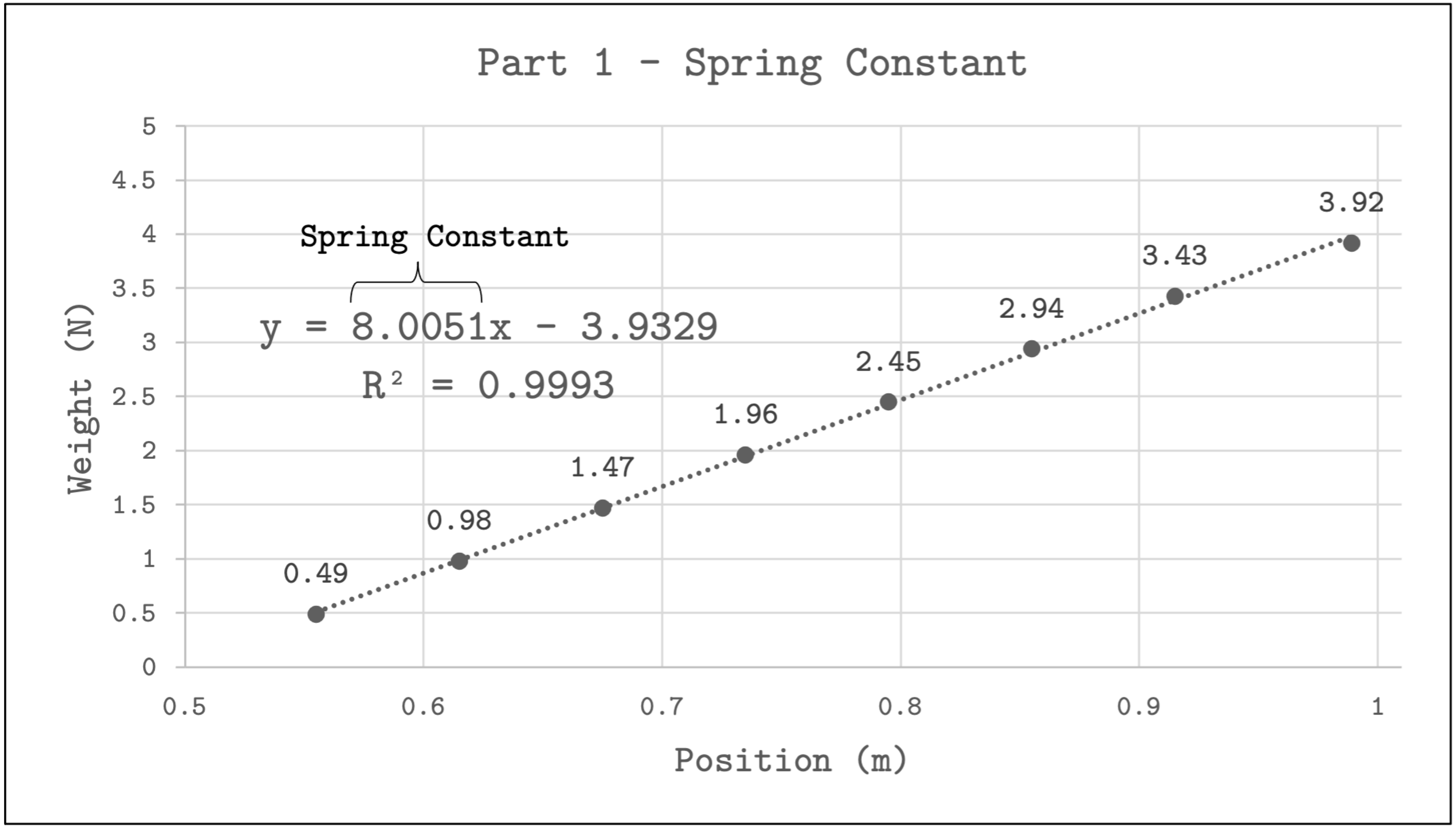
Mass (kg)	0.15	0.25	0.35	0.45
Period (s)	1.19	1.38	1.55	1.68
Measured T (s)	1.19	1.38	1.55	1.68
Predicted T (s)	1.236	1.421	1.585	1.734
Fractional Discrepancy	0.0375	0.0295	0.0226	0.0313

Table 3: Part 3 - Period of A Pendulum

Time for 5 Cycles (s)	9.93	9.89	9.93
Measured T (s)	1.986	1.978	1.986
Ideal T (s)	2	2	2
Real T (s)	1.778	1.754	1.756
Error Between Measured & Ideal (%)	0.7	1.1	0.7
Error Between Measured & Real (%)	11.69	12.77	13.09

Graphs

Figure 1: Part 1: Spring Constant



Questions

1. **Bearing in mind that Hooke's Law is F = -kx, determine (and record k from this graph.**

   The spring constant of our spring, was 8.0051 based on our graph.

2. **How do your measured results compare to the predicted value of T in each case? For which mass is the fractional discrepancy the greatest? The least? Why do the values differ between the measured and predicted?**

   Our measured results are somewhat close to the predicted value for T in each case. The mass with the greatest fractional discrepancy was 15 grams, and for the least, 35 grams. The difference between the measured and predicted values is most likely because the spring is NOT mass less compared to an ideal spring represented in Hooke's Law.

3. **There will still be some discrepancy between the predicted and the measured periods. To what might you attribute this?**

   The difference between the measured and predicted values is most likely because the spring is NOT mass less compared to an ideal spring represented in Hooke's Law.

4. **Which pendulum seemed to come closest to the expected? (The one with the mass at the end or without?) What do you think this meansin regards to the mass of the ruler?**

   The one with mass was closer to the expected. This is most likely because the mass of the meter stick is evenly distributed and not all at the bottom, which the equation requires.

5. **Does the magnitude of the swing matter in determining the period? (Does a bigger amplitude increase the period of the pendulum?) Does Equation 2 have a variable that affects the period?**

   No, the magnitude of the swing does not matter in determining the period.

6. **Were your results consistent with other lab groups? What problems did you experience in this lab that affected your results?**

   Our results were mostly consistent with other groups.

Conclusion

The purpose of this lab was to study how mass distribution affects the period of a spring and a pendulum. To do so we first needed to determine the spring's stiffness, also known as its spring constant, k. After placing masses of increasing weight on the spring, and measuring its displacement, we were able to determine the spring's stiffness or k. From our trials and data analysis, we determined the spring's constant to be 8.0051 (see Figure 1). Using this spring constant and equation 2, we were able to determine the spring's theoretical period if masses were hung from it. Once again, we placed masses of increasing weight on the spring, this time measuring oscillation with a motion sensor. We found that as the weight on the spring increased, so too did its measured period (see Table 2). We then calculated the period of an ideal spring with the same weight hung from it. We found that there was some discrepancy between our measured and predicted values. The mass with the greatest fractional discrepancy was 15 grams at 0.0375 , and for the least, 35 grams, at 0.0226 (see Table 2). The difference between the measured and predicted values is most likely because the spring is NOT mass less compared to an ideal spring represented in Hooke's Law (see Table 1). Were we to re conduct the experiment with a lighter spring, we would most likely see a lower discrepancy between our measured and predicted values.

In part 3, we measured the period of a pendulum under two different conditions: one in which there was a mass attached to the bottom, one in which there was not. The body of the pendulum we used was a meter stick. Using equation 3, we determined the ideal period. Our actual measurements were interesting. We found that the period of the meter stick with no mass attached was farther away from the ideal period than our measurements of the meter stick with a mass attached (see Table 3). The reason for this discrepancy is most likely due to the fact that the pendulum referred to in equation 3 is one in which all its mass is at the bottom. Attaching the mass to the meter stick allowed it to become a pendulum that met that condition. When we removed the mass from the meter stick, it become a uniform rod, with its mass distributed evenly throughout. This would would explain why our measurements of the pendulum's period with a mass attached is closer to the ideal period than the pendulum without a mass attached.