Name: ______________________________________

LAB 13. HOOKE'S LAW

Introduction

External force applied to an object will change the object's size or shape or both. Objects exhibiting elastic behavior will return to their original shapes when the stress is removed. The simplest approximation to the behavior of a spring is Hooke's law, $F = -kx$, where F is the force exerted by the spring, k is the stiffness of the spring, and x is its distortion from its equilibrium size.

The equation governing the motion of a mass m acted on only by a Hooke's law spring with force constant k is $m\, d^2x/dt^2 = -kx$. The general solution of this equation for displacement x of the mass as a function of time t is $x = A \cos(\omega t + \phi)$, where $\omega^2 = k/m$ and ϕ is a phase offset. Note that the oscillation frequency $2\pi\omega$ does not depend on the oscillation amplitude.

In this lab, you will determine if Hooke's law adequately models the behavior of several springs. You will further test the claim that $\omega^2 = k/m$, and that amplitude does not affect oscillation frequency.

Lab activity

Supplies

Three springs, several weights, meter stick, rod and table clamp, stopwatch or timer

Procedure

1. Measure and record the initial length l_0 of the spring.
2. Hang a known mass from the spring and allow the mass to come to rest. Record the spring's length l_1.
3. Set the mass into vertical oscillations. Time a number (say, 10–20) of complete oscillations. Record the number of oscillations and the total time. (Divide to find the period.) For a few of these, repeat with a different oscillation amplitude to check if the period of oscillation changes.
4. Add more known masses incrementally until you have seven (7) mass, length, and period measurements in addition to the zero-load length. Record these additional data as well.
5. Convert the masses to the forces they exert on the spring by multiplying by the gravitational field g. In other words, $F = mg$. Record these forces.
6. How confident can you be in the forces you calculated? (What factors might affect the validity of your result?)
7. Repeat the process with other springs, for a total of at least three springs.

Data Processing

You now have several data sets of tension, length, and oscillation period for several springs. From these data, estimate the spring constant k of each spring. Also use the data to evaluate the model claims that the length and tension of the spring are related by Hooke's law, and that the motion of the system is a sinusoid with angular frequency $\omega = \sqrt{k/m}$.

Lab Report

Abstract

Briefly describe the system. Identify the quantities that were measured, and the quantities that were inferred from the measurements.

Purpose

What are these measurements used for? To what end are they the means?

Theory

A lot of the important theory was described in the introduction to these instructions. Explain it back to me, in your own words. Also explain what Hooke's law predicts the outcome of the measurements to be.

Experimental

Describe the experimental apparatus and measuring equipment. Give the procedure you followed to make the measurements.

Observations and Data

You don't need to transcribe the data directly into a lab report, but you should clearly communicate what you found. If you choose to graph your data, it would make sense to use a spreadsheet. If you use a Google Sheets spreadsheet, you can link to it in your report.

Analysis and Discussion

What did the Hooke's law model predict for your observations? Did your observations conform to these predictions? Analyze how your data help to answer these questions.

Conclusion

Dos Hooke's law adequately describe the behavior of the springs you studied in this experiment?