The Free Mass-Spring Oscillator

Overview

In this and the next two labs, we employ the mass spring system, our prototype simple harmonic oscillator. In this lab we study the "free" mass-spring oscillator. By "free" we mean that there is no friction present to dampen the motion. The mass is influenced only by the forces of gravity and the spring. We take these forces to be conservative, so that energy is conserved. Once the system is set in motion, it oscillates forever…

Of course, there is no such thing as a truly free mass-spring oscillator. Friction is always present in some form, however small. There is the internal friction of molecules inside the spring, and the external friction of air molecules striking the mass. But the friction is weak in our system and oscillations persist for several minutes. For measurements made over a period of ten seconds, the amplitude of oscillation is nearly constant. Under these near ideal conditions, we are confident that having measured the motion, we may analyze our measurements using the theory of the free oscillator.

In this lab you will bring the mass-spring oscillator to life and analyze its motion. You will measure its oscillation frequency and spring force constant, and validate the theoretical relationship between these two quantities. Using Logger Pro you will effortlessly plot the spring force as well as the displacement, velocity and acceleration of the mass, all as functions of time. You will see at a glance the relative phases of these quantities, and know what is meant when we say that "a leads v leads x", that is, acceleration leads velocity, and velocity leads displacement.

Setup

Mount a force sensor and a position sensor as shown in the figure. Place the position sensor directly beneath the hanger, with about 20 cm distance between sensor and bottom of hanger. Set the force sensor range to 10N. Hook three springs in series to create a long spring. Hang a 100g mass (hanger plus 50g) from the spring, and hang the spring from the force sensor.

Procedure

Frequency and Force Constant

Open the Logger Pro template Force+3.cmbl, and with the system in equilibrium, zero the force sensor. Induce vertical oscillations in the mass and collect data for several seconds. Fit sine functions to the displacement, velocity, acceleration and force plots.

(W1) What is the oscillation frequency ω?

(W2) Ignore spring mass and use this value to determine the spring force constant. Let's name this value k_ω, the value of k determined from frequency ω. Show your calculations.

Relative Phases

(W3) To determine relative phases, can the force plot serve as the acceleration plot? Explain.

(W4) What are the phase differences between force and velocity, velocity and displacement, and force and displacement?

(W5) If someone gave you the acceleration plot of a simple harmonic oscillator, explain how you could quickly sketch the velocity and displacement plots.

(W6) Given the scale of the acceleration plot, show the quick calculations that give you the scale of the velocity and displacement plots.

Validation of the ω, k Relationship

Open the Logger Pro template SingleSpring.cmbl and collect data. For the three masses 50g, 100g and 150g, and with the system stationary, record hanger position and spring force. The three data points plot force versus position.

(W7) Determine the force constant. Let's name this value k_F, the value of k determined from force F.

(W8) What is the percent difference between k_ω and k_F?

Effect of Spring Mass on Frequency

In our experiment, we did not take into account the mass of the spring.

(W9) Given that the spring mass is about 19g, use massive spring theory, which takes spring mass into account, to determine the spring force constant. Let's name this value k'_ω. What is the percent difference between k'_ω and k_F?