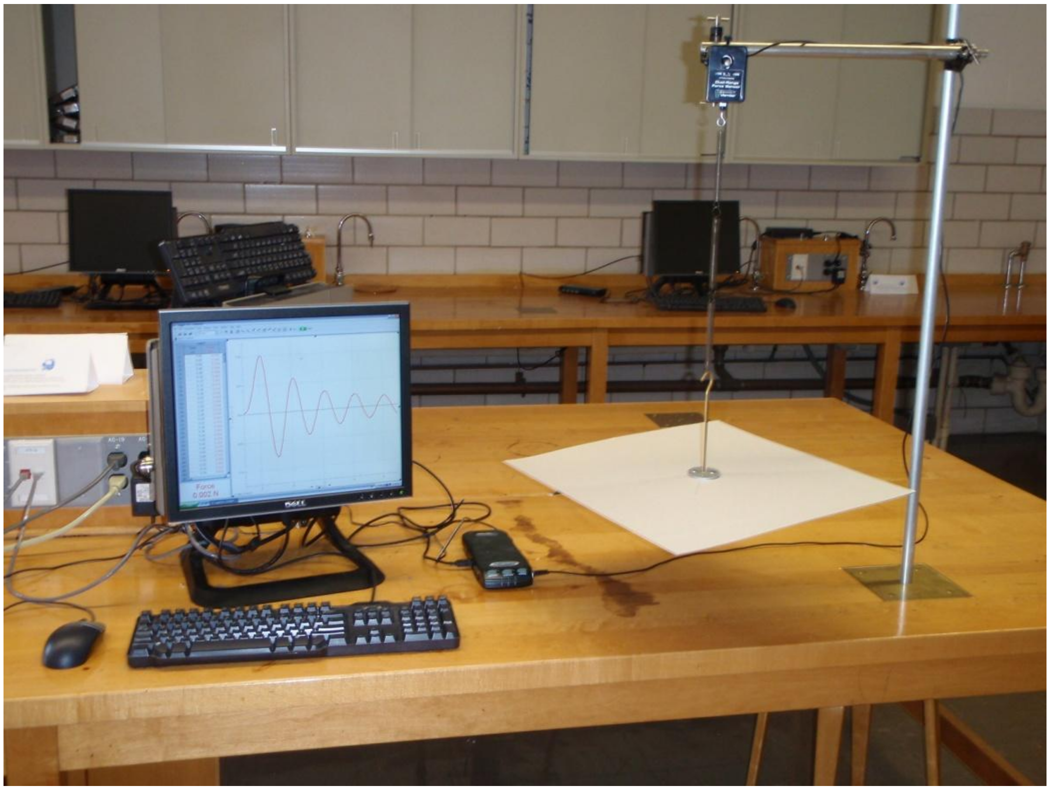
The Damped Mass-Spring Oscillator



Overview

If you apply friction to a free oscillator, you create an oscillator whose motion is "damped" by the friction. One way to apply friction to a mass-spring oscillator is to attach a large, flat panel of cardboard to the mass. The panel "grabs air" as the mass oscillates, creating air resistance, a non-conservative friction force. The force does negative work on the mass-spring system, which is another way of saying that it draws energy out of the system, and thereby reduces the amplitude of the oscillatory motion. If the damping is strong, the amplitude decays within a few cycles. We specify the strength of the damping with the damping coefficient γ. But damping does more than "wear down" the motion, it slows down the motion by lowering the oscillation frequency. We label this "damped" frequency ω_d, and distinguish it from ω_0, the frequency of the free oscillator.

In this lab you measure ω_0 of the free oscillator, then apply damping and measure γ and ω_d, then use these to calculate ω_0, and finally compare this with the measured value. To obtain the damping coefficient and frequency, you use Logger Pro to plot the spring force amplitude over several cycles, fit an exponentially decaying sinusoid to the plot and read γ and ω_d directly from the fit parameters.

Setup

Mount a force sensor as shown in the figure. Set the force sensor range to 10N. Connect three springs in series, hang the spring from the sensor, place a 50g mass on the hanger, add additional mass equal to the mass of the damping panel, and hang the assembly from the springs. Let's name the mass of the hanger assembly m_{hang} .

Procedure

Determine the Free Oscillation Frequency

Open the Logger Pro template .\cmbl_Templates\mk_damped.cmbl, induce vertical oscillations in the mass, and collect data for several cycles. Auto-fit the $sin(..)$ function to the force plot.

(W1) Read the fit parameters and record the free oscillation frequency ω_0.

The spring mass is about $m_{spring} \cong 19g$.

(W2) Neglect m_{spring} and use only m_{hang} and ω_0 to determine the spring force constant k.

(W3) Now use m_{hang} , m_{spring} and ω_0 to determine the spring force constant k. For this you need the formula

$$\omega_0^2 = \frac{k}{m_{hang} + m_{spring}/3}.$$

(W4) What is the percent difference between the two determinations?

Determine the Damped Oscillation Frequency

Replace the additional mass with the large damping panel as shown in the figure (keep the 50g mass on the hanger), induce vertical oscillations and collect data for several cycles. Fit the $exp(..)sin(..)$ function to the force plot.

(W5) Read the fit parameters and record the damping coefficient γ and damped frequency ω_d.

Assume the damping of the system is proportional to velocity (the linear model developed in lecture).

(W6) Use the values of γ and ω_d to calculate the free oscillation frequency $\omega_0{}'$ of the system.

(W7) Is the system over damped, critically damped, or under damped?

(W8) What is the percent difference between ω_0 and $\omega_0{}'$?

(W9) Given this percent difference, is the above assumption valid?