



### 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  $\gamma$ . But damping does more than “wear down” the motion, it slows down the motion by lowering the oscillation frequency. We label this “damped” frequency  $\omega_d$ , and distinguish it from  $\omega_0$ , the frequency of the free oscillator.

In this lab you measure  $\omega_0$  of the free oscillator, apply damping, measure  $\gamma$  and  $\omega_d$ , use these to calculate  $\omega_0$ , and 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  $\gamma$  and  $\omega_d$  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 mk\_damped.cmbl, induce vertical oscillations in the mass, and collect data for several cycles. Auto-fit the  $\sin(\dots)$  function to the force plot.

**(W1)** Read the fit parameters and record the free oscillation frequency  $\omega_0$ .

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

**(W2)** Neglect  $m_{spring}$  and use  $m_{hang}$  and  $\omega_0$  to determine the spring force constant  $k$ .

**(W3)** Now use  $m_{hang}$ ,  $m_{spring}$  and  $\omega_0$  to determine the spring force constant  $k$ .

**(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  $\exp(\dots)\sin(\dots)$  function to the force plot.

**(W5)** Read the fit parameters and record the damping coefficient  $\gamma$  and damped frequency  $\omega_d$ .

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

**(W6)** Use the values of  $\gamma$  and  $\omega_d$  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  $\omega_0$  and  $\omega_0'$ ?

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