Damped Simple Harmonic Oscillator and the Driven Damped Harmonic Oscillator

Harmonic Oscillator and Spring Constant

1. Get two springs from the instructor and measure the spring constant of both springs. Make sure you do **not** stretch the spring beyond 3 times the unstretched length. We would like to measure the spring constant as accurately as possible so think about different ways to make the measurement and how you might reduce the systematic and random uncertainties.
2. Plot the data (using Excel, Maple, MatLab, or DataStudio) and use a least-square fit to find the spring constant. Use a program that will give you the uncertainty for the slope and intercept. Your uncertainty should be only a few percent.

Damped Harmonic Oscillator

Underdamped

1. Set up the Pasco track and cart with your two springs holding the cart near the center of the track. Set up a sonic motion detector to measure the displacement of the cart. You may want to use a small cardboard square to reflect the sonic signal. Make sure it is not to large to cause damping.
2. Record the motion of the cart with as little damping as possible. You may want to clean the track grooves and check the cart wheels.
3. Use your recorded data and any other measurements needed to calculate the spring constant and compare it to the values found in procedure 1. You should have uncertainties (error) bars or root-mean-squared for your k values so that you can make a statement if they are equal or not. Procedure 1 was a static measurement whereas the measurement you just made was a dynamical one. They are not the same, but the difference is small.
4. Next we will add damping to the oscillator (cart). It will be convenient to use magnetic damping because it is much easier to control. Make (some of you are engineers) an aluminum rail that fits on the cart and something to hold magnets close to the rail. The more magnets or closer the magnets to the rail the larger the damping.
5. Record the motion for three or four different damping parameters. The decay time should be between 5 and 20 seconds.
6. Analyze the recorded motion in procedure 5 to find the damping parameter for each case. Use DataStudio, Maple, or MatLab to do a nonlinear fit to the motion data.

Overdamped

1. Now increase the damping so that the oscillator is overdamped and record the motion for three or four different damping parameters.
2. Analyze the motion to find the damping parameter.

Critically Damped

1. Can you find the critically damped case? It should be the motion with the shortest settling time.

2. Using the natural frequency and damping parameters found in procedure 6 calculate the damping parameter for critical damping. Does it agree with what you found in procedure 1?

Driven Damped Harmonic Oscillator

Underdamped (the only case we will study)

1. Use the same set-up but add a motor to drive the spring-cart system. Add damping so that the motion damps out in about 10 seconds with *no drive*. Turn on the motor and adjust the voltage until the drive frequency is about one-half the resonance frequency. After 10 to 20 seconds the motion should settle down into the steady-state motion. (Junior do you know what that is?).
2. Now we want to record the motion as the transient dies out and steady-state grows. The way to do this is to hold the card steady at its equilibrium position and start the motor. After a 20 or 30 seconds start recording the motion with Science Workshop and at the same time let the cart go. Record until the transient dies out and you can see the steady-state for 10 or 20 seconds.
3. From the recorded motion try to find the time for the transient to die out. Does it agree with what you found in procedure 1? It should.
4. Repeat procedures 1 through 3 for two or three different drive frequencies.

Resonance

1. Next we would like to plot the resonance curve for the set-up used above. We can use the data collected above but would like to add 8 to 10 more data points (drive frequencies). This time you only need to record the steady-state motion. Start the motor, adjust the frequency and them wait 20 or 30 seconds and record the steady-state motion for 10 to 15 oscillations.
2. From the recorded data find the amplitude and frequency and plot a resonance curve.
3. Next use Science Workshop to do a nonlinear least-squared fit of the amplitude equation to the data and see if the fitting parameters agree with your measurements.
4. Repeat procedures 1 and 3 for a different damping constant.