PHY 221 LAB 04-2: Simple Harmonic Oscillator

Objective: Determine the angular frequency, amplitude, and phase for an oscillating spring-mass system. Calculate the velocity, momentum, and net force on the object.

Introduction

Let's begin with a simplified system. Suppose we have an object (i.e. particle) of mass m attached to spring. It is in space, far from any significant gravitational or electromagnetic interactions. Thus, the only object interacting with the mass is a spring (the other end of the spring is attached to a rigid wall of some kind). A picture of the situation is shown in Figure 1.

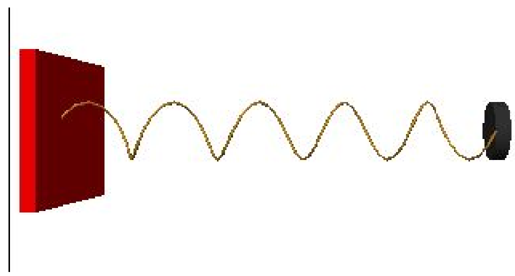

Figure 1:

The spring is initially unstretched. Then, we pull the object back from this position and release it from rest. Its position as a function of time will be sinusoidal and can be written in general as

$$x = Acos(\omega t + \phi) \tag{1}$$

The *phase*, ϕ, is related to the initial conditions, x_0 and v_{x0}, of the oscillator. Think of the phase in this way–depending on when you start the clock (t=0), the phase tells you the position and velocity of the object when the clock starts.

The x-velocity of the object is

$$v_x = \frac{dx}{dt} \tag{2}$$

The x-momentum of the object is

$$p_x = mv_x \tag{3}$$

The net force on the object is

$$F_{net,x} = \frac{dp_x}{dt} \tag{4}$$

Experiment

1. Set up a vertical spring with a 200-gram mass hanging from the spring. Set up the motion detector on the floor. Be sure that the mass does not fall on top of the detector because the detector is fragile. It's best to use the masses with hooks.

2. Set up the LabPro data acquisition interface. Plug the motion detector into the LabPro in the first digital input port.

3. Start the Logger Pro software.

4. You should see two graphs of position and velocity vs. time. Delete the graph of velocity vs. time and go to Page→Auto Arrange in order to make the graph of position vs. time appear as large as possible in the window.

5. With the mass hanging in equilibrium, zero the motion detector. (You may have to do this by going to the menu Experiment→Zero.)

6. Holding a meterstick next to the mass, pull the mass down about 3 cm. Record exactly how far you pulled down the mass from equilibrium. This is called the amplitude. Be sure and record the amplitude below.

7. Release it from rest. Be sure that it oscillates up and down without "bouncing" around from side to side.

8. Click the Collect button to begin collecting data. After it oscillates for about 3 to 4 cycles, click the Stop button.

9. Autoscale the graph.

10. Sketch below what you observe.

11. Where is the object when the graph of x vs. t is at its peak (i.e. maximum)?

12. Where is the object when the graph of x vs. t is at its minimum?

13. Where is the object and what direction is it moving when the graph of x vs. t is at x=0 with a negative slope?

14. Where it the object and what direction is it moving when the graph of x vs. t is at x=0 with a positive slope?

15. Measure the clock reading when the graph is at a maximum? (You can just put the cursor over a maximum and read the coordinates of the cursor that are displayed in a corner of the graph window. Or there is a tool on the toolbar that allows you to place your cursor over a data point. It then gives you the value of the data point.)

16. Measure the clock reading when the graph is at the next later maximum?

17. Use these clock readings to determine the time interval for one cycle. This is called the *period*.

18. Measure the period using two minima on the graph and record the result.

19. Measure the period using two points where x=0 and record the result. Do all of your measurements for period agree?

20. Calculate the *frequency*, f, using $f = 1/T$. Its units are cycles per second, or Hz.

21. Determine the *angular frequency*, ω, by converting cycles per second to radians per second. There are 2π radians in one cycle.

22. Go to Analyze→Curve Fit, and click Define Function. Type the following function into the box:

$$A * cos(B * t + C) + D \quad (5)$$

23. Click Try Fit for the program to calculate the constants for the equation that best fits your data. Write the best-fit function below.

24. Examine the values of the constants. Which constant gives you the angular frequency of the oscillation and what is the value of that constant? Does it agree with your previous calculation?

25. Which constant gives you the amplitude of the oscillation and what is the value of that constant? Does it agree with the amplitude that you measured with the meterstick?

26. Measure the mass of the object attached to the spring using a mass balance.

$$m = \quad (6)$$

27. Calculate the angular frequency of the mass-spring system according to theory, using $\omega = \sqrt{k/m}$.

$$\omega = \quad (7)$$

28. How does this compare to what you measured? Calculate a percent difference.

29. Calculate an equation for the x-velocity as a function of time by taking the derivative of your function of $x(t)$.

30. Calculate an equation for the x-momentum as a function of time.

31. Calculate an equation for the x-component of the net force on the object as a function of time by taking the derivative of your function of $p_x(t)$.

Application

1. What was the maximum speed of the object? Measure this from the x-velocity vs. time graph and compare it to what you saw in your equation for $v_x(t)$.
2. What was the maximum net force on the object? Measure this from the equation for $F_{net,x}(t)$. Compare to what you get from $|F_{spring}| = ks$ where s is the amplitude when the spring is maximally stretched or compressed.
3. If you increase the stiffness of the spring, what will happen to the frequency? (stay the same, increase, or decrease) Use a different spring and redo your experiment. You can try a less stiff or more stiff spring. Measure the frequency and compare.
4. If you increase the mass of the object, what will happen to the frequency? (stay the same, increase, or decrease) Use the same spring but a different mass. Measure the frequency and compare.