Physics 110 Lab: Periodic Motion

Name ______________________________

Introduction

Periodic motion is motion that repeats itself. You can see the repetition in the position-, velocity-, or acceleration-time graphs. The length of time to go through one cycle and begin to repeat the motion is called the period. The number of cycles in each second is called the frequency. The unit of frequency, cycles per second is given a special name–Hertz.

Motion of a Mass Hanging from a Spring

In this lab you will investigate the periodic motion of a mass hanging from a spring. This model can be applied to many physical situations.

Apparatus

- Large spring
- Motion detector and protective shield
- Variety of masses
- *Science Workshop 750 Interface*
- *DataStudio* software (*periodic_motion_1* file)

Activity 1: Periodic Motion of a Mass-Spring System

(a) Open the *periodic_motion_1* file in *DataStudio*. Hang the large spring from the force probe hook with the large diameter coils down and hang a 200-g mass from the spring. Place the motion detector facing up directly below the spring. Place the protective shield over the motion detector and adjust position so that the motion detector window is not blocked. Push the mass straight upward 15 cm, and let go. Adjust the height of the support so that the mass comes no closer than 0.15 m to the detector. Record data for a few seconds to display position-time and velocity-time graphs of the motion. Print out your graph.

Comment: Note that when an object returns to the same position, it does not necessarily mean that a cycle is ending. It must return to the same position, and the velocity and acceleration must also return to the same values in both magnitude and direction for this to be the start of a new cycle.

(b) Label the graphs with: "B" at the Beginning of a cycle and "E" at the End of the same complete cycle. "A" on each spot where the mass is moving Away from the detector fastest. "T" on each spot where the mass is moving Toward the detector fastest. "S" on each spot where the mass is standing Still. "F" where the mass is Farthest from the motion detector. "C" where the mass is Closest to the motion detector.

(c) Do the position and velocity graphs appear to have the same period? Do their peaks occur at the same times? If not, how are the peaks related in time?

(d) Use the Smart Tool to measure the period and frequency of the motion. (For better accuracy, measure the total time over as many cycles as possible and divide by the number of cycles.

Period = ____________ Frequency = ____________

(e) Using the Smart Tool, determine and record the maximum displacement. Then record data with the mass at rest to find the equilibrium position. Draw a straight line on your position graph indicating the equilibrium position in terms of the distance from the motion detector. Calculate and record the amplitude of the motion (the difference between the maximum displacement and the equilibrium position).

Amplitude = ____________

Simple Harmonic Motion

The motion of a mass hanging from a spring that you looked at in Activity 1 is a close approximation to a kind of periodic motion called simple harmonic motion (sometimes abbreviated SHM).

Activity 2: Predictions: What Factors Determine the Period of the Mass-Spring System?

Without using the experimental equipment, predict what you can do to change the period of the SHM of the mass-spring system. Predict what will happen to the period if you increase the amplitude. Increase the mass? Increase the spring constant (use a stiffer spring)?

Activity 3: The Period of SHM and the Amplitude

(a) Repeat the procedure of Activity 1, but with a different starting position (other than 15 cm). (Warning: Do not make the amplitude so large that the mass comes closer than 0.15 m from the motion detector.) When you have good graphs, find and record the period and the amplitude using the methods described in Activity 1.

(b) Find ratios of the period and the amplitude of Activity 1 to those determined here.

(c) Is there evidence that the period depends on amplitude? (Did the change in amplitude result in a comparable change in period?) Explain. How does this compare with your prediction?

Activity 4: The Dependence of the Period of a SHM on the Mass

(a) Carefully measure the period for four other masses. Record the masses and the measured periods in a table in the space below along with the mass and period from Activity 1.

(b) Does the period depend on the mass? Does it increase or decrease as mass is increased?

(c) Determine the mathematical relationship between the period T and the mass m by finding a function that fits the data. Write the equation that provides the best fit to the data in the space below.

Comment: You should have found that T is independent of amplitude and proportional to $\sqrt{m}$. The actual expression for the period is

$$T = 2\pi\sqrt{\frac{m}{k}} \tag{1}$$

Activity 5: Determining the Spring Constant

(a) Using your data from Activity 4, determine the spring constant of the spring. Explain your method below and provide your result.

(b) Think of another method to determine the spring constant. In the space below, write a brief description of your method, provide a table of data that you obtained to find the spring constant, and your result.

(c) How do the spring constants you obtained in part (a) and (b) compare?

Activity 6: Determination of the Mass of the Spring

In the above exercises, we have assumed that the spring is massless. In this part we will test this assumption.

Consider Equation (1). Where would the mass of the spring appear in the equation? Write this new equation.

Devise a method of plotting your data so that you can derive the spring constant and the mass of the spring. Hint: Figure out how to plot the data so that you find a linear relationship and can extract k and m_{spring} from the slope and/or y-intercept. (You may be able to use the plot you already made for Activity 4, if you plotted the correct quantities.) Explain your method in the space below and provide a result for the mass of the spring. How reasonable is the assumption of a massless spring for your setup?

Hand-In

- This worksheet
- All graphs, clearly plotted and labeled, with correct units on the axes.