**Experiment**

**1**

Oscillatory Motion

## EQUIPMENT

* *PASCO 750* ComputerInterface
* motion sensor
* ±50 N force sensor
* wave driver
* spring (k between 3 and 4 N/m)
* masses and mass hanger
* mass balance (±0.01 g)

## Part 1: Simple Harmonic Motion

## PURPOSE

The purpose of this experiment is to investigate the oscillatory motion of a vertical spring mass and verify the formula for the period of its oscillation.

## THEORY

Imagine a spring of length L (called its rest length) hanging vertically from a support. When a mass m is added to the spring, it causes the length of the spring to increase by ΔL. The equilibrium position of the mass is now a distance L + ΔL from the spring’s support. What happens when the mass is pulled down a small distance from the equilibrium position? The spring exerts a restoring force, **F = -kx**, where **x** is the distance the spring is pulled down and **k** is the force constant of the spring (also called the “spring constant”). The negative sign indicates that the force points opposite to the direction of the displacement of the mass. When the mass is released, the restoring force causes it to oscillate up and down. The period of oscillation depends on the mass and the spring constant according to the following equation.



**Equation 1:**

As the mass oscillates, the energy continually interchanges between kinetic energy and some form of potential energy (mgh and 1/2kx2). If friction is ignored, the total energy of the system remains constant. When the mass is at its highest point, the gravitational potential energy (mgh) is at its maximum. When it is at its lowest point, the elastic potential energy (1/2kx2) is at its maximum. Before beginning this experiment, read sections 13.1 – 13.4 of your text, then define each of the following in the space provided.

1. Oscillatory Motion:
2. Simple Harmonic Motion (SHM):
3. Amplitude:
4. Period
5. Frequency:

## INTRODUCTION

In Part 1A of this experiment, the force sensor will measure the force that stretches the spring as mass is added to one end of the spring. The motion sensor will measure the amount of distance that the spring stretches. The *Data Studio* program displays the force and the position. The slope of the best-fit line of a graph of force versus position is the spring constant “k”. Why?

In the Part 1B, the motion sensor will measure the motion of the mass that is suspended from the end of the spring. The *Data Studio* program records the motion and displays the position of the oscillating mass versus time. The program is used to determine the period of oscillation, which is compared to the theoretical period of oscillation according to Equation1.

**PROCEDURE**

## Part 1A: Determining the Spring Constant

1. Open the *Data Studio* document titled as shown: *oscillation\_part1a.ds*.
2. Suspend the spring and mass hanger from the force sensor’s hook so that it hangs vertically.
3. Place the motion sensor on the floor directly beneath the mass (without any additional mass added).
4. Press the tare button on the side of the force sensor to zero the force sensor.
5. Click the “Start” button to begin data recording.
6. When the mass hanger has stabilized (motionless), click the **Keep** button to record the position of the bottom end of the mass hanger as the spring is at its equilibrium position.Both values of force and position will appear on the Data Table window.

Force

Sensor

Unstretched

spring

Stretched spring

(position 1)

Mass

and

hanger

Motion Sensor

To Interface

1. Add 10 grams of mass to the end of the spring. Stabilize the mass hanger and click the **Keep** button again to record the new position of the end of the bottom end of the mass hanger. The new data set appears as well as the first one.
2. Continue to add mass in 10 gram increments until you have added 70 grams. Stabilize the mass hanger and then click the **Keep** button each time to record your data.
3. Click the “Stop” button to end data recording.
4. Click on the graph to make it active and click the “Scale to fit” button ( DataStudio_autoscale copy ) to rescale the graph.
5. Click the “Curve Fit”button( DataStudio_curvefit ) and select **Linear Fit.** The absolute value of the slope will be the spring constant “k”.
6. Record the value of “k” under Results, Part 1, print the graph and attach it to this report.

*Select* ***Quit*** *from* ***File*** *menu when you finish. An alert window will appear. Click* ***Don’t Save****.*

## Part 1B: Kinematics of an Oscillating Spring Mass

1. Open the *Data Studio* document titled as shown: *oscillation\_part1b.ds.*
2. Use the mass hanger with no additional mass.



1. Pull the mass hanger down a few centimeters and then release it. Try to obtain a vertical oscillation only. Let it oscillate a few times so any unwanted oscillations can dampen out.
2. Click the “Start” button to begin recording data. The plots of the position, velocity and acceleration of the oscillating mass will appear in the graph display. Continue recording for about 10 seconds.
3. Click "Stop" button to end data recording.
4. Click the “Zoom Select” button ( ZoomSelect ) to rescale the graphs and see more detail.
5. Click the “Smart Tool” button ( Smart%20Tool ) and the cursor changes to a cross-hair when you move it into the display area of the graph. Exam each consecutive peak in the plot and record the value of time in Data Table below.
6. Find the period of each oscillation by calculating the difference between the times for seven successive peaks and record these in Data Table.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Peak # | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Time (sec) |  |  |  |  |  |  |  |
| Period (sec) |  |  |  |  |  |  |  |

## Table 1: Measuring the Period

1. Calculate the average period and frequency of oscillation and record it under “Results, Part 1”.
2. Remove the mass hanger from the spring. Measure and record its mass (in kilograms). Calculate the theoretical value for the period of oscillation (Equation 1) based on the measured value of the spring constant in Part 1A and the mass, and record under Results,

Part 1.

**Mass** = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ kg

1. Print your graph of position, velocity and acceleration versus time and attach it to this report. Why are these sinusoidal graphs “out of phase”?

**RESULTS, Part 1**

Spring Constant**: \_\_\_\_\_\_\_\_\_\_\_\_\_\_**

Average Period of Oscillation: \_\_\_\_\_\_ Average frequency of Oscillation:\_\_\_\_\_\_\_\_

Theoretical Period of Oscillation: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

% Error: \_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Part 2 - SIMPLE PENDULUM**

As discussed in lecture or your book, a pendulum’s (a mass on a string) motion can be described by simple harmonic motion, SHM.

In this portion of the lab you will measure the period of oscillation for the “simple pendulum”. [[1]](#footnote-1) You will measure the period [[2]](#footnote-2) of this motion as it undergoes a few simple changes; a change in the mass on the string, and a change in the length of the pendulum’s string.

Apparatus: You will have 2 pendulums to work with. One is specifically for changing the mass. One is specifically for changing the length of the rope.

**PROCEDURE:**

1. Change the mass
   1. Use the pendulum with the WOODEN bob.
   2. Do not add any of the additional metal weights to begin.
   3. Bring the pendulum back to the 10 degree line and release.
   4. Use your stopwatch to record 10 full periods of this motion
   5. Now, add FIVE of the metal washers onto the wooden bob. Repeat parts c and d.
   6. Repeat part e

Table 2a – Changing the Mass

|  |  |  |
| --- | --- | --- |
|  | **Time for 10 periods** | **Time for 1 period (divide by 10)** |
| **No masses added** |  |  |
| **5 Masses added** |  |  |
| **10 Masses added** |  |  |

1. Change the length
   1. Use the pendulum with the METAL bob.
   2. Measure the length of the pendulum’s string. Remember, the metal ball contributes to the length of the string as it is treated as a point particle at it’s center of mass.
   3. Measure the Diameter of the metal bob with Vernier Callipers.
   4. Bring the pendulum back to the 10 degree line and release.
   5. Use your stopwatch to record 10 full periods of this motion and record.
   6. Change the length of your string and repeat parts c and d.
   7. Do this for 4 different lengths.

**Table 2b – Changing the Length**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Length** | **Time for 10 periods** | **Time for 1 period** |
| **Length 1:** |  |  |  |
| **Length 2:** |  |  |  |
| **Length 3:** |  |  |  |
| **Length 4:** |  |  |  |

**Please describe any trends you can quantify from your results in Table 2a and 2b below. How do these trends relate back to the *known* equation for the period of a simple pendulum?**

1. Remember, the simple pendulum is the case where the angle from the vertical is small [↑](#footnote-ref-1)
2. The period is how long (in seconds) it takes to go one full circular oscillation, i.e. from one side’s highest amplitude, to the other side, then back again. [↑](#footnote-ref-2)