Experiment 10

Pendulum Periods

INTRODUCTION

The introductory treatment of the motion of a pendulum leaves one with the impression that the period of oscillation is independent of the mass and the amplitude, and depends only on the length of the pendulum. These relationships are generally true so long as two important conditions are met:

1. the amplitude is small (<< 1 radian), and
2. the mass of the system is concentrated at the end of the string.

In this experiment and the next you will examine the behavior of a pendulum in greater detail to see what occurs when these conditions are no longer true. You will examine the approximations made to simplify the analysis of the pendulum and determine when and why these approximations begin to break down. The first of these is the subject of this experiment; the second will be examined in Experiment 18.

OBJECTIVES

In this experiment, you will

- Collect angle *vs.* time data for a simple pendulum.
- Determine the best-fit equation for the angle *vs.* time graph.
- From an analysis of the forces acting on the pendulum bob, derive the equation describing the motion of the pendulum.
- Relate the parameters in the best-fit equation for the angle *vs.* time graph to their physical counterparts in the system.
- Determine the period of oscillation from an analysis of the angle *vs.* time graph.
- Account for the deviation from constant periods when the amplitude becomes large.

MATERIALS

Vernier data-collection interface
Logger *Pro* or LabQuest App
Vernier Rotary Motion Sensor
Vernier Rotary Motion Accessory Kit
vertical support rod and clamp
right-angle clamp
protractor
metric ruler or tape

PART 1 – EXAMINATION OF THE MOTION OF A SIMPLE PENDULUM AT VARIOUS AMPLITUDES

PROCEDURE

1. Make sure that the vertical support rod for the Rotary Motion Sensor is securely attached to a bench or table. When the pendulum is set in motion the sensor should be stationary.

2. Measure the distance between the point of attachment of the rod to the 3-step pulley and the center of mass of the weight at the end of the rod. Record this value as the length, *l,* of the pendulum.

3. Connect the sensor to the interface and start the data-collection program. Two graphs: angle *vs.* time and velocity *vs*. time will appear in the graph window. For this experiment, you will need to view only the angle *vs.* time graph.

4. The default data-collection rate is appropriate. However, you should increase the resolution of the sensor by selecting the X4 mode.
   - In Logger *Pro*, choose Set Up Sensors from the Experiment menu. Once you select your interface, click on the icon for the RMV and then select X4 Mode.

5. Because the default data-collection mode automatically resets the zero position when you start data collection, it is unnecessary to manually zero the sensor before collecting data. However, the bob must be motionless before you begin data collection.

6. Start data collection. Then, using a protractor to measure the angle, pull the rod through a 5° angle and release. Be sure that the pendulum swings freely for at least five seconds. Store this run as SP5degreerun.cmbl. Make sure you know where you have saved the file. It is easier if you save it on the desktop.

7. Repeat Step 6 for amplitudes of 10°, 15° and 20°, storing each run. You will return to them later in the experiment.

EVALUATION OF DATA

Determination of ω using Logger *Pro*

8. Before you fit a curve to the position-time graph, turn off Connect Points and turn on Point Protectors.

9. Drag-select that portion of the graph for your first run where the bob is swinging freely. Fit a sine curve to these data. Record the value of the *B* parameter to the sine fit. Repeat this process for your other runs. Copy and paste all the graphs in your worksheet (question 1).

10. The *B* parameter is the angular frequency, ω, for this oscillation. Answer question 2 in your worksheet.

11. Slide the weight a few centimeters higher on the rod. Measure the new length, l, of the pendulum. Calculate the expected value of ω for this pendulum.

12. Collect angle-time data for another run using an amplitude between 10 and 20°. Determine ω as you did before. Compare this value to the one you calculated.

PART 2 – EFFECT OF AMPLITUDE ON PERIOD

PROCEDURE

1. Return the weight to its original position at the end of the aluminum rod. Re-open your experiment file from Part 1.

2. Collect angle *vs.* time data for the pendulum as before with an amplitude of 25°. Determine the period, T, of the oscillation, and record the amplitude, angular frequency, and the period in your worksheet

   - In Logger *Pro*, perform a sine curve fit on the appropriate part of the angle-time graph. Record the value of ω for this run. Leaving the curve fit information window open speeds up this process for subsequent runs.

3. Repeat step 2, increasing the amplitude by 5° each time until you reach 60°. It is unnecessary to store these runs. Beyond this angle, increase the amplitude by 10° until you reach 100°. Record the period for each run.

4. Disconnect the sensor from the interface and choose New from the File menu.

   - In Logger *Pro*, manually enter all the calculated frequency (omega) for all runs and corresponding amplitude in degrees in two columns and use a calculated column to determine the period.

5. Examine the graph of period *vs.* amplitude. Be sure to scale the vertical axis from zero. Examine the statistics on the first four data points for this graph. Perform a linear fit for this same portion of the graph. Note at what point the data show that the period is no longer independent of amplitude. Copy and paste the graph into your worksheet.