Factors That Affect the Period of a Pendulum

Inquiry Investigation Laboratory Report

Section 1: Introduction and Guiding Question

Abstract

A simple pendulum is a small object (sometimes called a pendulum bob) of considerable mass attached to a cord or string. The cord or string is assumed not to stretch and has negligible mass compared to the hanging object. The motion of a pendulum is a swinging back and forth in a simple harmonic motion. Simple harmonic motion as defined by dictionary.com (n.d.) is “vibratory motion in a system in which the restoring force is proportional to the displacement from equilibrium.” Therefore, the pendulum will swing in an oscillating motion along the arc of a circle to an equal distance on both sides of the equilibrium point. The maximum distances away are classified as the amplitude and the equilibrium point is where the pendulum mass would hang vertically (refer to Figure 1). (Giancoli, 1998, p. 296)

Figure 1: (“PhysisLAB: Period of a Pendulum,” n.d.)

The equation for the period of a pendulum is: (Giancoli, 1998, p. 297)

\[ T = 2\pi \sqrt{\frac{l}{g}} \]

The equation above demonstrates that the period of a pendulum is directly affected by the length of the string and by the acceleration of gravity when moving at small angles less than 15°. The period of the pendulum should not depend upon the amplitude as Galileo noted when looking at a swinging lamp in the cathedral at Pisa (refer to Figure 2). This discovery by Galileo resulted in the invention of the pendulum clock, a precise instrument that became a standard in timing for hundreds of years. Most pendulums will experience damped harmonic motion due to air resistance and internal friction within the system.
Goal of the Investigation:
To determine a factor that affects the period of a pendulum.

Guiding Question:
What is the one factor that affects the period of a pendulum? Is that factor proportional or not?

Section 2: Method

Procedure:
Students will test various factors to determine if it affects the period of a pendulum (time it takes for a pendulum to make one complete cycle). Students will use Vernier Photogates (shown below) to determine the period of a pendulum with great precision. **Note:** Small angles less than 15˚ should be used when testing the period.

Students will choose and test an independent variable (test variable) and do at least five trials changing that variable (even if it does not seem to change the period right away). Students will record the test variable and the results of the dependent variable (period of a pendulum).

If the dependent variable (period of the pendulum) does not change due to the test variable, repeat using a different test variable.

Figure 3:
Data:

Experiment A:

During Experiment A, the mass on the pendulum was manipulated while the length of the string was held at a constant length. The dependent variable measured by the Vernier photogates was the period of the pendulum in seconds. The results are recorded in Data Table A.

**Data Table A:**

<table>
<thead>
<tr>
<th>Test Variable</th>
<th>Responding Variable</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass (kg)</td>
<td>Period of Pendulum (seconds)</td>
<td>Length (m)</td>
</tr>
<tr>
<td>0.10</td>
<td>1.71</td>
<td>0.80</td>
</tr>
<tr>
<td>0.20</td>
<td>1.72</td>
<td>0.80</td>
</tr>
<tr>
<td>0.30</td>
<td>1.73</td>
<td>0.80</td>
</tr>
<tr>
<td>0.40</td>
<td>1.73</td>
<td>0.80</td>
</tr>
<tr>
<td>0.50</td>
<td>1.71</td>
<td>0.80</td>
</tr>
</tbody>
</table>

Experiment B:

During Experiment B, the length of the pendulum string was manipulated while the mass on the pendulum was held at a constant length. The dependent variable measured by the Vernier photogates was the period of the pendulum in seconds. The results are recorded in Data Table B.

**Data Table B:**

<table>
<thead>
<tr>
<th>Test Variable</th>
<th>Responding Variable</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (m)</td>
<td>Period of Pendulum (seconds)</td>
<td>Mass (kg)</td>
</tr>
<tr>
<td>0.80</td>
<td>1.71</td>
<td>0.10</td>
</tr>
<tr>
<td>0.62</td>
<td>1.58</td>
<td>0.10</td>
</tr>
<tr>
<td>0.56</td>
<td>1.48</td>
<td>0.10</td>
</tr>
<tr>
<td>0.49</td>
<td>1.39</td>
<td>0.10</td>
</tr>
<tr>
<td>0.43</td>
<td>1.30</td>
<td>0.10</td>
</tr>
</tbody>
</table>

**Section 3: The Argument**

**Experiment A:**

The data recorded in Experiment A are shown in the graph in Graph A.
It is clearly demonstrated through the data found in Data A and the Graph in Experiment A that mass (kg) has no effect on the period of a pendulum. As mass increased by factors of 2, 3, 4, and 5, the period of the pendulum was found to be recorded within +/-0.01 seconds of the mean of 1.72 sec. Therefore, the mass of the pendulum is not a factor in changing the period of a pendulum.

**Experiment B:**

The data recorded in Experiment B are shown in the graph in Graph B.

**Graph B:**
It is clearly demonstrated through the data found in Data B and the Graph in Experiment B that length (m) has a significant effect on the period of a pendulum. As the length of the string increased, the period of the pendulum increased. To determine if this relationship is proportional, comparing two trials and its results will be investigated (refer to Data Table C).

**Data Table C:**

<table>
<thead>
<tr>
<th>Trial</th>
<th>Length (m)</th>
<th>Factor of Length Increase</th>
<th>Period of Pendulum (sec)</th>
<th>Factor of Period Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.43</td>
<td>1.14</td>
<td>1.30</td>
<td>1.07</td>
</tr>
<tr>
<td>2</td>
<td>0.49</td>
<td>1.14</td>
<td>1.39</td>
<td>1.07</td>
</tr>
<tr>
<td>1</td>
<td>0.43</td>
<td>1.86</td>
<td>1.30</td>
<td>1.32</td>
</tr>
<tr>
<td>5</td>
<td>0.80</td>
<td>1.86</td>
<td>1.71</td>
<td>1.32</td>
</tr>
</tbody>
</table>

As demonstrated in Data Table C, the results of length and period of pendulum are not proportional. In one set of trials, as the length increased by a factor of 1.14, the period only increased by a factor of 1.07. In another set of trials, as the length increased by a factor of 1.86, the period only increased by a factor of 1.32. If these results were proportional, then there would be a direct correlation between the factor of increase in length and the factor of increase in period.

Since the equation to the period of the pendulum (shown below) has the square root of the length, a proportional relationship could be determined with graphing the square root of the length of the string against the period of a pendulum (refer to Graph C). (Giancoli, 1998, p. 297)

\[
T = 2\pi \sqrt{\frac{l}{g}}
\]

**Graph C**
The equation to the linear graph on Graph C is $y = 1.737x + 0.1768$

The acceleration of gravity can be approximately determined using the slope of this line.

$$slope = 1.737 = 2\pi \left( \frac{1}{\sqrt{g}} \right)$$

$$\sqrt{g} = \frac{2\pi}{1.737}$$

$$g = 13.08$$

$$\% \text{ error} = \frac{13.08 - 9.8}{9.8} \times 100\% = 33.5\% \text{ error}$$

**Sources of Error:**

The instruments of measurement used in this experiment were a metric ruler to measure the length and a Vernier photogate to measure the period of the pendulum. Therefore the largest source of error to account for the 33.5% error was the metric ruler of length (m). The Vernier photogate measured the time to three significant digits. The length was only measured to two significant digits. To reduce this source of error in the measurement of length would be to use a digital laser ruler which would measure to a greater amount of significant digits or to use greater precision in reading the ruler to a greater amount of significant digits to at least match the precision of the photogate.

The larger acceleration of gravity value that was calculated using the data demonstrated that the lengths measured were longer than what the actual length of the string. This error in length measurement could have been attributed by the fact that students were not measuring to the center of the pendulum’s mass.

**References:**


