**Coursework Title**

**Report 1: Simple Harmonic Motion (SHM) in the Form of a Pendulum**

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|  | **Class (e.g. C18)** | B28 |
|  | **Group Number**  **(e.g. Group 1)** | Group 5 |
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| **Module Title:** Foundation Science A | | **Module Convenor:**  Neil Arnold |
| **Coursework Title:** Report 1: Simple Harmonic Motion in the Form of a Pendulum. | | **Module Code:** CELEN039 |

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### **SUMMARY:**

The period and length of the pendulum was measured to investigate the hypothesis that the relationship between a pendulum’s length and time period can be accurately modelled by using Christiaan Huygens’ law. The pendulum bob was stated swinging through a constant angular amplitude of approximately 6 degree. The angular amplitude was represented by the angle between vertical direction and the string and the time for the pendulum bob to complete 10 oscillations was measured by a stopwatch so that the average time for 1 oscillation could be calculated. The procedure was repeated with different length of the pendulum. Only three predicted periods were consistent with the measured periods. When rational uncertainties from measurement and modelling assumptions were taken into consideration, these results could not be used to support the hypothesis.

### **OBJECTIVES**

The objective of this experiment was to investigate Christiaan Huygens’s law, which states that

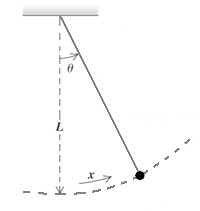
The period of the pendulum is equal to the product of the and the square root of the quotient of the pendulum’s length and the acceleration of gravity

Eqn.1

where the units of T, L, g are s, m and m/s2  respectively.

### **INTRODUCTION:**

Christiaan Huygens proposed his theory and design of the pendulum clock in 1673. It was been found to be used in accurate timekeeping. In this experiment, we investigated whether the relationship between a pendulum length and time period can be accurately modelled by using the Christiaan Huygens’s law.



**Figure 1.** Forces acting on an idealised simple pendulum.

String was assumed to be massless and unstretchable. The bob was modelled as a point mass. The restoring force on the bob was proportional to sin. However, for small , , so the motion was approximately simple harmonic motion.

So the displacement x measured along the arc is given by

Eqn.2

Since for small values

Eqn.3

Eqn.4

Eqn.5

By comparing the formula of acceleration, we can then equalize them for the same side

Eqn.6

Therefore

Eqn.7

Eqn.8

Eqn.1

### **APPARATUS**

* Pendulum bob
* String
* Test frame
* Stopwatch
* Ruler
* protractor

### **PROCEDURE**

The apparatus was assembled and the length of the pendulum was measured. The initial position was adjusted by using a protractor so that the pendulum oscillated at a constant angular amplitude of 0.1 radians. The pendulum bob was released with zero initial velocity and the time for the pendulum bob to complete 10 oscillation was measured by using a stopwatch. The step was repeated by reducing the length of the pendulum 2.5cm for each new measurement. By using the Christiaan Huygens’s law, the predicted time period for the pendulum for each different length could be calculated and theses values were recorded in Table1.

**RESULTS:**

Equation (9), given in the objective section of this report, was used together with the measured length L and T to obtain the predicted values of period; these are recorded in the six column of Table 1. As an example, when length was 0.65 m, the measured period and the predicted period were calculated to be

Eqn.9

Eqn.10

**Table 1.** Measured and predicted period.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Measurement no.** |  |  |  | **Measured period** | **Predicted period** |
| 1 | **0.650** | 0.806 | 16.240 | 1.624 | 1.618 |
| 2 | **0.625** | 0.791 | 16.200 | 1.620 | 1.587 |
| 3 | **0.600** | 0.775 | 15.740 | 1.574 | 1.555 |
| 4 | **0.575** | 0.758 | 15.000 | 1.500 | 1.522 |
| 5 | **0.550** | 0.742 | 14.900 | 1.490 | 1.488 |
| 6 | **0.525** | 0.725 | 14.600 | 1.460 | 1.455 |
| 7 | **0.500** | 0.701 | 14.350 | 1.435 | 1.420 |
| 8 | **0.475** | 0.689 | 13.950 | 1.395 | 1.384 |

**Figure 2.**

**UNCERTAINTY ANALYSIS:**

All lengths were measured by a ruler with a precision of uncertainty of 1 mm. This leads to uncertainty in each length

Eqn.11

The standard uncertainty associated with the predicted period value was calculated using equation (12)

Eqn.12

The standard uncertainty was calculated to be +/- 0.00026s, and is shown in the first row of column 6 of Table 2. All figures in Table 2 are given to five decimal places.

The uncertainty associated with the measured time, 𝛿10𝑇, is a type B uncertainty (measurement uncertainty) and since the stopwatch used to determine the time is digital we use the formula for a digital type B uncertainty

Eqn.13

The uncertainty associated with the measured time period, 𝛿𝑇 , is calculated by

simply diving the uncertainty in the measured time, 𝛿10𝑇, by a factor of 10.

Eqn.14

**Table 2.** Uncertainty associated with measured and predicted period.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Measurement no.** |  |  |  |  |  |
| 1 | **0.000210** | 0.000130 | 0.20000 | 0.02000 | 0.00026 |
| 2 | **0.000210** | 0.000133 | 0.20000 | 0.02000 | 0.00027 |
| 3 | **0.000210** | 0.000135 | 0.20000 | 0.02000 | 0.00027 |
| 4 | **0.000210** | 0.000139 | 0.20000 | 0.02000 | 0.00028 |
| 5 | **0.000210** | 0.000142 | 0.20000 | 0.02000 | 0.00028 |
| 6 | **0.000210** | 0.000145 | 0.20000 | 0.02000 | 0.00029 |
| 7 | **0.000210** | 0.000149 | 0.20000 | 0.02000 | 0.00030 |
| 8 | **0.000210** | 0.000152 | 0.20000 | 0.02000 | 0.00030 |

**DISCUSSION:**

It is clear from examining Tables 1 & 2 that three out of eight of the measured period values come within the corresponding predicted period value range; Figure 2 shows a graphical representation of this fact. By comparing both Tables 1 & 2 and Figure 2 there is a clear and definitive trend that as the value of length increases the measured period values become great and six out of eight of the measured period values are greater than the predicted values. This demonstrates there is an issue with either the mathematical model used for this experiment or an error in the experimental technique, regardless these results do not support the initial hypothesis. One result which do not agree with predicted values is larger than expected, another result is less than the expected, therefore the most likely causes of this discrepancy are:

* The apparatus may not be used on a horizontal plane and there was a reaction time error when measuring the time by using a stopwatch.
* The assumption that the motion of the pendulum was simple harmonic may be not true, the initial position could easily influence the motion so maybe the simple harmonic motion changed to conical pendulum motion, whose period was less than the period of simple harmonic motion as for the same apparatus.

From Figure 2 we can obtain the equation which can best depict the measured values

Eqn.15

Compare this to equation(1)

Eqn.1

As y=T and has been plotted the theoretical straight line equation is

+0 Eqn.16

Comparing these values

|  |  |  |
| --- | --- | --- |
|  | Predicted Value | Measured Value |
| Gradient | 2.00639+0.00360 | 1.99610+0.18040 |
| Intercept | 0+0.00270 | 0.00185+0.13570 |

Obviously the predicted and measured values do not correspond one another so this experiment cannot be used to support out initial hypothesis. However, the value of the coefficient of determination, R2 is 0.96060 and the product moment correlation coefficient, *r*, is 0.98010, which implies that there is a very strong relationship between the x and y values. Although the equation which modelled for this relationship is not what was expected, there is a clear relationship between time period and the square root of pendulum’s length.

**CONCLUSION:**

To conclude, in this experiment, the relationship between a pendulum length and time period modelled by Christiaan Huygens’s law was investigated. Only three of the results obtained were found to be within the corresponding predicted period value ranges, while for the others, this was not the case. Although the value of exactly suggest a strong relationship between the variables drawn in Figure 2, this cannot provide solid evidence to support our initial hypothesis. The key factor which affected the results is mostly likely to be the motion of the pendulum bob was not completely simple harmonic motion, which would have caused a big discrepancy when measuring the time period. This experiment could be further improved by;

* ensuring the apparatus was perfectly horizontal and the pendulum bob could start at the same initial position and move in a same direction.
* using a pendulum that has a big mass.
* measuring the time using another device to reduce the time of reaction.