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| **2.1 – Bouncing Mass**  Waimea Crest 200x300 600dpi | **EXEMPLAR**  **Number AS91168**  Version 2  **Carry out a practical physics investigation that leads to a non-linear mathematical relationship**  4 Credits  Internal |

## Aim

To find the relationship between the mass and period of an object bouncing on the end of a spring

## Equipment

Spring, masses, stop watch, retort stand, clamp arm and boss head, electronic balance

## Task

Set up the equipment:

* Make sure the clamp stand and clamp arm are firmly fixed and that there is no wobble.
* Attach the spring to the clamp arm.

Carry out the experiment:

The period of a bounce is the time it takes to do one complete (up and down) bounce. (This time does **not** change as the amplitude of the bounces changes and so timing multiple bounces is an option.)

## Theory

Physics theory states that, for a mass, **m**, bouncing **smoothly** on the end of a spring, the period, **T** is given by:

Where **k** is the spring constant of the spring you calculated in class earlier. Enter the value you calculated and SI units in the box below:

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| k (spring constant) = **60** ( **Nm-1** ) |

## Method

State the name of the dependant and independent variables suggested by the aim

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| Dependant Variable |  | Independent Variable |
| **Time period of bounce** | **Mass on spring** |

##### Results

Record **all** raw measurements in the following table. It is important that you include an appropriate heading, show units and the correct significant figures. (You must make sufficient measurements to allow you to draw a graph that will help you determine the required relationship.)

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| --- | --- | --- | --- | --- |
| Mass on spring (Kg) | Time period (s) | | | |
| trial 1 (10T) | trial 1 (10T) | trial 1 (10T) | Average (1T) |
| 0.10 | 3.27 | 2.77 | 3.27 | 0.31 |
| 0.15 | 3.04 | 2.94 | 4.04 | 0.33 |
| 0.20 | 3.43 | 4.13 | 4.33 | 0.40 |
| 0.30 | 4.54 | 4.94 | 5.14 | 0.49 |
| 0.40 | 5.43 | 5.73 | 5.43 | 0.55 |
| 0.50 | 6.44 | 6.54 | 5.94 | 0.63 |

##### First Graph

Graph your averaged data on the following graph paper. Make sure you label your graph axis, give units and draw a curve of best fit (the raw data will not give a straight-line graph).

##### Method

A diagram and notes on your experimental setup may be useful when completing your discussion. You can use this space for that purpose if you wish.

##### Relationship

What relationship does your graph suggest between your two variables? You must state the name of the variables as well as the relationship.

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| **Time period is proportional to the square root of mass** |

##### Processing Data

Use the relationship you have stated above and the theoretical formula to decide which variable should be transformed. Transform your data accordingly in the table below. It is important that you put units at the top of each column in your table

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| Time period (s) | Mass on spring (Kg) | Square root of mass (√Kg) |
| 0.31 | 0.10 | 0.32 |
| 0.33 | 0.15 | 0.39 |
| 0.40 | 0.20 | 0.45 |
| 0.49 | 0.30 | 0.55 |
| 0.55 | 0.40 | 0.63 |
| 0.63 | 0.50 | 0.71 |

##### Second Graph

Graph your processed data on the following graph paper. Make sure you label your graph axis, give units and draw a line of best fit.

y-intercept = 0.02 s

Rise = 0.70 – 0.04 = 0.64 s

Run = 0.80 – 0.04 = 0.76 √Kg

## Conclusion

Calculate the gradient of your graph. Show a triangle on your graph to demonstrate how you obtained the data for calculating your gradient. Calculate your gradient below:

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| Gradient = |

State the y-intercept of your graph:

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| Y-intercept = 0.02 s |

Use your graph to write the mathematical equation relating the two variables**:**

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## Discussion

Use your equation, together with the theoretical formula, to show:

* What physical quantities are represented by the gradient/y-intercept of your graph
* Show/calculate what you would expect them to be
* Compare your gradient/y-intercept with the theoretical values
* If an unexpected result is obtained you should discuss how it could have been caused

Show all working/reasoning

Gradient:

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| This means the gradient of my graph should be equal to , this means I can check that my gradient gives a k value of 60 Nm-1 which is the value of the spring I was using:   |  |  | | --- | --- | | Theory:  Graph: | My gradient predicts a k value of 56 Nm-1 which is close to the actual value of 60 Nm-1 of the springs that we were using.  My gradient is slightly on the high side (should be about 0.81 if k = 60 Nm-1), this means the times I was measuring for the larger masses were to high and/or the times for the lighter mass were too short. I believe it is more likely to be the timing of the low masses that caused this error.  The oscillation of the low masses was very quick, this made timing hard to do accurately despite the timing techniques I used to increase my accuracy which I will explain later. |   Also I may have been consistently fast at stopping the stop watch. This quickness would have a greater effect on my low mass times as the oscillations were quicker therefore fast reactions would cause a bigger percentage change to these times. |

Y-intercept:

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| The theoretical formula suggests the y-intercept should be zero, which means the spring will not oscillate if there is no mass on it. I observed that this is not the case. As the spring itself has mass it will still oscillate if no mass is attached and the mass of the spring would explain this non-zero y-intercept. You could predict the mass of the spring from the graph by finding the x intercept and squaring that value. |

Explain any variables that must be controlled, how you controlled them and **discuss** the effect they may have on the outcome of the experiment

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| Control variable | How it was controlled | Possible effect on experiment outcome |
| Spring constant, k | By using the same spring throughout the experiment and insuring too much mass wasn’t put on the spring causing it to stretch permanently | If the spring constant was increased by switching to a stiffer spring the times periods measured wound have decreased. If the spring constant became less either changing the spring or over stretching the time periods would have increased |
| Release height | Every time we started the masses bouncing we dropped them from the same height (4cm above the equilibrium) | The formula doesn’t suggest that the drop height will affect the time period, but it does have some effect on the swinging that also occurs. We dropped the masses from the same height to try and keep the swing consistent. |
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Identify things you did to increase the accuracy of your data and **discuss** how these techniques increase accuracy

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| What you did | How it increases accuracy |
| Timed 10 oscillations and then divided by 10 to get the time period | The amplitude of the oscillation does not affect the time period, so I timed 10 oscillations. This means human error, due to fast/slow reactions, is spread over ten oscillation not just one. Also it is hard to time the quick oscillations of the lightest masses, timing 10 oscillations made it easier to predict when to start and stop the stop watch. |
| Start and stop the timer from the equilibrium position | Because the mass is travelling the slowest at the top and bottom of the bounce it is hard to predict exactly when it reaches the top or bottom. To overcome this we timed from the equilibrium position where the mass is travelling the fastest. We used a post-it note attached to the retort stand to easily mark the position and observed from straight on to decrease parallax error. |
| Repeated and averaged | Due to random error some measurements will be too low and others will be too high. We repeat each measurement 3 times and averaged the results. This way the high values cancel out the low values and the average is closer to the true value. |

Describe any difficulties you encountered when making measurements. The state how these difficulties were overcome and the effect they would have on your result if they were not

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| Difficulty encountered | How it was overcome | The possible effect on the outcome |
| The mass swinging as it bounced | * Decreased the mass * Decreased the drop height * Let the mass stabilise before starting timing * Discarded and repeated measurements that swung too-much | The swinging may have caused the time-period to increase or decrease. In my trials I figured out the best drop height to decrease swinging and the max mass that had the least swing. |
| The oscillations becoming too small to time | * Selecting a large enough drop height that didn’t also cause too much-swinging * Timing no more than 10 oscillations | I noticed in trials if I timed more than 10 oscillations the amplitude became too small to accurately time. To being able to observe the oscillations correctly would have increased the random error in the experiment, causing more variation in my data and making my data points to stray further from the line of best fit. |
| Unsettled bouncing immediately after dropping | * Allow the mass to oscillate two times before starting timing * Selecting reasonable low drop height | This would have made it hard to accurately see when the mass passed the timing point so would have increased random error. Causing more variation in my data as above. |

Give a reason why there was a limit to the range of values you chose for the independent variable and discuss the implications/validity of this limit

Upper limit

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| 500g  I choose this value for two reasons:   * In my trials I noticed large masses caused more swinging to occur * I also didn’t want a large mass to stretch my spring and therefore change its spring constant   For these reasons I choose an upper limit of 500g instead of 600g for the mass. |

Lower limit

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| 100g  I choose this value for two reasons:   * Light masses had faster oscillations, in my trials I decided it would be too hard to time 50g accurately * I also noticed that with only 50g on the spring the spring did not straighten properly. I felt this might cause my spring constant to be different for this value, and since it is an important control variable I decided to go with 100g   I choose to go up in 50g increments for my first 3 values as I recognized the relationship was a square root and knew that it may look linear if I didn’t have enough low mass measurements. |