National Certificate of Educational Achievement
TAUMATA MĀTAURANGA Ā-MOTU KUA TAEA

Exemplar for Internal Achievement Standard

Physics Level 3 version 2

This exemplar supports assessment against:

Achievement Standard 91521

Carry out a practical investigation to test a physics theory relating two variables in a non-linear relationship

An annotated exemplar is an extract of student evidence, with a commentary, to explain key aspects of the standard. It assists teachers to make assessment judgements at the grade boundaries.

New Zealand Qualifications Authority

To support internal assessment

<table>
<tr><td></td><td>Grade Boundary: Low Excellence</td></tr>
<tr><td>1.</td><td>For Excellence, the student needs to carry out a comprehensive practical investigation to test a physics theory relating two variables in a non-linear relationship.

This involves a discussion which addresses issues critical to the practical investigation, such as:

• the other variables that could have changed and significantly affected the results and how they could have changed the results
• limitations to the theory’s applicability
• unexpected outcomes, how they were caused and the effect they had on the validity of the conclusion.

This student is testing the theory of simple harmonic motion as it applies to a child bouncing in a baby bouncer.

This student has provided a discussion on the applicability of the theory of simple harmonic motion to a child bouncing in a baby bouncer (1).

This student has provided a discussion on unexpected outcomes, how they were caused and the effect they could have on the validity of the conclusion (2).

For a more secure Excellence, this student could clearly discuss how other variable(s) were controlled, such as external forces or spring constant, and how they could have changed and significantly affected the results.</td></tr>
</table>

Student 1: Low Excellence

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Note: This student evidence comes from student work related to the task Baby Bouncer. The following is a snippet of the complete report that was written by the student.

Discussion

① For the masses that I used for the experiment, the greatest was 0.2kg. This is nowhere near the mass of a baby what the experiment was designed to model. My data fits the graph well and there is little variation, however I cannot be assured that this period will occur for the actual mass of a baby. This means that the final analysis possibly won't be valid in real life. This experiment was designed to model a baby on a baby bouncer but there are some flaws: the spring is not the same shape as the double elastic harness, and it is not built of the same material. There it is not known whether the spring would behave and oscillate the same way as a double elastic harness. However, without a real double elastic harness this can't be tested.

On a baby bouncer the mass (baby) bounces knees up with their feet inputting their own energy into the oscillation. The resultant force of this would vary. This meaning that the period of oscillation in a real life baby bouncer wouldn't be able to be replicated by my experiment. As in my experiment this was not taken into consideration. Also the fact the baby lifts off its feet demonstrates that the baby bouncer is not SHM. Where in my model the mass was oscillating with SHM, meaning in a real life model conclusions wouldn't be valid, and the equation $T = 2\pi\sqrt{\frac{m}{k}}$ is not applicable to my model/equation.

The relationship I determined was: $T^2 = 3.7 \pm 0.2m + 0.2 \pm 0.01$

The theoretical formula is: $T = 2\pi\sqrt{\frac{m}{k+5\%}}$ $k = 11\ Nm^{-1} \pm 5\%$

(Square to make it equivalent to mine)

$T^2 = \frac{4\pi^2 m}{k+5\%}$

$T^2 = 3.589m$ $T^2 = 3.6m$ (2sf)

② The gradient of this fits with my experimental relationship, as the gradient is within the gradient range. However, the y-intercept of C is not within my y-intercept range. This means there could possibly be a constant systematic error. This is probably due to the reaction time causing the measured time period to be longer than it should be.

	Grade Boundary: High Merit
2.	For Merit, the student needs to carry out an in-depth practical investigation to test a physics theory relating two variables in a non-linear relationship. This involves: • describing the control of other variable(s) that could significantly affect the results • using techniques to improve the accuracy of measurements • determining uncertainties in one of the variables expressed in the graphical analysis • graphical analysis which expresses the uncertainty in the relationship consistent with the uncertainty in the data • providing a conclusion that makes a quantitative comparison between the physics theory and the relationship/quantity obtained from the experimental data which includes consideration of uncertainties. This student is testing the theory of simple harmonic motion as it applies to a child bouncing in a baby bouncer. The student has described the control of a variable that could significantly affect the results, i.e. the starting point of the bounce (1), used techniques to improve the accuracy of measurements, i.e. repeating measurements (2), and determined uncertainties in one of the variables expressed in the graphical analysis, i.e. the mass and the time period (3). This student has also carried out a graphical analysis which expresses the uncertainty in the relationship consistently with the uncertainty in the data, i.e. using error bars and an error line (4), and provided a conclusion that makes a quantitative comparison between the physics theory and the gradient obtained from the experimental data, which includes the consideration of uncertainties (5). To reach Excellence, this student could discuss limitations to the applicability of the theory of simple harmonic motion to the child bouncing in a baby bouncer. For example, the student could explain why the baby's movement sideways would limit the comparison of its movement to that of simple harmonic motion.

Student 2: High Merit

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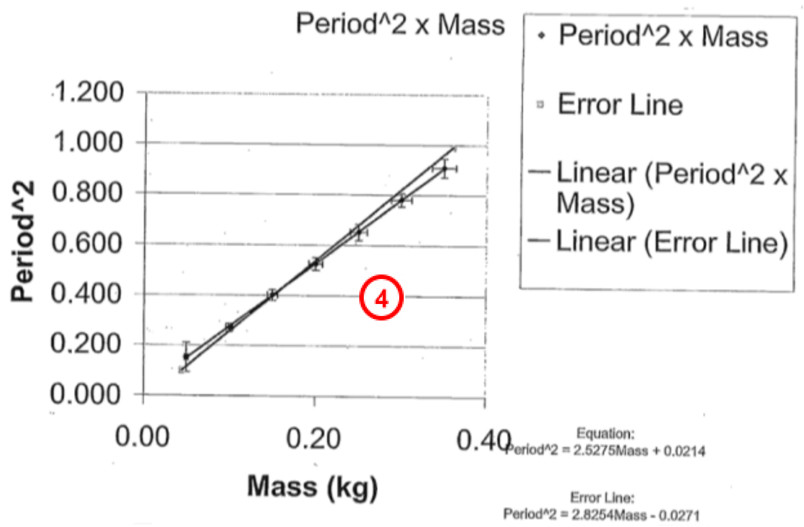

Raw Data

Mass (Kg)	**Time 1** (2)	**Time 2** (2)	**Time 3** (2)	**Average (for 10 oscillations)**
0.05	3.8	3.96	3.91	3.89
0.10	5.19	5.22	5.19	5.20
0.15	6.31	6.36	6.34	6.34
0.20	7.28	7.23	7.25	7.25
0.25	8.05	8.06	8.09	8.07
0.30	8.81	8.84	8.83	8.83
0.35	9.52	9.56	9.52	9.53

Processed Data

Mass (Kg)	**Time (s)**	**Time²**
0.05±(0.05 x 0.04)=0.002	0.389±(3.96-3.81)=0.075	
0.05±0.002 (3)	0.389±0.075 (3)	0.058
0.10±0.004	0.520±0.015	0.016
0.15±0.006	0.634±0.017	0.022
0.20±0.008	0.725±0.017	0.025
0.25±0.010	0.807±0.020	0.032
0.30±0.012	0.807±0.015	0.026
0.35±0.014	0.953±0.020	0.038

Spring constant k=15±0.75

Final Equation:

$T^2 = (2.5275 \pm 0.2979)\ m + (0.0214 \pm 0.0485)$

Where T^2=Period^2 and m=mass

$T^2 = (2.53 \pm 0.030)\ m + (0.02 \pm 0.05)$

5 We can check the validity of the final equation by comparing it to the theoretical equation, which states that $2\pi\sqrt{\frac{m}{k}}$. As k=15, we can simplify the equation so that $T^2=4\pi^2\frac{m}{15}$. Then $T^2 = 2.63m$. The final equation was $T^2= (2.53 \pm 0.03)\ m + (0.02 \pm 0.05)$, which matches the theoretical equation, so the final equation is valid. Unexpected results from the experiment could have been caused by friction, which would cause the period of oscillation to decrease as the number of oscillations increases. However, the uncertainty caused by friction would be
1 quite small. Other variables which could have significantly changed the results include the distance at which the spring was released from. A long distance can cause the spring to move uncontrollably, which would cause a major change in the period of oscillation. To avoid this, the spring was released from 0.05m below its expansion.

Limitations of applying the theoretical formula to the practical situation of a real bay bouncer include the fact that babies tend to move around a lot in a horizontal as well as vertical directions while on the baby bouncer. This can cause period to change. Also, babies push up off the ground to start moving, which can cause the vertical force to increase.

At extreme values of mass, the theory is less applicable, as springs have an elastic limit. So at high values of mass, the spring extension will stop increasing as it physically impossible for it to stretch further. This will mean that the period will stop increasing.

An issue that could have affected our results was the inability to stop the stop watch at the exact same time as when an oscillation had complete due to human's slow reactions times. While repeating and averaging makes a result more accurate, we may have stopped the stopwatch too early or too late every time, which would make the results consistently wrong. Depending on whether the stopwatch was stopped consistently before or after the period of oscillation actually ended, the gradient of the final equation could be out by more than the current uncertainty value.

<table>
<tr><td></td><td>Grade Boundary: Low Merit</td></tr>
<tr><td>3.</td><td>For Merit, the student needs to needs to carry out an in-depth practical investigation to test a physics theory relating two variables in a non-linear relationship.

This involves:

• describing the control of other variable(s) that could significantly affect the results
• using techniques to improve the accuracy of measurements
• determining uncertainties in one of the variables expressed in the graphical analysis
• graphical analysis which expresses the uncertainty in the relationship consistent with the uncertainty in the data
• providing a conclusion that makes a quantitative comparison between the physics theory and the relationship/quantity obtained from the experimental data which includes consideration of uncertainties.

This student is testing the theory of simple harmonic motion as it applies to a child bouncing in a baby bouncer.

This student has used techniques to improve the accuracy of measurements, i.e. repeating and multiple measurements (1), and determined the uncertainty in the variables expressed in the graphical analysis, i.e. the mass and the time period (2).

This student has also used graphical analysis which expresses the uncertainty in the relationship consistent with the uncertainty in the data, i.e. drawing a line of best fit, error bars and an error line (3), and attempted to provide a conclusion that makes a quantitative comparison between the physics theory and the quantity obtained from the experimental data, i.e. the gradient (4).

For a more secure Merit, this student could describe, in more detail, the control of other variable(s) that could significantly affect results, such as the spring constant or the distance the spring is pulled.</td></tr>
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Student 3: Low Merit

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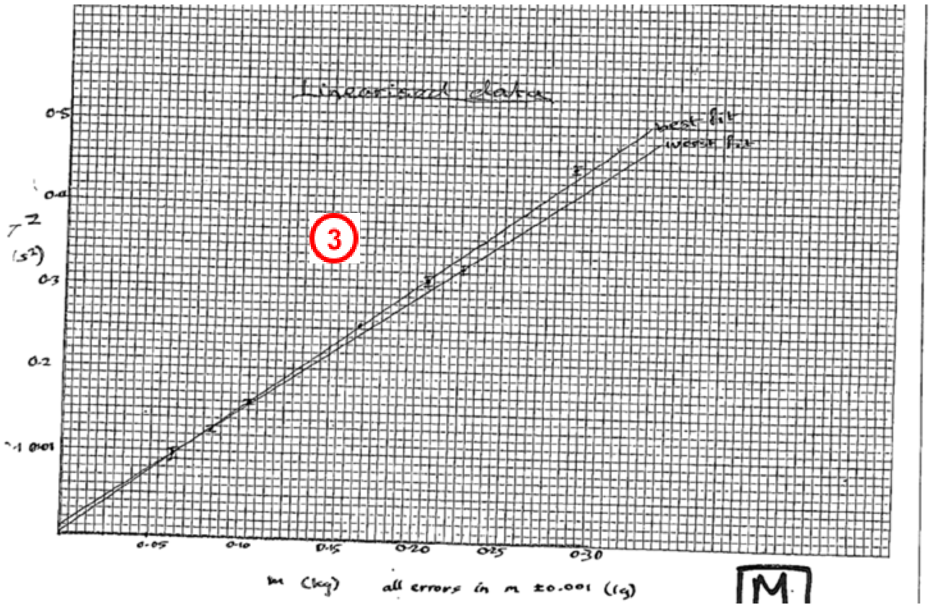

$T^2=\frac{4\pi^2}{k}m$ k=29±1Nm^{-1}

Mass	Δm (2)	s t 20sw (1)	S T	S ΔT± (2)	%ΔT	s^2 T^2 to level of accuracy in errors	Abs err T^2 1sf
63	±1	6.2 6.4 ~~6.9~~ ~~6.1~~ ~~6.4~~	0.314	0.0075	2	0.099	0.004
105	±1	8.0 8.0 8.0 7.9	0.399	0.0025	0.6	0.159	0.002
168	±1	10.1 10.1 10.1 10.1	0.505	0	0	0.255	0
226	±1	11.5 11.4 ~~11.2~~ 11.6 11.4	0.574	0.005	0.9	0.329	0.006
290	±1	~~12.9~~ 13.3 13.4 13.5	0.670	0.005	0.7	0.449	0.006
84	±1	7.1 7.2 7.1 7.2	0.358	0.0025	0.7	0.128	0.002
206	±1	11.2 11.0 11.1 11.3	0.558	0.0075	1	0.311	0.006

From calculator: best fit = $T^2 = 1.513\ m + 7.5x10^{-5}$
From graph: worst fit=$T^2 = \frac{0.329-0.0886}{0.226-0.063}$ m + 0.01
$T^2 = 1.41m + 0.01$
Δgradient= 1.41-1.51= 0.1 (1sf)
∴ relationship: T^2= (1.5±0.1) m + 7.5 x 10^{-5}

±7%

4 Test the physics theory does 1.5 ± 0.1= $\frac{4\pi^2}{k}$?

$\frac{4\pi^2}{k} = \frac{4\pi^2}{29\pm1}$ =1.36 ± 0.05 or k=$\frac{4\pi^2}{1.5}$ = 26 ± 2Nm^{-1}

The errors are within range of each other, and the %age difference is 10% so the theory could be considered accurate, although more accurate testing would be needed to confirm its validity.
The experiment seems simple enough, but as usual, some unforeseen error comes in somewhere. In this experiment, it was in the bouncing of the mass. With larger masses, something in the system started it swinging like a pendulum, which had slightly different frequency, leading it to periodic increases and decreases in the amount the mass bounced, at times making it difficult to count the oscillations and possibly causing me to count 19 or 21 oscillations instead of the required 20. This reduced the accuracy of the readings taken with larger masses.

Also, something that couldn't be accounted for was the mass of the spring. This mass meant that, even with no mass, the spring would oscillate, leading to a systematically longer time period and the zero error in my final relationship. This would have to be taken into account when designing the bay bouncer itself would add mass to the system, increasing the time period.

Issues regarding the spring's dimensions for the bay bouncer are also raised. To allow a comfortable bouncing speed, a longer time period (>1second) should be aimed for, while still having the spring capable of holding 5 -10 Kg without reaching its elastic limit. This requires a heavy-duty spring with a low spring constant and high extension so it will probably be made of thick wire and quite long.

There was only one other variable to control in this experiment-the spring constant-and I still managed to allow errors into that. The clamp stand used for the experiment was seen bending when using the heavier masses, which would have decreased the spring constant slightly, thus increasing the time period slightly, as with the results compared to the theory-slightly higher than predicted.

Also, although it notes in the instructions that the uncertainty in the mass of the washers used as weight was 4 %, I didn't know how to apply that information. Instead I guessed an appropriate mass, then weighed it on a balance to make sure. Thus, my error in mass was ±1g instead of 4%.

	Grade Boundary: High Achieved
4.	For Achieved, the student needs to needs to carry out a practical investigation to test a physics theory relating two variables in a non-linear relationship. This involves: • collecting data relevant to the aim • determining uncertainties in the raw data • using graphical analysis, including a consideration of uncertainties, from which the equation of the relationship/ value of the physics quantity can be determined • providing a conclusion that states the equation of the relationship/value of the physics quantity as determined from the graph, and includes a comparison with the physics theory. This student is testing the theory of simple harmonic motion as it applies to a child bouncing in a baby bouncer. This student has collected data which is relevant to the aim (1), determined the uncertainty in the raw data, i.e. for the mass and the time (2), and used graphical analysis, including a consideration of uncertainties, i.e. plotted both error bars and an error line (3). This student has also provided a conclusion that states equation for the relationship (4), and attempts to compare the physics theory with the value of a physics quantity, i.e. ‘k’, the spring constant, as determined from the graph (5). To reach Merit, this student could provide a conclusion that makes a quantitative comparison between the physics theory and the relationship obtained from the data which includes consideration of uncertainties.

Student 4: High Achieved

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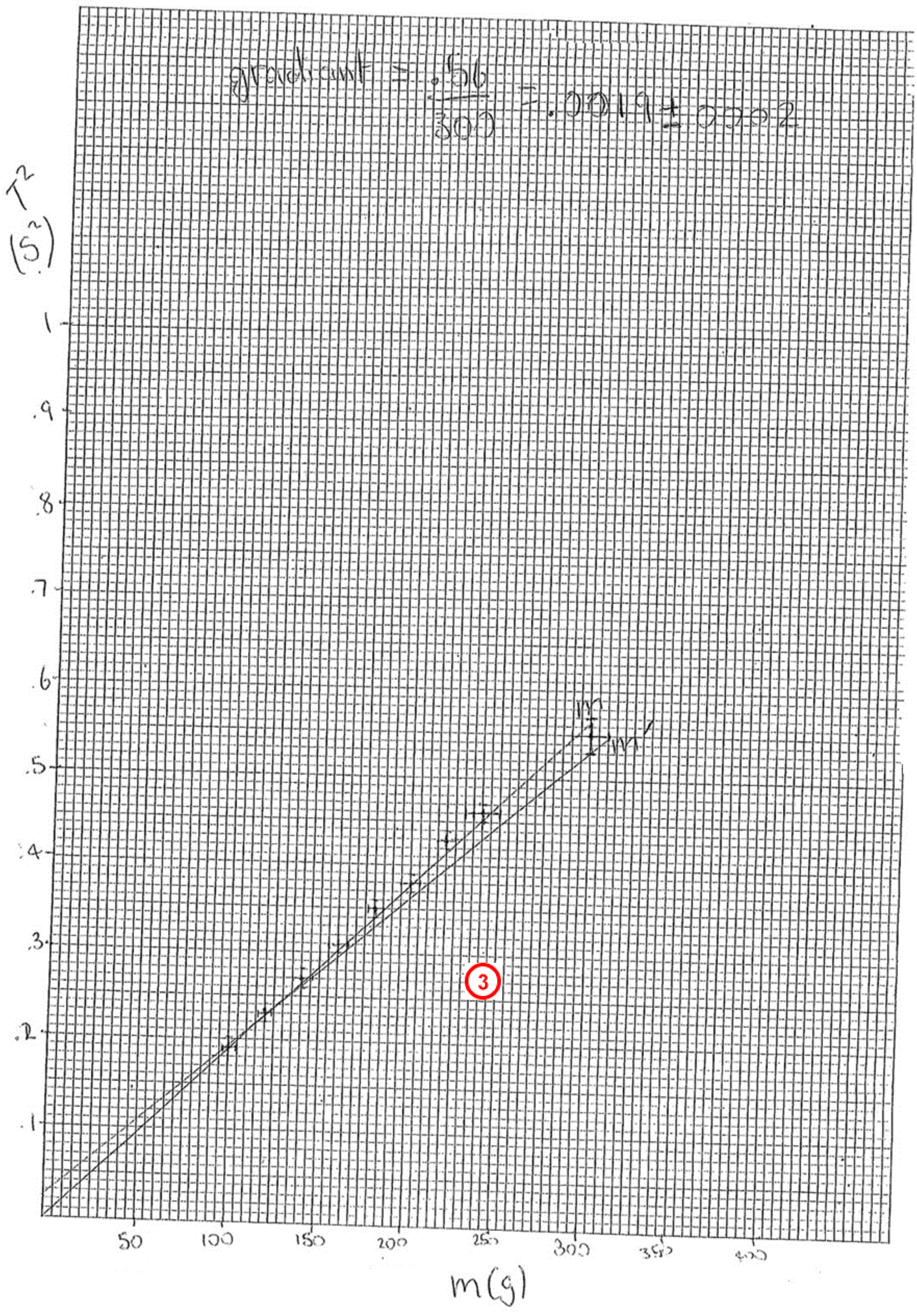

(1)

m	T for 10 swings				T_{av}	T_{av} for 1 swing	T^2	ΔT (2)	%ΔT	%x 2	ΔT^2	%Δm (2)	Abs Δm (2)
100	4.5	4.4	4.4	4.4	4.4	.44	0.19	.01	2.3	4.6	.01	4%	4
120	4.8	4.8	4.8	4.9	4.8	.48	.23	.01	2.1	4.2	.01	4%	5
140	5.2	5.2	5.3	5.2	5.2	.52	.27	.01	1.9	3.8	.01	4%	6
160	5.6	5.6	~~6.0~~	5.5	5.6	.56	.31	.01	1.8	3.6	.01	4%	6
180	5.8	5.8	5.9	5.9	5.9	.59	.35	.01	1.7	3.4	.01	4%	7
200	6.2	6.2	6.1	6.2	6.2	.62	.38	.01	1.6	3.2	.01	4%	8
220	6.5	6.5	6.4	6.5	6.5	.65	.43	.01	1.5	3	.01	4%	9
240	6.8	6.7	6.8	6.8	6.8	0.68	.46	.01	1.5	3	.01	4%	10
260	7.5	7.4	7.4	7.4	7.4	0.74	.55	.01	1.4	2.8	.02	4%	12

Not $^1/_2$ range

$m=0.0019=\frac{.56}{300}$

$m'=0.0017=\frac{.51}{300}$

$k=\frac{4\pi^2}{m}$ =21,000 2sf

gradient for T^2 against mass in Kg
m=1.87
$T^2= 1.87 \pm .17$ $T^2= 1.9 \pm 2m$ (4)

(5) $k=\frac{4\pi^2}{m}$ =21.1 Nm^{-1}

21.1/2.9 x 100 = 73%

K was a constant, my independent variable was T and my dependant one was mass. I did 4 trials for each mass and timed for 10 swings to minimize reactions times, random error and equipment error. I then divided each time by 10 to make it more accurate. My gradient was very different to the given gradient. I think this was because my spring had some bends in and it may have exceeded its elastic constant. I eliminated a result from my raw data because it was far off from all others for that mass I looked on the spring face to avoid parallax error.

	Grade Boundary: Low Achieved
5.	For Achieved, the student needs to needs to carry out a practical investigation to test a physics theory relating two variables in a non-linear relationship. This involves: • collecting data relevant to the aim • determining uncertainties in the raw data • using graphical analysis, including a consideration of uncertainties, from which the equation of the relationship/ value of the physics quantity can be determined • providing a conclusion that states the equation of the relationship/ value of the physics quantity as determined from the graph and includes a comparison with the physics theory. This student is testing the theory of simple harmonic motion as it applies to a child bouncing in a baby bouncer. This student has collected data which is relevant to the aim (1), determined the uncertainty in the raw data, i.e. the mass (2), and started to use graphical analysis to determine the equation for relationship (3). This student has also provided a conclusion that attempts to include a comparison between the physics theory and the equation of the relationship as determined from the graph (4). For a more secure Achieved, this student could improve the testing of the physics theory by: • determining accurately the uncertainty in time measurements, for example by dividing the time range by 2, or • describing in more detail how the graph was analysed, in order to determine the gradient from which the equation of the relationship was determined.

Student 5: Low Achieved

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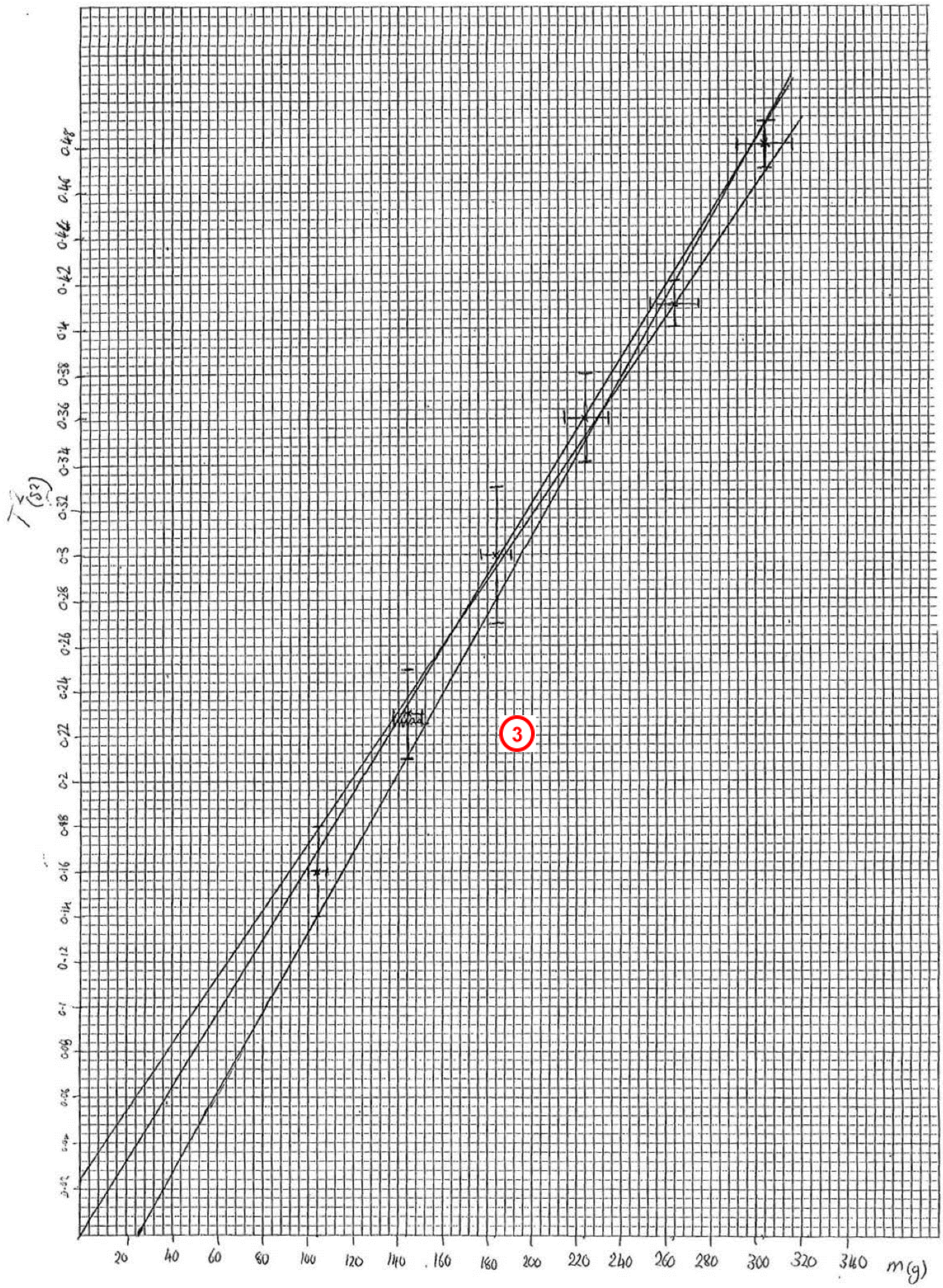

%ΔT² not correct

Mass 0g) ①	Error ±4% ②	Time (s) ①	Average time (s)	Error ② in t (0.5 range)	% error in T	$T^2(s^2)$	Error in T^2	% error in T^2
103	±4	0.41, 0.4, 0.41, 0.39, 0.4	0.40	0.02	5%	0.16	0.04	25%
143	±6	0.48, 0.48, 0.47, 0.49, 0.48, 0.48	0.48	0.02	4%	0.23	0.04	17%
183	±7	0.53, 0.55, 0.56, 0.55, 0.54, 0.54	0.55	0.03	5%	0.30	0.06	20%
223	±9	0..61, 0.60, 0.60, 0.61, 0.59, 0.61	0.60	0.02	3%	0.36	0.04	11%
263	±11	0.64, 0.64, 0.64, 0.64, 0.63, 0.63	0.64	0.01	2%	0.41	0.02	5%
303	±12	0.69, 0.69, 0.69, 0.69, 0.69, 0.68	0.69	0.01	1%	0.48	0.02	4%

④ ∴ 1.6 ± 0.2 = 1.4, 1.5, 1.6, 1.7, 1.8

∴T^2=1.6 ± 0.2m is = $T^2 = \frac{4\pi^2}{k}$m

	Grade Boundary: High Not Achieved
6.	For Achieved, the student needs to needs to carry out a practical investigation to test a physics theory relating two variables in a non-linear relationship. This involves: • collecting data relevant to the aim • determining uncertainties in the raw data • using graphical analysis, including a consideration of uncertainties, from which the equation of the relationship/ value of the physics quantity can be determined • providing a conclusion that states the equation of the relationship/ value of the physics quantity as determined from the graph and includes a comparison with the physics theory. This student is testing the theory of simple harmonic motion as it applies to a child bouncing in a baby bouncer. This student has collected data which is relevant to the aim (1), determined appropriate uncertainties in the raw data, i.e. drawn the error bars for the mass on the graph (2), and stated the equation for the relationship (3). To reach Achieved, this student could provide a conclusion that includes a comparison between the physics theory and the equation of the relationship/value of the physics quantity, as determined from the graph.

Student 6: High Not Achieved

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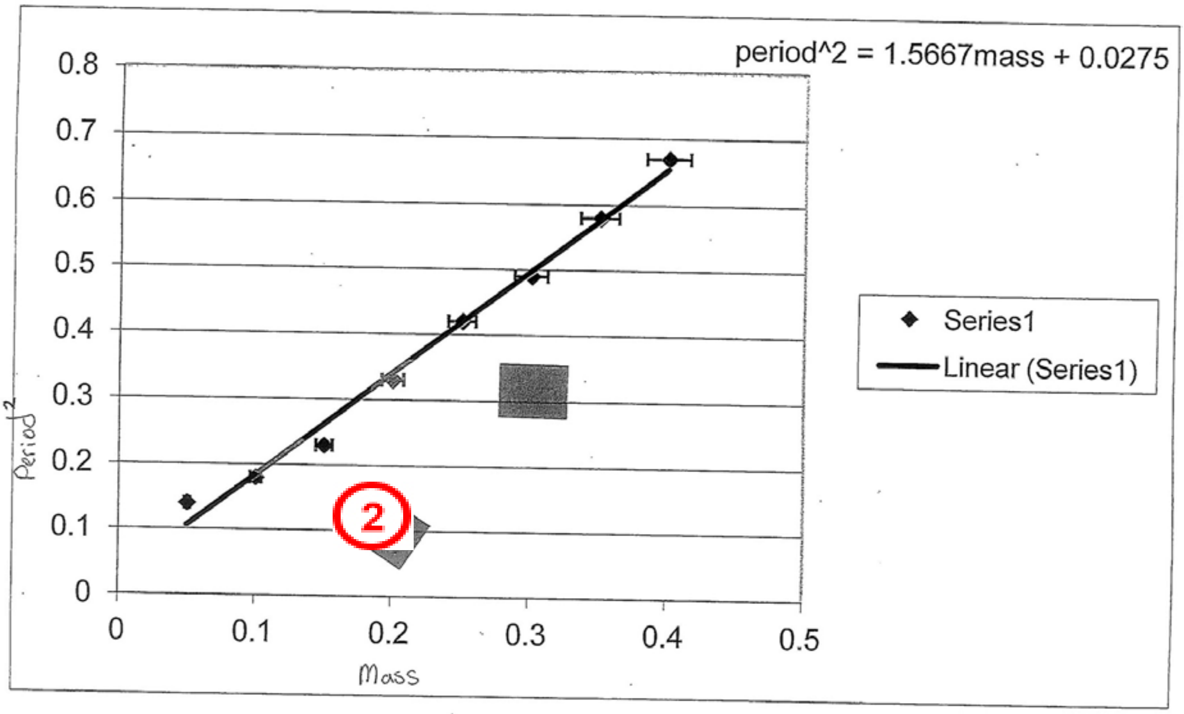

Dependant Variable - The period (t) Independent Variable - Mass (kg)

The spring constant was kept the same throughout the experiment as changing this would have affected the results somehow,

Techniques used to improve accuracy - multiples I measured the period as how long it took for the spring to take 10 oscillations and then divided that result by 10 to increase the accuracy of the single period.

Another method that I used to improve my accuracy was repeating the experiment for each weight several times then averaging the results of them to find the average period for one oscillation.

3 The relationship between the data as show by my graphs shows that the period^2 is equal to the 1.5667 multiplied by the mass.

1

mass (g)	10period (s) avg	mass (kg)	period T (s)
50	3.74	0.05	0.374
100	4.24	0.1	0.424
150	4.78	0.15	0.478
200	5.76	0.20	0.576
250	6.5	0.25	0.65

300	6.97	0.30	0.697
350	7.6	0.35	0.76
400	8.19	0.4	0.819

to find uncert 10T 0.25 by 10T avg uncert 10T	mass uncertainty	K uncertainty
6.68%	4%	5%
5.90%		
5.23%		
4.34%		
3.85%		
3.59%		
3.29%		
3.05%		

Mass	Period squared
0.05	0.14
0.1	0.18
0.15	0.23
0.2	0.33
0.25	0.42
0.3	0.49
0.35	0.58
0.4	0.67

T uncertainty	uncertainty of m %multiplied by mass
0.25	0.002