Candidate 10 evidence

Procedure 1: Compound Pendulum:

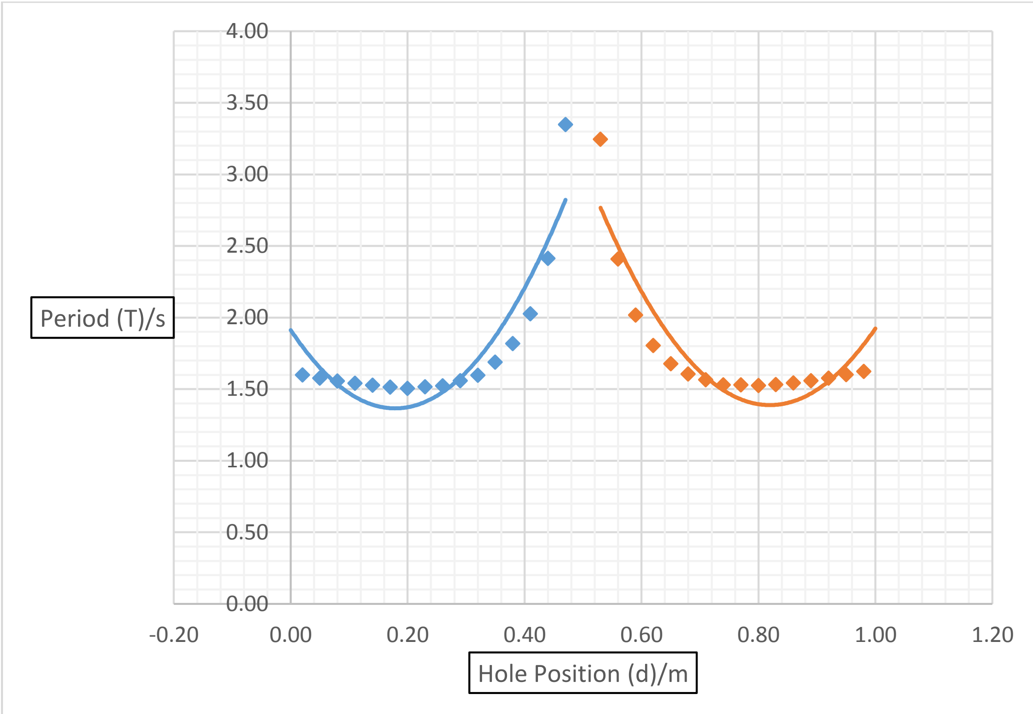
Apparatus:

- Compound pendulum constructed from a calibrated metre stick, with holes drilled at regular intervals along its full length.
- Thin rod for the pendulum to balance on.
- Two stands to hold the thin rod aloft and level.
- A pair of tall platforms to capacitate the height of the pendulum.
- A digital stop-clock.

Raw Data:

Hole position (d)/m	Time 1(t1)/s	Time 2(t2)/s	Time 3(t3)/s	Time 4(t4)/s	Time 5(t5)/s	Average Time (t(av))/s
0.02	16.00	16.00	16.00	16.03	15.97	16.00
0.05	15.78	15.81	15.69	15.75	15.81	15.77
0.08	15.66	15.53	15.5	15.59	15.59	15.57
0.11	15.41	15.31	15.44	15.41	15.47	15.41
0.14	15.28	15.22	15.28	15.19	15.35	15.26
0.17	15.13	15.13	15.06	15.18	15.22	15.14
0.20	15.07	14.97	15.13	14.94	15.15	15.05
0.23	15.06	15.15	15.25	15.12	15.25	15.17
0.26	15.15	15.37	15.32	15.22	15.09	15.23
0.29	15.56	15.66	15.47	15.62	15.65	15.59
0.32	15.97	15.97	15.87	16.07	16.00	15.98
0.35	16.85	16.91	16.81	16.90	16.90	16.87
0.38	18.25	18.22	18.06	18.12	18.22	18.17
0.41	20.22	20.25	20.31	20.31	20.22	20.26
0.44	24.03	24.07	24.18	24.43	24.00	24.14
0.47	33.44	33.34	33.44	33.47	33.67	33.47
0.50	n/a	n/a	n/a	n/a	n/a	n/a
0.53	32.40	32.74	32.93	32.09	32.06	32.44
0.56	24.06	24.09	24.15	24.16	23.97	24.09
0.59	20.09	20.09	20.34	20.22	20.12	20.17
0.62	17.90	18.06	18.18	17.94	18.16	18.05
0.65	16.69	16.79	16.84	16.78	16.78	16.78
0.68	16.06	16.09	16.03	16.04	16.06	16.06
0.71	15.69	15.63	15.69	15.56	15.68	15.65
0.74	15.31	15.34	15.31	15.32	15.25	15.31
0.77	15.28	15.25	15.35	15.34	15.25	15.29
0.80	15.31	15.25	15.25	15.12	15.28	15.24
0.83	15.29	15.35	15.35	15.28	15.34	15.32
0.86	15.48	15.41	15.41	15.47	15.44	15.44
0.89	15.62	15.68	15.50	15.59	15.56	15.59
0.92	15.84	15.78	15.72	15.78	15.75	15.77
0.95	16.07	15.93	16.00	16.03	16.03	16.01
0.98	16.18	16.22	16.28	16.13	16.34	16.23

Processed Data:
The period (T) was sketched against the Hole Position (d):



In order to calculate a value of g, the Equivalent Pendulum Length first needs to be calculated. As this is a compound pendulum, the values for length (L) are given by the Equivalent Pendulum Length rather than the hole position along the metre stick, and it is these values of L that are used in the calculation for g.

Equivalent Pendulum Length (EPL) is defined as the radius of oscillation for a compound pendulum, and can be extracted from the graph above. For any given Period on the graph, if the four points along the x-axis that correspond to that period are considered A,B,C,D going from left to right, then the average EPL for that Period will be equal to (AC + BD)/2.

Using this method, the following EPL values and their corresponding Periods were calculated:

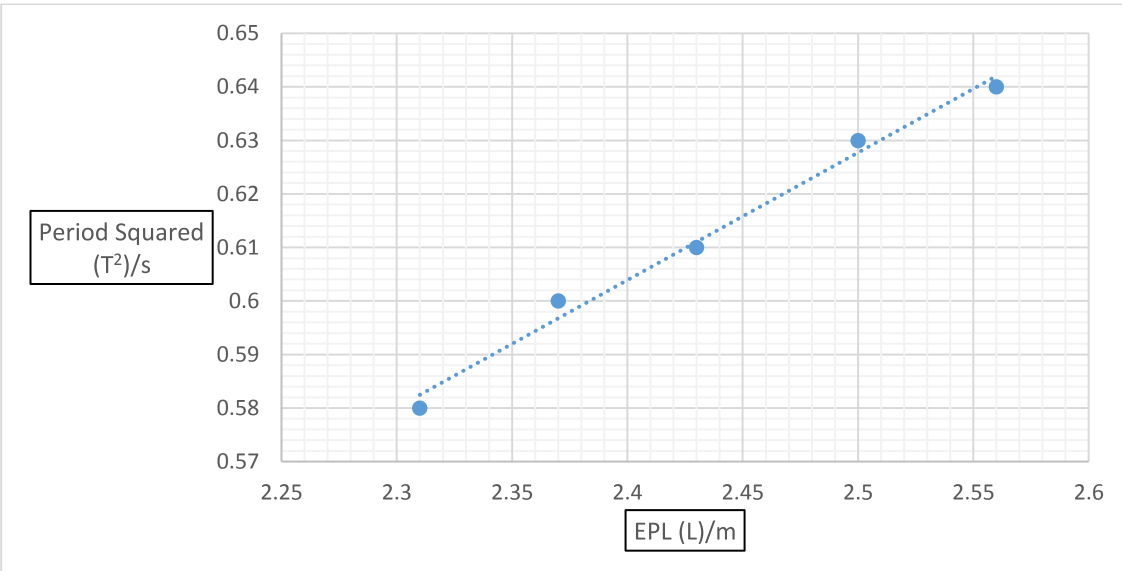
Period Squared (T^2)	EPL (L)
2.31	0.58
2.37	0.60
2.43	0.61
2.50	0.63
2.56	0.64

The following equation gives the relationship between the Period Squared and the Equivalent Pendulum Length:

$$T^2 = (g / 4\pi^2) \times L$$

Where g is the acceleration due to gravity.

From the data above, T^2 against L was graphed. Since the equation above is in the form y=mx+c, the gradient of the graph will be equal to $g/4\pi^2$:



The equation of the line of best fit through all the points was found to be T^2=0.24L+0.03, yielding a value of 0.24 for the gradient.

If the gradient (m) is equal to g divided by $4\pi^2$, then the measurement of g must therefore be equal to $4\pi^2$ multiplied by m, or $4\pi^2$ multiplied by 0.24. This yields a value of g of 9.47 ms^{-2}, and considering the acceleration due to gravity is equal to the gravitational field strength, we can consider the gravitational field strength to equal 9.47 Nkg^{-1}.

Uncertainties:

The average random uncertainty calculated for each set of repeated measurements in Procedure 1 was found to be ±0.08s.

The metre stick used for measuring the hole position used millimetres as its smallest unit of measurement. Therefore, the scale reading uncertainty from the metre stick was found to be ±0.005m.

The stopclock used in the procedure measure time in seconds to two decimal places. Therefore, the scale reading uncertainty on the stopclock was found to be ±0.01s.

Conclusions:

The genuine value of g is known to be equal to $9.81 Nkg^{-1}$. The value measured in Procedure 1 was equal to $9.47\ Nkg^{-1}$, a figure approximately 3.47% smaller than the known value. This is a fair minimal percentage, and as a result the first procedure was considered a success, as a fairly accurate value of g was calculated.

Evaluation:

In Procedure 1, measurements were taken for a large number of hole positions, and 5 readings of 10 oscillations were taken for each position. If the experiment were to be conducted again, a possible recommendation would be to measure the time taken for 20 oscillations rather than 10. This would yield a more accurate result, as more oscillations have been measured per hole position. This would also require the pendulum to be swung from a larger angle, in order to accommodate the greater time for which it would swing.

Overall, the value measured for g was fairly accurate, being less than 5% smaller than the known value for g. In this regard, Procedure 1 was very successful.

Procedure 2: Rolling mass in a sphere:

Apparatus:

- A large spherical bowl for the mass to roll in.
- A solid, spherical mass to roll.
- A metal beam for the bowl to stand on.
- A digital stop-clock

Raw Data:

Trial No.	Time(t)
1	12.57
2	12.28
3	12.29
4	12.31
5	12.31
6	12.22
7	12.28
8	12.29
9	12.38
10	12.25

Processed Data:

Consider the ball travelling in a rotational motion, it can be considered a pendulum in terms of classical physics.

From the experiment, it was calculated that the radius of the bowl – as a segment of a sphere – was equal to 0.292m, which when combined with the diameter of the ball itself (0.025m) gives a total length for the pendulum of 0.317m.

The equation for g is as follows:

$$T = 2\pi \cdot \sqrt{\frac{L}{g}}$$

$$1.23 = 2\pi \cdot \sqrt{\frac{0.317}{g}}$$

$$\frac{0.317}{g} = \left(\frac{1.23}{2\pi}\right)^2$$

$$g = \frac{0.317}{\left(\frac{1.23}{2\pi}\right)^2}$$

g = 8.27Nkg^{-1}

Uncertainties:

The random uncertainties in the measurements taken for the ball rolling in the sphere was found to be equal to ±0.18s.

The stopclock used in the procedure measure time in seconds to two decimal places. Therefore, the scale reading uncertainty on the stopclock was found to be ±0.01s.

These two uncertainties can be combined to give an overall uncertainty for the time. This uncertainty is equal to the root of the sum of both of the previous uncertainties squared.

0.18^2 is equal to 0.03.

0.01^2 is equal to 0.001.

The sum of these is equal to 0.031.

The square root of this value is equal to 0.18s.

Therefore, the overall uncertainty for the time measured in Procedure 2 was found to be 12.32±0.18s, or (12.32±1.46%)s.

This percentage uncertainty in the time measured will be equal to the uncertainty in the Period, and hence the overall uncertainty for the value of g was found to be equal to 8.27±0.20Nkg^{-1}, or (8.27±2.42%)Nkg^{-1}.

Conclusion:

The genuine value of g is known to be equal to 9.81Nkg^{-1}. The value measured in Procedure 2 was equal to 8.27Nkg^{-1}, a figure approximately 15.70% smaller than the known value. A potential reason for this off figure is that the value of L was unable to be varied in Procedure 2, as several masses of identical mass but varying volumes would be required in order to accommodate this process.

Evaluation:

In Procedure 2, a major flaw with the method was that there was only a single value of L that could be tested. An improvement to the procedure would be to test other balls of identical mass but varying volume, so that measurements for other values of L could be taken. The presence of one solitary object made repeated results the only way of obtaining a more accurate result of g.

Procedure 3: Mass Oscillating On a Spring:

Apparatus:

- A metal spring, capable of withstanding the weight of increasingly heavier masses.
- A stand from which to hang the spring.
- A series of identical modular weights, wherein one can be added upon another and so on for the purpose of increasing mass.
- A device to measure length, i.e. a meter stick or measuring tape.

Raw Data:

Mass(m)/ g	Extention(L)/ m	Time 1(t1)/ s	Time 2(t2)/ s	Time 3(t3)/ s	Time 4(t4)/ s	Time 5(t5)/ s	Average Time 1(t(av))/ s	Period 1(T)/s
200	0.07	5.69	5.59	5.65	5.66	5.69	5.66	0.57
250	0.09	6.37	6.42	6.79	6.47	6.66	6.54	0.65
300	0.11	6.88	6.88	6.90	6.87	6.81	6.87	0.69
350	0.13	7.36	7.54	7.43	7.12	7.69	7.43	0.74
400	0.15	8.02	7.89	8.13	7.91	7.90	7.97	0.80
450	0.17	8.58	8.16	8.21	8.14	8.11	8.24	0.82
500	0.19	9.21	9.17	9.04	9.06	9.13	9.12	0.91

Processed Data:

The equation for the relationship between the Period (T) and the Extension (L) is as follows:

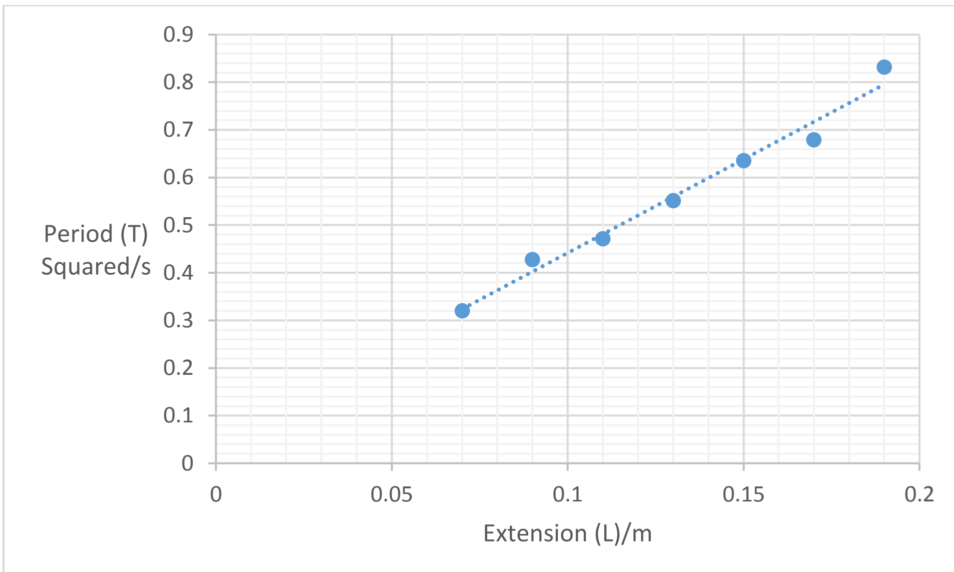
$$T^2 = (4\pi^2 L) \div g$$

This can be rearranged into the following:

$$T^2 = (4\pi^2 / g)L$$

Since this equation is in the form y=mx+c, if the Period was plotted on a graph against the extension, the gradient of the graph would be equal to $4\pi^2/g$.

The following graph was produced.



From tis graph, the gradient was found to have a value of 3.91. If this value is set to equal $4\pi^2/g$, then the value of g is therefore equal to $4\pi^2/3.91$. This yielded a value for the measurement of g of $10.10Nkg^{-1}$.

Uncertainties:

The metre stick used in Procedure 3 used millimetres as its smallest unit of measurement. Therefore, the scale reading uncertainty from the metre stick was found to be ±0.005m.

The stopclock used in the procedure measure time in seconds to two decimal places. Therefore, the scale reading uncertainty on the stopclock was found to be ±0.01s.

Conclusions:

The genuine value of g is known to be equal to 9.81Nkg^{-1}. The value measured in Procedure 2 was equal to 10.10Nkg^{-1}, a figure approximately 2.96% greater than the known value. This is a fairly accurate result, and the closest to the correct figure out of all three procedures. It also did not require as many readings to be taken as Procedure 1, but still successfully yielded a very accurate result.

Evaluation:

The value of g obtained in Procedure 3 was fairly accurate, however improvements could still be made to the method. Notably, there were only a small number of masses that could be tested on the spring, The presence of a broader range of masses would allow for more measurements to be taken, and therefore a more solid measurement of g. Repeating results would also have benefitted the experiment, as although five measurements were taken for each mass, taking 10 measurements could still have further solidified the result.