Science: Spring Oscillation

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INTRODUCTION

"An object can store energy as a result of its position" (The Physics Classroom, 2018). The energy stored due to positioning of an object is called potential energy. When in its original position, the object holds no energy however when moved from its usual equilibrium position, the object is able to store energy. This is all due to the change in position. An example of this is with a bow. When the bow is in a relaxed, non-drawn position (its original state) it holds no energy. However, once the bow is drawn, it gains and stores energy to be exerted during release, acting on the arrow.

Potential energy can be divided into two types; gravitational potential energy and elastic potential energy. Gravitational potential energy is the energy stored in an object as the result of it's vertical position and height. The energy is stored due to the gravitational attraction of the Earth acting upon the object. Elastic potential energy on the other hand, is the energy stored in elastic materials due to their stretching and/or compression. Elastic potential energy is the primary acting energy found in a spring.

Springs are said to follow Hooke's Law. If a spring is not stretched or compressed than there is no elastic potential energy stored. During this time, the position the spring is at is equilibrium position with no force being applied. Hooke's Law can be expressed through $f=kx$. F stands for the force expressed in Newtons (N). K stands for the spring constant, expressed in Newtons per meter (N/m) and x stands for extension, expressed in meters (m). This concept will be applied below.

AIM

The experiment had two primary questions.

1. Does the weight applied to the end of a spring affect the period of oscillation? How?
2. Does the type of spring with a constant weight affect the period of oscillation? How?

We investigated both these questions using three different springs and six weights. The aim of this experiment was to determine how the weight and spring type affected the oscillation period.

HYPOTHESIS

Springs carry out simple harmonic motion or a periodic motion consisting of a singular or multiple vibratory motions symmetrical to the equilibrium. Because of the broader aim of this experiment, which produces results specialised in two separate categories, there are going be two hypothesis. Concerning the effect mass has on a springs period of oscillation, it is predicted that increasing the mass will increase the period of oscillation.Therefore, with a lighter mass, the period of oscillation will be shorter.

Concerning the spring type, it is predicted that the more stiff the spring is, the lower the period of oscillation. Due to the short time it takes (seconds) for a spring to complete one period of oscillation, the time taken for three oscillations will be measured to get an approximate time for a singular oscillation.

VARIABLES

This experiment was carried out in two categories, with multiple trials.

Category One: How weight affects the oscillation of a spring?

Independent: The weight on the end of the spring

Dependent: The time taken for the spring to make three oscillations when different masses are added to it.

The mass of the weights added to the spring

Constant:

1. The height of the stand and clamp as well as their stability.

The height of the stand and clamp affects how easy it is to see the oscillations occur. When set on a flat, elevated surface, it improves the efficiency of the experiment and allows for a better line of sight. It is also important that both were stable to remove risk factors such as both shaking or falling during the experiment, disrupting the natural oscillation of the spring.

2. The spring

The aim was to determine if mass affected the period of oscillation. Springs are affected by both time and wear factors. These factors would come into play even if using two springs of the same length, diameter, stiffness and circumference. To eliminate these factors, we used the same spring in each set of trials.

3. The hook

The hook supplied weighed 20 grams. If we changed hooks, aspects such as the weight, shape, strength and stability would affect the results. To eliminate these possible factors, we used the same hook in all trials.

4. The stopwatch used and individual timing the oscillations

Stopwatches are known to provide varying results when compared with one another. To eliminate possible differences in time, we used a singular stopwatch.
Each person has a different reaction time. This affects when they start and stop timing. To remove the reaction time factor we had one person time the oscillation periods but we performed each trials three times to provide a more reliable result.

Category Two: How the type of spring affects the oscillation of the spring?

Independent: The type of spring (spring length, diameter and stiffness)
Dependent: The time taken for each spring to make three oscillations with the same weight
The mass of the weight used
Constant:

1. The weight

The aim was to determine how the type of spring affected the period of oscillation measured when using a singular weight. To determine how the spring type was affecting the results given, we had to use the same weight. Using a different weight would provide two possible reasons as to why our results were as they were and we would be unable to pinpoint which factor was influencing the results and to what extent.

2. Stand and clamp

Stated above

3. The springs

Springs are easily affected by time and wear. Three springs were supplied all with different diameters and rigidity. The springs supplied for this experiment were not new and could have changed from their original state due to wear, impacting their rigidity and shape. If two different springs of the same diameter, length, thickness and circumference were used, their would still be a wear factor that would have to be taken into account. To avoid this, the same springs were used for each trial.

4. The hook

Stated above

5. The stopwatch (and person timing)

Stated above

MATERIALS

1x metal stand
1x clamp
1x stopwatch (iPhone timer)
1x hook (20g in weight)
1x 5g weight
1x 10g weight
1x 20g weight
4x 50g weight
1x large diameter spring (thick) (A)
1x medium diameter spring (medium) (B)
1x small diameter spring (thin) (C)

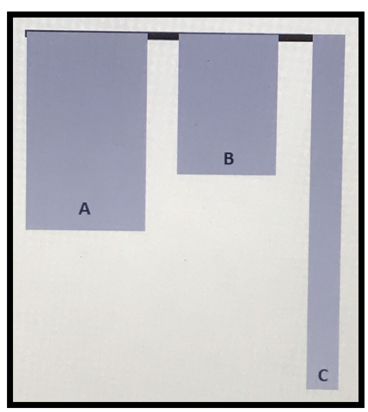

Image One: Approximate spring size when compared to one another

METHOD

1. Gather all the materials

Ensure you have all the materials stated above

2. Set up stand and clamp

Attach the clamp to the stand. Place the stand on a flat surface. To obtain more accurate data, place the stand on a flat table, with one side against a pole or wall. This will make it easier to time the oscillations and keep the stand in place.

3. Place the thick spring on the clamp

Hook the thickest spring onto the clamp, ensuring that it is straight.

4. Attached the 5g weight to the hook

Because of the hole size, it is necessary to thread the hook through the weight, ensuring that it is secure.

5. Attach the hook (with weight) onto the spring

Place the hook onto the bottom of the spring with the weight. Hold the spring horizontally as you place the hook. This avoids the spring swinging or dropping diagonally. It is also important to hold the spring in place so that it does not fall off the clamp. Hold the weight so that it is not applying any pressure to the spring.

6. Drop the hook

This experiment was conducted in groups. It is important that all members communicate to ensure the collection of accurate results. Before dropping the hook ensure all members are ready.

7. Time this process

Time how long it takes for the spring to make three complete oscillations. Complete steps 6 and 7 three times to eliminate factors such as reaction time and human error.

8. Carry out steps 4 to 8 with the 10g, 20g, 50g, 100g and 200g weights

9. Carry out step 8 (including the 5g weight) with each type of spring (thick, medium and thin)

10. Record the data

RESULTS AND ANALYSIS

Note: Due to the weight of the hook (20 grams) the figures listed below (weights) are additional to this 20 grams. For example, where it says 5 grams that was how much additional weight was being added. The hook plus weight would mean 25 grams was used. The additional weights are the weights mentioned below.

Raw Data:

	5 grams	10 grams	20 grams	50 grams	100 grams	200 grams
Oscillation Time for Thick Spring (s)	0.88* 0.90 * 0.93 *	0.66 0.69 0.67	0.80 0.95** 0.80	0.83 0.86 0.81	1.20 1.20 1.13**	1.56 1.50 1.35**
Oscillation Time for Medium Spring (s)			0.59** 0.52 0.49	0.78 0.78 0.78	0.98 1.05** 0.98	1.36 1.29 1.33
Oscillation Time for Thin Spring (s)					0.49 0.49 0.55**	0.92 0.90 0.93

Table One: The table above shows the raw data collected from the experiment for three oscillations.
**erroneous data* ***possible erroneous data*

"Raw data is a term for data collected from a source. Raw data has not been subjected to processing or any other manipulation, and are also referred to as primary data" (Definitions, 2018). The data inputted in rows labelled 'Thick Spring, ' Medium Spring' and 'Thin Spring' is raw data. It has not been manipulated and is the exact numbers collected from the experiment. The raw data collected was mostly within close range of one another per weight category. This shows the near accuracy of the times gathered when compared to one another. It also enables a pattern to be seen. The grey squares indicate where the oscillation was too fast that it was unable to be recorded. The data collected for the thick spring for 5 grams is erroneous data as it does not coincide with trends found in the other results collected and thus, that trial can be disregarded completely. It is likely that the error was in the timing as we were not accustomed to using a stopwatch at the beginning. Some of the times collected for the other weight categories were inconsistent and did not fit in with the trend formed. These have been labelled as possible erroneous data.

Raw Data Analysis:

- 5 grams

The 5 gram weight was so light that the oscillation period was only measurable on the thick spring. The range between the figures is 0.05 seconds, showing the consistency of the readings obtained. However, the readings do not coincide with the trends found and thus this data set is most likely erroneous.

- 10 grams

The 10 gram weight was also considerably light that the oscillation period was only measurable on the thick spring. The range between the figures is 0.03 seconds, again showing consistency in the readings obtained when compared to one another.

- 20 grams

The 20 gram weight was light, but the oscillation period was able to be measured on the thick and medium sized springs. The range between the figures collected for the thick spring is 0.15 seconds however it should be noted that two of the three readings were identical, thus allowing the conclusion to be made that the 0.95s reading had a delay. The range between the figures collected for the medium spring is 0.10 seconds. Two of the readings were within 0.03 seconds of each other, leading to the presumption that the 0.59s reading was delayed. These trials were semi-consistent with only one reading being delayed, which in turn, has affected the average (listed below).

- 50 grams

The 50 gram weight had a reasonable amount of weight to it however was only able to be measured by the thick and medium sized springs. The range between the figures collected for the thick spring is 0.05 seconds, with all readings being relatively consistent. The range between the figures collected for the medium spring is 0 seconds. All figures collected were the same. This shows great consistency in these results.

- 100 grams

The 100 gram weight was the first weight holding enough mass to be measured on all springs. The range between the figures measured for the thick springs is 0.07 seconds, showing some consistency. The range between the figures measured for the medium spring is also 0.07 seconds. Finally the range between the figures measured for the thin spring is 0.06 seconds. All the times measured for this weight shows some consistency.

- 200 grams

The 200 gram was the final weight measured, and like the 100 gram weight, was able to be measured on all springs. The range between the collected figures for the thick spring is 0.21 seconds. This shows a lack of consistency however it should be noted that the 1.35s time shows some delay. The other two figures collected only had 0.06 seconds difference. The range collected for the medium spring is 0.07 seconds showing some consistency. The range between the collected figures for the thin spring is 0.03 seconds showing consistency.

Averages:

	5 grams	**10 grams**	**20 grams**	**50 grams**	**100 grams**	**200 grams**
Average Oscillation Time for Thick Spring (s)	0.90*	0.67	0.85	0.83	1.18	1.47
Average Oscillation Time for Medium Spring (s)			0.53	0.78	0.98	1.33

Average Oscillation Time for Small Spring (s)					0.51	0.92

*Table Two: The averages calculated from the raw data above. This is now processed data. It is for three oscillations. *possible erroneous data*

The table above shows the averages calculated from the raw data table (Table One). This table proves the hypothesis that the heavier the weight, the longer the oscillation period (for three oscillations). The thick spring and five gram is erroneous data, not fitting in to the trend set by the other data and could be discarded.

Refined Data:

	5 grams	**10 grams**	**20 grams**	**50 grams**	**100 grams**	**200 grams**
Oscillation Time for Thick Spring (s)		0.66 0.67	0.80 0.80	0.83 0.81	1.20 1.20	1.56 1.50
Oscillation Time for Medium Spring (s)			0.52 0.49	0.78 0.78	0.98 0.98	1.36 1.33
Oscillation Time for Thin Spring (s)					0.49 0.49	0.92 0.93

Table Three: The table above shows the refined data collected from the experiment for three oscillations.

If one figure from each category was removed (one with the largest margin of error), the data collected when analysed would produce more reliable results. The table above shows the data remaining after this removal.

Refined Averages:

	5 grams	**10 grams**	**20 grams**	**50 grams**	**100 grams**	**200 grams**
Average Oscillation Time for Thick Spring (s)		0.67	0.8	0.82	1.2	1.53
Average Oscillation Time for Medium Spring (s)			0.51	0.78	0.98	1.35
Average Oscillation Time for					0.49	0.93

Small Spring (s)						

Table Four: The refined averages calculated from the refined data table.

The table above shows the refined averages taken from Table Two. These averages are more accurate and reliable.

Period of Oscillation (:
To calculate the period of oscillation, the average time (a) is divided by the number of oscillations measured (b). The equation is as follows; a/b = period of oscillation. The period of oscillation is how long it took for the spring to make one complete oscillation.

	5 grams	**10 grams**	**20 grams**	**50 grams**	**100 grams**	**200 grams**
Oscillation Period for Thick Spring (s)		0.22	0.27	0.27	0.4	0.51
Oscillation Period for Medium Spring (s)			0.17	0.26	0.33	0.45
Oscillation Period for Thin Spring (s)					0.16	0.31

Table Five: The oscillation period for each trial

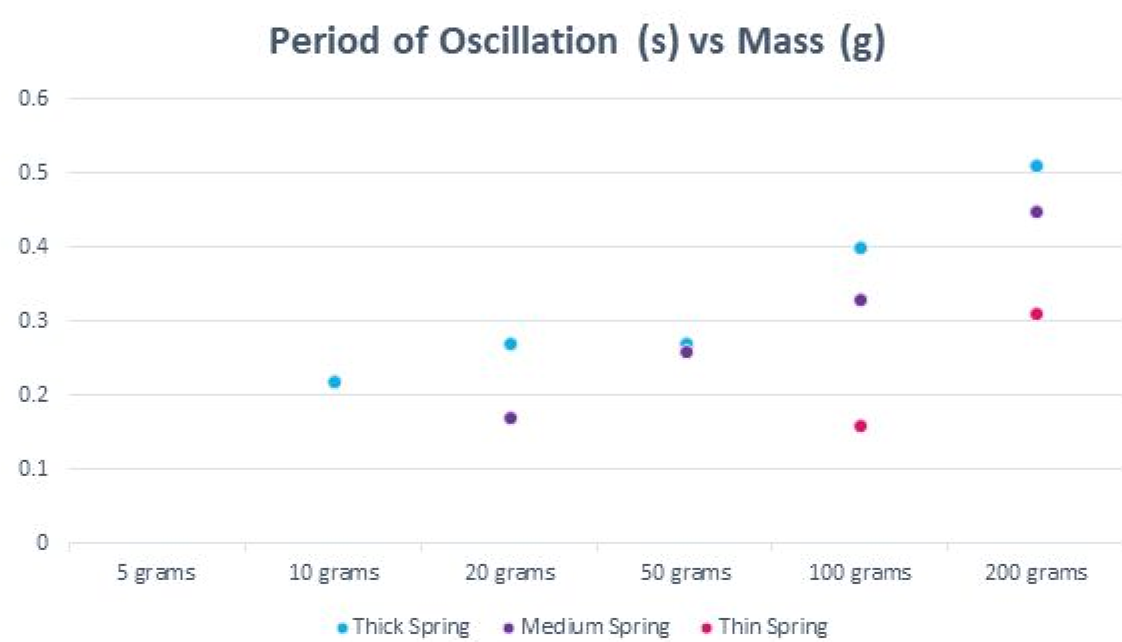

Chart One: Period of Oscillation in seconds vs the mass applied in grams (Experimental values based off revised averages)

The chart and table above show the period of oscillation (measured in seconds), compared to the mass applied (measured in grams). It is based off the experimental values taken from the revised averages table. It was predicted that as the mass increased, so would the period of oscillation. This is mostly proven however the 20 and 50 gram weights of the thick spring show a constant period. This is most likely due to the rounding of the averages and oscillation periods to two decimal places. This is then followed by the predicted increase. Both the medium and thin springs showed the predicted increase expected. It can be seen in all instances that the thick spring had the highest period of oscillation for all masses, the medium spring holding the second highest and the thin spring holding the lowest. When no number is shown, this represents when the oscillations were too fast to be counted or timed by the naked eye. There was data for the 5 gram weight in the raw data table but it is considered erroneous and thus removed from the revised tables. A scatter graph was used as a line graph infers measurements that were not taken.

Spring Extension:

	Thick Spring	**Medium Spring**	**Thin Spring**
Original Spring (State of Equilibrium)	3.4 cm	2.3 cm	6.3 cm
Spring + 50 gram hook	4.5 cm	2.5 cm	6.5 cm
Spring + 300 grams (Hook + 250 grams in weight)	13 cm	7.4 cm	8.4 cm

Table Six: The spring extension of each spring with a specific weight

Hooke's Law (or the law of elasticity) states "that for relatively small deformations of an object, the displacement or size of the deformation is directly proportional to the deforming force or load. Under these conditions the object returns to its original shape and size upon removal of the load" (Encyclopedia Britannica, 2018). Hooke's Law, *F=kx*, was used to determine the spring constant by reversing the process as shown below. The final figures are expressed in Newtons per meter.

300 grams = 0.3kg = 3N (Three Newtons)
F= 3N (rounded)
Thick Spring extension= 0.096 m
Medium Spring Extension= 0.051 m
Thin Spring Extension= 0.021 m

Thick Spring: Medium Spring: Thin Spring:

3N= k(0.096)
K= 3N/0.096
K= 31.25 N/m

3N= k(0.051)
K= 3N/0.051
K= 58.82 N/m

3N= k(0.021)
K=3N/0.021
K= 142.86 N/m

F is equal to force, measured in Newtons. *K* is equal to spring constant. *X* is equal to the length of displacement measured in meters. The higher the spring constant (k), the stiffer the spring. As seen above, the thin spring is the stiffest with a spring constant of 142.86 N/m.

Theoretical Value vs Experimental Value

Going off Hooke's Law (which allows k to be worked out), I was able to work out the theoretical value for the period of oscillation using; $T^2= 4\pi^2 m/k$. The theoretical value and experimental value will almost always have some form of difference as the experimental value is impacted by sources of error like those listed in the evaluation section. To calculate the percentage of accuracy, the experimental period is divided by the theoretical period before being multiplied by 100/1.

Thick Spring:

Thick spring and 5 gram weight:

$T^2= 4\pi^2 m/k$
$T^2= 39.48 \times 0.005/31.25$
$T^2= 0.1974/31.25$
$T^2= 0.006$
T=0.08
E= N/A

Thick spring and 10 gram weight:

$T^2= 4\pi^2 m/k$
$T^2= 39.48 \times 0.01/31.25$
$T^2= 0.3948/31.25$
$T^2= 0.01$
T=0.1
E= 0.22
0.22/0.1 x 100/1
=220%

Thick spring and 20 gram weight:

$T^2= 4\pi^2 m/k$
$T^2= 39.48 \times 0.02/31.25$
$T^2= 0.7896/31.25$
$T^2= 0.03$
T=0.17
E= 0.28
0.28/0.17 x 100/1
=164.71%

Thick spring and 50 gram weight:

$T^2= 4\pi^2 m/k$
$T^2= 39.48 \times 0.05/31.25$
$T^2= 1.974/31.25$
$T^2= 0.06$
T=0.24
E= 0.28
0.28/0.24 x 100/1
=116.67%

Thick spring and 100 gram weight:

$T^2= 4\pi^2 m/k$
$T^2= 39.48 \times 0.1/31.25$
$T^2= 3.948/31.25$
$T^2= 0.13$
T=0.36
E= 0.39
0.39/0.41 x 100/1
=108.33%

Thick spring and 200 gram weight:

$T^2 = 4\pi^2 m/k$
$T^2 = 39.48 \times 0.2/31.25$
$T^2 = 7.896/31.25$
$T^2 = 0.25$
$T=0.5$
$E = 0.49$
$0.49/0.5 \times 100/1$
$=98\%$

Medium Spring:

<u>Medium spring and 5 gram weight:</u>
$T^2 = 4\pi^2 m/k$
$T^2 = 39.48 \times 0.005/58.82$
$T^2 = 0.1974/58.82$
$T^2 = 0.003$
$T=0.05$
E= N/A

<u>Medium spring and 10 gram weight:</u>
$T^2 = 4\pi^2 m/k$
$T^2 = 39.48 \times 0.01/58.82$
$T^2 = 0.3948/58.82$
$T^2 = 0.007$
$T=0.08$
E= N/A

<u>Medium spring and 20 gram weight:</u>
$T^2 = 4\pi^2 m/k$
$T^2 = 39.48 \times 0.02/58.82$
$T^2 = 0.7896/58.82$
$T^2 = 0.01$
$T=0.1$
$E = 0.18$
$0.18/0.1 \times 100/1$
$=180\%$

<u>Medium spring and 50 gram weight:</u>
$T^2 = 4\pi^2 m/k$
$T^2 = 39.48 \times 0.05/58.82$
$T^2 = 1.974/58.82$
$T^2 = 0.03$
$T=0.17$
$E = 0.26$
$0.26/0.17 \times 100/1$
$=152.94\%$

<u>Medium spring and 100 gram weight:</u>
$T^2 = 4\pi^2 m/k$
$T^2 = 39.48 \times 0.1/58.82$
$T^2 = 3.948/58.82$
$T^2 = 0.07$
$T=0.26$
$E = 0.33$
$0.33/0.26 \times 100/1$
$=126.92\%$

<u>Medium spring and 200 gram weight:</u>
$T^2 = 4\pi^2 m/k$
$T^2 = 39.48 \times 0.2/58.82$
$T^2 = 7.896/58.82$
$T^2 = 0.13$
$T=0.36$
$E = 0.44$
$0.44/0.36 \times 100/1$
$=122.22\%$

Thin Spring:

Thin spring and 5 gram weight:

$T^2 = 4\pi^2 m/k$

$T^2 = 39.48 \times 0.005/142.86$

$T^2 = 0.1974/142.86$

$T^2 = 0.001$

$T=0.03$

E= N/A

Thin spring and 10 gram weight:

$T^2 = 4\pi^2 m/k$

$T^2 = 39.48 \times 0.01/142.86$

$T^2 = 0.3948/142.86$

$T^2 = 0.002$

$T=0.04$

E= N/A

Thin spring and 20 gram weight:

$T^2 = 4\pi^2 m/k$

$T^2 = 39.48 \times 0.02/142.86$

$T^2 = 0.7896/142.86$

$T^2 = 0.005$

$T=0.07$

E= N/A

Thin spring and 50 gram weight:

$T^2 = 4\pi^2 m/k$

$T^2 = 39.48 \times 0.05/142.86$

$T^2 = 1.974/142.86$

$T^2 = 0.01$

$T=0.1$

E= N/A

Thin spring and 100 gram weight:

$T^2 = 4\pi^2 m/k$

$T^2 = 39.48 \times 0.1/142.86$

$T^2 = 3.948/142.86$

$T^2 = 0.03$

$T=0.17$

E= 0.17

0.17/0.17 x 100/1

=100%

Thin spring and 200 gram weight:

$T^2 = 4\pi^2 m/k$

$T^2 = 39.48 \times 0.2/142.86$

$T^2 = 7.896/142.86$

$T^2 = 0.05$

$T=0.22$

E= 0.31

0.31/0.22 x 100/1

=140.90%

Analysis of Theoretical Values vs Experimental Values:

Above, the calculations to determine the theoretical value of a single oscillation was calculated before being compared to the time determined by the experiment or the experimental value. T stands for the time for a singular oscillation period. M stands for the mass of the weight in kilograms. K stands for the spring constant in Newtons per meter. The spring constant has been calculated above. The experimental value was then divided by the theoretical value to get the percentage of accuracy.

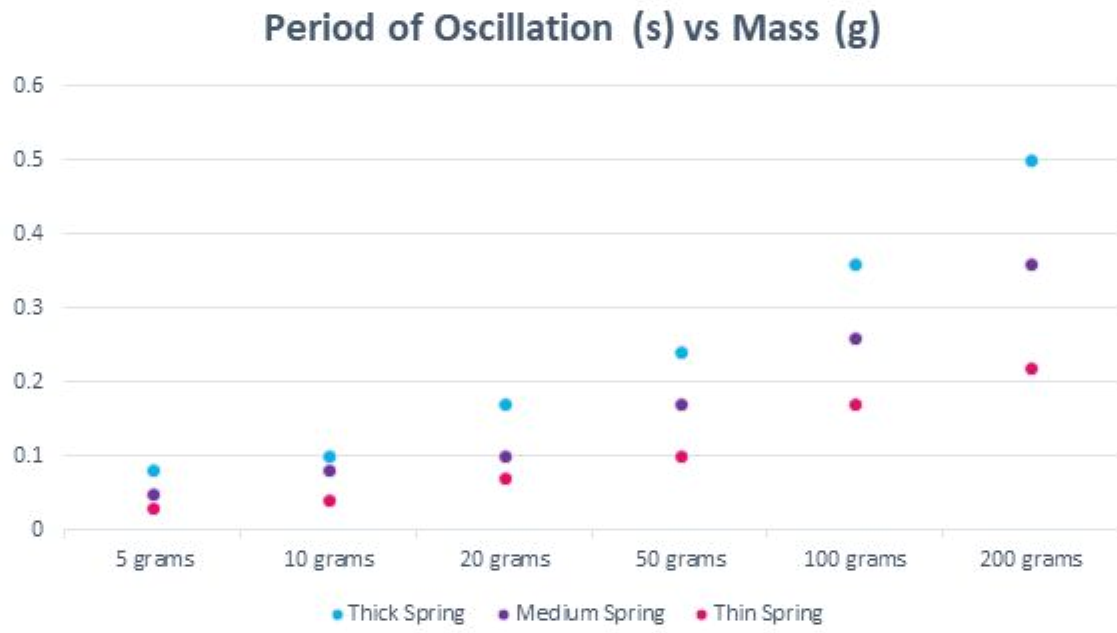

Chart Two: Period of Oscillation measured in seconds vs mass measured in grams (theoretical)

The chart above is a representation of the period of oscillation vs the mass using the theoretical values calculated. This chart coincides with the prediction that by increasing mass, the period of oscillation will also increase. It also proves that the stiffer the spring, the lower the oscillation time.

Analysis of the percentage of accuracy:

SPRING TYPE	MASS	PERCENTAGE	OFF BY
Thick Spring	10 G	220%	120%
	20 G	164.71%	64.71%
	50 G	116.67%	116.67%
	100 G	108.33%	8.33%
	200 G	98%	2%
Medium Spring	20 G	180%	80%
	50 G	152.94%	52.94%
	100 G	126.92%	26.92%
	200 G	122.22%	22.22%

Thin Spring	100 G	100%	0%
	200 G	140.90%	40.90%

Table Seven: The percentage of accuracy and how much the experimental values were off by

The table above shows the percentage of accuracy for each trial. The closer this percentage is to 100%, the closer it is to complete accuracy in accordance with the theoretical and experimental values calculated. Experiments are affected by multiple sources of error, which affects the results obtained. These sources of error are further discussed in the evaluation section and are the most likely candidates as to why the results obtained were off what should have theoretically been obtained. This data shows that the level of accuracy usually increased with the mass of the object. This is expected because the oscillation period is longer, lowering the margin of error. However, the largest contradiction for this trend is with the thin spring and 200 gram weight. This measurement clearly had a large margin of error and could have been affected by reaction time or the way in which the hook was dropped.

CONCLUSION

This experiment proved the predictions made in the hypothesis. It was proven that increasing the mass applied to each spring almost always increased the time taken one oscillation (period). Through observation, the larger the mass, the larger the distance covered by the spring in a downwards direction. The experiment showed that the stiffer the spring, the lower the oscillation period, proving a second prediction.

EVALUATION

This experiment was affected by multiple sources of error including but not limiting too:

1. Human reaction time

Humans are unable to stop or start a timing mechanism, or place a weight on a spring at the exact time. This is because it takes time for our brains to process what we have to do before sending signals to the necessary parts of the body. Therefore, it would be near impossible for one to start or stop a timing mechanism at the exact beginning and end of three oscillations. This would affect the results collected and the results that theoretically should have been collected. This, in no way, proves the inaccuracy of the experiment but more so shows how we have to allow leniency to the things humans cannot do.

2. The springs

The springs used carried rust and had been used countless times before. This would affect their elasticity and thus the results gathered. They were all different lengths and diameters and thus multiple factors could have affected the results. The thin spring also had a small loop at the end where the hook had to be, thus making it harder to stop the hook putting strain on the spring before dropping it. This could have affected the way the hook was dropped on the thin spring and how it was held because of this.

3. Stopwatch inaccuracy

Stopwatches are never completely accurate or precise and this paired with human reaction time, leads to less accurate times. To try and account for this and human reaction time, we ran the experiment three times to get an average as opposed to completely relying on one set of results.

4. Rounding
   The figures collected were all rounded to two decimal places and thus were not completely accurate, but as close as we could get them.

If I were to conduct this experiment again, I would use increasingly heavier weights as with the thin spring, we were only able to measure the period of oscillation for 100 and 200 grams. I would use tighter weights as the 50 gram weights kept slipping off the hook. This caused setting up some trials to take a long time and required a lot of balance of the stand and table. I would also measure the distance travelled as the spring extends downwards, to work out the acceleration of the spring as it reacts to the additional mass being applied. Finally, I would conduct between 4 and 6 trials to get a more reliable result.

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