



AN INVESTIGATION OF HOW THETA CHANGES WHEN A MASS IS APPLIED

University of Wales Trinity Saint David

School of Engineering

Thomas Crocker

1801936

BEng Motorsport Engineering
(Foundation Year)

15/01/19

Science M3X01513

TABLE OF CONTENTS

Table of Contents.....	1
Section 1 – Rationale	2
Section 1.1 – Background Information.....	2
Section 1.2 – Aim.....	4
Section 1.3 – Hypothesis	4
Section 2 – Apparatus	4
Section 2.1 – Equipment List.....	4
Section 2.2 – Diagram	5
Section 3 – Method.....	5
Section 3.1 – Procedure.....	5
Section 3.2 – Variables	6
Section 3.3 – Precautions	6
Section 3.4 – Risk Assessment.....	7
Section 4 – Results.....	7
Section 4.1 – Results Table	7
Section 4.2 – Graph.....	8
Section 4.3 – Uncertainties	8
Section 5 – Conclusion.....	9

SECTION 1 – RATIONALE

SECTION 1.1 – BACKGROUND INFORMATION

If a body is in equilibrium it can be said that the forces acting on the body are equal and opposite, therefore cancelling out and giving a resultant force of zero. If you apply this to a body supported by two springs, as seen in figure 1, we can say that the downward force from the mass is equal to the supporting forces from the two springs and therefore the resultant force of the entire system is zero. Putting this an equation we can say that:

$$M = F_2 + F_1 \quad \text{Equation 1.1}$$

Where M is the mass from the body acting down and F_1 and F_2 is the supporting forces from the springs acting down. Therefore, if both springs are completely uniform then the individual force supplied by each spring will be the same and can be shown as:

$$M = 2F \quad \text{Equation 1.2}$$

Where M is the mass and F is the force supplied by each spring.

To find F, the system shown in figure 1 should be split into the individual springs to resemble a triangle, as shown in figure 2.

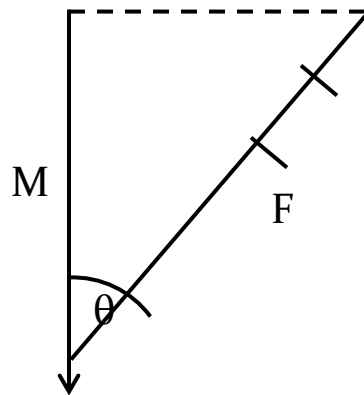


Figure 1.1

The mnemonic SOH CAH TOA, where SOH is using the sine function involving the opposite and hypotenuse of a right-angled triangle, CAH uses the cosine function and the adjacent and hypotenuse and TOA uses the opposite and adjacent sides of the right-angled triangle, can be

used in order to find the force of the spring. To find F, the cosine function should be used as the value for the adjacent length is known and the hypotenuse is the supporting force from the spring, which we are trying to find. From this, we can say that:

$$\cos \theta = \frac{M}{F} \quad \text{Equation 1.3}$$

However, the experiment involves measuring the angle between the two springs, as shown in figure 3.

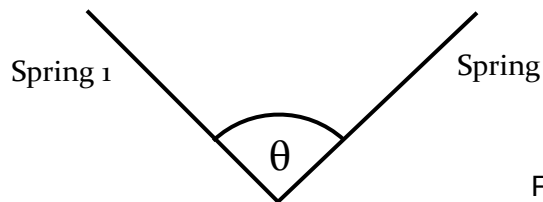


Figure 1.2

To only find the support force of one spring the measured angle will need to be halved. This will give the effect of:

$$\cos \left(\frac{\theta}{2} \right) = \frac{M}{F} \quad \text{Equation 1.4}$$

However, to find the support force from the spring the equation will need to be rearranged to make F the subject of the formula, giving the equation:

$$F = \frac{M}{\cos \left(\frac{\theta}{2} \right)} \quad \text{Equation 1.5}$$

For this experiment, a graph of length (L) against $\frac{M}{\cos \left(\frac{\theta_{av}}{2} \right)}$ will need to be plotted. From the graph a gradient should be calculated using the equation:

$$m = \frac{(y_2 - y_1)}{(x_2 - x_1)} \quad \text{Equation 1.6}$$

SECTION 1.2 – AIM

The aim of the investigation is to find how the angle between the length of string (θ) varies when a mass is applied to the system.

SECTION 1.3 – HYPOTHESIS

The length of the springs will increase as the angle θ between the string decrease when a mass is applied to the springs.

SECTION 2 – APPARATUS

SECTION 2.1 – EQUIPMENT LIST

Protractor (Precision ± 1 degree)

30cm Ruler (Precision ± 1 mm)

Metre Ruler

Clamp Stand

2 x Springs

Length of String

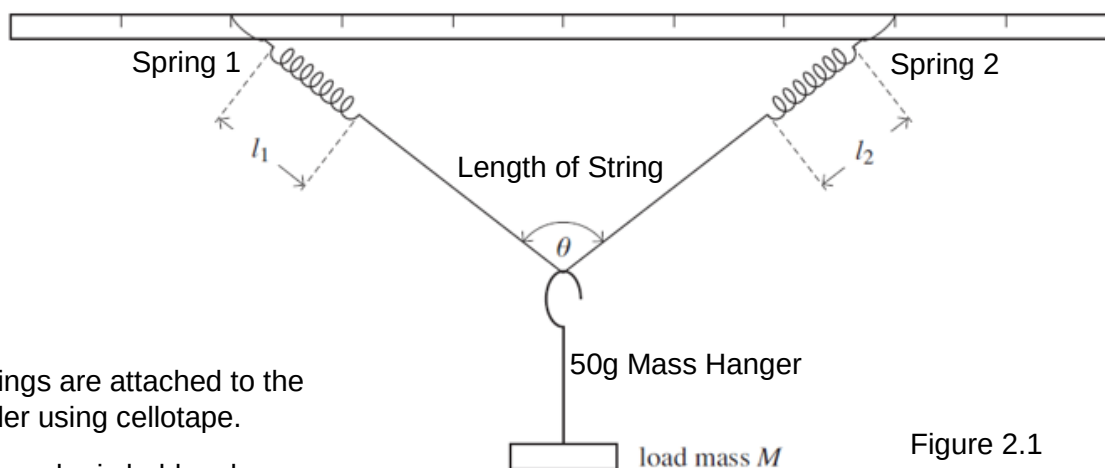
Cellotape

50g Mass Hanger

50g Masses up to 550g

30cm Ruler

SECTION 2.2 – DIAGRAM



Both springs are attached to the metre ruler using cellotape.

The metre ruler is held up by a clamp stand.

Figure 2.1

SECTION 3 – METHOD

SECTION 3.1 – PROCEDURE

1. Set up the equipment, stated in section 2.1, as shown in the diagram in section 2.2
2. Create a results table as shown in section 3.4 below
3. Measure the length of spring 1 and 2 (including the end loops) with no mass applied to them. The assumption that the angle between the string (θ) is 180 degrees can be made.
4. Apply 100g of mass to the string (note that the mass hanger itself weighs 50g) and measure the lengths of spring 1 and 2 using a 30cm ruler as well as the angle θ between the string using a protractor and record the data in your results table.
5. Add 100g of mass (note that each mass is 50g) incrementally, recording the results for the spring lengths and angle in the results table each time.
6. Repeat step 5 until a total mass of 600g is applied.
7. Calculate the average values for the length and angle of each mass. As well as this, calculate the value of $\frac{M}{\cos(\frac{\theta_{av}}{2})}$ for each of the masses.
8. Plot a graph of the length (L) on the y axis and $\frac{M}{\cos(\frac{\theta_{av}}{2})}$ on the x axis. After this, calculate the gradient of the graph.

SECTION 3.2 – VARIABLES

The dependent variable is the variable in the experiment that is going to be measured. In this experiment the dependent variable will be the length L of spring 1 and spring 2 as well as the angle θ between the string. The independent variable is the variable that is changed during the experiment in order to obtain data. For this experiment the independent variable will be the mass applied to the spring. The control variable is anything used in the experiment that should be kept the same in order to obtain valid data. The control variables for this experiment will be the springs used, length of string, positioning of the mass hanger on the string and the amount of mass added to the hanger each time.

SECTION 3.3 – PRECAUTIONS

During the experiment, precautions should be taken in order to have valid and reliable data for your graph. Firstly, the 30cm ruler used to measure the length of the springs has a precision of 1mm and therefore each data point has an uncertainty of $\pm 1\text{mm}$. To reduce the effect this uncertainty has on your graph, each data point should be an average of multiple measurements. This same process can be applied to the measurement of angle θ between the string, where you use a protractor with a precision of 1 degree to find the angle θ between the string as shown in the diagram in section 2.2.

Another precaution that should be taken is that the investigator should always measure the lengths L and angle θ from eye level to negate the effects of parallax error. Parallax error is the displacement in the apparent position of a point caused by the viewing angle being anything but perpendicular to the point. This is a form of random error which can give wildly varying data, however pairing both using mean values for each measurement as well as taking measurements at eye level can reduce the effects of random errors.

SECTION 3.4 – RISK ASSESSMENT

The experiment involves hanging a mass from a length of string, which is suspended by a spring on each end of the string. A risk of the experiment is that the masses could come off the string and fall onto the feet of the investigator, possibly causing injury to their feet. A solution to this could be to firmly attach the mass hanger to the string using cellotape in order to prevent any injury to the investigator. As well as this, the experiment involves the measuring of springs at eye level, which could pose the risk of the spring becoming detached from the metre ruler and possibly causing injury to the investigator's eyes. A solution to this problem should be to wear goggles whenever taking any measurements throughout the experiment.

SECTION 4 – RESULTS

SECTION 4.1 – RESULTS TABLE

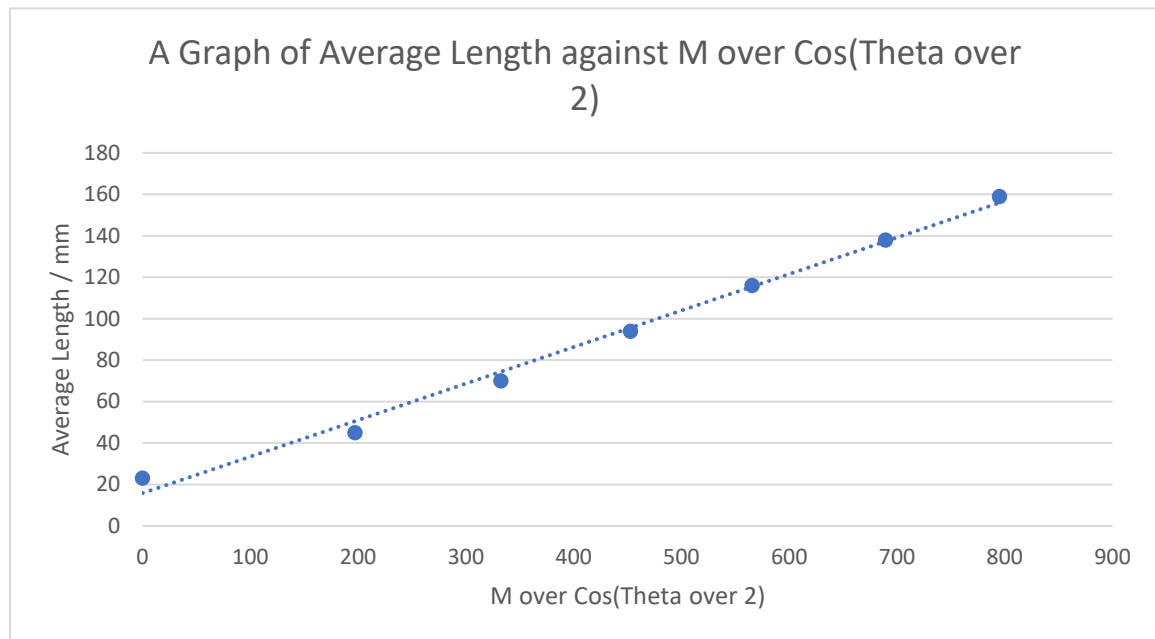
Mass/g	Reading1			Reading2					M
	L1/mm	L2/mm	θ /degree	L1/mm	L2/mm	θ /degree	Av L/mm	Av θ /deg	$\cos\theta_m/2$
0	23	22	180	23	22	180	23	180	0
100	47	42	119	46	43	118	45	119	197.02
200	72	66	104	71	70	108	70	106	332.33
300	96	89	97	96	93	96	94	97	452.75
400	116	117	90	120	112	89	116	90	565.69
500	141	136	86	140	136	87	138	87	689.3
600	161	156	82	162	158	81	159	82	795.01

Table 4.1 – The results of the investigation to find how theta varies when a mass is applied to it

Where Av L is the average length, Av θ is the average angle θ and θ_m is the average angle.

SECTION 4.2 – GRAPH

Figure 4.2



SECTION 4.3 – UNCERTAINTIES

As mentioned in section 3.2, errors will affect the data measured during the experiment and therefore there will be an uncertainty for each data point. This can be worked out using the equation:

$$\text{Percentage } U = \frac{\left(\frac{\text{Range}}{2}\right)}{\text{Value}} \times 100 \quad \text{Equation 4.1}$$

M/g	Av L	%u for L	Av θ	%u for θ
0	23	2%	180	0
100	45	6%	119	0.40%
200	70	4%	106	2%
300	94	4%	97	0.50%
400	116	3%	90	0.50%
500	138	2%	87	0.60%
600	159	2%	82	0.60%

Table 4.2 – A table for the percentage uncertainties for the average length and average angle θ

SECTION 5 – CONCLUSION

In conclusion, the experiment proved the hypothesis in section 1,3 which stated that the length of the springs will increase as the angle θ between the string decrease when a mass is applied to the springs. This can be proven by looking at the graph in section 4.2, which is a straight line not going through the origin showing the positive relationship between L and the equation $\frac{M}{\cos(\frac{\theta_{av}}{2})}$.

This proves the hypothesis because if the value for θ_{av} decreases, as seen in the data from section 4.1, then the overall value for the equation $\frac{M}{\cos(\frac{\theta_{av}}{2})}$ will increase, thus showing that the

increase in L will result in the decrease of θ . However, a perfect representation of the hypothesis would be a straight line that goes through the origin but the graph in section 4.2 does not go through the origin. This can be due to errors in the measurements causing unreliable data that will affect the outcome of the graph data. These errors could have come from the measurements for the length and the angle θ due to the equipment used not being precise enough for accurate and reliable data.

If the experiment was repeated, the same procedure would be used as it was simple to use and gave valid data, which proved the hypothesis. However, different equipment would be used in order to give much more precise and valid data. For example, a Vernier caliper would be used to measure the lengths of each spring to give a more valid set of data for the length L, possibly angling the line of best fit towards the origin.