

University of Wales Trinity Saint David

School of Engineering

Forces in Equilibrium Practical Experiment

Bradley Burton

1803066

Foundation Beng. Motorcycle Engineering

23/01/2019

M3X01513

Contents

3. Rationale

4. Apparatus set-up

5. Method

6 - 8. Results

9. Conclusion

Rationale

The forces in equilibrium practical experiment is the investigation into how an angle between two sides of a piece of string differs as the mass it is supporting is increased. The experiment will also show how the length of the springs attached to the string increase as the mass is added.

The report will state how to conduct the experiment and show how to structure the findings so a conclusion can be drawn from the data collected.

Apparatus required:

- Retort Stand
- Boss Clamp
- 1m Wooden Rule
- 2x Springs
- 0.3m Rule
- Protractor
- Spirit Level
- 0.05kg Mass Hanger
- 11x 0.05kg Slotted Masses
- Length of String
- Tape

Apparatus set-up

To commence, check all the equipment listed above is present. Place the Retort Stand on your workbench making sure the surface is level and stable. Attach the Boss Clamp to the extreme top of the Retort Stand and tighten the boss retaining screw. Then open the jaws of the Boss Clamp and place the Wooden Rule into said jaws so that .5m mark is in the centre of the clamp, then tighten to secure. Attach springs to either side of a length of string, making sure that the distance between the springs when the string is taut is .6m. Securely fasten the springs to the ruler using another small piece of string to tie around the ruler for each spring. Adhere one of the small pieces of string to the wooden rule at .2m and attach the other side to the .8m mark using the tape to secure in place. Once attached, ensure the rule is horizontal using a spirit level. Before moving forward with the experiment create a data table to record the results and double check that the equipment is setup as stated above.

Method

Before starting the experiment, to ensure accuracy, check that the 1m Wooden Rule is level using the spirit level.

First, using the .3m rule, measure both the left and right springs at eye level and with elbows supported by the work surface where possible to ensure accuracy. The measurement is to be taken from the very end of the springs rings with zero mass applied and record the data in the results table.

Then add a .05kg slotted mass to the mass hanger to give a total mass of .1kg and suspend at the centre line of the string. Wait for the springs to cease oscillating, measure and record the length of the springs (L_1 / L_2) as well as the angle between the two sides of the string (θ) with the protractor which should also be taken at eye level with elbows supported.

After, check the wooden rule is still level and add .1kg (2x Slotted Masses) incrementally up until and including .6kg and record all results in the data table.

Once you have one set of data for all the seven masses including zero, remove the mass hanger and repeat the same process to give you a second set of data to ensure reliability.

Make sure all the data in the results table is in the correct units, mass in kilograms (kg), length of springs in meters (m) and angles in degrees ($^{\circ}$).

From your data calculate the mean values for the length of the springs (L_m) using the all four measurements for L_1 and L_2 . The mean is calculated by adding lengths from both tests for each mass including zero and dividing by the amount; $\frac{L_1+L_2+L_1+L_2}{4} = L_m$. Also calculate the mean of both angles taken for each mass; $\frac{\theta+\theta}{2} = \theta_m$.

Using the mean value for the angle of the string, carry out the following calculation; $\frac{M}{\cos(\frac{\theta_m}{2})}$. Input the calculated data for each mass into the results table.

All data from the above calculation for can be input into a scatter graph that should show an ascending linear result.

Results

Table 1. Forces in Equilibrium Experiment Results Table.

Forces in Equilibrium Results Table									
Mass (kg)	Reading 1			Reading 2			Derived Data		
	L1 (m)	L2 (m)	θ (°)	L1 (m)	L2 (m)	θ (°)	Lm (m)	θ m (°)	$\frac{M}{\cos(\frac{\theta}{2})}$
0	0.049	0.049	180	0.049	0.049	180	0.049	180	0
0.1	0.074	0.070	120	0.073	0.069	119	0.072	120	0.2
0.2	0.101	0.098	108	0.099	0.092	107	0.098	108	0.34
0.2	0.121	0.119	99	0.119	0.114	98	0.118	99	0.461
0.4	0.147	0.138	90	0.144	0.134	89	0.141	90	0.566
0.5	0.173	0.16	85	0.169	0.158	86	0.165	86	0.684
0.5	0.197	0.179	81	0.182	0.177	81	0.184	81	0.789

The above results table shows that method of the experiment has been carried out correctly as the results for the first reading are similar to that of the second reading. We can infer from this that the results shown above are reliable.

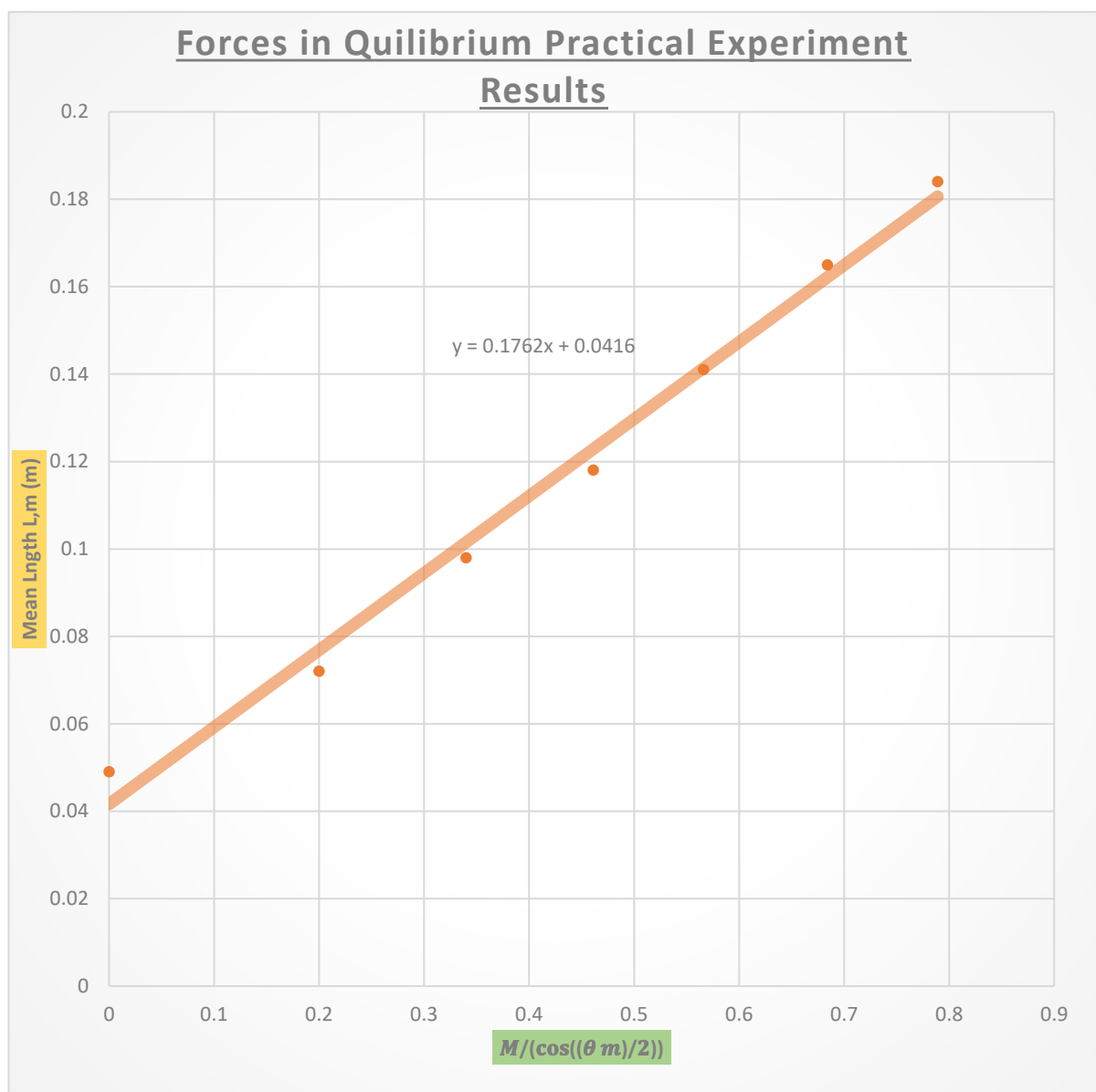


Figure 1. Forces in Equilibrium Experiment Results Graph.

The scatter graph above shows the results of L_m and the calculation $\frac{M}{\cos(\frac{\theta m}{2})}$ for each added increment of mass. As aforementioned, the graph clearly shows an ascending linear result.

To validate the experiment, uncertainties and percentage uncertainties of both spring length and string angle have to be calculated from the results to show the limitations of the experiment.

Table 2. Uncertainties and Percentage Uncertainties for Spring Length

Mass (g)	Range (mm)	Uncertainty (mm)	% Uncertainty
0	0	± 0	0
100	5	± 2.5	3.5
200	9	± 4.5	4.6
300	7	± 3.5	3
400	13	± 6.5	4.6
500	15	± 7.5	4.6
600	20	± 10	5.4

Table 3. Uncertainties and Percentage Uncertainties for String angle

Mass (g)	Range (°)	Uncertainty (°)	% Uncertainty
0	0	± 0	0
100	1	± 0.5	0.4
200	1	± 0.5	0.5
300	1	± 0.5	0.5
400	1	± 0.5	0.6
500	1	± 0.5	0.6
600	0	± 0	0

The results in the tables above show the experiments uncertainties. These are calculated to the precision of the equipment used, for example the mass applied has a precision of 1g, the rule used to measure the spring length has a precision of 1mm and the protractor used to measure the angle between the springs has a precision of 1°.

The majority of the results in *Figure 3.* show that, as the mass is increased the percentage uncertainty also increases up to 5.4%.

The results for *Figure 4.* show a very small increase in percentage uncertainty per increment of mass added.

Conclusion:

To conclude, the results taken show that the angle between both sides of the string decreases and that the length of the attached springs increases as each increment of mass is applied. This statement is supported by the data presented in graph *Figure 1*, which shows that the line of best fit has a linear ascending result.

From the information in the graph we can use equation $y = mx + c$ to calculate the gradient of the line of best fit that shows the relation between the spring length and string angle.



LOCATION: SWANSEA

LLEOLIAD: ABERTAWE

LEVEL 3

LEFEL 3

EXAMINATION PERIOD
JANUARY 2019

CYFNOD ARHOLIADAU
IONAWR 2019

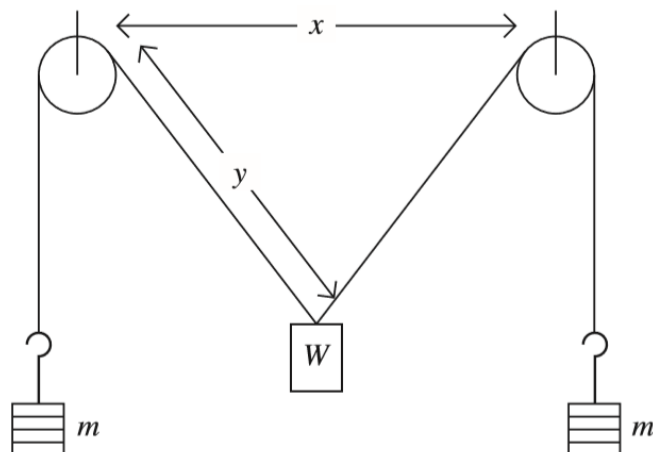
MODULE CODE: M3X01513
SCIENCE

COURSEWORK PART 2

2

In an experiment similar to the one you performed in Stage 1 an unknown load, of weight, W , was supported by two strings kept in tension by equal masses, m , hung from their free ends, with each string passing over a frictionless pulley. The arrangement was symmetrical and is shown in **Figure 1**.

Figure 1



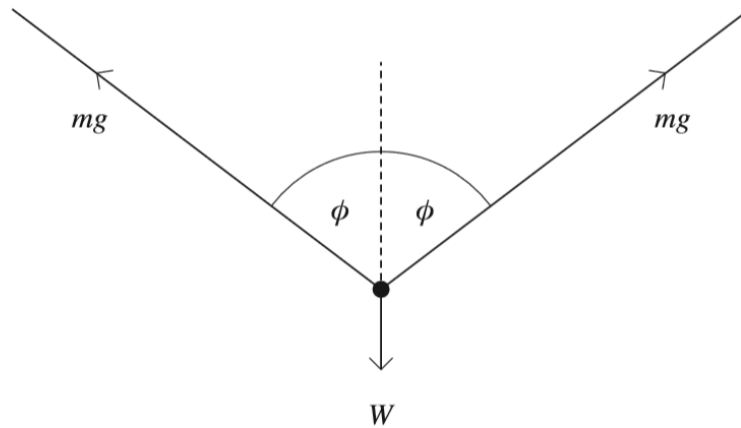
The distance x was kept constant throughout the experiment. The length y was measured for different values of m . The results are shown in the table.

The distance between the strings at the pulleys, $x = 0.500$ m

m/kg	y/m	$(\frac{x}{y})^2$	$\frac{1}{\sqrt{4 - (\frac{x}{y})^2}}$
0.250	0.736	0.462	0.532
0.275	0.484	1.067	0.584
0.300	0.400	1.563	0.641
0.325	0.360	1.929	0.695
0.350	0.339	2.175	0.740
0.375	0.322	2.411	0.793
0.400	0.308	2.635	0.856

- 2 (a)** **Figure 2** shows the three forces acting through the point at which the strings are attached to the load. The weight of the load is W and the tension in each string is mg , where g is gravitational field strength.

Figure 2



- 2 (a) (i)** By resolving the forces vertically show that $m = \frac{W}{2g\cos\phi}$

where ϕ is the angle between each string and the vertical.

$$\cos \phi = 2mg/W$$

$$mg \cos \phi + mg \cos \phi = W$$

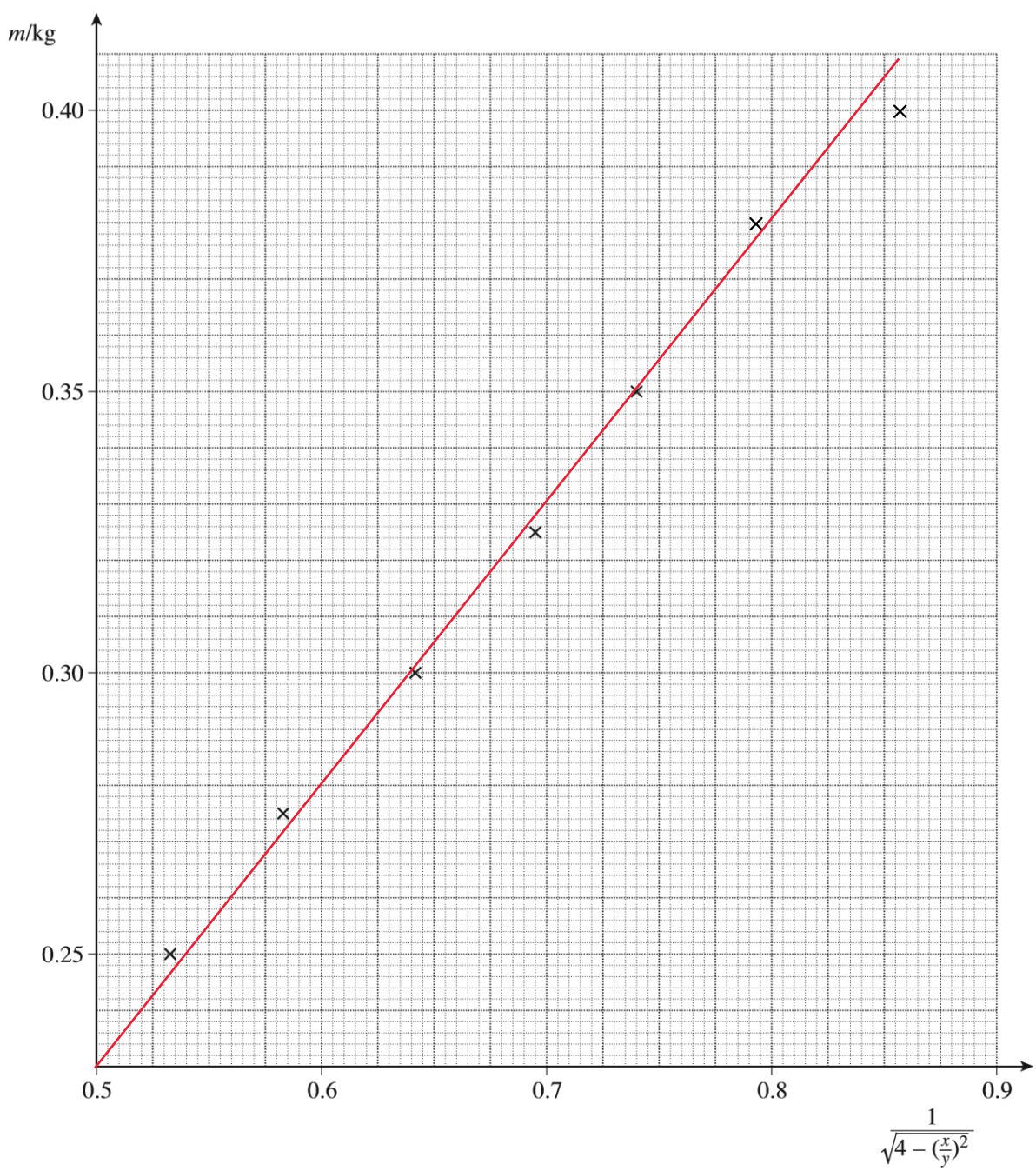
(1 mark)

- 2 (a) (ii)** Complete the table on page 4.

(2 marks)

- 2 (a) (iii)** Complete the graph on the following page by plotting the missing two points and drawing a straight line of best fit.

(2 marks)



2 (b) (i) Determine the gradient of your graph.

$$y = mx + c$$

$$m = (.28 - .23) / (.60 - .50) = .5$$

$$y = .5x + c$$

$$.23 = (.48)(.5) + c$$

$$c = -0.01$$

(3 marks)

2 (b) (ii) The equation for the straight line is $m = \frac{W}{g} \times \frac{1}{\sqrt{4 - (\frac{x}{y})^2}}$

Given that $g = 9.81 \text{ N kg}^{-1}$, determine a value for W .

$$W = m g / \sqrt{y - (x / y)^2}$$

$$W = (.48) (.695) (9.81) = 3.273$$

(2 marks)

2 (c) The uncertainty in the measurement of x was $\pm 1 \text{ mm}$ and the uncertainty in the measurement of y was $\pm 2 \text{ mm}$. Calculate the percentage uncertainty in $(\frac{x}{y})^2$ for $m = 0.300 \text{ kg}$.

$$\text{Range} = 2.173$$

$$2.173 / 2 = + \text{ or } - 1.087$$

$$U = + \text{ or } - 1.087$$

$$\text{Mean} = 1.749$$

$$\%U = 1.087 / 1.749 = 0.61$$

$$\%U = 0.61\%$$

(3 marks)

2 (d) (i) Explain the term *systematic error*.

Are errors that are not determined by chance but are introduced by an inaccuracy
inherent to the system.

(1 mark)

2 (d) (ii) There may be a systematic error in this experiment because of friction in the pulleys. When the measurements were taken, increasing values of m were used. State and explain how friction in the pulleys would have affected the measured values of y .

The force of friction effects motion. Friction acts in the opposite direction of the
motion, therefore it would produce a slightly inaccurate result in a practical experiment.

(2 marks)