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ENGS121 Mechanics Lab Section B
Graphical analysis of the Hooke's Law

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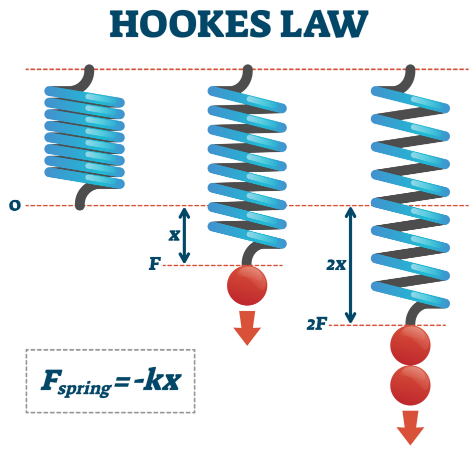
1 Introduction

The experiment investigates the relationship between the force applied to to a spring and the extended length of the spring.



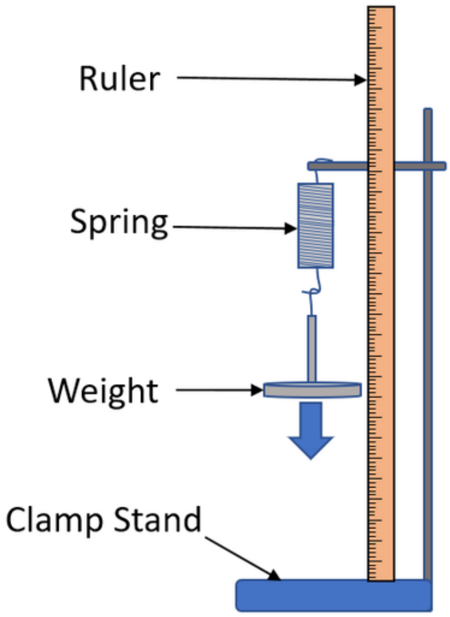
In theory, they follow Hooke's Law, which states that there is a linear relationship between the extension of the spring and the force that it exerts:

$$F = -kx$$

where k is the spring constant and x is the extension of the spring. But, our measurements are taken in the equilibrium positions, when the force of the spring and the force of the weight are equal, thus we hypothesise that there is a linear relation between the force applied to the spring and the extention of the spring.

2 Measurements and data

A spring was mounted from a stand, and a string was looped approximately from the middle of the string to the bottom of the spring. This loop will later prevent further extension of the spring, from there onward. Different measures of weights were attached to the spring and the different lenghts of the spring were recorded.



Variable	Value	Resolution
Attached weight	Controlled	1g
Oscillation	Controlled	1mm
Length of Spring	Measured	1mm

Table 1: List of variables

Instrument or material	Description
Ruler	A long ruler of at least 30cm, with a resolution of 1mm.
Stand	Lab Stand
Spring	Lab Spring
Weighing scale	With an accuracy of 1g
Weights	Different, to provide sufficient data points

Table 2: List of instruments and materials

Source of error	Type of error	Countermeasures
Oscillations	Random	With heavier weights, the spring starts to oscillate, which can be prevented by stopping the spring by hand and waiting a few seconds for it to reach equilibrium

Table 3: Estimated errors

The length of the spring was measured $6.6cm$, and the part without the loop was $2.4cm$.

m (g)	62	82	93	111	122	185	204	251
l (cm)	8.9	9.6	10.3	10.9	11.3	13.8	14.5	16.5
m (g)	306	353	403	454	505	555	607	
l (cm)	18.6	20.5	21.4	22.3	23.1	23.9	24.9	

Table 4: Spring Data

3 Calculations and plots

The weights were translated to gravitational forces, with the formula $F = mg$. Grams were turned into SI units, kilograms, and centimeters were turned into SI units, meters.

F (N)	0.606	0.804	0.911	1.988	1.196	1.813	1.999	2.460
l (m)	0.089	0.096	0.103	0.109	0.113	0.138	0.145	0.165
F (N)	2.999	3.459	3.949	4.449	4.949	5.439	5.949	
l (m)	0.186	0.205	0.214	0.223	0.231	0.239	0.249	

Table 5: Force - Length Data

The data points were plotted, the breaking point was noted and the equations of the two resulting lines were calculated.

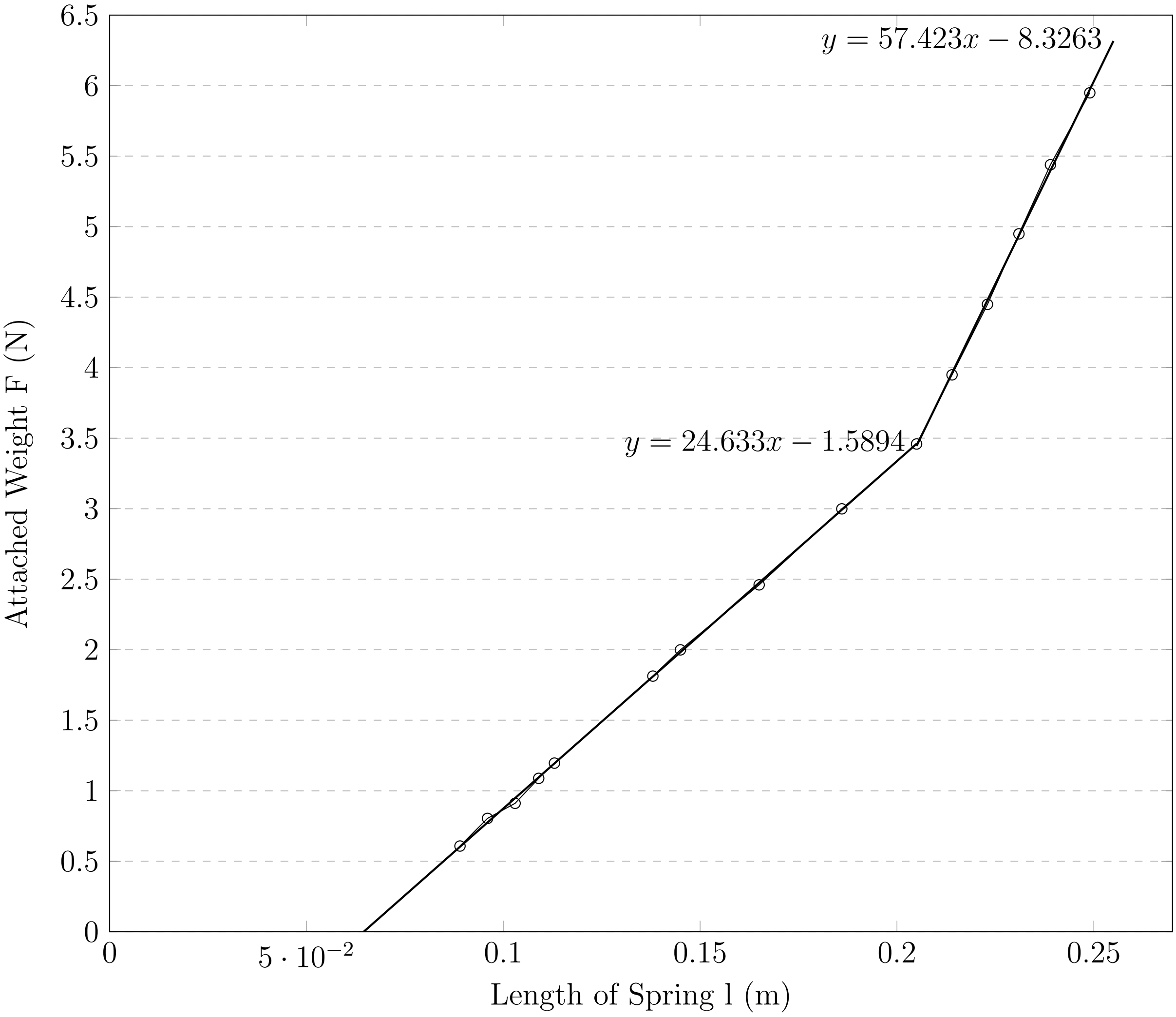


Figure 1: Plot of attached weight and length of spring

F (predicted)	0.603	0.775	0.948	1.096	1.194	1.810	1.982	2.475
$\mathbf{l^2}$	0.00792	0.00922	0.01061	0.01188	0.01277	0.01904	0.02103	0.02723
F (predicted)	2.992	3.445	3.962	4.479	4.938	5.398	5.972	
$\mathbf{l^2}$	0.03460	0.04203	0.04580	0.04973	0.05336	0.05712	0.06200	

Table 6: Data for error calculation

4 Evaluation

Since we plotted the data of the lengths of the spring, instead of the extension, our x-intercept will be the length of our spring, which is calculated to be $6.5cm$, which has an error of 1.5% from the measured value. The breaking point of the graph corresponds to when the loop of string started to cause partial extension of the spring. The two slopes of the two lines correspond to the spring constants of the two cases. The spring constant of the entire spring is $24.6N/m$, and the spring constant of the leftover part after the loop of string engaged $57.4N/m$. Using the formula $k \cdot l = k_1 \cdot l_1$, the length of the looped part is calculated to be $2.7cm$, which has an error of 12.5%.

From the graph, we find the error of the first slope $\Delta k = 0.15N/m$, $\Delta k_1 = 0.45N/m$ for the second line's slope, and $\Delta l = 0.0008m$ for the intercept of the first line. Overall, the error for the small part of the spring is calculated $\Delta l_1 = 0.0007m$, which is much lower than the real error. This suggests a systematic error, which may be caused by the inaccurate measurement with a ruler.

5 Conclusion

An experiment was carried out to test the relationship between force and extension of a spring, and it was found to be linear. The spring constant was calculated $24.6N/m$, with a length of spring of $6.5cm$, which has an error of 1.5% from the measured value, while the length of the not looped part of the spring was calculated to be $2.7cm$, which has an error of 12.5%. Overall, it was shown that the relationship is linear, in correspondence with Hooke's Law.

References

Khan, S. (2024). *What is hooke's law?* Khan Academy. Retrieved from `https://www.khanacademy.org/science/physics/work-and-energy/hookes-law/a/what-is-hookes-law`

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