Investigating springs

Specification references

- *1.1.2 a) c)*
- *1.1.3 d) (i) (ii)*
- *1.1.4 a) d)*
- *1.2.1 c) d) j)*
- *1.2.2 c)*
- *3.4.1 a) b) c) d) (i) (ii)*

Learning outcomes

After completing the practical you should be able to:

- know how to measure extension
- use a force–extension graph to calculate the force constant
- identify the limit of proportionality on a force–extension graph
- observe plastic deformation of a spring.

Background

In this experiment you will investigate how the extension x of a helical spring is affected by the applied force F, and you will plot a force–extension graph. This will enable you to measure the limit of proportionality and determine the force constant of the spring.

To do this you will need to use Hooke's law, $F = k\,x$,

where F = applied force, N

k = force constant, N m^{-1}

x = extension, m

Safety

- Eye protection should be worn.
- Attach the masses securely to the spring and ensure that, should the masses fall, they will not fall on your feet. You may need to protect the floor.
- The clamp stand must be securely attached to the bench with a G-clamp.

Equipment and materials

- a spring
- a clamp stand
- a G-clamp
- some masses and a mass hanger
- some string
- a metre rule
- a set square
- a second stand with two clamps

Method

1 Secure the first stand to the bench and hang the spring from the clamp. Tie a loop of string through the bottom of the spring. Adjust the ruler and secure it in place as close to the spring as possible, using the second stand and both its clamps. Use the set square to ensure that the ruler is vertical (see Figure 1).

2 Use the set square to ensure that the line between the spring and the ruler is horizontal. Read the position of the top and the bottom ring of the spring. Subtract these values to calculate the length of the spring. Estimate the precision of each reading.

3 Add the mass hanger (whose mass should be the same as the individual masses to be added later) to the loop of string and measure the new length of the spring.

4 For each measurement, calculate the extension of the spring by subtracting the original length of the spring from the new length, $h_1 – h_2$.

5 Continue to add masses and measure the new length of the spring each time until it is clear that the results are no longer linear. At this point, caution must be taken and the masses should be added in smaller increments.

6 After the spring has been extended beyond its linear region, repeat the measurements as you unload the spring.

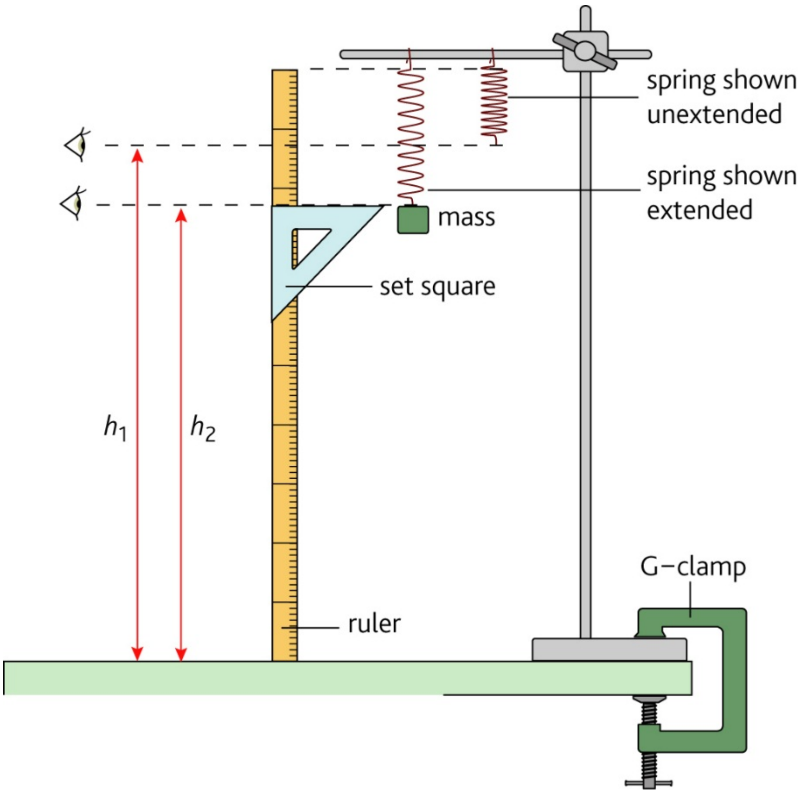


Figure 1 *Experimental set-up to measure the extension of a spring*

Results

Tabulate your results. For each extension, calculate the force applied and the extension of the spring. Enter these values into your table. Estimate the probable uncertainty in each extension measurement. Plot a graph of force against extension. Differentiate, on your graph, between the measurements taken when loading and when unloading the spring.

Questions

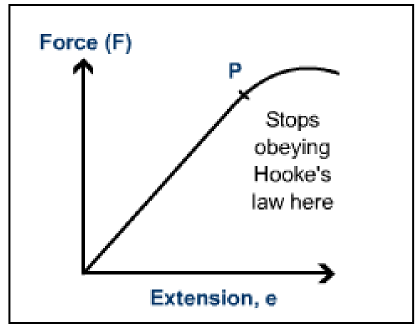
1 Calculate the force each of your masses exerts on the spring. (*1 mark*)

2 Explain how you calculated the extension of the spring from your measurements. (*1 mark*)

3 Use your graph to find the values for the force constant and the limit of proportionality of your spring. Estimate the probable uncertainty of this limit. (*3 marks*)

4 When unloading the spring, what do you notice about the gradient (and therefore the force constant) of the new line? (*2 marks*)

Hooke's Law



What did Hooke discover?

- the more **force** that was put on materials the more they ___________________
- With some materials they also extended in a regular way

  -eg. if the force was ___________________ so did the extension

- this was true as long as their ___________________ ___________________ was not exceeded

What is the elastic limit?

- The material no longer shows elastic ___________________

  -ie does not return to ___________________ size when stretching force is ___________________ ___________________

  -i.e. is ___________________ or ___________________ than ___________________

- The material is ___________________ as the above effects are caused by ___________________ of some atomic ___________________

Since Force is *proportional* to extension Hookes Law could be put as $F \propto x$

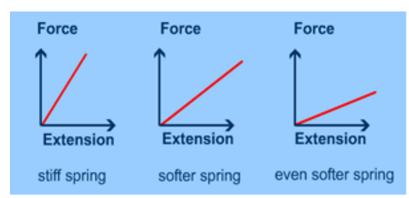
Where *F* is the applied force in ___________________

x is the extension in ___________________

Or if *k* is the ___________________ constant $F=kx$

What does k mean in F=kx?

- *k* is called the ___________________ **constant** and is a measure of the ___________________ of the ___________________ or material
- It has units of ___________________ (newtons per metre)
- The ___________________ the *k* the ___________________ the spring
- Materials with a ___________________ *k* need a ___________________ force to for a given ___________________



Example

- A spring is 0.38m long.
- When it is pulled by a force of 2.0 N, it stretches to 0.42 m.
- What is the spring constant? (Assume the spring behaves elastically.)

Extension:

An engineer needs to know how far a long beam will sag under a load. The table shows some results:

load (N)	1000	2000	3200	4400	5200	6500
sag (cm)	2.0	4.0	6.6	8.8	10.4	13.4

SAG: to sink, bend, or curve, esp. in the middle, from weight or pressure; to hang down unevenly or loosely; to lose firmness, strength, or intensity

a] Plot a graph of the sag against load. **(Plot x = load, y = sag)**

b] One of the measurements for sag is wrong.

(i) Which? (ii) What should the result be?

c] What would be the sag for a load of 4500 N?

d] What load would give a sag of 5.2 cm?

e] Would a longer beam sag more or less? Sketch its graph on the same axes.