Elasticity and Springs
Student Worksheet

In this experiment you will be testing the behaviour of a spring to see whether it behaves according to Hooke's law and, if so, to find the spring constant.

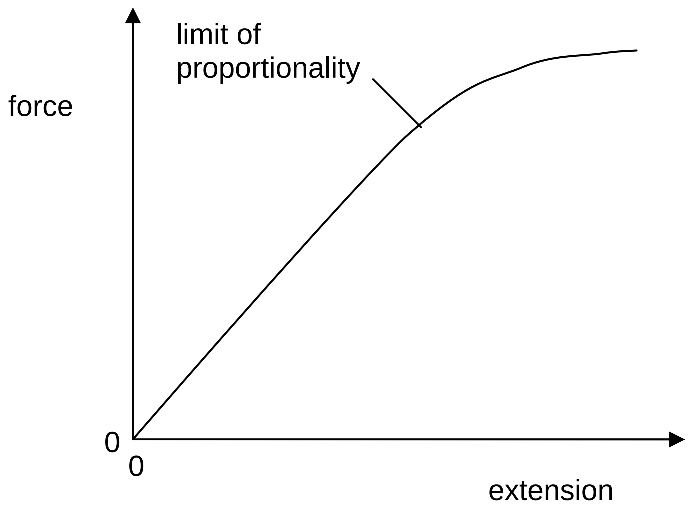
Theory

Hooke's law states that the extension x of an object is directly proportional to the force F applied. This may be written as

$$F = kx$$

where k is a constant known as the spring constant.

This behaviour only holds true for certain objects under certain loads. Once the load exceeds a limit, known as the limit or proportionality, the behaviour is no longer linear. This is shown in the force-extension graph below.



The work that must be done to extend a spring is equal to the area under the force-extension graph.

In this experiment you will:

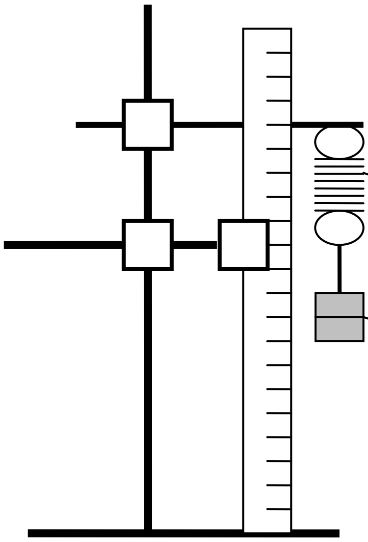
- find the spring constant for a spring that you have been given;
- find the energy stored in that spring for a certain force by calculating the area under the force-extension graph;
- investigate the same behaviour for different arrangements of springs in series and parallel.

Making measurements and observations

Safety Notice During this experiment springs will be extended under various loads. There is a chance that a spring will come loose and fly off. You must wear safety glasses at all times during this experiment.

1 Take a single spring and loop it over the bar of a clamp attached to a stand.

2 Attach a second clamp to the stand and use this to hold a half-metre rule. Arrange the rule close to the spring and is a position where it is easy to take a reading of the length of the spring. The arrangement is shown in the diagram.



3 Measure the total length of the unloaded spring. You may wish to use a pair of set squares to help get accurate readings.

4 Add a mass m to the spring.

5 Calculate the load F on the spring using

$$F = mg$$

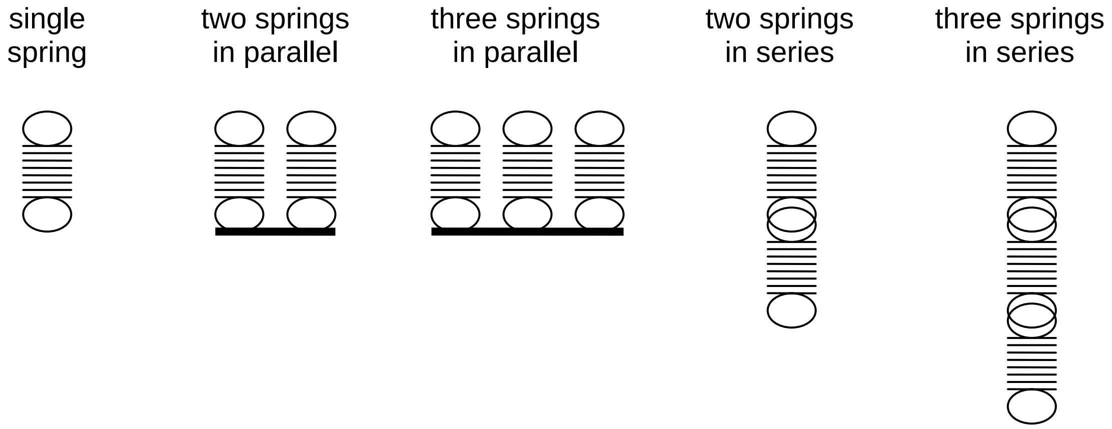
where $g = 9.8 \text{ m s}^{-1}$.

6 Record the load and the new length of the spring.

7 Repeat **4** – **6** for values of m in the range $0 \le m \le 0.40$ kg.

8 Continue adding greater loads until the spring fails. This will often happen because the loop at the end unwinds. If you need to, you should ask your teacher for extra masses.

7 Repeat **3** - **7** for different arrangements of springs in series and parallel such as those shown below. Do **not** test these springs to failure. In each case, the total mass should **not** go above 0.40 kg.
When connecting the springs in parallel, you will need to use a small piece of wooden dowel through the bottom loops of the spring. You should hang the loads from the piece of dowel so that the load is distributed between the springs. You may need to use small pieces of Blu-tack to stop the dowel from slipping.



Recording and presenting your data

1 For each combination of springs (including the single spring), draw up a table of results showing **all** the measurements you have taken. Each table of results should include a column for the extension of the springs.

2 For each combination of springs (including the single spring), plot a graph of force F (y-axis) against extension x (x-axis).

Analysing your data

1 Use the force-extension graph for the single spring to calculate the energy required to extend the spring to the limit of proportionality.

2 Calculate the gradient of the linear section of each of your force-extension graphs.

3 Use your answers to **2** to determine the spring constant k for each combination of springs (including the single spring).

4 For each combination of springs (including the single spring), calculate the value of k / K where K is the spring constant of the single spring.

5 Comment on your answers to **4**, drawing parallels to the resistances of combinations of electrical resistors.

Evaluation

1 Describe any steps that you took to reduce errors.

2 Any limitations or problems with the method chosen.

3 Suggest one way in which the accuracy of the measurements could be improved.

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Teaching Notes

Link to theory

10(b) describe the behaviour of springs in terms of load, extension, elastic limit, Hooke's law and the spring constant (i.e. force per unit extension)
10(f) deduce the strain energy in a deformed material from the area under a force extension graph

Key learning objectives

- To demonstrate the behaviour or materials that obey Hooke's law.
- To show what happens to a spring that is loaded beyond its elastic limit.

Notes

This experiment should be done before the Young modulus experiment as many of the foundation ideas of that practical are found in this one. They follow one into the other.

The students work will include calculations and a number of graphs. The key points to look for in their work are

- the correct identification of the limit or proportionality on the graph for a single spring;
- the correct area under the graph calculated (the most common mistake is to use g and cm instead of N and m, giving power of 10 errors);
- a correct value of the spring constant for the single spring.

Expected results

arrangement	**value of *k* / *K***
single spring	1
two springs in series	½
three springs in series	⅓
two springs in parallel	2
three springs in parallel	3

Possible extension work

Students can use their force-extension graph for a single spring as a calibration graph. They can suspend some objects from the spring and, by measuring the extension, determine the weight.

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Technical Notes

Apparatus requirements

1 **Stand, two bosses and two clamps.**

2 **Two set squares.**

3 **Blu-tack.**

4 **Half-metre rule.**

5 **100 g mass hanger and nine 100 g slotted masses.**

6 **Small piece of dowel,** about 10 cm in length, which can fit through the loops at the ends of the springs.

7 **Four springs,** identical, with loops at both ends. The spring constant should be approximately 25 N m^{-1} and the springs should fail with loads of more than 400 g but less than 1.0 kg. Expendable steel springs are suitable.

8 **Safety glasses or goggles.**

Notes

Even though the loads are relatively low**,** eye protection needs to be worn because, when the spring fails, it may fly off in an unpredictable direction.