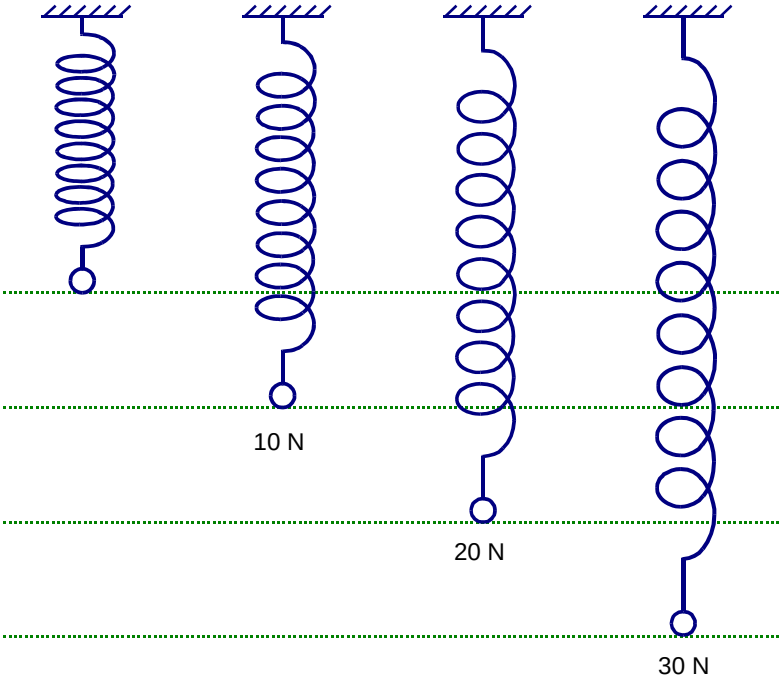
TAP 228- 2: Hooke's law and the Young modulus

Purpose

The Young modulus tells you about what happens when a material is stretched – how stiff is it? You have probably done an experiment to see how stiff a spring is. This reading explains how these two ideas are related.

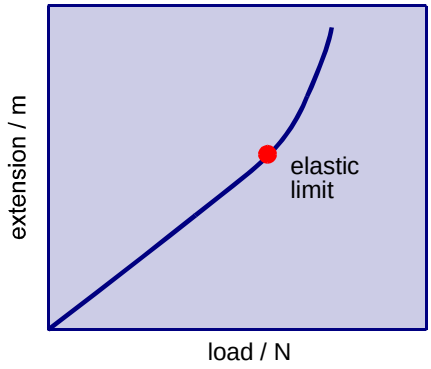
Relating stretching materials to stretching springs



You have probably done an experiment like the one shown here; use a load to stretch a spring, and the increase in length (extension) of the spring is proportional to the load. If a spring (or anything else) behaves like this, with extension proportional to load, we say that it obeys Hooke's law.

At first, if you remove the load, the spring returns to its original length. This is elastic behaviour.

Eventually, the load is so great that the spring becomes permanently deformed. You have passed the elastic limit.



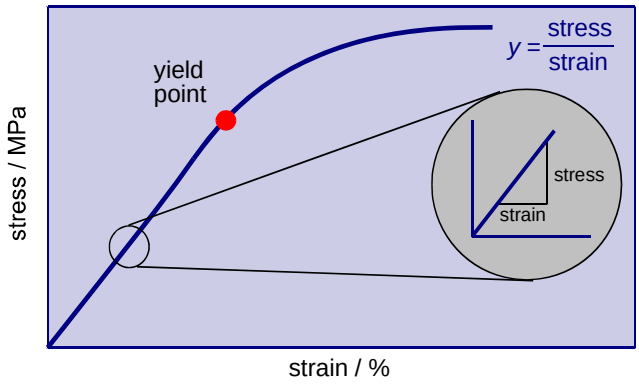
A graph is a good way to show this behaviour, one way is above, but it's usual to plot load on the y-axis and extension on the x-axis so that the spring constant k is measured in Nm^{-1} is the slope of the graph. (For the reason see: TAP 227-2: Tension and extension)

The initial straight-line part of the graph shows that the extension is proportional to the load.

After the elastic limit, the graph is no longer linear. Remove the load, and the spring is permanently stretched.

The initial slope of the load vs. extension graph shows how stiff the spring is – how many Newtons are needed to produce each centimetre (or metre) of extension. This is sometimes called the spring's stiffness or spring constant k.

Now compare this with the stress–strain graph for a copper wire.



The initial straight-line part of the graph shows that the strain is proportional to the stress.

After the elastic limit or yield point, the graph is no longer linear. Remove the load, and the wire is permanently stretched.

From the initial slope of the graph, we can deduce the Young modulus.

The graph will bend the same way to the Hooke's law graph if Tension is on the y-axis and extension on the x-axis. From the definitions of stress and strain, you should see that:

- stress corresponds to load
- strain corresponds to extension

Practical advice

At pre-16 level (or earlier), most students will have carried out a spring-stretching experiment. They may not be familiar with the formal term 'Hooke's law'.

This reading relates the measurement of the Young modulus to Hooke's law; students may need help with the idea of proportionality, and how this can be deduced from a graph.

The reading also considers the non-linear part of the graph. Conventionally, the axes are reversed for the Young modulus graph.

Social and human context

Robert Hooke and Thomas Young are both interesting characters who have far more to them than this relationship.

External references

This activity is taken from Advancing Physics Chapter 4, reading 40S