MINISTRY OF EDUCATION

SECONDARY ENGAGEMENT PROGRAMME

GRADE 10

PHYSICS

WEEK 9 **LESSON 1**

TOPIC: Forces

SUB-TOPIC: Deformation and Hooke's Law

OBJECTIVE: At the end of this lesson, students will be able to:

i) Describe experiments to determine extension-force graphs for springs and elastic bands

j) Calculate the spring constant

k) Identify regions on graphs of extension against force where Hooke's law does not apply

CONTENT

To cause an object to become deformed in Physics, means to cause it to change in size or shape. The deformation may be temporary (elastic deformation) or permanent (plastic deformation). The attractive forces between the molecules in a solid provide its characteristic elastic or stretchy properties. When we stretch a solid, we are very slightly increasing the spacing of its molecules. Then tension we can feel in a stretched spring is due to all the forces of attraction between the molecules in the spring.

Experimental Set-Up

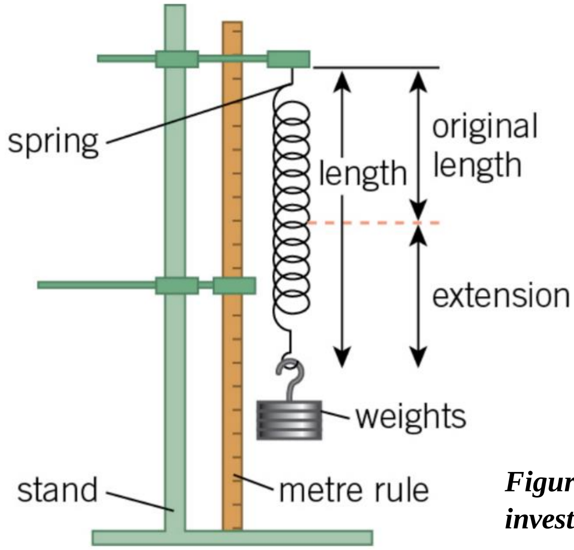


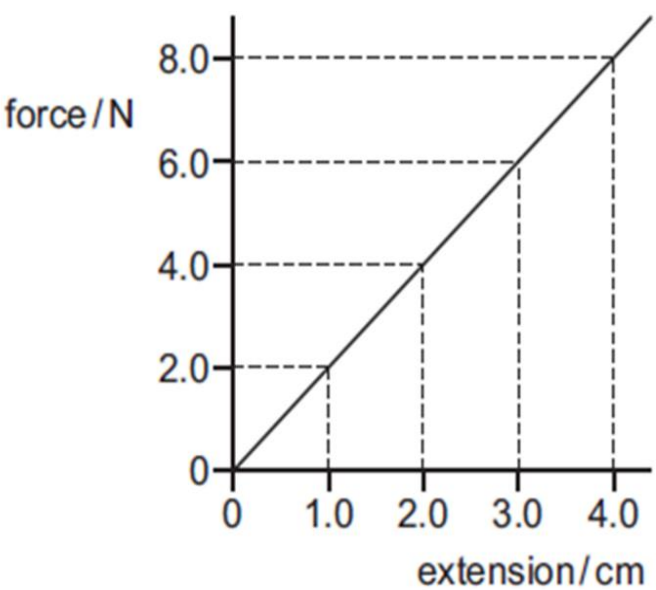
Figure 1 showing set up of apparatus to investigate the extension of a spring

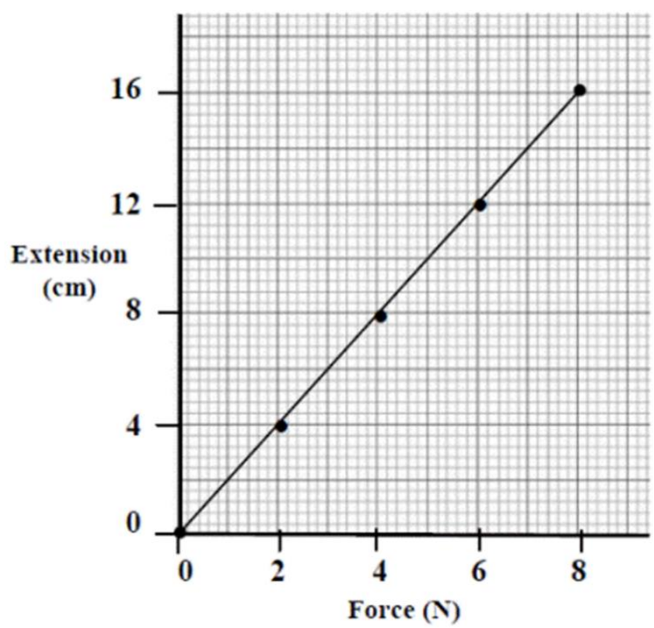
Method

- Arrange a stand to hold a millimeter scale close to a hanging spiral spring
- Attach a pointer to the end of the spring and take a scale reading of the pointer for an upstretched, unloaded spring.
- Hang a slotted mass hanger on the end of the spring and take a series of scale readings as incremental masses are added to the hanger, increasing the stretching force or load.
- Record your readings in a table like the one shown below

Mass on hanger (kg)	Stretching force (N)	Scale reading for length of spring (mm)	Extension of spring (mm)	$\frac{Force}{Extension}$ (Nmm^{-1})

- Calculate the stretching force using the formula F = m x g, where g = 10 or 9.8 N/kg
- Calculate the increase in length/extension of the spring by subtracting the initial length or scale reading for the unloaded spring from all the loaded readings
- **Calculate for all the readings the value of the ratio:** $\frac{stretching\ force}{extension}$
- Plot a graph of strength force or load (y axis) against extension (x axis).





Graph 1 showing Force vs Extension, while Graph 2 is showing Extension against Force

The graph of extension against the stretching force is a straight line showing that the extension of a spiral spring is directly proportional to the stretching force. In other words, if the stretching force is doubled the extension is doubled and so on.

$$Extension \propto Stretching\ Force$$

Provided that the spring is not stretched to the extent that it is damaged, a straight-line graph through the origin should be obtained, thus verifying Hooke's law.

The slope or gradient of the Force vs. Extension graph is equal to the force constant (k) of the spring.

Precautions to minimize errors

In Science, precautions serve to minimize errors as well as protect us from harm.

- It is ensuring that a pointer is fixed firmly to the bottom of the spring during the experiment to clearly record the length of the spring.
- Eye level readings are taken when the spring is at rest
- To reduce random error, the spring is loaded and unloaded and the average scale reading is calculated.
- It is ensured that the spring's support is firm so that it does not shift during the experiment

Spring Constant Calculation

We have already established that:

Extension ∝ Stretching Force

$$x \propto \mathrm{F}$$

The extent by which the extension will change as Force increases is constant up to a certain point. As such we can introduce the constant of proportionality or spring constant.

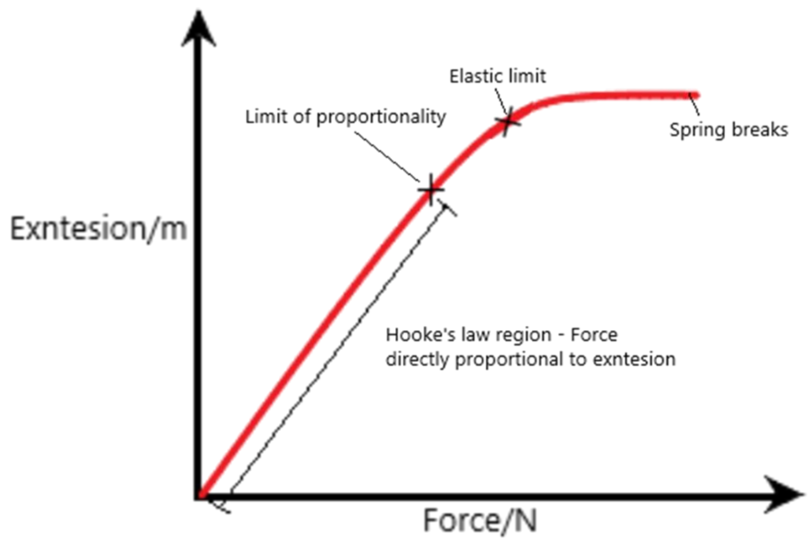
$$\text{Spring Constant} = \frac{Force}{Extenstion}$$

$$k = \frac{F}{x}$$

$$F = kx$$

Analyzing Force-extension Graphs:

- The proportional limit (P) is the point beyond which any further increase in the load applied to a spring will produce an extension that is no longer proportional to the force.
- The elastic limit (E) is the point beyond which any further increase in the load applied to a spring will produce a permanent stretch.
- For loads (forces) within the elastic limit, there is elastic deformation. This means that if the load is removed the spring will return to its original size and shape.
- Beyond the elastic limit, there is plastic deformation, meaning that the material is permanently stretched and incapable of returning to its original size and shape.
- The area between the graph line and the extension axis represents the work done in stretching the spring. If it is within the proportional limit, it is represented by the area of the enclosed triangle.



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