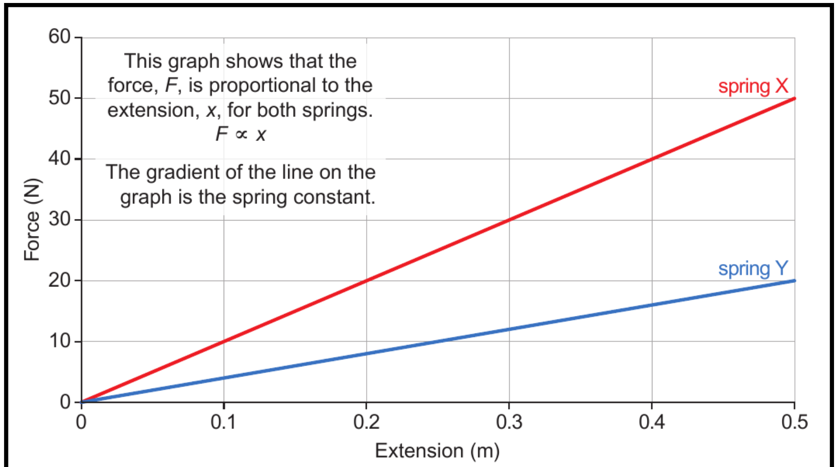
KS4: Physics: **Forces and Motion**

Keyword	Definition
direct proportion	A linear relationship in which one variable doubles as the other does.
elastic	An elastic material changes shape when there is a force on it but returns to its original shape when the force is removed.
inelastic	An inelastic material changes shape when there is a force on it but does not return to its original shape when the force is removed.
extension	The amount by which a spring or other stretchy material has stretched. It is worked out from the stretched length minus the original length.
linear relationship	A relationship between two variables shown by a straight line on a graph. For a linear relationship the line does not have to go through the origin.
non-linear relationship	A relationship between two variables that does not produce a straight line on a graph.
spring constant	A measure of how stiff a spring is. The spring constant is the force needed to stretch a spring by 1 m.
work done	A measure of the energy transferred when a force acts through a distance.



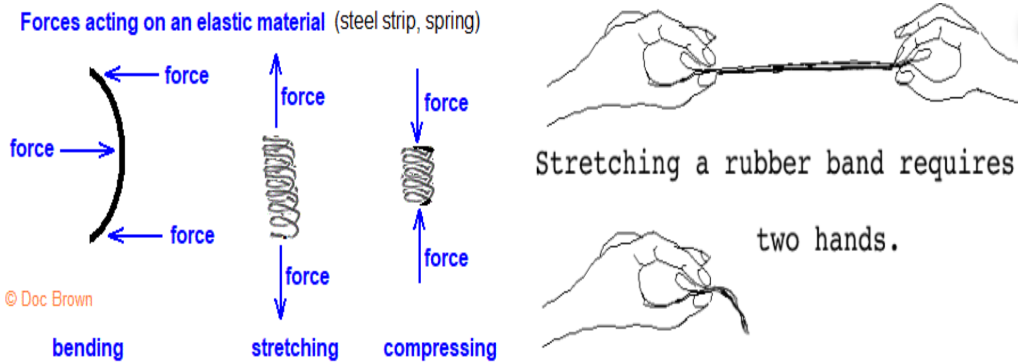
A Force-extension graph for two springs. The ∝ symbol means 'directly proportional to'.

To calculate the force exerted on a spring.
Extension is directly proportional to Force

$$F = k \times X$$

F= force (N)
K= spring constant (N/m)
X= extension (m)

Elastic objects return to their original shape after they've been stretched, **inelastic** ones don't!
Stretching, bending or compressing an object transfers **energy** and requires **more than one force. One force** is needed to hold one end whilst another force is needed to make the object move.



The spring constant, **k**, of a spring tells you how stretchy that spring is.

The spring constant (k) depends on the object that you are stretching.

Worked example W1

Calculate the spring constant for spring X in graph A.

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

$$= \frac{50\,N}{0.5\,m}$$

$$= 100\,N/m$$

You can choose any point on the graph to read off a force and extension.

Core Practical: Investigating force and extension with a spring

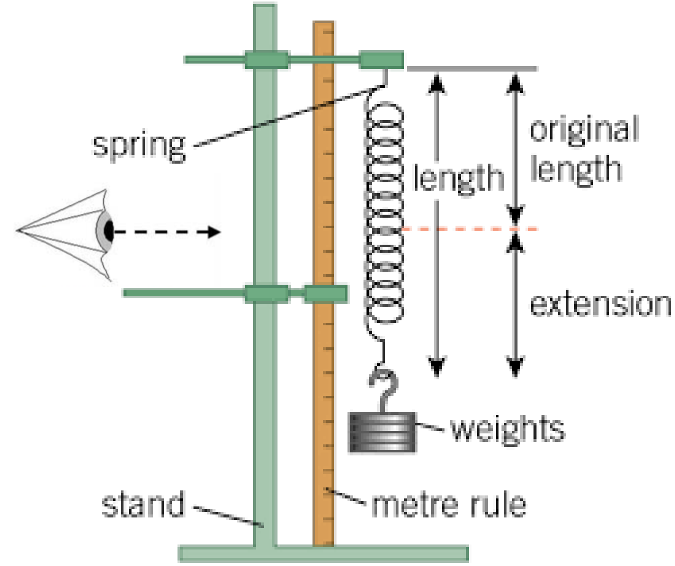
Safety: Hazard; Spring recoiling, wear eye protection
Apparatus: spring, clamp stand, 2 clamps and bosses, G-clamp, masses, ruler

Method

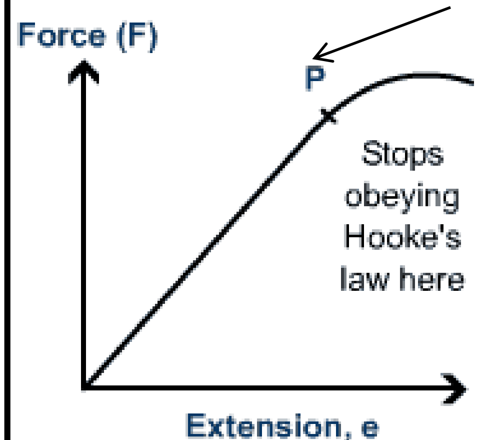
1. Secure a clamp stand to the bench using a G-clamp or a large mass on the base.
2. Use bosses to attach two clamps to the clamp stand.
3. Attach the spring to the top clamp and a ruler to the bottom clamp.
4. Adjust the ruler so that it is vertical and with its **zero level** with the top of the spring.
5. Measure and record the unloaded length of the spring.
6. Hang a 100g mass (0.1kg) from the spring. Measure and record the new length of the spring.
7. Add a 100g mass to the carrier. Measure and record the new length of the spring.
8. Repeat step 7 until you have added a total of 500g.
9. Record your results in a suitable table.
10. 10. Plot a line graph with extension (y axis) and force on x axis.

Force (N)	Extension of spring (length-original length) (cm)	Extension of spring (m)
0		

Read the extension with your eye level with the bottom of the spring



Point P is the limit of proportionality, past this point the equation F=k x X is no longer true.



The spring constant, **k**, of a spring tells you how stretchy that spring is.
Use the **gradient** of the line (force ÷ extension) to find the spring constant (k).

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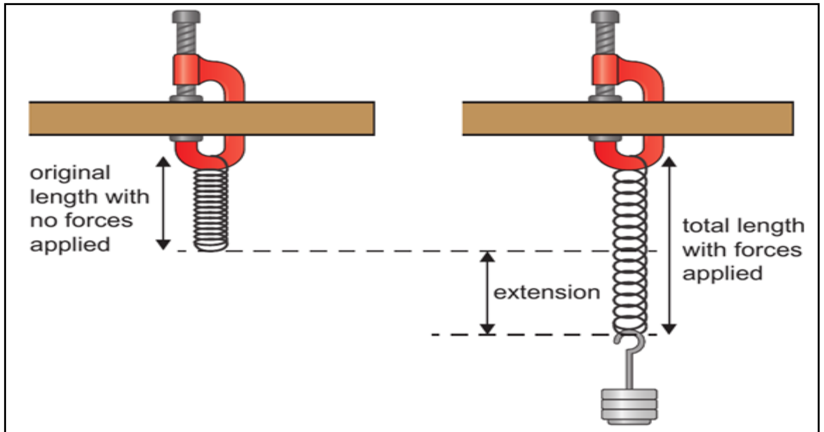
Core Practical: Investigating force and extension with a spring

Hazard	Risk	Precaution
Equipment falling off table	Heavy objects falling on feet - bruise/fracture	Use a G-clamp to secure the stand
Sharp end of spring recoiling if the spring breaks	Damage to eyes and cuts to skin	Wear eye protection and support and gently lower masses whilst loading the spring
Masses falling to floor if the spring fails	Heavy objects falling on feet - bruise/fracture	Gently lower load onto spring and step back

Two equations:
To learn off by heart:
$F = k \times X$

To be able to use:
$E = \frac{1}{2} kx^2$



C The *extension* of a spring is not the same as its length.

Worked example W2

Calculate the energy transferred when a spring with a spring constant of 100 N/m is stretched by 0.2 m.

$E = \frac{1}{2} \times k \times x^2$

$= \frac{1}{2} \times 100\ \text{N/m} \times (0.2\ \text{m})^2$

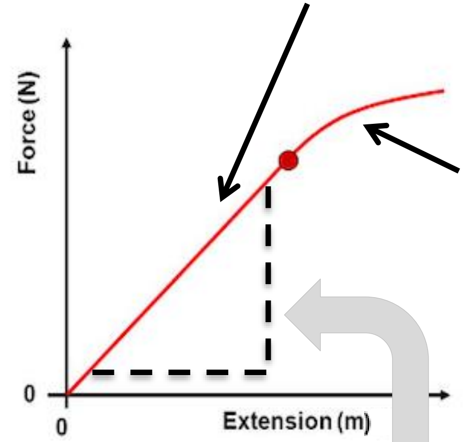
$= 2\ \text{J}$

To calculate work done for linear relationship (i.e. if the spring is not stretched past its limit):

$$E = \frac{1}{2} kx^2$$

E= energy
K= spring constant
X= extension

For an elastic object (e.g a spring) the extension is directly **proportional** to the force applied. For example, if the force is doubled, the extension doubles. The relationship is **linear.**



If a spring is stretched so much that is becomes distorted, force will no longer be proportional to extension. A **non-linear** relationship.