

Forces and matter

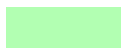
Specification 1SC0 · Pearson Edexcel

Free edition

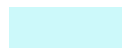
Revision notes for one topic, free to download.

These are the summary notes only. The full edition of this booklet also carries the worked examples, the required practicals and the formula sheets, with every topic in one place.

Colour Codes



Definitions



Diagrams



Notes and warnings



Sub-topic headings

This booklet is a study aid written from the published specification.
It is not affiliated with, endorsed by or approved by Pearson Edexcel.

**Free to download and share for personal study.
Please do not sell or republish it as your own.
For enquiries, please email pcfgyrdi@gmail.com**

Define Deformation (distortion)

- a change in the shape or size of an object caused by forces: stretching, bending or compressing.

Define Elastic distortion

- the object returns to its original shape and size when the forces are removed.

Define Inelastic distortion

- the object does **not** return to its original shape when the forces are removed; it stays permanently deformed.

Define Spring constant (k)

- the force needed per metre of extension, in newtons per metre (N/m); a measure of the stiffness of a spring.

Define Non-linear relationship

- the force–extension graph curves; extension is no longer proportional to force.

Define Elastic energy store

- the energy transferred to an object when work is done stretching or compressing it, recovered when it returns to its original shape.

Define Weight

- the force on a mass in a gravitational field, $W = m \times g$; this is the force that stretches a spring when masses are hung on it.

NOTE

READ THIS FIRST — COMBINED SCIENCE IS SPRINGS ONLY

Combined Science has just **six statements, 15.1–15.6**, and they are all about **springs**. Edexcel states that **specification points 15.7 to 15.17 are in the GCSE in Physics only**, so Combined Science does **not** include atmospheric pressure and height, pressure in a fluid, the equation $P = F \div A$, pressure with depth and density, the equation $P = h \times \rho \times g$, or upthrust, floating and sinking.

Combined Science does include: that stretching, bending or compressing needs more than one force (15.1); elastic and inelastic distortion (15.2); $F = k \times x$ and the spring constant (15.3); $E = \frac{1}{2} \times k \times x^2$ (15.4); linear and non-linear force–extension relationships (15.5); and **Core Practical 15.6**.

Tiering: nothing in Topic 15 is bold in the Combined Science specification, so **no part of this topic is Higher Tier only** — every statement is examined at both tiers, and **both** equations appear on the Foundation as well as the Higher formulae arrangements.

Define Extension

- the increase in length of an object compared with its original (unstretched) length.

Define Linear relationship

- force and extension are directly proportional, giving a straight line through the origin on a force–extension graph.

Define Limit of proportionality

- the point beyond which extension is no longer directly proportional to the force, so the graph stops being a straight line.

Define Work done in stretching

- the energy transferred by the stretching force; the area under a force–extension graph.

15.1 Stretching, bending and compressing need more than one force

- To **stretch, bend or compress** an object, more than one force must act on it. A single force would simply accelerate the object instead of changing its shape.
- Stretching a spring: you pull down on the bottom while the **hook or clamp pulls up** on the top. Hang a spring in mid-air and pull it with one force and it just moves.
- Bending a ruler: a downward force in the middle and **upward forces at both ends**. Compressing a spring: an inward force at each end.
- The forces must be **opposing** each other; if they are equal and opposite the object stays still while it changes shape.

15.2 Elastic and inelastic distortion

	Elastic distortion	Inelastic distortion
When the force is removed	Returns to its original shape and length	Stays permanently deformed
Energy transferred	Stored elastically , and recovered when the object springs back	Not fully recovered — some is transferred to the surroundings by heating
Example	A spring below its limit of proportionality; a bouncy ball; a bow	A stretched-out spring; a squashed drinks can; Blu-tack

- A spring stretched **beyond its limit of proportionality** eventually becomes **inelastically** distorted, and will not return to its original length.
- Elastic distortion is what allows a spring to store energy and give it back — the basis of clockwork, catapults and vehicle suspension.

15.3 Force and extension: the spring constant

ANALOGY

Spring constant — how much a pull "costs". The spring constant is the price of one metre of stretch. A stiff spring with $k = 500 \text{ N/m}$ charges 500 N per metre, so your 10 N pull buys you only 2 cm. A floppy spring with $k = 20 \text{ N/m}$ gives you 50 cm for the same 10 N. Big k means stiff; small k means easily stretched.

15.4 The energy stored in a stretched spring

Work is done when a force stretches a spring, and this energy is stored **elastically** in the spring. If the distortion is elastic, all of it is transferred back when the spring returns to its original length.

WATCH OUT

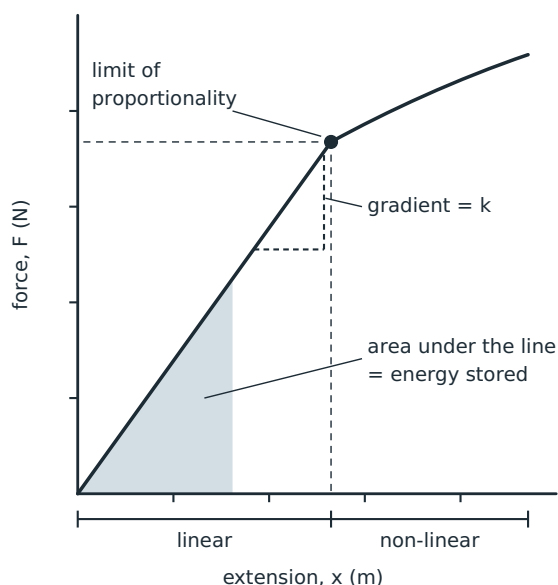
The energy stored is **not** $F \times x$. The force grows from zero as the spring stretches, so you use the **average** force — which is where the factor of $\frac{1}{2}$ comes from, and why the answer is the **triangular area** under a force–extension graph, not the whole rectangle.

15.5–15.6 Linear and non-linear force–extension relationships

- A **linear** relationship gives a **straight line through the origin** on a force–extension graph: extension is **directly proportional** to force, and $F = k \times x$ applies. Double the force, double the extension.
- The **gradient** of a force–extension graph is the **spring constant** (force on the y-axis, extension on the x-axis). A steeper line means a stiffer spring.
- The **limit of proportionality** is the point where the line stops being straight. Beyond it the relationship is **non-linear**: the graph curves, the extension increases more for each extra newton, and $F = k \times x$ no longer works.
- Stretch further still and the spring is **inelastically** distorted — it will not return to its original length when unloaded.
- Rubber bands are **non-linear** from the start, and follow a different path when loaded and unloaded.

Force–extension graphs, the spring constant and the energy stored

Force-extension graph for a spring



Extension

The increase in length from the unstretched spring.

Linear region

force exerted on a spring (newton, N)
= spring constant (N/m) × extension (m)

$$F = k \times x$$

The gradient of the straight part of the graph is the spring constant, k .

Limit of proportionality

Beyond this point the graph is no longer a straight line: the relationship between force and extension becomes non-linear.

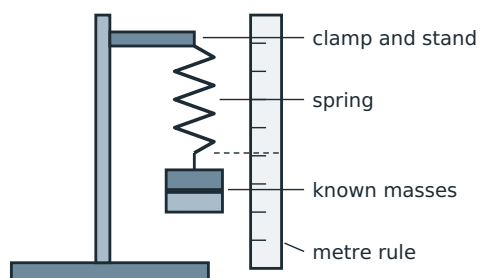
Energy transferred in stretching

= the area under the line

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

Core practical 15.6

Investigate the extension and work done when applying forces to a spring.



Method

- 1 Measure the length of the spring with no masses attached.
- 2 Add a known mass, measure the new length and work out the extension.
- 3 Repeat, adding one mass at a time.
- 4 Plot force (weight) against extension and calculate the work done.

Elastic and inelastic distortion

Elastic: the spring returns to its original length when the force is removed.

Inelastic: the spring is permanently stretched and does not return.

Use of mathematics in this topic

- Use ratios and proportional reasoning to **convert units**: cm and mm to metres, g to kg.
- Rearrange $F = k \times x$ for any of the three quantities, and take the **spring constant from the gradient** of a force–extension graph.
- Calculate stored energy with $E = \frac{1}{2} \times k \times x^2$, and find the **work done from the area under a force–extension graph**; convert between newton-metres and joules ($1 \text{ N m} = 1 \text{ J}$).
- Make calculations of the energy changes associated with changes in a system, selecting the relevant equation.
- Suggested practical: investigate the stretching of rubber bands.