

Forces and elasticity

4.5.3 · Forces · revision notes

Stretching, squashing or bending an object needs more than one force. You need $F = k e$, the difference between elastic and inelastic deformation, the limit of proportionality, force–extension graphs and the required practical on a spring. The equation for elastic potential energy, $E_e = \frac{1}{2} k e^2$, is given on the equations sheet.

Key facts

- $F = k e$ (force = spring constant $\times$ extension)
- Extension = stretched length – original length
- $F \propto e$ up to the limit of proportionality
- Units: F in N, k in N/m, e in m
- Elastic deformation: returns to original shape; inelastic deformation: does not
- Gradient of a force–extension graph (force on the y-axis) = k

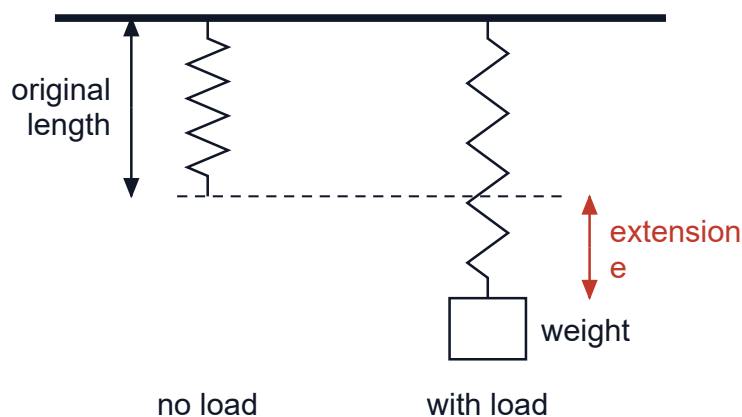
Notes

Changing shape

- To stretch, bend or compress an object you need **more than one force**. To stretch a spring, you pull on both ends, or hang a weight from it while a clamp holds the top.
- **Elastic deformation**: the object returns to its original length and shape when the forces are removed.
- **Inelastic deformation**: the object does not return to its original length and shape when the forces are removed.

Force and extension: $F = k e$

- force = spring constant $\times$ extension: $F = k e$
- F in newtons (N), k in newtons per metre (N/m), e in metres (m).
- Extension is the **increase** in length: extension = stretched length – original length. The same equation works for compression.

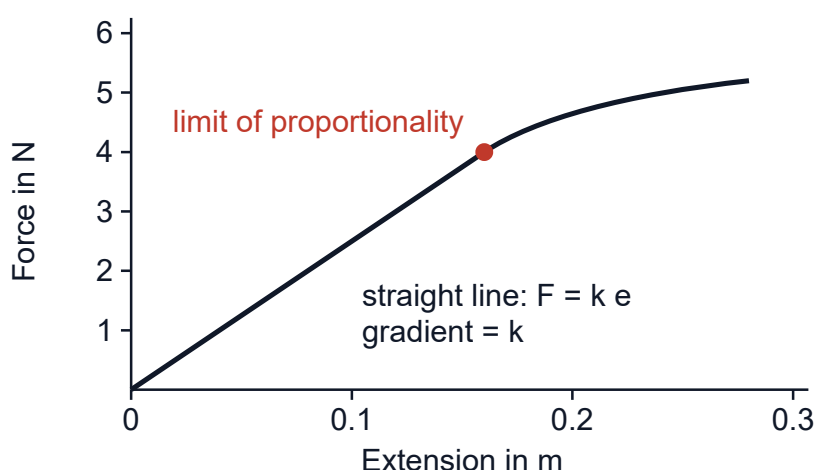


Extension = stretched length – original length.

- The extension of an elastic object is **directly proportional** to the force applied, provided the **limit of proportionality** is not exceeded.
- A stiffer spring has a larger spring constant: it needs a bigger force for each metre of extension.

Force–extension graphs

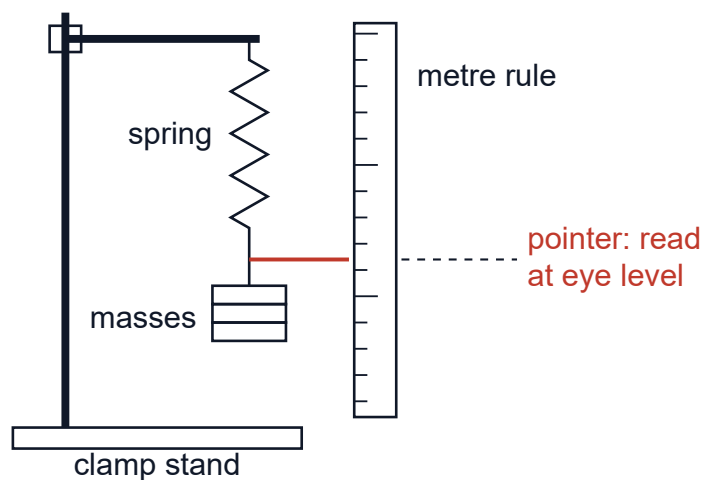
- With force on the y-axis and extension on the x-axis, the graph is a straight line through the origin (linear) up to the limit of proportionality.
- The gradient of this straight section is the spring constant, k .
- Beyond the limit of proportionality the line curves (non-linear): extension is no longer proportional to force.



Straight up to the limit of proportionality (here $k = 4.0 \div 0.16 = 25 \text{ N/m}$), then it curves.

Required practical: force and extension of a spring

- Clamp the spring next to a vertical metre rule and measure its original length.
- Hang weights in equal steps. Each time, measure the new length and calculate the extension. Read the ruler at eye level, using a pointer on the bottom of the spring.



Force and extension of a spring: add masses in equal steps and read the pointer each time.

- Plot force (the weight added) against extension.

How to answer each type of question

Calculate using $F = k e$

2 to 3 marks

Grade 5

1. Work out the extension (new length – original length).
2. Convert it to metres.
3. Substitute into $F = k e$ (or rearrange for k or e).

Example. A spring has a spring constant of 25 N/m. Its original length is 12.0 cm. A force stretches it to a length of 18.0 cm. The limit of proportionality is not exceeded. Calculate the force.

Model answer. extension = $18.0 - 12.0 = 6.0 \text{ cm} = 0.060 \text{ m}$ (1)

$F = 25 \times 0.060$ (1)

$F = 1.5 \text{ N}$ (1)

Don't lose marks

- ✗ Using the stretched length instead of the extension.
- ✗ Forgetting to convert cm or mm to metres.
- ✗ Using $E_e = \frac{1}{2} k e^2$ beyond the limit of proportionality.
- ✗ Plotting extension on the y-axis and calling the gradient k . With extension on the y-axis, the gradient is $1 \div k$.

✗ Squaring $k \times e$ instead of squaring only the extension.

More tips

Memory tricks

- Extension, not length: always subtract the original length first.
- cm to m: divide by 100, so 6.0 cm = 0.060 m.
- Stiff spring = steep force–extension line = big k .
- For $\frac{1}{2} k e^2$, square the extension first, then multiply by k , then halve.

Exam technique

- $F = k e$ must be recalled; $E_e = \frac{1}{2} k e^2$ is on the equations sheet.
- Before using a graph, check which quantity is on each axis.
- In method questions, name the instrument (metre rule), what you measure (length), what you calculate (extension) and what you plot.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 3

Explain why more than one force is needed

To stretch, bend or compress an object, forces must act on it in different directions.

Grade 4

Distinguish elastic and inelastic deformation

An elastically deformed object returns to its original shape when the forces are removed; an inelastically deformed one does not.

Grade 5

Calculate force or extension with $F = ke$

For example, $k = 40 \text{ N/m}$ and $e = 0.15 \text{ m}$ give $F = 6.0 \text{ N}$.

Grade 5

Describe the spring extension required practical

Hang known weights on a spring, measure its length each time, calculate the extension and plot force against extension.

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