# 6 Deformation of solids – Part 1

Name: _____ Class: _____ Date: _____

## Vocabulary

*Write each word three times.*

| **English** | **Write it 3 times** (English) | | |
|---|---|---|---|
| deformation | | | |
| extension | | | |
| Hooke's law | | | |
| spring constant | | | |
| limit of proportionality | | | |
| elastic | | | |
| plastic | | | |
| Stress | | | |
| strain | | | |
| Young modulus | | | |
| elastic potential energy | | | |

## Recall

At IGCSE you stretched springs. Bring this with you:

- When you stretch or squash a solid you cause **deformation** .
- The **extension** is how much longer a spring becomes when you pull it.
- You met **Hooke's law** : the extension is proportional to the force, up to a



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point.

At AS we write this exactly and extend it to any material with stress, strain and the Young modulus.

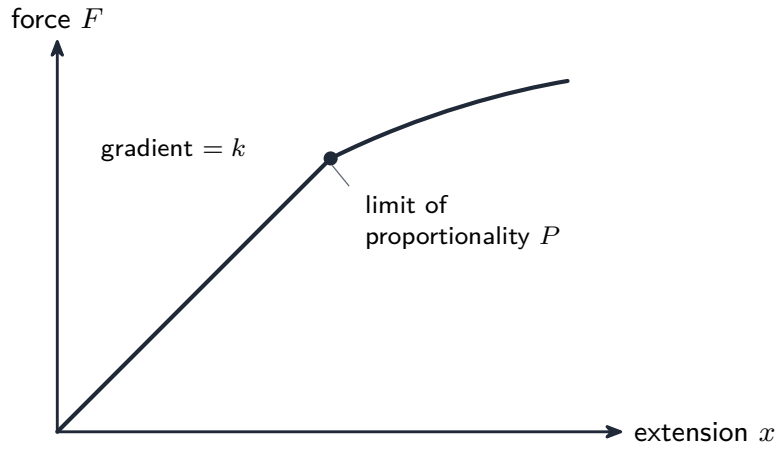
## New ideas

### ■ 1 Hooke's law

For a spring, force and extension are proportional:

$$F = kx,$$

where $k$ is the **spring constant** (in N m$^{-1}$) and $x$ is the extension. This holds only up to the **limit of proportionality** .




Below the **elastic** limit a material springs back to its shape; beyond it the change is **plastic** (permanent).

*Worked example.* A spring needs 6.0 N to stretch it 0.15 m: $k = \dfrac{F}{x} = \dfrac{6.0}{0.15} = 40$ N m$^{-1}$.

### ■ 2 Stress, strain and the Young modulus

For a wire of cross-sectional area $A$ and original length $L$ stretched by $x$:

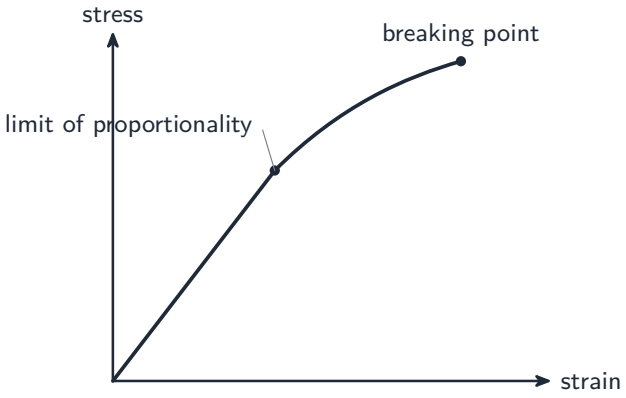
$$\text{stress } \sigma = \frac{F}{A}, \qquad \text{strain } \varepsilon = \frac{x}{L}.$$

**Stress** has units Pa; **strain** is just a ratio (no unit). Their ratio is the **Young modulus** , a fixed number for each material:

$$E = \frac{\sigma}{\varepsilon}.$$

*Worked example.* A wire ($A = 5.0\times10^{-7}$ m$^2$, $L = 2.0$ m) stretches 1.0 mm under 50 N: $\sigma = \dfrac{50}{5.0\times10^{-7}} = 1.0\times10^{8}$ Pa, $\varepsilon = \dfrac{1.0\times10^{-3}}{2.0} = 5.0\times10^{-4}$, so $E = \dfrac{1.0\times10^{8}}{5.0\times10^{-4}} = 2.0\times10^{11}$ Pa.

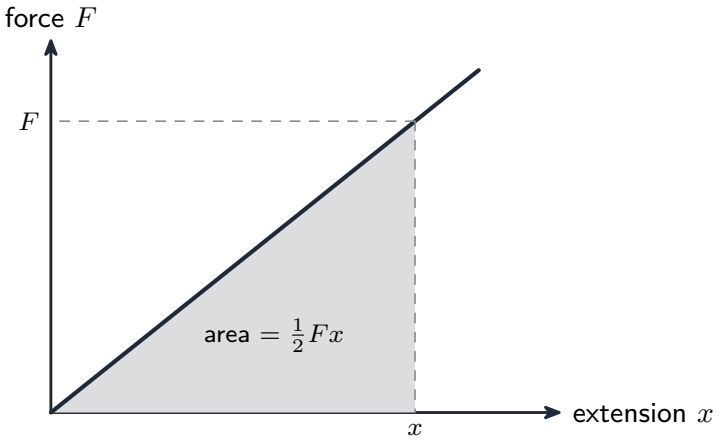

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**Watch out:** the Young modulus is a property of the *material*, not the wire – a thicker or longer wire of the same metal has the same $E$.

### 3 Elastic potential energy

The energy stored in a stretched spring is the area under its force–extension line – the **elastic potential energy** :




$$E = \tfrac{1}{2}Fx = \tfrac{1}{2}kx^2.$$

## Practice

**6.1** A spring has spring constant 25 N m$^{-1}$. Find the force needed to stretch it 0.20 m. [2]

**6.2** Explain the difference between elastic and plastic behaviour. [2]

**6.3** A wire of cross-sectional area $4.0 \times 10^{-7}$ m$^2$ carries a load of 32 N. Find the stress. [2]

**6.4** A 2.5 m wire stretches by 2.0 mm. Find the strain. [1]

**6.5** Using the stress from 6.3 and strain from 6.4, find the Young modulus. [2]

**6.6** Find the elastic potential energy stored in the spring of 6.1 when stretched 0.20 m. [2]

**6.7 Challenge.** Two wires are of the same material and thickness, but one is twice as long. Under the same pulling force, explain which one stretches more. [2]