

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 propor- tionality	_____	_____	_____
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 point.

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

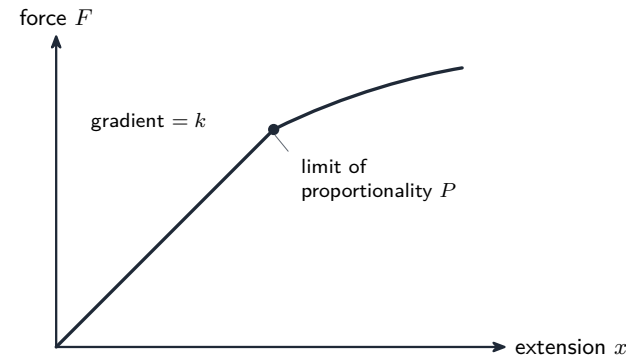
New ideas

■ 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: $k = \frac{F}{x} = \frac{6.0}{0.15} = 40 \text{ N m}^{-1}$.

■ 2 Stress, strain and the Young modulus

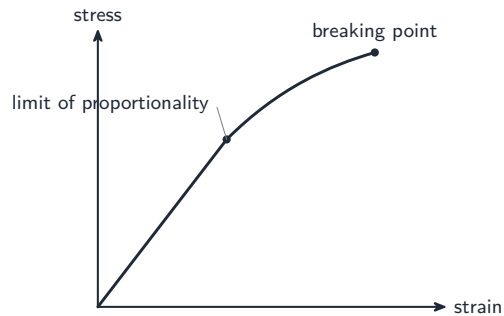
For a wire of cross-sectional area A and original length L stretched by x :

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

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

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

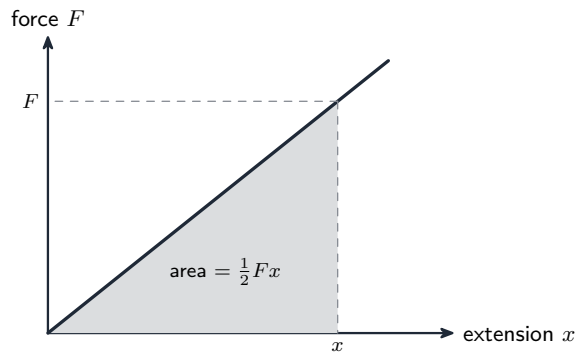
Worked example. A wire ($A = 5.0 \times 10^{-7} \text{ m}^2$, $L = 2.0 \text{ m}$) stretches 1.0 mm under 50 N:
 $\sigma = \frac{50}{5.0 \times 10^{-7}} = 1.0 \times 10^8 \text{ Pa}$, $\varepsilon = \frac{1.0 \times 10^{-3}}{2.0} = 5.0 \times 10^{-4}$, so $E = \frac{1.0 \times 10^8}{5.0 \times 10^{-4}} = 2.0 \times 10^{11} \text{ Pa}$.



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**:



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

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 $4.0 \times 10^{-7} \text{ m}^2$ 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]