6.1 Stress and strain

Name: ____________ Class: ________ Date: __________ **Total: 16 marks**

Objective

Build the skills to answer exam questions on **stress and strain** —Hooke's law, the spring constant, and the Young modulus.

You must be able to:

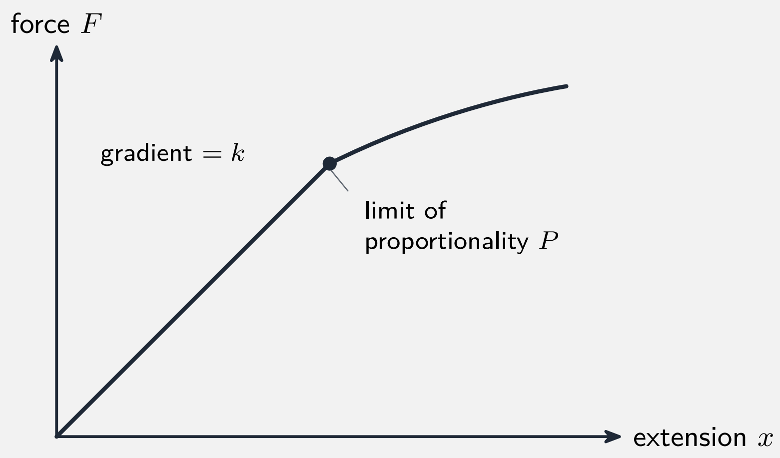
- use **Hooke's law** $F = kx$ and find k from a graph
- define and use **stress**, **strain** and the **Young modulus**
- describe the experiment to measure the **Young modulus** of a wire

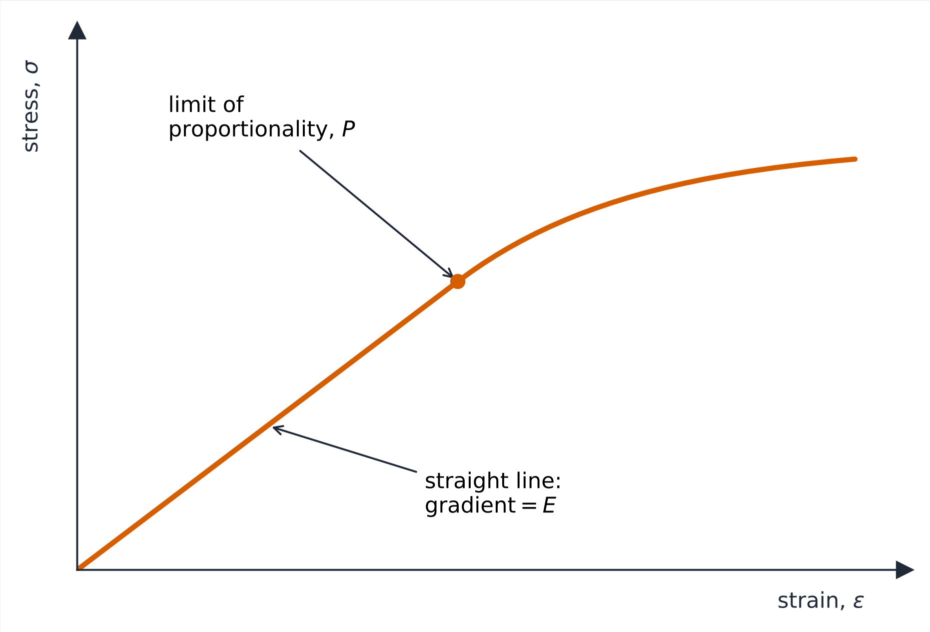
1 Worked examples

Study these first. Each one shows the method for a question type used later —follow the steps and you can do the Practice and Exam-style questions yourself.

■ Hooke's law and spring constant

For small loads, **extension is proportional to load**: $F = kx$, so the **spring constant** $k = F/x$ (unit N m^{-1}). On a force–extension graph the **gradient is** k in the straight region, up to the **limit of proportionality**:





The stress-strain graph for a material

Worked example. A spring extends 4.0 cm under a 2.0 N load: $k = F/x = 2.0/0.040 = 50\ \text{N m}^{-1}$.

■ **Stress, strain, Young modulus**

$$\text{stress } \sigma = \frac{F}{A}\ (\text{Pa}), \qquad \text{strain } \varepsilon = \frac{x}{L}\ (\text{no unit}), \qquad E = \frac{\sigma}{\varepsilon}\ (\text{Pa}).$$

Young modulus experiment (wire): measure the original length L and diameter ($\rightarrow$ area A); add known loads; measure the extension x (e.g. with a marker and ruler/travelling microscope); plot stress against strain; E is the gradient of the straight part.

2 Practice

Now apply the methods above.

2.1 State **Hooke's law**. [1]

2.2 A spring extends 4.0 cm when a 2.0 N load is hung from it. Find the **spring constant**. [2]

2.3 Define **stress** and **strain**. [2]

2.4 State the unit of the **Young modulus**. [1]

3 Exam-style questions

3.1 In the straight region, the **gradient** of a force–extension graph gives the: [1]

- **A** Young modulus
- **B** spring constant
- **C** stress
- **D** strain

3.2 A wire of length 2.0 m and cross-sectional area 1.0×10^{-6} m^2 stretches by 1.0 mm under a 100 N load. Calculate (a) the stress, (b) the strain, (c) the Young modulus. [4]

3.3 Describe an experiment to measure the **Young modulus** of a metal wire. [4]

3.4 Explain what is meant by the **limit of proportionality**. [1]

4 Go further

You are now ready for the real exam questions on this subtopic. Open the **6.1 Stress and strain** past-paper sheet in the Library, or try these in **Practice mode**:

- 9702/22 N25 —Q3 (Young modulus calculation)
- 9702/21 N25 —Q3 (stress, strain and Young modulus)
- 9702/11 J25 —Q21 (Hooke's law)
- 9702/24 J25 —Q3 (Young modulus)

Solutions

2.1 The **extension is proportional to the load** (up to the limit of proportionality).

2.2 $k = F/x = 2.0/0.040 = 50$ N m^{-1}.

2.3 **Stress** = force per unit cross-sectional area (F/A); **strain** = extension per unit original length (x/L).

2.4 **Pa** (N m^{-2}).

3.1 **B** —spring constant.

3.2 (a) $\sigma = F/A = 100/(1.0 \times 10^{-6}) = 1.0 \times 10^{8}$ Pa. (b) $\varepsilon = x/L = (1.0 \times 10^{-3})/2.0 = 5.0 \times 10^{-4}$. (c) $E = \sigma/\varepsilon = (1.0 \times 10^{8})/(5.0 \times 10^{-4}) = 2.0 \times 10^{11}$ Pa.

3.3 Any four: measure original length L and diameter ($\rightarrow$ area A); hang the wire and add known loads; measure the extension with a marker against a fixed scale; plot stress against strain and find E from the gradient of the straight part.

3.4 The point beyond which **extension is no longer proportional to load** (the F–x line stops being straight).