

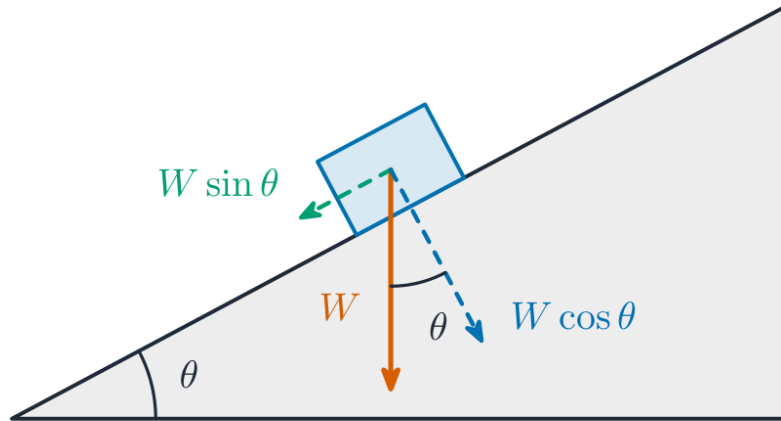
Exercise walk-through

1.8

Solid materials: Hooke's law, stress–strain and strain energy (statements 27–32, core practical 3)

Pearson Edexcel · International A-Level · Physics

Resolve from the marked angle



- Draw a right triangle: the adjacent component uses cosine, the opposite uses sine.
- For a slope at angle θ :
 $W_{\parallel} = W \sin \theta$, $W_{\perp} = W \cos \theta$.
- Combine perpendicular components with Pythagoras and give a direction.

Read the stages of a stress–strain curve

- Proportional limit ends the straight region; elastic limit ends fully recoverable deformation.
- Yield behaviour varies by material; beyond the elastic limit there is permanent strain.
- Gradient of the initial straight region gives Young modulus; fracture sets breaking stress.

Core practical 3: Young modulus of a wire

- Measure original length; measure diameter at several positions and orientations with a micrometer.
- Add loads in steps; measure extensions and plot stress against strain in the proportional region.
- Use the gradient for E ; repeat/unload to check elastic behaviour and control zero errors.

Exercises 2.1·2.3

2.1 A spring extends 4.0 cm under 10 N. Calculate its stiffness. [2]

2.2 Define (a) stress and (b) strain, giving the unit of each. [2]

2.3 A wire of cross-sectional area $2.0 \times 10^{-6} \text{ m}^2$ carries 50 N. Calculate the stress. [2]

Exercises 2.1·2.3

2.1 A spring extends 4.0 cm under 10 N. Calculate its stiffness. [2]

$$\mathbf{2.1} \quad k = \frac{\Delta F}{\Delta x} = \frac{10 \text{ N}}{0.040} = 250 \text{ N m}^{-1}.$$

2.2 Define (a) stress and (b) strain, giving the unit of each. [2]

2.2 (a) stress = force per cross-sectional area, unit Pa; (b) strain = extension per original length, no unit.

2.3 A wire of cross-sectional area $2.0 \times 10^{-6} \text{ m}^2$ carries 50 N. Calculate the stress. [2]

$$\mathbf{2.3} \quad \sigma = \frac{F}{A} = \frac{50 \text{ N}}{2.0 \times 10^{-6} \text{ m}^2} = 2.5 \times 10^7 \text{ Pa}.$$

Exercises 2.4·3.1

2.4 A spring obeys Hooke's law with $k = 250 \text{ N m}^{-1}$. Calculate the elastic strain energy stored when it is stretched by 6.0 cm. [*Hint: find F first.*] [3]

3.1 A spring is stretched beyond its elastic limit and the force is then removed. What happens? [1]

☐

- A** the force was proportional to the extension throughout
- B** the spring returns to its original length
- C** plastic deformation began before the elastic limit
- D** the spring keeps a permanent extension

Exercises 2.4·3.1

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2.4 $F = k \Delta x = 250 \text{ N m}^{-1} \times 0.060 \text{ m} = 15 \text{ N}$; $\Delta E_{\text{el}} = \frac{1}{2} F \Delta x = \frac{1}{2} \times 15 \text{ N} \times 0.060 \text{ m} = 0.45 \text{ J}$.

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A the force was proportional to the extension throughout

B the spring returns to its original length

C plastic deformation began before the elastic limit

D the spring keeps a permanent extension

3.1 D. Beyond the elastic limit the deformation is plastic, so a permanent extension remains. A fails at the limit of proportionality; B describes elastic deformation; C starts plasticity too early.

Exercise 3.2

3.2 The stress on a sample is increased until it breaks. What does the gradient of the straight part of the stress–strain graph give? [1]

☐

A the area under the graph

B the Young modulus

C the breaking stress

D the yield point

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3.2 B. The gradient of stress over strain is the Young modulus. The breaking stress is a point on the stress axis, the yield point a point on the curve, and the area is the strain energy per unit volume – not the gradient.

Exercise 3.3

3.3 A climbing rope sample has original length 40.0 m and stretches to 41.4 m under load.

(a) Calculate the strain in the sample. [2]

(b) The rope's cross-sectional area is $1.1 \times 10^{-4} \text{ m}^2$ and the stress at this strain is 95 MPa. Calculate the force on the rope. [3]

(c) Calculate the Young modulus of the rope material. [2]

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3.3 (a) $\varepsilon = \frac{\Delta x}{x} = \frac{41.4 \text{ m} - 40.0 \text{ m}}{40.0 \text{ m}} = 0.035$. (b) $\sigma = \frac{F}{A} \Rightarrow F = \sigma A$: $F = 95 \times 10^6 \text{ Pa} \times 1.1 \times 10^{-4} \text{ m}^2 = 1.0 \times 10^4 \text{ N}$. (c) $E = \frac{\sigma}{\varepsilon} = \frac{95 \times 10^6 \text{ Pa}}{0.035} = 2.7 \times 10^9 \text{ Pa}$.

Full solution 3.3

$$\mathbf{3.3} \text{ (a) } \varepsilon = \frac{\Delta x}{x} = \frac{41.4 \text{ m} - 40.0 \text{ m}}{40.0 \text{ m}} = 0.035. \text{ (b) } \sigma = \frac{F}{A} \Rightarrow F = \sigma A: F = 95 \times 10^6 \text{ Pa} \times 1.1 \times 10^{-4} \text{ m}^2 = 1.0 \times 10^4 \text{ N. (c) } E = \frac{\sigma}{\varepsilon} = \frac{95 \times 10^6 \text{ Pa}}{0.035} = 2.7 \times 10^9 \text{ Pa.}$$

Exercise 3.4

3.4 A brick in a wall is compressed. Its force–compression graph is a straight line through the origin passing through (50 nm, 100 N).

(a) Calculate the stiffness of the brick in compression. [2]

(b) Determine the increase in elastic strain energy in the brick as the force rises from 100 N to 200 N. [3]

(c) State what is meant by **elastic** deformation. [1]

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Full solution 3.4

3.4 (a) $k = \frac{\Delta F}{\Delta x} = \frac{100 \text{ N}}{50 \times 10^{-9} \text{ m}} = 2.0 \times 10^9 \text{ N m}^{-1}$. (b) The increase is the area of the trapezium between the two forces: $\Delta E_{\text{el}} = \frac{1}{2}F_2x_2 - \frac{1}{2}F_1x_1$ with $x_1 = 50 \text{ nm}$, $x_2 = 100 \text{ nm}$; $\Delta E_{\text{el}} = \frac{1}{2}(200 \text{ N} \times 100 \text{ nm} - 100 \text{ N} \times 50 \text{ nm}) = \frac{1}{2}(2.0 \times 10^{-5} - 5.0 \times 10^{-6}) \text{ J} = 7.5 \times 10^{-6} \text{ J}$. (c) The material returns to its original size and shape when the force is removed.