Solutions

Each answer shows the steps, then the **result**.

2.1

- a **tensile** force is a pair of forces pulling **outwards** on the ends of an object, stretching it so that it becomes longer
- a **compressive** force is a pair pushing **inwards**, squashing it so that it becomes shorter

2.2

- the **limit of proportionality** is the point beyond which the extension is **no longer proportional** to the load, so the graph stops being a straight line
- the **elastic limit** is the point beyond which the specimen no longer returns to its **original length** when the load is removed
- they are different points: the elastic limit lies just beyond the limit of proportionality

2.3

- springs in series each carry the **whole** load

$$x_{\text{each}} = \frac{F}{k} = \frac{3.0\ \text{N}}{25\ \text{N m}^{-1}} = 0.12\ \text{m}$$

- the extensions add

$$x_{\text{total}} = 2 \times 0.12\ \text{m} = \mathbf{0.24}\ \text{m}$$

2.4

- the **Young modulus** of the material

2.5

- a force-extension graph changes if the wire is made **thicker or shorter**, even for the same metal, so it describes that specimen
- dividing force by **area** and extension by **original length** removes the specimen's dimensions, so every specimen of the same material gives the **same** stress-strain graph

2.6

- the radius is half the diameter, so

$$A = \pi r^2 = \pi(0.20 \times 10^{-3}\ \text{m})^2 = 1.26 \times 10^{-7}\ \text{m}^2$$

$$\sigma = \frac{F}{A} = \frac{25\ \text{N}}{1.26 \times 10^{-7}\ \text{m}^2} = \mathbf{2.0 \times 10^8}\ \text{Pa}$$

3.1 B

- the gradient of stress against strain is $\dfrac{\sigma}{\varepsilon}$, which is the **Young modulus**
- **A** and **C** are the gradient of a **force-extension** graph and depend on the wire's dimensions; **D** is a single point on the graph, not its gradient

3.2

(a)

- use $k = F/x$

$$k = \frac{8.0\ \text{N}}{0.16\ \text{m}} = \mathbf{50}\ \text{N m}^{-1}$$

(b)

- in parallel the load is **shared**, so each spring carries 4.0 N

$$x = \frac{4.0\ \text{N}}{50\ \text{N m}^{-1}} = \mathbf{0.080}\ \text{m}$$

- the extension of the pair is the extension of each one, not the sum

(c)

- the spring has been **permanently deformed**
- it does not return to its original length: some extension remains after the load is removed

3.3

(a)

- the radius is half the diameter

$$A = \pi \left(\frac{0.38 \times 10^{-3}\ \text{m}}{2}\right)^2 = \mathbf{1.13} \times \mathbf{10^{-7}}\ \text{m}^2$$

(b)

- start from the definitions

$$E = \frac{\sigma}{\varepsilon} = \frac{F/A}{x/L} = \frac{F}{x} \times \frac{L}{A}$$

- and $\frac{F}{x}$ is the **gradient** of the load-extension graph, so $E = \text{gradient} \times \frac{L}{A}$

(c)

- substitute

$$E = 9.0 \times 10^3\ \text{N m}^{-1} \times \frac{2.50\ \text{m}}{1.13 \times 10^{-7}\ \text{m}^2} = \mathbf{2.0} \times \mathbf{10^{11}}\ \text{Pa}$$

(d)

- the **diameter** of the wire
- it is the smallest quantity measured, so its percentage uncertainty is the largest, and it is **squared** in the area, which **doubles** that percentage uncertainty in A and therefore in E

(e)

- any **two** of: measure the diameter at **several points** along the wire and in different directions, and take a mean; use a **longer** wire so the extension is larger; use a **travelling microscope** or a vernier scale to read the extension; check the wire returns to its original length as the loads are removed; take readings for both increasing and decreasing loads