Solutions

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

2.1

- the **extension is proportional to the load** (up to the limit of proportionality)

2.2

- $k = F/x$

$$k = \frac{2.0 \text{ N}}{0.040 \text{ m}} = \mathbf{50} \text{ N m}^{\mathbf{-1}}$$

2.3

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

2.4

- **pascal**, Pa (N m^{-2})

3.1 B

- in the straight region $F = kx$, so the gradient is $F/x = k$, the **spring constant**
- **A** is the trap: the Young modulus is the gradient of a **stress–strain** graph

3.2

(a)

$$\sigma = \frac{F}{A} = \frac{100 \text{ N}}{1.0 \times 10^{-6} \text{ m}^2} = \mathbf{1.0 \times 10^8} \text{ Pa}$$

(b)

$$\varepsilon = \frac{x}{L} = \frac{1.0 \times 10^{-3} \text{ m}}{2.0 \text{ m}} = \mathbf{5.0 \times 10^{-4}}$$

(c)

$$E = \frac{\sigma}{\varepsilon} = \frac{1.0 \times 10^8 \text{ Pa}}{5.0 \times 10^{-4}} = \mathbf{2.0 \times 10^{11}} \text{ Pa}$$

3.3 any four of

- 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; E is 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)

3.5

(a) the **ratio of stress to strain** (below the limit of proportionality)

(b) $R_0 = \rho L/A$

(c) $k = F/x$ and $E = (F/A)/(x/L) = FL/(Ax)$

- so $E = k_0 L/A \Rightarrow k_0 = EA/L$

(d)

- **resistance**: straight line of **positive** gradient from $(0, R_0)$ — stretching makes the wire longer and thinner
- **spring constant**: **horizontal** line from $(0, k_0)$ — k is constant below the limit of proportionality
- both axes labelled, each line labelled

(e) diameter 1.6 mm $\Rightarrow$ radius 0.80 mm

$$A = \pi r^2 = \pi(0.80 \times 10^{-3}\ \text{m})^2 = 2.01 \times 10^{-6}\ \text{m}^2$$

$$L = \frac{R_0 A}{\rho} = \frac{(0.034\ \Omega)(2.01 \times 10^{-6}\ \text{m}^2)}{1.7 \times 10^{-8}\ \Omega\,\text{m}} \approx \mathbf{3.8}\ \text{m}$$

(f) use $L = 3.8$ m from (e)

$$k_0 = \frac{EA}{L} = \frac{(1.3 \times 10^{11}\ \text{Pa})(2.01 \times 10^{-6}\ \text{m}^2)}{3.8\ \text{m}} = \mathbf{6.9 \times 10^4}\ \text{N m}^{\mathbf{-1}}$$