

Solutions

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

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

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

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

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.

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.

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) $E = \frac{\sigma}{\varepsilon} = \frac{95 \times 10^6 \text{ Pa}}{0.035} = 2.7 \times 10^9 \text{ Pa}.$

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: $\Delta E_{\text{el}} = \frac{1}{2} F_2 x_2 - \frac{1}{2} F_1 x_1$ 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.