6.1 Axial loading

Name: _____ Class: _____ Date: _____ **Total: 14 marks**

KEY WORDS normal stress • strain • Poisson's ratio

Objective

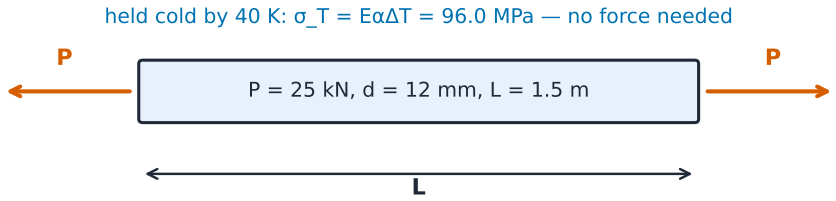
Compute axial stress, elongation and Poisson thinning, and turn a constrained temperature change into stress.

1 Key knowledge and worked examples

■ **The one-dimensional toolkit**

$\sigma = P/A$, $\delta = PL/AE$, $\varepsilon_{lat} = -\nu\varepsilon$ with $\nu = 0.30$; held: $\sigma_T = E\alpha\Delta T$.

the tie rod: one dimension, four traps



σ = P/A = 221.0 MPa · δ = PL/AE = 1.658 mm · ε = 0.001105

*The elongation builds linearly along L

■ **Worked example. The 12 mm tie rod**

$P = 25$ kN: $\sigma = 221.0$ MPa, $\delta = 1.658$ mm; held and cooled 40 K: $\sigma_T = 96.0$ MPa.

2 Practice

Steel rods throughout: $E = 200$ GPa, $\alpha = 12 \times 10^{-6}$/K, $\nu = 0.30$.

2.1 A rod of $d = 20$ mm and $L = 2.0$ m carries $P = 40$ kN tension: the normal stress (one decimal, MPa) and the elongation (two decimals, mm). [4]

2.2 For that same rod and load, with Poisson's ratio $\nu = 0.30$ and $E = 200$ GPa: the axial strain (six decimals), the lateral strain (six decimals, magnitude) and the change in diameter (two decimals, micrometres, magnitude). [4]

2.3 The same rod fitted between rigid walls and heated by 50 K ($E = 200$ GPa, $\alpha = 12 \times 10^{-6}$/K): the stress induced (one decimal, MPa). [3]

2.4 One sentence each: why does a free rod heated by 50 K carry no stress, and why does the wall-mounted one carry stress with no applied force? [3]

Solutions

2.1

- $A = \pi(0.010)^2 = 3.142 \times 10^{-4}$ m^2; $\sigma = 40 \times 10^3 / (3.142 \times 10^{-4}) = \mathbf{127.3}$ MPa.
- $\delta = PL/(AE) = 80\,000/(6.283 \times 10^7) = \mathbf{1.27}$ mm.

2.2

- $\varepsilon = \sigma / E = \mathbf{0.000637}$.
- $\varepsilon_{lat} = 0.30 \times 0.000637 = \mathbf{0.000191}$; $\Delta d = 20 \times 0.000191 = \mathbf{3.82}$ μm thinning.

2.3

- $\sigma_T = E\alpha\Delta T = 200 \times 10^9 \times 12 \times 10^{-6} \times 50 = \mathbf{120.0}$ MPa compression.

2.4

- Free expansion just lengthens the rod - no internal force, so no stress.
- Held ends block the expansion; the constraint supplies the reaction force, and force over area is stress.

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