inkPhysics

ANSWER BOOK

Stress, strain and the Young modulus

Materials · Year 12

AQA 3.4.2.2 · CIE 6.1 · OCR A 3.4.2

10 questions · 30 marks

NAVY EDITION

SECTION A · Warm-up

A1 Tensile stress = force / cross-sectional area ($\sigma = F/A$), unit pascal (Pa). Tensile strain = extension / original length ($\varepsilon = \Delta L/L$), which has no unit. [2]

A2 $\sigma = F/A = 40/(2.0 \times 10^{-6}) = 2.0 \times 10^{7}$ Pa. [2]

A3 $\varepsilon = \Delta L/L = 1.0 \times 10^{-3}/2.5 = 4.0 \times 10^{-4}$. [2]

SECTION B · Standard

B1 (a) $\sigma = 60/(1.5 \times 10^{-6}) = 4.0 \times 10^{7}$ Pa. (b) $\varepsilon = 0.80 \times 10^{-3}/2.0 = 4.0 \times 10^{-4}$. (c) $E = \sigma/\varepsilon = 1.0 \times 10^{11}$ Pa. [4]

B2 $\Delta L = FL/(AE) = (50 \times 3.0)/(1.0 \times 10^{-6} \times 2.0 \times 10^{11}) = 7.50 \times 10^{-4}$ m (0.75 mm). [3]

B3 The graph is a straight line from the origin up to the limit of proportionality, then curves; the elastic limit lies just beyond it. The Young modulus is the gradient of the straight, initial part (stress ÷ strain). [3]

B4 (a) $E = \tfrac{1}{2}F\Delta L = \tfrac{1}{2} \times 60 \times 0.80 \times 10^{-3} = 0.024$ J. (b) energy density $= \tfrac{1}{2}\sigma\varepsilon = \tfrac{1}{2} \times 4.0 \times 10^{7} \times 4.0 \times 10^{-4} = 8000$ J m^{-3}. [3]

SECTION C · Stretch

C1 $A = \pi(d/2)^2 = \pi \times (0.25 \times 10^{-3})^2 = 1.96 \times 10^{-7}$ m^2. Maximum force $= \sigma_{break}A = 4.0 \times 10^{8} \times 1.96 \times 10^{-7} = 78.5$ N. [3]

C2 $A = FL/(E\Delta L) = (100 \times 1.5)/(2.0 \times 10^{11} \times 0.50 \times 10^{-3}) = 1.50 \times 10^{-6}$ m^2. $d = \sqrt{(4A/\pi)} = 1.38$ mm. [4]

C3 Clamp a long thin wire, hang increasing known loads and measure the extension with a marker and ruler (or vernier), plus the original length with a rule and the diameter with a micrometer (to get area). Plot stress against strain; the gradient of the straight region gives E. [3]