TAP 228- 8: Stress, strain and the Young modulus

1. A long strip of rubber whose cross section measures 12 mm by 0.25 mm is pulled with a force of 3.0 N. What is the tensile stress in the rubber?

2. Another strip of rubber originally 90 mm long is stretched until it is 120 mm long. What is the tensile strain?

The marble column in a temple has dimensions 140 mm by 180 mm.

3. What is its cross-sectional area in mm^2?

4. Now change each of the initial dimensions to metres – what is the cross-sectional area in m^2?

5. If the temple column supports a load of 10 kN, what is the compressive stress, in N m^{-2}?

6. The column is 5.0 m tall, and is compressed by 0.1 mm. What is the compressive strain when this happens?

7. Use your answers to parts 5 and 6 to calculate the Young modulus for marble.

A 3.0 m length of copper wire of diameter 0.4 mm is suspended from the ceiling. When a 0.5 kg mass is suspended from the bottom of the wire it extends by 0.9 mm.

8. Calculate the strain of the wire.

9. Calculate the stress in the wire.

10. Calculate the value of the Young modulus for copper.

Practical advice

Initially students will need help converting from square mm to square m. They should do simple calculations of stress and strain before attempting to directly calculate the Young modulus of a material.

You might find it useful to ask students to solve problems involving rectangular dimensions or given cross sections before they attempt circular cross sections which have the added hazard of remembering to convert diameters to radii.

Social and human context

You can make up your own questions, using interesting contexts, by consulting a table of values for the Young modulus.

Answers and worked solutions

1.

$$\text{stress} = \frac{\text{load}}{A} = \frac{3\ \text{N}}{12 \times 10^{-3}\ \text{mm} \times 0.25 \times 10^{-3}\ \text{mm}} = 1 \times 10^{6}\ \text{Pa}$$

2.

$$\text{strain} = \frac{\text{extension}}{\text{length}} = \frac{120\ \text{mm} - 90\ \text{mm}}{90\ \text{mm}} = 0.33$$

3. 140 mm x 180 mm = 25200 mm^2

4. 0.140 m x 0.180 m = 0.0252 m^2

5.

$$\frac{10\ \text{kN}}{0.025\ \text{m}^2} = 4.0 \times 10^5\ \text{N m}^{-2}$$

6.

$$\frac{1 \times 10^{-4}\ \text{m}}{5.0\ \text{m}} = 2.0 \times 10^{-5}$$ (the units cancel out)

7.

$$E = \frac{\text{stress}}{\text{strain}} = \frac{4.0 \times 10^5\ \text{Pa}}{2.0 \times 10^{-5}} = 2 \times 10^{10}\ \text{Pa}$$

8.

$$\text{strain} = \frac{\text{extension}}{\text{length}} = \frac{0.9 \times 10^{-3}\ \text{m}}{3.0\ \text{m}} = 3.0 \times 10^{-4}$$

9.

$$\text{stress} = \frac{\text{load}}{\text{cross sectional area}} = \frac{5.0\ \text{N}}{\pi\left(0.2 \times 10^{-3}\ \text{m}\right)^2} = 4.0 \times 10^7\ \text{Pa}$$

10.

$$E = \frac{\text{stress}}{\text{strain}} = \frac{4.0 \times 10^7\ \text{Pa}}{3.0 \times 10^{-4}} = 1.3 \times 10^{11}\ \text{Pa}$$

External References

This activity is taken from Advancing Physics Chapter 4, 50D