TAP 228- 7: Calculations on stress, strain and the Young modulus

Practice questions

These are provided so that you become more confident with the quantities involved, and with the large and small numbers.

Try these

A strip of rubber originally 75 mm long is stretched until it is 100 mm long.

1. What is the tensile strain?

2. Why has the answer no units?

3. The greatest tensile stress which steel of a particular sort can withstand without breaking is about 10^9 N m^{-2}. A wire of cross-sectional area 0.01 mm^2 is made of this steel. What is the greatest force that it can withstand?

4. Find the minimum diameter of an alloy cable, tensile strength 75 MPa, needed to support a load of 15 kN.

5. Calculate the tensile stress in a suspension bridge supporting cable, of diameter of 50 mm, which pulls up on the roadway with a force of 4 kN.

6. Calculate the tensile stress in a nylon fishing line of diameter 0.36 mm which a fish is pulling with a force of 20 N

7. A large crane has a steel lifting cable of diameter 36 mm. The steel used has a Young modulus of 200 GPa. When the crane is used to lift 20 kN, the unstretched cable length is 25.0 m. Calculate the extension of the cable.

Practical Advice

The correct use of quantity algebra will help to remind students to convert mm to m, and similar traps.

Answers and worked solutions

1.

$$\text{strain} = \frac{\text{extension}}{\text{original length}}$$

$$= \frac{25\ \text{mm}}{75\ \text{mm}}$$

Strain = 0.33

This is sometimes expressed as a strain of 33%.

2. Strain has mm/mm. These cancel out to give a quantity with no units.

3.

$$\text{stress} = \frac{\text{force}}{\text{area}}$$

so F = stress x A

$= 10^{9}\ \text{N m}^{-2} \times 10^{-8}\ \text{m}^{2}$

F = 10 N

4.

$$\text{stress} = \frac{\text{force}}{\text{area}}$$

so

$$\text{area} = \frac{\text{force}}{\text{stress}}$$

$$= \frac{15\,\text{kN}}{75\,\text{MN}\,\text{m}^{-2}}$$

Area = $2 \times 10^{-4}\ \text{m}^{2}$

$$A = \frac{\pi d^{2}}{4}$$

so

$$d = \sqrt{\frac{\pi d^{2}}{4}}$$

$$d = \sqrt{\frac{4 \times 2 \times 10^{-4}\ \text{m}^{2}}{3.14}}$$

$d = 1.6 \times 10^{-2}$ m or 1.6 cm

5.

$$A = \frac{\pi d^2}{4}$$

$$= \frac{3.14 \times (50 \times 10^{-3}\text{m})^2}{4}$$

$=1.96 \times 10^{-3}\ \text{m}^2$

$$\text{stress} = \frac{\text{force}}{\text{area}}$$

$$= \frac{4\ \text{kN}}{1.96 \times 10^{-3}\ \text{m}^2}$$

Stress = $2.0 \times 10^{6}\ \text{N m}^{-2}$ or 2.0 MPa

6.

$$A = \frac{\pi d^2}{4}$$

$$= \frac{3.14 \times (0.36 \times 10^{-3}\text{m})^2}{4}$$

$= 1.017 \times 10^{-7}\ \text{m}^2$

$$\text{stress} = \frac{\text{force}}{\text{area}}$$

$$= \frac{20\ \text{N}}{1.017 \times 10^{-7}\ \text{m}^2}$$

Stress = 200 MPa

7.

$$A = \frac{\pi d^2}{4}$$

$$= \frac{3.14 \times (3.6 \times 10^{-2}\,\text{m})^2}{4}$$

$=1.02 \times 10^{-3}\ \text{m}^2$

$$E = \frac{F/A}{\Delta l/l}$$

so

$$\Delta l = \frac{F \times l}{A \times E}$$

$$= \frac{20 \times 10^{3}\,\text{N} \times 25\,\text{m}}{1.02 \times 10^{-3}\ \text{m}^2 \times 2 \times 10^{11}\ \text{N m}^{-2}}$$

ecf answer should be 2.5×10^{-1} m or 25 cm

I make 25mm

$\Delta l = 2.5 \times 10^{-3}$ m or 2.5 mm

External References

This activity is taken from Advancing Physics Chapter 4, 45S