CHAPTER NO. 17(PHYSICS OF SOLIDS)

Question 17.1:- A 1.25 cm diameter cylinder is subjected to a load of 2500 kg. Calculate the stress on the bar in mega pascals.

Solution:- Diameter of the cylinder = d = 1.25 cm

Load on the cylinder = m = 2500 kg

Stress = $\sigma = \frac{F}{A} = \frac{mg}{\pi d^2/4} = \frac{4\,m\,g}{\pi\,d^2} = \frac{4\,(2500)\,(9.8)}{3.14\,(0.0125)^2}$

σ = 199745222 Pa

σ = 200 x 10^6 Pa

σ = 200 MPa

Question 17.2:- A 1.0 m long copper wire is subjected to stretching force and its length increases by 20 cm. Calculate the tensile strain and the percent elongation which the wire undergoes.

Solution:- Length of copper wire = l = 1.0 m

Change in length if copper wire = Δl = 20 cm = 0.20 m

Tensile strain = ε = Δl/l = 0.20/1

ε = 0.20

Percent elongation = Tensile strain x 100 %

Percent elongation = (0.20) x 100 %

Percent elongation = 20 %

Question 17.3:- A wire 2.5 m long and cross sectional area 10^{-5} m² is stretched 1.5 mm by a force of 100 N in the elastic region. Calculate (i) the strain (ii) Young's modulus (iii) the energy stored in the wire.

Solution:- Length of wire = l = 2.5 m

Cross sectional area of wire = 10^{-5} m^2

Change in length of wire = Δl = 1.5 mm = 1.5 x 10^{-3} m

Stretching force = F = 100 N

(a) Strain = ε = Δl/l = (1.5 x 10^{-3})/2.5 = 0.6 x 10^{-3}

ε = 6.0 x 10^{-4}

(b) Young's modulus = Y = Stress/Strain = σ/ε

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

$Y = \frac{100/10^{-5}}{6\,x\,10^{-4}}$

Y = 0.166 x 10^{11} Pa

$Y = 1.66 \times 10^{10}$ Pa

(c) Energy stored in the wire = $W = \frac{1}{2} F \Delta l = \frac{1}{2} (100)(1.5 \times 10^{-3})$

$W = 7.5 \times 10^{-2}$ J

Question 17.4:- What stress would cause a wire to increase by 0.01 % if the Young's modulus of the wire is 12×10^{10} Pa. What force would produce this stress if the diameter of the wire is 0.56 mm?

Solution:- Diameter of the wire = d = 0.56 mm = 0.56×10^{-3} m

Young's modulus of wire = Y = 12×10^{10} Pa

Strain in the wire = ε = 0.01 %

$\varepsilon = 0.01/100 = 1 \times 10^{-4}$

Stress of the wire = σ

Young's modulus = Y = Stress / Strain = σ/ε

Stress = $\sigma = Y \times \varepsilon = (12 \times 10^{10}) \times (1 \times 10^{-4})$

$\sigma = 1.2 \times 10^{7}$ Pa ∴ The answer in the book is not correct

Area of cross section of wire = $A = \frac{\pi d^2}{4} = \frac{3.14 \, x \, (0.56 \, x \, 10^{-3})(0.56 \, x \, 10^{-3})}{4}$

$A = 2.466 \times 10^{-7}$ m^2

σ = F/A

F = σ A

$F = (1.2 \times 10^{7}) \times (2.466 \times 10^{-7})$

F = 2.96 N

Question 17.5:- The length of a steel wire is 1.0 m and its cross-sectional area is 0.03×10^{-4} m^2. Calculate the work done in stretching the wire when a force of 100 N is applied within the elastic region. Young's modulus of steel is 3.0×10^{11} N m^{-2}.

Solution:- Length of wire = l = 1.0 m

Cross sectional area of wire = A = 0.03×10^{-4} m^2

Applied force = F = 100 N

Young's modulus of wire = Y = 3.0×10^{11} N m^{-2}

Change in length of wire = Δl

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

$\Delta l / l$ = F/AY

$$\Delta l = Fl/AY$$

$\Delta l = (100)(1.0)/(0.03 \times 10^{-4})(3.0 \times 10^{11})$

$\Delta l = 1.11 \times 10^{-4}$ m

Work done = W = $\frac{1}{2}$ F Δl = $\frac{1}{2}$ (100) (1.11 x 10^{-4}) = 0.555 x 10^{-2} J

W = 5.6 x 10^{-3} J

Question 17.6:- A cylindrical copper wire and a cylindrical steel wire each of length 1.5 m and diameter 2.0 mm are joined at one end to form a composite wire 3.0 m long. The wire is loaded until its length becomes 3.003 m. Calculate the strain in copper and steel wires and the force applied to the wire. (Young's modulus of copper is 1.2 x 10^{11} Pa and for steel is 2.0 x 10^{11} Pa).

Solution:- Length of steel wire = l_S = 1.5 m

Length of copper wire = l_C = 1.5 m

Combined length of wires = l = $l_S + l_C$ = 3.0 m

Final length of combined wire = l' = 3.003 m

Change in length of combined wire = Δl = l' – l = 3.003 – 3.0 = 0.003 m

We know that $\Delta l = \Delta l_S + \Delta l_C = 0.003$ & $\Delta l_S = 0.003 - \Delta l_C$

Young's modulus of steel wire = Y_S = 2.0 x 10^{11} Pa

Young's modulus of steel wire = Y_C = 1.2 x 10^{11} Pa

Diameter of both wires = d = 2.0 mm = 2.0 x 10^{-3} m

Area of cross section of both wires = A = π $\frac{d^2}{4}$ = (3.14) $\left({(2.0\,x10^{-3})^2}/{4}\right)$

A = 3.14 x 10^{-6} m^2

Both wires of same diameter are connected to form a composite wire, therefore applied stress would be same on both.

$\sigma_S = \sigma_C$

$Y_S \times \frac{\Delta l_S}{l_S} = Y_C \times \frac{\Delta l_C}{l_C}$

(2.0 x 10^{11}) (0.003 - Δl_C) = (1.2 x 10^{11}) Δl_C ∴ $l_C = l_S$

0.006 – 2 Δl_C = 1.2 Δl_C

3.2 Δl_C = 0.006

Δl_C = 0.001875 m

(i) Strain in copper wire = $\varepsilon_C = \Delta l_C / l_C$ = (0.001875)/1.5

ε_C = 1.25 x 10^{-3}

(ii) Strain in steel wire = $\varepsilon_S = \Delta l_S / l_S$ = (0.003 - Δl_C)/1.5 = (0.003 – 0.001875)/1.5

ε_S = 0.75 x 10^{-3}

(iii) Force applied to the wire = F

We know that Young's modulus can be determined by $Y = \frac{F/A}{\Delta l / l}$.

We can find force by using any of the following relation $F = \frac{Y_C\, A\, \Delta l_C}{l_C}$ or $F = \frac{Y_S\, A\, \Delta l_S}{l_S}$

We use $F = \frac{Y_S\, A\, \Delta l_S}{l_S} = Y_S\, A\, \varepsilon_S$

$F = (2.0 \times 10^{11})\ (3.14 \times 10^{-6})\ (0.75 \times 10^{-3})$

$F = 4.71 \times 10^{2}$ N

F = 471 N