

Physics

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(Chapter 9) (Mechanical Properties of Solids) (Exercises)
(Class 11)

Question 9.11:

A 14.5 kg mass, fastened to the end of a steel wire of unstretched length 1.0 m, is whirled in a vertical circle with an angular velocity of 2 rev/s at the bottom of the circle. The cross-sectional area of the wire is 0.065 cm². Calculate the elongation of the wire when the mass is at the lowest point of its path.

Answer 9.11:

Mass, $m = 14.5$ kg and Length of the steel wire, $l = 1.0$ m

Angular velocity, $\omega = 2$ rev/s

Cross-sectional area of the wire, $a = 0.065$ cm²

Let Δl be the elongation of the wire when the mass is at the lowest point of its path.

When the mass is placed at the position of the vertical circle, the total force on the mass is:

$$F = mg + m\omega^2 l = 14.5 \times 9.8 + 14.5 \times 1 \times (2)^2 = 200.1 \text{ N}$$

$$\text{Young's modulus} = \frac{\text{Stress}}{\text{Strain}} \Rightarrow Y = \frac{\frac{F}{A}}{\frac{\Delta l}{l}} = \frac{F}{A} \frac{l}{\Delta l}$$

$$\therefore \Delta l = \frac{Fl}{AY}$$

Young's modulus for steel = 2×10^{11} Pa

$$\begin{aligned} \therefore \Delta l &= \frac{200.1 \times 1}{0.065 \times 10^{-4} \times 2 \times 10^{11}} = 1539.23 \times 10^{-7} \\ &= 1.539 \times 10^{-4} \text{ m} \end{aligned}$$

Hence, the elongation of the wire is 1.539×10^{-4} m.

Question 9.12:

Compute the bulk modulus of water from the following data: Initial volume = 100.0 litre, Pressure increase = 100.0 atm (1 atm = 1.013×10^5 Pa), Final volume = 100.5 litre. Compare the bulk modulus of water with that of air (at constant temperature). Explain in simple terms why the ratio is so large.

Answer 9.12:

Initial volume, $V_1 = 100.0 \text{ l} = 100.0 \times 10^{-3} \text{ m}^3$

Final volume, $V_2 = 100.5 \text{ l} = 100.5 \times 10^{-3} \text{ m}^3$

Increase in volume, $\Delta V = V_2 - V_1 = 0.5 \times 10^{-3} \text{ m}^3$

Increase in pressure, $\Delta p = 100.0 \text{ atm} = 100 \times 1.013 \times 10^5 \text{ Pa}$

$$\begin{aligned} \text{Bulk modulus} &= \frac{\Delta p}{\frac{\Delta V}{V_1}} = \frac{\Delta p \times V_1}{\Delta V} \\ &= \frac{100 \times 1.013 \times 10^5 \times 100 \times 10^{-3}}{0.5 \times 10^{-3}} \\ &= 2.026 \times 10^9 \text{ Pa} \end{aligned}$$

Bulk modulus of air = 1.0×10^5 Pa

$$\therefore \frac{\text{Bulk modulus of water}}{\text{Bulk modulus of air}} = \frac{2.026 \times 10^9}{1.0 \times 10^5} = 2.026 \times 10^4$$

The ratio is very high because air is more compressible than water.

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