

Mechanical Properties of Solids — Assignment 2

Class 11 Physics · Higher-difficulty challenge set + integrated problems · Answer key included · Narayan Gurukul Academy

Instructions: (1) Attempt all questions; start with the topic-wise challenge set, then attempt the integrated (multi-topic) problems.
(2) Give all answers with correct SI units. $g = 10 \text{ m/s}^2$ unless stated.
(3) A final answer key is provided at the end — try the full set before checking it.

Part A — Topic-wise challenge questions

Elasticity, Stress and Strain

2 Mark Questions

1. A wire of length 2 m stretches by 2 mm under load. Find the longitudinal strain.

3 Mark Questions

1. A steel wire of diameter 1 mm and length 2 m is stretched by a force of 50 N. If Young's modulus of steel is $2 \times 10^{11} \text{ N m}^{-2}$, find the increase in its length.

Hooke's Law and the Stress–Strain Curve

3 Mark Questions

1. A wire of length 4 m and area 10^{-6} m^2 stretches by 1 mm under a load of 20 kg. Assuming Hooke's law applies, find the stress and strain, and the Young's modulus of the wire.

The Three Moduli of Elasticity

2 Mark Questions

1. A wire of length 2 m and area 10^{-6} m^2 is stretched by 1 mm under a load of 5 kg. Find its Young's modulus. ($g = 10 \text{ m/s}^2$.)

3 Mark Questions

1. A uniform pressure of $2 \times 10^6 \text{ N m}^{-2}$ is applied to a solid of bulk modulus 10^{10} N m^{-2} . Find the fractional change in its volume.

Poisson's Ratio

2 Mark Questions

1. A wire of diameter 1 mm is stretched so that its longitudinal strain is 2×10^{-3} . If Poisson's ratio is 0.3, find the change in its diameter.

3 Mark Questions

1. A wire of length 3 m and diameter 1 mm is stretched by 3 mm. If Poisson's ratio is 0.25, find the decrease in its diameter.

Elastic Potential Energy and Applications

2 Mark Questions

1. A steel wire of Young's modulus $2 \times 10^{11} \text{ N m}^{-2}$ is stretched to a strain of 10^{-3} . Find the energy stored per unit volume.
2. A spring of spring constant 200 N m^{-1} is stretched by 5 cm. Find the elastic energy stored in it.

Part B — Integrated problems (multi-topic)

1. A wire of length 2 m stretches by 2 mm under load. Find the longitudinal strain, the stress if the Young's modulus of the wire is $2 \times 10^{11} \text{ N m}^{-2}$, and the elastic energy stored per unit volume.
2. A steel wire of diameter 1 mm and length 2 m is stretched by a force of 50 N. If Young's modulus of steel is $2 \times 10^{11} \text{ N m}^{-2}$, find the increase in length and the energy stored per unit volume.
3. A wire of length 2 m and area 10^{-6} m^2 is stretched by 1 mm under a load of 5 kg. Find its Young's modulus ($g = 10 \text{ m/s}^2$). A uniform pressure of $2 \times 10^6 \text{ N m}^{-2}$ is then applied to a solid of bulk modulus 10^{10} N m^{-2} — find the fractional change in volume.
4. A wire of diameter 1 mm is stretched so that its longitudinal strain is 2×10^{-3} . If Poisson's ratio is 0.3, find the change in its diameter. Explain why rubber has a Poisson's ratio near 0.5 while steel is near 0.3.
5. A spring of spring constant 200 N m^{-1} is stretched by 5 cm. Find the elastic energy stored in it. A steel wire of Young's modulus $2 \times 10^{11} \text{ N m}^{-2}$ is then stretched to a strain of 10^{-3} — find the energy stored per unit volume.

Answer Key**Elasticity, Stress and Strain**

2M(2): longitudinal strain = $\Delta l/l = 2 \times 10^{-3}/2 = 10^{-3}$. 3M(1): $A = \pi r^2 \approx 7.85 \times 10^{-7} \text{ m}^2$; $\Delta l = FL/(AY) = 50 \times 2/(7.85 \times 10^{-7} \times 2 \times 10^{11}) \approx 6.4 \times 10^{-4} \text{ m}$.

Hooke's Law and the Stress–Strain Curve

3M(1): stress = $F/A = (20 \times 10)/10^{-6} = 2 \times 10^8 \text{ N m}^{-2}$; strain = $10^{-3}/4 = 2.5 \times 10^{-4}$; $Y = \text{stress/strain} = 2 \times 10^8/2.5 \times 10^{-4} = 8 \times 10^{11} \text{ N m}^{-2}$.

The Three Moduli of Elasticity

2M(0): $Y = (mg \times l)/(A \times \Delta l) = 50 \times 2/(10^{-6} \times 10^{-3}) = 10^{11} \text{ N m}^{-2}$. 3M(1): $\Delta V/V = P/B = 2 \times 10^6/10^{10} = 2 \times 10^{-4}$.

Poisson's Ratio

2M(0): lateral strain = $0.3 \times 2 \times 10^{-3} = 6 \times 10^{-4}$; $\Delta d = 6 \times 10^{-4} \times 10^{-3} = 6 \times 10^{-7} \text{ m}$. 3M(1): longitudinal strain = $3 \times 10^{-3}/3 = 10^{-3}$; lateral strain = 0.25×10^{-3} ; $\Delta d = 2.5 \times 10^{-7} \text{ m}$.

Elastic Potential Energy and Applications

2M(0): $u = \frac{1}{2} \text{ stress} \times \text{strain} = \frac{1}{2} \times 2 \times 10^{11} \times (10^{-3})^2 = 10^5 \text{ J m}^{-3}$. 2M(2): $U = \frac{1}{2} kx^2 = \frac{1}{2} \times 200 \times (0.05)^2 = 0.25 \text{ J}$.

Integrated problems

1: strain = 10^{-3} ; stress = $Y \times \text{strain} = 2 \times 10^8 \text{ N m}^{-2}$; $u = \frac{1}{2} \times 2 \times 10^8 \times 10^{-3} = 10^5 \text{ J m}^{-3}$. 2: $\Delta l \approx 6.4 \times 10^{-4} \text{ m}$; strain = $6.4 \times 10^{-4}/2 = 3.2 \times 10^{-4}$; $u = \frac{1}{2} \times 2 \times 10^{11} \times (3.2 \times 10^{-4})^2 \approx 1.0 \times 10^4 \text{ J m}^{-3}$. 3: $Y = 10^{11} \text{ N m}^{-2}$; $\Delta V/V = 2 \times 10^{-4}$. 4: $\Delta d = 6 \times 10^{-7} \text{ m}$; rubber is nearly incompressible ($\sigma \rightarrow 0.5$), steel is more compressible ($\sigma \approx 0.3$). 5: $U = 0.25 \text{ J}$; $u = 10^5 \text{ J m}^{-3}$.