Mechanical Properties of Solids

Standard difficulty · 20 questions · 40 marks · Time: 36 minutes

Name: _____ Date: _____ Score: ____ / 40

Show your working for Sections B and C. Answers are on the last page — try every question first!

Section A — Choose the correct answer — 8 × 1 = 8 marks

1. A load of 2100 N hangs from a wire of cross-section 2 mm^2. The stress in the wire is:

(a) $1{,}050 \times 10^6$ N/m^2 **(b)** $1{,}050 \times 10^3$ N/m^2

(c) $4{,}200 \times 10^6$ N/m^2 **(d)** $1{,}050$ N/m^2

2. A glass wire 8 m long, of cross-section 25 mm^2, carries a load of 3600 N. Its extension is ($Y = 65 \times 10^9$ N/m^2):

(a) 35.45 mm **(b)** 1.77 mm **(c)** 17.72 mm **(d)** 177.23 mm

3. A wire 2 m long and 25 mm^2 in cross-section stretches by 0.76 mm under a load of 1900 N. Its Young's modulus is:

(a) 2000×10^9 N/m^2 **(b)** 200×10^6 N/m^2

(c) 20×10^9 N/m^2 **(d)** 200×10^9 N/m^2

4. A pressure of 21×10^6 N/m^2 acts on aluminium (bulk modulus 72×10^9 N/m^2). The fractional decrease in its volume is:

(a) 2.92×10^{-4} **(b)** 2.92×10^{-5} **(c)** 0.292 **(d)** 0.00292

5. Hooke's law says that, within the elastic limit, stress is proportional to:

(a) strain **(b)** the square of strain

(c) density **(d)** temperature

6. A wire 5 m long stretches by 3 mm. The strain is:

(a) 1.67 **(b)** 0.6 **(c)** 0.0006 **(d)** 0.006

7. Two wires of the same material carry the same load. Wire A has length 2L and diameter 3d; wire B has length 3L and diameter 2d. The ratio of their extensions A : B is:

(a) 2 : 3 **(b)** 27 : 8 **(c)** 4 : 9 **(d)** 8 : 27

8. Assertion (A): If a wire carrying 3000 N is replaced by one of the same material with twice the cross-section, the stress becomes twice as large.
Reason (R): Stress is the force per unit cross-sectional area.

(a) Both A and R are true, and R is the correct explanation of A.

(b) Both A and R are true, but R is not the correct explanation of A.

(c) A is true, but R is false.

(d) A is false, but R is true.

Section B — Short answer — 8 × 2 = 16 marks

9. A glass wire 8 m long with cross-section 2 mm^2 supports 3600 N. Find the stress, the strain and the extension. ($Y = 65 \times 10^9$ N/m^2)

10. In an experiment, a wire 10 m long with cross-section 25 mm^2 stretches 18.86 mm when 3300 N is hung on it. Find Young's modulus. Which material could it be?

11. 9 litres of steel is put under an extra pressure of 34×10^6 N/m^2. Find the decrease in its volume. (Bulk modulus = 160×10^9 N/m^2)

12. An iron block has a face of area 500 mm^2. A shearing force of 37,000 N acts on it. Find the shear strain (angle of shear, in radians). (Shear modulus = 70×10^9 N/m^2)

13. A wire stretches by 10.46 mm under a load of 3400 N. Find the elastic potential energy stored in it.

14. An iron wire and a steel wire, each 1 m long with cross-section 10 mm^2, are joined end to end and carry a load of 1700 N. Find the extension of each and the total. (Y: iron 190 GPa, steel 200 GPa)

15. The breaking stress of a metal is 500×10^6 N/m^2. What is the greatest load a wire of cross-section 10 mm^2 can hold? What mass is that? (Take g = 10 m/s^2.)

16. Find the compressibility of glass, whose bulk modulus is 37×10^9 N/m^2, and the percentage decrease in its volume under an extra pressure of 155×10^6 N/m^2.

Section C — Word problems — 4 × 4 = 16 marks

17. Two wires, one iron (Y = 190 GPa) and one steel (Y = 200 GPa), have the same length 4 m and cross-section 10 mm^2. Each carries 1500 N. (a) Find the stress in each. (b) Find the extensions and their ratio. (c) Which material is more elastic?

18. A wire 4 m long, cross-section 4 mm^2, gives these extensions: 300 N → 2.5 mm; 600 N → 5 mm; 900 N → 7.5 mm; 1200 N → 10 mm. (a) Show that the extension is proportional to the load. (b) Find Young's modulus. (c) Which material is it?

19. An iron ball is taken to a depth of 700 m in the sea. (a) What is the extra pressure on it? (b) What is the fractional decrease in its volume? (Bulk modulus 100 × 10^9 N/m^2; density of water 1000 kg/m^3; g = 10 m/s^2.)

20. An aluminium wire (Y = 70 × 10^9 N/m^2) 5 m long, cross-section 8 mm^2, carries 1300 N. Find (a) the stress, (b) the strain, (c) the energy stored per unit volume, (d) the total energy stored.

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Answer key

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Q	Answer	Working
1	**(a) 1,050 × 10^6 N/m^2**	stress = F/A = 2100 ÷ (2 × 10^{-6})
2	**(c) 17.72 mm**	ΔL = FL/(AY); with A in mm^2 and Y in GPa, ΔL comes out in mm
3	**(d) 200 × 10^9 N/m^2**	Y = FL/(AΔL)
4	**(a) 2.92 × 10^{-4}**	ΔV/V = p/B
5	**(a) strain**	—
6	**(c) 0.0006**	strain = ΔL/L = 3 × 10^{-3} ÷ 5
7	**(d) 8 : 27**	ΔL ∝ L/d^2
8	**(d) A is false, but R is true.**	A is false: stress = F/A, so doubling A halves the stress. R is true.
9	**Stress 1,800 × 10^6 N/m^2; strain 0.0277; extension 221.54 mm**	strain = stress/Y; ΔL = strain × L
10	**70 × 10^9 N/m^2; aluminium**	Y = FL/(AΔL)
11	**0.00191 litres (= 1.91 cm^3)**	ΔV = pV/B
12	**0.00106 rad**	θ = F/(AG)
13	**17.78 J**	U = ½FΔL = ½ × 3400 × 10.46 × 10^{-3}
14	**iron: 0.89 mm; steel: 0.85 mm; total 1.74 mm**	the same tension acts in both wires
15	**5,000 N; 500 kg**	load = breaking stress × area
16	**2.70 × 10^{-11} m^2/N; 0.419%**	compressibility = 1/B; ΔV/V = p/B
17	**(a) Both 150 × 10^6 N/m^2. (b) 3.16 mm and 3 mm, ratio 20 : 19. (c) steel, which has the larger Young's modulus (less strain for the same stress).**	—
18	**(a) Load ÷ extension = 120 N/mm each time, so they are proportional (Hooke's law). (b) 120 × 10^9 N/m^2. (c) copper.**	Y = (F/ΔL) × L/A
19	**(a) 7.00 × 10^6 N/m^2; (b) 7.00 × 10^{-5}**	p = ρgh; ΔV/V = p/B
20	**(a) 162.5 × 10^6 N/m^2; (b) 0.00232; (c) 1.89 × 10^5 J/m^3; (d) 7.54 J**	u = ½ × stress × strain; volume = AL

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