PHYSICS – CLASS XI

Chapter 8 : Mechanical Properties of Solids

SOLUTIONS AND MARKING SCHEME (Step-by-Step)

Marks for each step are shown in brackets. Alternative correct methods carry full marks.

Quick answer key – Section A

Q	1	2	3	4	5	6	7	8
Ans	(a)	(a)	(a)	(a)	2×10^{11} N m^{-2}	2×10^{-3}	2×10^{-5} m^3	10^5 J m^{-3}

SECTION A

1. **Ans: (a) A.** **(1)**

In the region OA the curve is a straight line (stress ∝ strain); A is the proportional limit, so Hooke's law holds only up to **A**.

2. **Ans: (a) $\Delta L/2$.** **(1)**

$\Delta L = FL/(AY)$ with $A = \pi r^2$. New length $2L$ and new area $4A$: $\Delta L' = F(2L)/(4AY) =$ **$\Delta L/2$**.

3. **Ans: (a) [M L^{-1} T^{-2}].** **(1)**

Y = stress/strain; strain is dimensionless, so Y has the dimensions of stress = force/area = [M L T^{-2}]/[L^2] = **[M L^{-1} T^{-2}]**.

4. **Ans: (a).** **(1)**

Both are true. A material that shows less strain for a given stress (greater Y) is more elastic; steel does, so R correctly explains A.

5. **Ans: 2×10^{11} N m^{-2}.** **(1)**

From the graph at strain 0.002 the stress is 4×10^8 N m^{-2}. Y = stress/strain = $4 \times 10^8/0.002 =$ **2×10^{11} N m^{-2}**.

6. **Ans: 2×10^{-3}.** **(1)**

Shearing strain = $\Delta x/L = 1 \times 10^{-3}$ m/0.5 m = **2×10^{-3}** (no unit).

7. **Ans: 2×10^{-5} m^3.** **(1)**

$B = p/(\Delta V/V) \rightarrow \Delta V = pV/B = 2 \times 10^7 \times 0.1/(1 \times 10^{11}) =$ **2×10^{-5} m^3** (a decrease).

8. **Ans: 10^5 J m^{-3}.** **(1)**

u = ½ × stress × strain = ½ × $2 \times 10^8 \times 1 \times 10^{-3} =$ **1×10^5 J m^{-3}**.

SECTION B

9. Force $F = mg = 20 \times 10 = 200$ N. **(2)**

(i) Stress = $F/A = 200/(1 \times 10^{-6}) =$ **2×10^8 N m^{-2}**. (1)

(ii) $\Delta L = FL/(AY) = (2 \times 10^8 \times 2)/(2 \times 10^{11}) =$ **2×10^{-3} m** = 2 mm. (1)

10. **(i)** Material **B** has the greater Young's modulus, because the slope of its straight (elastic) part, stress/strain, is larger. (1) **(2)**

(ii) Material **A** is the stronger one, because it can withstand a larger maximum (ultimate) stress before it fractures. (1)

11. Poisson's ratio σ = lateral strain/longitudinal strain = $(\Delta d/d)/(\Delta L/L)$. (1) **(2)**
= 0.03%/0.1% = 0.03/0.1 = **0.3** (no unit). (1)

OR

(i) $Y = (F/A)/(\Delta L/L)$; **(ii)** $G = (F/A)/\theta$ (shearing stress/shearing strain); **(iii)** $B = -p/(\Delta V/V)$. (1½)
Only the bulk modulus B can be defined for liquids and gases (they have no definite shape, so Y and G apply to solids only). (½)

12. Maximum stress = $F\text{max}/A \rightarrow F\text{max}$ = stress × $A = 1 \times 10^{8} \times 6 \times 10^{-4} =$ **6×10^{4} N**. (1) **(2)**
Maximum mass = $F/g = 6 \times 10^{4}/10 =$ **6000 kg**. (1)

SECTION C

13. **(i)** Steel wire carries both masses: $T_s = (4 + 6) \times 10 =$ **100 N**. Brass wire carries only 6 kg: $T_b = 6 \times 10 =$ **60 N**. (1) **(3)**
(ii) $\Delta L_s = TL/(AY) = (100 \times 2.0)/(2 \times 10^{-6} \times 2 \times 10^{11}) = 200/(4 \times 10^{5}) =$ **5×10^{-4} m** (0.5 mm). (1)
(iii) $\Delta L_b = (60 \times 1.0)/(2 \times 10^{-6} \times 1 \times 10^{11}) = 60/(2 \times 10^{5}) =$ **3×10^{-4} m** (0.3 mm). (½) Total elongation = $5 \times 10^{-4} + 3 \times 10^{-4} =$ **8×10^{-4} m** (0.8 mm). (½)

14. **(i)** Shearing stress = $F/A = 8 \times 10^{4}/0.04 =$ **2×10^{6} N m^{-2}**. (1) **(3)**
(ii) Shearing strain = stress/$G = 2 \times 10^{6}/(5 \times 10^{9}) =$ **4×10^{-4}**. (1)
(iii) Strain = $\Delta x/h \rightarrow \Delta x = 4 \times 10^{-4} \times 0.1 =$ **4×10^{-5} m** (0.04 mm). (1)

OR

(i) $p = h\rho g = 2000 \times 1000 \times 10 =$ **2×10^{7} N m^{-2}**. (1)
(ii) $\Delta V/V = p/B = 2 \times 10^{7}/(2 \times 10^{9}) =$ **1×10^{-2}** (1%). (1)
(iii) $\Delta V = 10^{-2} \times 5 =$ **5×10^{-2} m^3** (a decrease of 0.05 m³). (1)

15. **(i)** From the graph $F = 100$ N at $\Delta L = 1$ mm. $Y = FL/(A\Delta L) = (100 \times 2)/(1 \times 10^{-6} \times 1 \times 10^{-3}) =$ **2×10^{11} N m^{-2}**. (1) **(3)**
(ii) Energy stored = area under the F–ΔL graph = ½ × 100 × 1 × $10^{-3} =$ **0.05 J**. (1)
(iii) Volume = $AL = 1 \times 10^{-6} \times 2 = 2 \times 10^{-6}$ m³. Energy per unit volume = $0.05/(2 \times 10^{-6}) =$ **2.5×10^{4} J m^{-3}**. (1)

SECTION D

16. **(a)** Hooke's law: within the elastic limit, stress is directly proportional to strain (stress = k × strain, where k is the modulus of elasticity). (1) **(5)**
(b) At the lowest point: $T - mg = m\omega^2 L \rightarrow T = 2 \times 10 + 2 \times (2)^2 \times 1.0 = 20 + 8 =$ **28 N**. (1)
(c) Stress = $T/A = 28/(1.0 \times 10^{-6}) =$ **2.8×10^{7} N m^{-2}**. (1)
(d) Strain = stress/$Y = 2.8 \times 10^{7}/(2 \times 10^{11}) =$ **1.4×10^{-4}**. (1)
(e) Elongation ΔL = strain × $L = 1.4 \times 10^{-4} \times 1.0 =$ **1.4×10^{-4} m** (0.14 mm). (1)

OR

(a) Total weight = 15 × 10 = 150 N shared equally: $T = 150/3 =$ **50 N**. (1)
(b) All three wires have the same original length and are attached to the same rigid bar; the bar stays horizontal only if each wire stretches by the same amount. (1)
(c) $\Delta L = TL/(AY)$ with $A = \pi d^2/4$, so $\Delta L =$ **$4TL/(\pi d^2 Y)$**. (1)
(d) Same T, L, $\Delta L \rightarrow d^2 Y$ is constant $\rightarrow d_{Cu}^{\,2}/d_{Fe}^{\,2} = Y_{Fe}/Y_{Cu} = 2 \rightarrow d_{Cu} : d_{Fe} =$ **$\sqrt{2} : 1$** ($\approx 1.41 : 1$). (1)
(e) Stress = $4T/(\pi d^2) \propto 1/d^2$: $\sigma_{Cu}/\sigma_{Fe} = d_{Fe}^{\,2}/d_{Cu}^{\,2} =$ **1 : 2**. (1)

17. **(5)**

(a) Yield strength is the stress at the yield point (elastic limit): beyond it the material is permanently deformed (plastic deformation). (1)

(b) Load $W = Mg = 10^4 \times 10 = 1 \times 10^5$ N. $A \geq W/\sigma_y = 10^5/(2.5 \times 10^8) = \mathbf{4 \times 10^{-4}\ m^2}$. (1)

(c) With a safety factor of 10: $A = 10 \times 4 \times 10^{-4} = \mathbf{4 \times 10^{-3}\ m^2}$. (1)

(d) Number of wires = $4 \times 10^{-3}/(4 \times 10^{-6}) = \mathbf{1000}$. (1)

(e) A single thick wire of that area would be practically a rigid rod, difficult to manufacture, bend over pulleys and handle; a braided rope of thin wires is flexible and easier to make while having the same strength. (1)

OR

(a) $\delta \propto 1/d^3$. Doubling d: $\delta' = \delta/2^3 = \mathbf{\delta/8}$. (1)

(b) $\delta \propto 1/b$. Doubling b: $\delta' = \mathbf{\delta/2}$. (1)

(c) Increasing the **depth** is far more effective (δ falls as $1/d^3$ compared with $1/b$). (1)

(d) If the depth is increased too much without the load being exactly at the right place, the deep, thin bar bends sideways (buckling). (1)

(e) The I-section gives a large load-bearing surface and enough depth to prevent bending, while saving material, weight and cost. (1)

— END OF SOLUTIONS —