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CHAPTER

Simple stress-strain and Elastic Constant

Q.1 A prismatic bar of volume V is subjected to a tensile force in longitudinal direction. If Poisson's ratio of the material is μ and longitudinal strain is e, then the final volume of the bar becomes

(a) $(1+e)(1-\mu)^2 V$ (b) $(1-e)^2(1+\mu e) V$

(c) $(1+e)(1-\mu e)^2 V$ (d) $(1-\mu e)^2 V$

Q.2 If all the dimensions of a prismatic bar of square cross section suspended freely from the ceiling of a roof is doubled, then the total elongation produced by its own weight will become

(a) eight times (b) four times

(c) three times (d) two times

Q.3 Three equally inclined members of a plane frame having tensile forces p_1, p_2 and p_3 respectively are joined at a point. The relationship between p_1, p_2 and p_3 will be

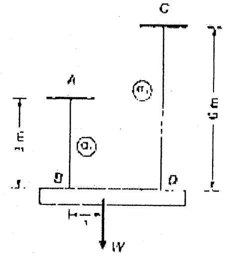
(a) $p_2 = 0$ and $p_3 = p_1$

(b) $p_2 = p_1$ and $p_3 = 0$

(c) $p_2 = \frac{\sqrt{3}}{2}p_1$ and $p_3 = \frac{\sqrt{3}}{2}p_1$

(d) $p_3 = p_1$ and $p_2 = p_1$

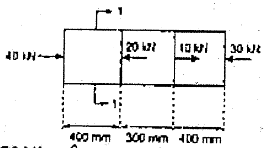
Q.4 In the given figure, the wires AB and CD made of the same material are used to suspend a rigid block to which the gradual load W is applied in such a way that both the wires get stretched by the same amount. If stresses in wire AB and CD are σ_1 and σ_2 respectively, then the ratio σ_1/σ_2 will be



(a) 3/2 (b) 2/3

(c) 2 (d) 1/2

Q.5 A bar of uniform cross-section of 400 mm² is loaded as shown in the figure. The stress at section 1-1 is



(a) 50 N/mm² (b) 100 N/mm²

(c) 25 N/mm² (d) 200 N/mm²

Q.6 A bar of uniform section is subjected to axial tensile loads such that the normal strain in the axial direction is 1.25 mm per m. If the Poisson's ratio of the material of the bar is 0.3, then the volumetric strain would be

(a) 2×10^{-4} (b) 3×10^{-4}

(c) 4×10^{-4} (d) 5×10^{-4}

Q.7 A square plate ($a \times a$) rigidly held at three edges is free to move along the fourth edge. If temperature of the plate is raised by 't', then the free expansion at the fourth edge will be (coefficient of thermal expansion of the material = α, modulus of elasticity of the material = E and its Poisson's ratio = m)

(a) $a\alpha t\mu$ (b) $a\alpha t(1+\mu)$

(c) $a\alpha t + \left(\frac{\alpha+\mu}{E}\right)$ (d) $a\alpha t(1-\mu)$

Q.8 The bulk modulus of elasticity of a material is twice its modulus of rigidity. The Poisson's ratio of the material is

(a) 1/7 (b) 2/7

(c) 3/7 (d) 4/7

Q.9 Development of temperature stresses in a rod depends on

1. Modulus of elasticity of the material
2. Coefficient of linear expansion
3. Area of rod
4. Length of rod

Which of these statements is/are correct?

(a) 1 and 3 (b) 1 and 2

(c) 1, 2 and 3 (d) 1, 2, 3 and 4

Q.10 The elongation of a conical bar under its own weight is equal to

(a) that of a prismatic bar of same length

(b) one half that of a prismatic bar of same length

(c) one third that of a prismatic bar of same length

(d) one fourth that of a prismatic bar of same length

Q.11 A uniform rise in temperature on a portal frame will cause

(a) no sway

(b) sway depending on the temperature

(c) sway depending on the relative properties of the members

(d) None of these

Q.12 If all the dimensions of a bar are increased in the proportion of n : 1, the proportion with which the maximum stress produced in the prismatic bar by its own weight, will increase will be

(a) 1 : n (b) n : 1

(c) $1 : \frac{1}{n}$ (d) $\frac{1}{n} : 1$

Q.13 For a given material, if E, G, K and $\frac{1}{m}$ are Young's modulus, shear modulus, bulk modulus and Poisson's ratio, which of the following relation does not hold good

(a) $E = \frac{9KG}{3K+G}$ (b) $E = 2K\left(1-\frac{2}{m}\right)$

(c) $E = 2G\left(1+\frac{1}{m}\right)$ (d) $\frac{1}{m} = \frac{3K-2G}{6K+2G}$

Q.14 If the normal cross-section A of a member is subjected to a tensile force P, the resulting normal stress in as oblique plane inclined at an angle θ to the transverse plane will be

(a) $\frac{P}{A}\sin\theta$ (b) $\frac{P}{A}\cos^2\theta$

(c) $\frac{P}{A}\cos\theta$ (d) $\frac{P}{A}\sin\theta\cos\theta$

Q.15 If two tensile stresses mutually perpendicular to each other acting on a rectangular parallelopiped bar are equal, then the resulting strain in one direction of the pipe, is

(a) $\frac{\sigma}{mE}(m-1)$ (b) $\frac{\sigma}{mE}(m+1)$

(c) $\frac{\sigma}{E}(m-1)$ (d) $\frac{\sigma}{E}(m+1)$

where $1/m$ is Poisson's ratio.

Q.16 Which of the following statement/s is/are correct?

1. Poisson's ratio is constant within elastic zone.
2. The ratio of lateral strain to longitudinal strain in non-elastic zone, is called contraction ratio.
3. Contraction ratio is not a constant.

(a) Only 1 (b) 2 and 3

(c) 1 and 2 (d) 1, 2 and 3

Q.17 A steel rail track is laid by joining 30 m long rails end to end.

At 30°C, there is no stress in the rails. $\alpha = 11 \times 10^{-6}$/°C and $E = 2 \times 10^5$ N/mm²

At 50°C,

1. The stress is the rail will be 22 MPa
2. If the length of track was 60 m, the stress in rail will be 44 MPa.

Out of the above statements

(a) Only 1 is correct (b) 1 and 2 are correct

(c) Only 2 is correct (d) Both are incorrect

Q.18 A composite bar is made of steel and aluminium strips, with $A_a = 3A_s$, where A_a and A_s are areas of cross-section of aluminium and steel bars, respectively and $E_s/E_a = 3$. Due to an external load, if the stress developed in the aluminium is 30 MPa, then what is the stress developed in the steel bar?

(a) 10 MPa (b) 30 MPa

(c) 90 MPa (d) None of these

Q.19 A metal rod rests on a frictionless surface. The length of rod is 2 m and cross-sectional area is 4 cm^2. The stress in the rod is zero at 20°C. If temperature is increased to 50°C, the stress and change in the length of rod will be
(Take $E = 2.1 \times 10^5$ N/mm^2, $\alpha = 1 \times 10^{-6}$/°C)
(a) 6.3 MPa, 0.06 mm (b) 6.3 MPa, 6 mm
(c) 0 MPa, 0.06 mm (d) 0 MPa, 6 mm

Q.20 A cubical specimen of side 1 m is confined in all directions between rigid bars. If bar is uniformly heated by 10°C, the force exerted in any direction is
($E = 2 \times 10^5$ N/mm^2, $\alpha = 10^{-6}$/°C.
Poisson's ratio = 0.2)
(a) 1.5 MN (b) 3.33 MN
(c) 3 MN (d) 2 MN

Q.21 The ratio of maximum stress at a cross-section in the middle of a bar to the maximum stress in the cross-section at a distance of $b/2$ from the end of the bar subjected to direct loading is
(a) 1.387 (b) 1
(c) 1.027 (d) 0.721

Q.22 A steel bolt is inserted through a copper tube and is tightened throughly. If the assembly is cooled, then
(a) No additional stresses are developed
(b) Stresses will increrase
(c) Stresses will decrease
(d) Stresses may increase or decrease

Q.23 Assertion (A): Poisson's ratio of a material is a measure of its ductility.
Reason (R): Poisson's ratio of the material gives the lateral strain for every linear strain in directions perpendicular to the direction of force.
(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 a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

Q.24 Assertion (A): Strain energy of an elastic body due to multiple loads is the sum of strain energy due to respective individual loads.
Reason (R): Strain energy is a quadratic function of loads.
(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 a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

Q.25 A rectangular bar is subjected to pure bending in vertical plane. Which strain tensor represents correct strain matrix?
(a) $\begin{bmatrix} p & 0 & 0 \\ 0 & q & 0 \\ 0 & 0 & r \end{bmatrix}$ (b) $\begin{bmatrix} p & 0 & 0 \\ 0 & p & 0 \\ 0 & 0 & p \end{bmatrix}$
(c) $\begin{bmatrix} p & 0 & 0 \\ 0 & q & 0 \\ 0 & 0 & q \end{bmatrix}$ (d) None of the above

Q.26 According to St. Venant's principle
(a) Deformations of all materials for a given loading are equal
(b) It is a method of determining stress conditions at the end of the plates
(c) Stress condition approach uniformly as the distance from the point of application of the load increases
(d) After a point of time the stresses in a loaded member tend to relieve

Q.27 A rod of length 'l' and cross-sectional area 'A' rotates about an axis passing through one end of the rod. The extension produced in the rod due to centrifugal forces is (w is the weight of the rod per unit length and ω is the angular velocity of rotation of the rod)
(a) $\omega w l^2 g E$ (b) $\omega^2 w l^3/3gE$
(c) $\omega^2 w l^3/gE$ (b) $3gE/\omega^2 Wl^3$

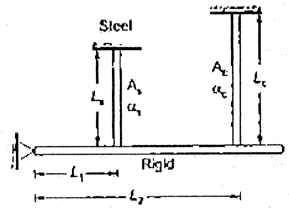
Q.28 If the value of Poisson's ratio is zero, then it means that
(a) the material is rigid
(b) the material is perfectly plastic
(c) there is no longitudinal strain in the material
(d) the longitudinal strain in the material is infinite

Q.29 A tapering bar (diameters of end sections being d_1 and d_2) and a bar of uniform cross-section 'd' has the same length and are subjected to the same axial pull. Both the bars will have the same extension if 'd' is equal to
(a) $(d_1 + d_2)/2$ (b) $\sqrt{d_1 d_2}$
(c) $\sqrt{d_1 d_2/2}$ (d) $\sqrt{(d_1 + d_2)/2}$

Q.30 Three strips of same area of cross-section share a load of 5.5 kN. If their Young's modulus are in the ratio of $E_1 = 2E_2 = 3E_3$, then what is the load, shared by the strip with Young's modulus E_1?
(a) 3 kN (b) 3.5 kN
(c) 2.5 kN (d) 2 kN

Q.31 Assertion (A): Hooke's law is the constitutive law for a linear elastic material.
Reason (R): Formulation of the theory of elasticity requires the hypothesis that there exists a unique unstressed state of the body, in which the body retaracts whenever all the forces are removed.
(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 a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

Q.32 For the assembly shown in figure. if the temperature is raised by T°C, then which of the following statements are true?



(i) If $\frac{L_s \alpha_s T}{L_c \alpha_c T} = \frac{L_1}{L_2}$, then bars will not carry additional stresses due to temperature rise
(ii) If $\frac{L_s \alpha_s T}{L_c \alpha_c T} > \frac{L_1}{L_2}$, steel bar will be in tension and copper bar will be in compression.
(a) Only 1 (b) Only 2
(c) 1 and 2 (d) None of these

Q.33 A straight bimetallic strip of copper and steel is heated. It is free at ends. The strip will
(a) expand and remain straight
(b) not expand but will bend
(c) expand and bend also
(d) twist only

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Answers **Simple Stress-strain and Elastic Constants**

1. (c)	2. (b)	3. (d)	4. (c)	5. (b)	6. (d)	7. (d)	8. (b)	9. (c)	10. (c)
11. (a)	12. (b)	13. (b)	14. (b)	15. (a)	16. (d)	17. (c)	18. (c)	19. (c)	20. (b)
21. (d)	22. (c)	23. (d)	24. (d)	25. (c)	26. (c)	27. (b)	28. (b)	29. (b)	30. (a)
31. (a)	32. (a)	33. (c)							

Explanations Simple Stress-strain and Elastic Constants

1. (c)

Initial volume = $V = lbd$

Final volume

$= V' = (V + \delta V)$

$= (l + \delta l)(b - \delta b)(d - \delta d)$

(since tension is in direction of l)

$$\therefore \frac{V'}{V} = \left(\frac{l+\delta l}{l}\right)\left(\frac{b-\delta b}{b}\right)\left(\frac{d-\delta d}{d}\right)$$

$\Rightarrow \quad V' = (1 + e)(1 - \mu e)(1 - \mu e)V$

$\Rightarrow \quad V' = (1 + e)(1 - \mu e)^2 V$

Note: If instead of tensile force, compressive force is acting in the direction of length, then

$V' = (1 - e)(1 + \mu e)^2 V$

2. (b)

$$\Delta = \frac{\lambda l^2}{2E}$$

λ = Specific weight

l = length

$\Delta \propto l^2$

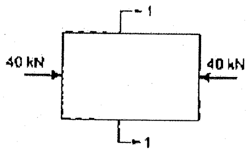
4. (c)

$$\Delta = \frac{\sigma_1 L_1}{E} = \frac{\sigma_2 L_2}{E}$$

$$\frac{\sigma_1}{\sigma_2} = \frac{L_2}{L_1} = \frac{6}{3} = 2$$

5. (b)

The free body diagram at section 1-1 is



$\therefore$ Stress at section 1-1

$$= \frac{40 \times 10^3}{400} \frac{\text{N}}{\text{mm}^2}$$

6. (d)

$$e_v = \frac{p}{E}(1 - 2\mu)$$

$\because \quad \frac{p}{E} = 1.25 \times 10^{-3}$

$\therefore \quad e_v = 1.25 \times 10^{-3}(1 - 2 \times 0.3)$

$e_v = 0.4 \times 1.25 \times 10^{-3} = 5 \times 10^{-4}$

7. (d)

Free expansion

$$= \frac{pa}{E}(1 + \mu)$$

But $\frac{p}{E} = \alpha t$

$\therefore$ Free expansion

$= a\,\alpha t(1 + \mu)$

9. (c)

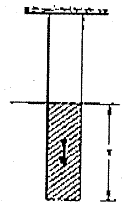
Temperature stress,

$\sigma = E\alpha \Delta t$

11. (a)

Sway is due to external load.

12. (b)



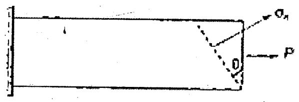
$$\sigma_x = \frac{W_x}{A} = \frac{\gamma A \cdot x}{A} = \gamma x$$

If dimensions are doubled then

$= \gamma n x$

$\therefore \quad \sigma'_x = \sigma = n \cdot 1$

14. (b)



$$\sigma_n = \frac{P\cos\theta}{\left(\frac{A}{\cos\theta}\right)} = \frac{P}{A}\cos^2\theta$$

15. (a)

$$\epsilon = \frac{\sigma}{E} - \frac{\mu\sigma}{E} = \frac{\sigma}{E}\left(1 - \frac{1}{m}\right) = \frac{\sigma(m-1)}{mE}$$

17. (c)

$\sigma = E\alpha\Delta t$

$= 2 \times 10^5 \times 11 \times 10^{-6} \times (50 - 30)$

$= 44$ MPa

The temperature stress does not depend on the length of rail.

18. (c)

The strain in both the bars will be same

$$\therefore \frac{P_s}{A_s E_s} = \frac{P_a}{A_a E_a}$$

$$\Rightarrow \frac{P_s}{A_s 3E_a} = \frac{P_a}{3A_s E_a}$$

$\Rightarrow \quad P_s = P_a$

$$p_s = \frac{P_s}{A_s}$$

and $p_a = \frac{P_a}{A_a} = \frac{P_s}{3A_s} = \frac{P_s}{3} = 30\text{MPa}$

$\therefore \quad p_s = 3p_a = 90$ MPa

19. (c)

Stress will be zero as rod is free to expand.

$\therefore \quad \Delta l = L\alpha\Delta t$

$= 2 \times 10^{-6} \times (50 - 20)$

$= 6 \times 10^{-5}$ m $= 0.06$ mm

20. (b)

$\Delta x = 0$

$$\Rightarrow L\alpha T - \frac{\sigma}{E}L + \mu\frac{\sigma}{E}L + \mu\frac{\sigma}{E}L = 0$$

$$\Rightarrow \quad \sigma = \frac{E\alpha T}{1 - 2\mu}$$

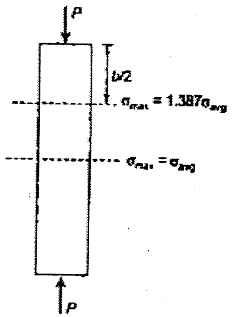
$$= \frac{2 \times 10^5 \times 10^{-6} \times 10}{1 - 2 \times 0.2}$$

$= 3.33$ MPa

$F = \sigma A = 3.33 \times 10^6 \times 1^2$ N

$= 3.33$ MN

21. (d)



$$\frac{\sigma_{max\ centre}}{\sigma_{max\ \frac{b}{2}}} = \frac{\sigma_{avg}}{1.387\sigma_{avg}} = 0.721$$

22. (c)

$\alpha_{copper} > \alpha_{steel}$

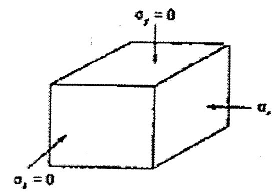
$\therefore$ Free contraction of copper > Free contraction of steel

Hence stresses will reduce on lowering of temperature.

24. (d)

Superposition principle is not valid in case of strain enegy as it is a quadratic function of load. Superposition is applicable for linear dependency problems.

25. (c)



M = Constant

$$\frac{dM}{dx} = 0$$

$\Rightarrow \quad \tau = 0$

$\therefore \quad \phi = 0$

$$\epsilon_{xx} = -\frac{\sigma_x}{E} = p$$

$$\epsilon_{yy} = \epsilon_{zz} = \frac{\mu\sigma_x}{E} = q$$

$$\therefore \text{Strain matrix is} \begin{bmatrix} p & 0 & 0 \\ 0 & q & 0 \\ 0 & 0 & q \end{bmatrix}$$

29. (b)

$$\delta_{taper} = \frac{4PL}{\pi E d_1 d_2}$$

$$\delta_{uniform} = \frac{4PL}{\pi E d^2}$$

$$\because \delta_{taper} = \delta_{uniform}$$

$$\therefore \quad d = \sqrt{d_1 d_2}$$

30. (a)

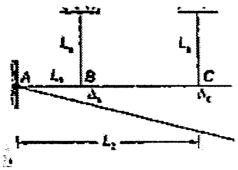
$$E_1 = 2E_2 = 3E_3$$

$$\therefore \quad P_1 = 2P_2 = 3P_3$$

$$\therefore \quad P_1 + \frac{P_1}{2} + \frac{P_1}{3} = 5.5$$

$$\Rightarrow \quad P_1 = 3 \text{ kN}$$

32. (a)



$$\frac{\Delta_s}{\Delta_c} = \frac{L_1}{L_2}$$

$$\Delta_s = L_s\alpha_s T + \frac{\sigma_s}{E_s}L_s$$

$$\Delta_c = L_c\alpha_c T + \frac{\sigma_c}{E_c}L_c$$

$$\Sigma M_A = 0$$

$$\Rightarrow \quad \sigma_s A_s L_1 + \sigma_c A_c L_2 = 0$$

In the given case, following conclusions may be drawn.

(i) If $\frac{L_s\alpha_s T}{L_c\alpha_c T} = \frac{L_1}{L_2}$, then bars will carry zero additional stresses

(ii) If $\frac{L_s\alpha_s T}{L_c\alpha_c T} > \frac{L_1}{L_2}$, steel bar will be in compression and copper bar will be in tension.

(iii) If $\frac{L_s\alpha_s T}{L_c\alpha_c T} < \frac{L_1}{L_2}$, steel bar will be in tension and copper bar will be in compression.

33. (c)

Expansion of copper is more than steel.
Hence bending will also occur.

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