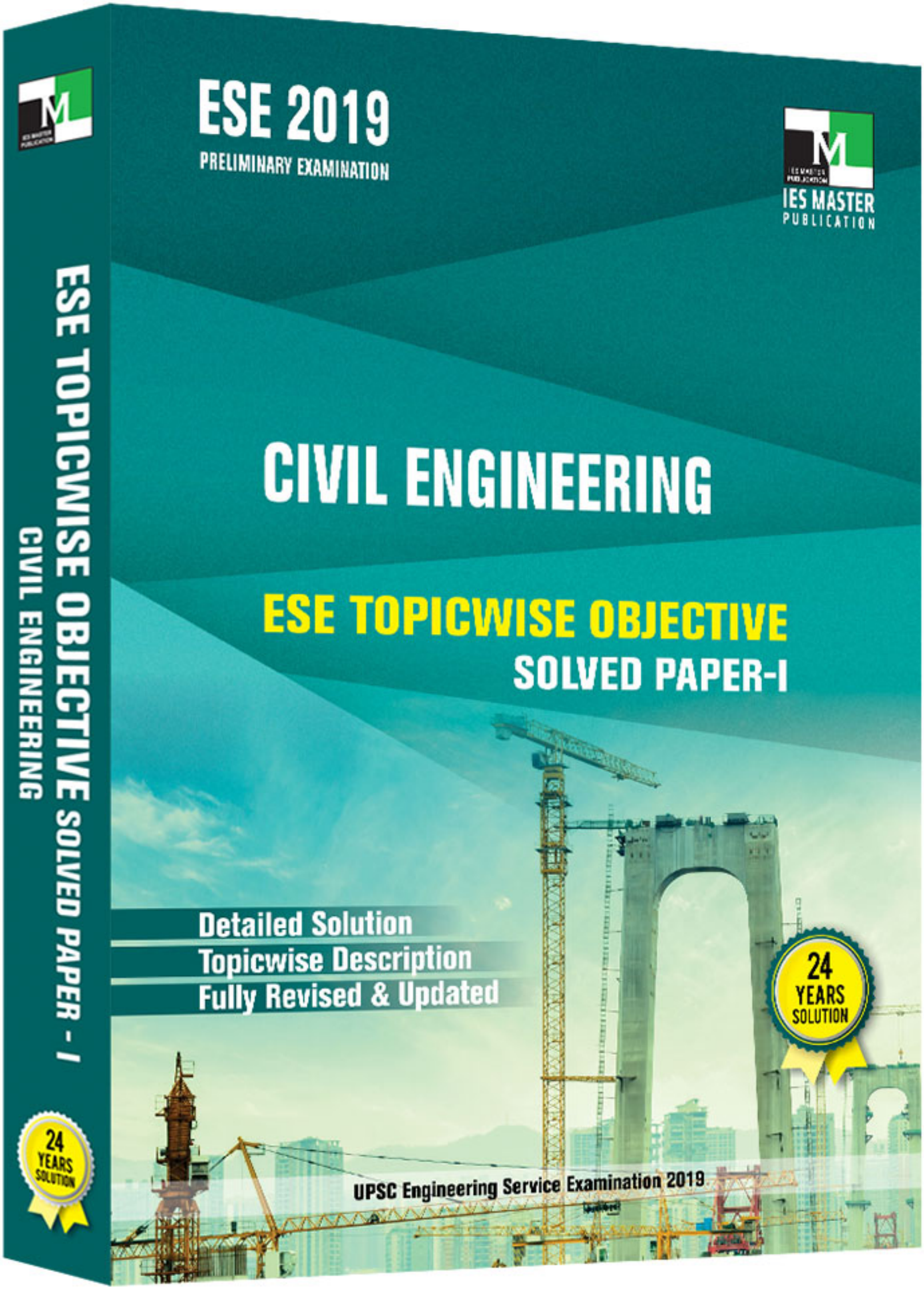
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CIVIL ENGINEERING

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UPSC Engineering Services Examination,

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Preface

It is an immense pleasure to present topic wise previous years solved paper of Engineering Services Exam. This booklet has come out after long observation and detailed interaction with the students preparing for Engineering Services Exam and includes detailed explanation to all questions. The approach has been to provide explanation in such a way that just by going through the solutions, students will be able to understand the basic concepts and will apply these concepts in solving other questions that might be asked in future exams.

Engineering Services Exam is a gateway to an immensly satisfying and high exposure job in engineering sector. The exposure to challenges and opportunities of leading the diverse field of engineering has been the main reason for students opting for this service as compared to others. To facilitate selection into these services, availability of arithmetic solution to previous year paper is the need of the day. Towards this end this book becomes indispensable.

Mr. Kanchan Kumar Thakur
Director–IES Master

CONTENTS

Unit 1

Strength of Materials

Syllabus

Elastic constants, stress, plane stress, Mohr's circle of stress, strains, plane strain, Mohr's circle of strain, combined stress, Elastic theories of failure; Simple bending, shear; Torsion of circular and rectangular sections and simple members.

Contents

CHAPTER

1

Strength of Materials

IES-1995

1. Given that for an element in a body of homogeneous isotropic material subjected to plane stress; $\varepsilon_x, \varepsilon_y$ and ε_z are normal strains in x, y, z directions respectively and μ is the Poisson's ratio, the magnitude of unit volume change of the element is given by

(a) $\varepsilon_x + \varepsilon_y + \varepsilon_z$ (b) $\varepsilon_x - \mu(\varepsilon_y + \varepsilon_z)$

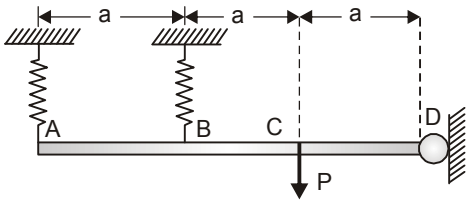
(c) $\mu(\varepsilon_x + \varepsilon_y + \varepsilon_z)$ (d) $1/\varepsilon_x + 1/\varepsilon_y + 1/\varepsilon_z$

2. A solid metal bar of uniform diameter D and length L is hung vertically from a ceiling. If the density of the material of the bar is ρ and the modulus of elasticity is E, then the total elongation of the bar due to its own weight is

(a) $\rho L / 2E$ (b) $\rho L^2 / 2E$

(c) $\rho E / 2L$ (d) $\frac{\rho E}{2L^2}$

3. A rigid beam ABCD is hinged at D and supported by two springs at A and B as shown in the given figure. The beam carries a vertical load P at C. The stiffness of spring at A is 2K and that of B is K.

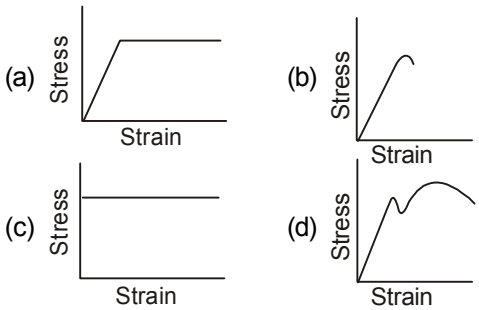


The ratio of forces of spring at A and that of spring at B is

(a) 1 (b) 2

(c) 3 (d) 4

4. The stress-strain curve for an ideally plastic material is



5. A steel cube of volume 8000 cc is subjected to an all round stress of 1330 kg/sq. cm. The bulk modulus of the material is 1.33×10^6 kg/sq. cm. The volumetric change is

(a) 8 cc (b) 6 cc

(c) 0.8 cc (d) 10^{-3} cc

6. In terms of bulk modulus (K) and modulus of rigidity (G), the Poisson's ratio can be expressed as

(a) (3K – 4G)/(6K+4G) (b) (3K+4G)/(6K– 4G)

(c) (3K – 2G)/(6K+ 2G) (d) (3K+2G)/(6K – 4G)

7. Two bars one of material A and the other of material B of same length are tightly secured between two unyielding walls. Coefficient of thermal expansion of bar A is more than that of B. When temperature rises the stresses induced are

(a) tension in both materials

(b) tension in material A and compression in material B

(c) compression in material A and tension in material B

(d) compression in both materials

8. A column of height 'H' and area at top 'A' has the same strength throughout its length, under its own weight and applied stress 'P_0' at the top. Density of column material is 'ρ'. To satisfy the above condition, the area of the column at the bottom should be.

(a) $Ae^{\left(\frac{HP_0}{\rho g}\right)}$ (b) $Ae^{\left(\frac{-\rho gH}{P_0}\right)}$

(c) $Ae^{\left(\frac{\rho gH}{P_0}\right)}$ (d) $Ae^{\left(\frac{H}{\rho gP_0}\right)}$

9. A bar of diameter 30 mm is subjected to a tensile load such that the measured extension on a gauge length of 200 mm is 0.09 mm and the change is diameter is 0.0045 mm. The Poisson's ratio will be

(a) 1/4 (b) 1/3

(c) 1/4.5 (d) 1/2

10. When a mild-steel specimen fails in a torsion-test, the fracture looks like

(a) 

(b) 

(c) 

(d) 

11. A 2 m long bar of uniform section 50 mm^2 extends 2 mm under a limiting axial stress of 200 N/mm^2. What is the modulus of resilience for the bar?

(a) 0.10 units (b) 0.20 units

(c) 10000 units (d) 200000 units

12. The stress level, below which a material has a high probability of **not** failing under reversal of stress, is known as

(a) elastic limit (b) endurance limit

(c) proportional limit (d) tolerance limit

13. If E = 2.06 × 10^5 N/mm^2, an axial pull of 60 kN suddenly applied to a steel rod 50 mm in diameter and 4 m long, causes an instantaneous elongation of the order of

(a) 1.19 mm (b) 2.19 mm

(c) 3.19 mm (d) 11.9 mm

IES-1996

14. A bar of circular cross-section varies uniformly from a cross-section 2D to D. If extension of the bar is calculated treating it as a bar of average diameter, then the percentage error will be

(a) 10 (b) 25

(c) 33.33 (d) 50

15. The length, coefficient of thermal expansion and Young's modulus of bar 'A' are twice that of bar 'B'. If the temperature of both bars is increased by the same amount while preventing any expansion, then the ratio of stress developed in bar A to that in bar B will be

(a) 2 (b) 4

(c) 8 (d) 16

16. The lists given below refer to a bar of length L, cross sectional area A, Young's modulus E, Poisson's ratio μ and subjected to axial stress 'p'. Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I	List-II
A. Volumetric strain	**1.** $2(1 + \mu)$
B. Strain energy per unit volume	**2.** $3(1 - 2\mu)$
C. Ratio of Young's modulus to bulk modulus	**3.** $\frac{p}{E}(1-2\mu)$
D. Ratio of Young's modulus to modulus of rigidity	**4.** $\frac{p^2}{2E}$
	5. $2(1 - \mu)$

Codes:

	A	B	C	D
(a)	3	4	2	1
(b)	5	4	1	2
(c)	5	4	2	1
(d)	2	3	1	5

17. If all dimensions of prismatic bar of square cross-section suspended freely from the ceiling of a roof are doubled then the total elongation produced by its own weight will increase

(a) eight times (b) four times
(c) three times (d) two times

18. The stress at which a material fractures under large number of reversals of stress is called.

(a) endurance limit (b) creep
(c) ultimate strength (d) residual stress

Directions: *The following items consist of two statements, one labelled the* ***'Assertion A'*** *and the other labelled the* ***'Reason R'*** *you are to examine these two statements carefully and decide if the Assertion A and the Reason R are individually true and if so, whether the Reason is a correct explanation of the Assertion. Select your answers to these items using the codes given below and mark your answer sheet accordingly.*

Codes:

(a) Both **A** and **R** are true and **R** is 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

19. **Assertion (A) :** Strain is a fundamental behaviour of the material, while the stress is a derived concept

Reason (R) : Strain does not have a unit while the stress has a unit.

20. **Assertion (A) :** The amount of elastic deformation at a certain point, which an elastic body undergoes, under given stresses is the same irrespective of the stresses being tensile or compressive.

Reason (R) : The modulus of elasticity and Poisson's ratio are assumed to be the same in tension as well as compression.

21. **Assertion (A) :** A mild steel tension specimen has a cup and cone fracture at failure.

Reason (R): Mild steel is weak in shear and failure of the specimen in shear takes place at 45° to the direction of the applied tensile force.

IES-1997

22. A round steel bar of overall length 40 cm consists of two equal portions of 20 cm each having diameters of 10 cm and 8 cm respectively. If the rod is subjected to a tensile load of 10 tones, the elongation will be given by

$\left(E = 2 \times 10^6 \text{ kg/cm}^2\right)$

(a) $\frac{1}{10\pi}\left(\frac{1}{25}+\frac{1}{16}\right)$ cm (b) $\frac{2}{10\pi}\left(\frac{1}{25}+\frac{1}{16}\right)$ cm
(c) $\frac{3}{10\pi}\left(\frac{1}{25}+\frac{1}{16}\right)$ cm (d) $\frac{4}{10\pi}\left(\frac{1}{25}+\frac{1}{16}\right)$ cm

23. A copper bar of 25 cm length is fixed by means of supports at its ends. Supports can yield (total) by 0.01 cm. If the temperature of the bar is raised by 100°C, then the stress induced in the bar for $\alpha_c = 20 \times 10^{-6}$/°C & $E_c = 1 \times 10^6$ kg/cm^2 will be

(a) 2×10^2 kg/cm^2 (b) 4×10^2 kg/cm^2
(c) 8×10^2 kg/cm^2 (d) 16×10^2 kg/cm^2

24. A given material has Young's modulus E, modulus of rigidity G and Poisson's ratio 0.25. The ratio of Young's modulus to modulus of rigidity of this material is

(a) 3.75 (b) 3
(c) 2.5 (d) 1.5

25. A prismatic bar of uniform cross-sectional area of 5 cm^2 is subjected to axial loads as shown in the given figure.

ANSWERS

1. (a)	24. (c)	47. (b)	70. (c)	93. (c)	116. (b)
2. (b)	25. (c)	48. (b)	71. (a)	94. (a)	117. (c)
3. (c)	26. (d)	49. (a)	72. (c)	95. (b)	118. (a)
4. (c)	27. (a)	50. (a)	73. (c)	96. (b)	119. (b)
5. (a)	28. (d)	51. (a)	74. (a)	97. (d)	120. (d)
6. (c)	29. (a)	52. (b)	75. (a)	98. (d)	121. (d)
7. (d)	30. (b)	53. (a)	76. (d)	99. (c)	122. (b)
8. (c)	31. (a)	54. (b)	77. (c)	100. (a)	123. (c)
9. (b)	32. (c)	55. (b)	78. (a)	101. (d)	124. (c)
10. (a)	33. (d)	56. (a)	79. (b)	102. (a)	125. (b)
11. (a)	34. (c)	57. (c)	80. (b)	103. (a)	126. (d)
12. (b)	35. (a)	58. (c)	81. (c)	104. (d)	127. (a)
13. (a)	36. (a)	59. (c)	82. (a)	105. (d)	128. (c)
14. (a)	37. (d)	60. (c)	83. (a)	106. (c)	129. (a)
15. (b)	38. (a)	61. (b)	84. (a)	107. (c)	130. (b)
16. (a)	39. (d)	62. (d)	85. (d)	108. (c)	131. (b)
17. (b)	40. (b)	63. (b)	86. (c)	109. (a)	132. (a)
18. (a)	41. (a)	64. (c)	87. (b)	110. (a)	133. (*)
19. (b)	42. (a)	65. (d)	88. (b)	111. (b)	134. (b)
20. (a)	43. (d)	66. (c)	89. (d)	112. (b)	136. (c)
21. (a)	44. (a)	67. (c)	90. (d)	113. (d)	136. (c)
22. (a)	45. (d)	68. (b)	91. (b)	114. (d)	137. (b)
23. (d)	46. (b)	69. (c)	92. (c)	115. (a)	138. (a)

SOLUTION...

1. (a) Unit volume change,

$$\frac{\Delta V}{V} = \frac{\text{Final volume} - \text{Initial volume}}{\text{Initial volume}}$$

$$\frac{\Delta V}{V} = \frac{(1+\varepsilon_x)(1+\varepsilon_y)(1+\varepsilon_z)-1}{1}$$

$$= 1 + \varepsilon_x + \varepsilon_y + \varepsilon_z + \varepsilon_x\varepsilon_y + \varepsilon_y\varepsilon_z + \varepsilon_z\varepsilon_x + \varepsilon_x\varepsilon_y\varepsilon_z - 1$$

product of strain terms are very small, so neglecting them

hence $\frac{\Delta V}{V} = \varepsilon_x + \varepsilon_y + \varepsilon_z$

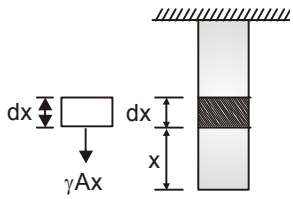
2. (b) Elongation in length, dx is $d\delta$

$$d\delta = \frac{Pdx}{AE} \text{ for a force of P on element (dx)}$$

$$\int d\delta = \int_0^L \frac{Ax\,\gamma\,dx}{AE}$$

$$\delta = \int_0^L \frac{\gamma}{E}\frac{x^2}{2}$$

$$= \frac{\gamma L^2}{2E}$$



$$\delta = \gamma\int_0^L \frac{x^2}{2E} = \frac{\gamma L^2}{2E}$$

Alternative

The elongation of bar due to its own weight (w) is

$$\Delta = \frac{WL}{2AE} = \frac{(\gamma AL)\cdot L}{2AE}$$

$$\Delta = \frac{\gamma L^2}{2E}$$

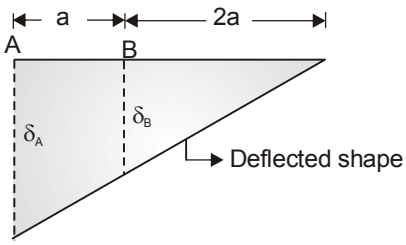
3. (c) Given, $K_A = 2\,K_B$

Force carried by spring at A

$= F_A = k_A\delta_A \Rightarrow 2k_B\delta_A$

Force carried by spring at B

$= F_B = k_B\delta_B$



From similar triangles

$$\frac{\delta_A}{3a} = \frac{\delta_B}{2a} \Rightarrow \delta_A = 1.5\delta_B$$

$$\frac{F_A}{F_B} = \frac{2k_B\delta_A}{k_B\delta_B} = \frac{2\delta_A}{\delta_B} = \frac{2\times 1.5\delta_B}{\delta_B} = 3$$

4. (c) An ideal plastic material experiences no work (non strain) hardening during plastic deformation.

5. (a) Bulk modulus $= \frac{-P}{\Delta V / V}$

$$1.33\times 10^6 = -\frac{1330}{\Delta V / 8000}$$

$$\Delta V = -8 \text{ cc}$$

(–) ve sign indicates reduction in volume if stress is compressive in nature.

6. (c) We know,

$$E = 2G(1+\mu) \quad \text{... (i)}$$

$$E = 3K(1-2\mu) \quad \text{... (ii)}$$

(where μ is poisson's ratio)

Equation (i) ÷ (ii)

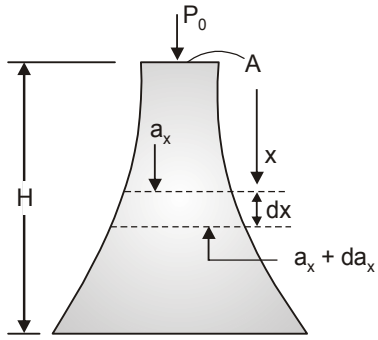
$$1 = \frac{2}{3}\frac{G}{k}\frac{(1+\mu)}{(1-2\mu)}$$

$$3K - 6k\mu = 2G + 2G\mu$$

$$\mu = \frac{3k-2G}{6k+2G}$$

7. (d) As the temperature rises, both the bars will have tendency to expand but they are fixed between two unyielding walls so they will not be allowed to expand. Hence in both the bars compressive stress will develop.

8. (c)

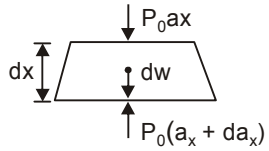


As we move down weight of column will add up to produce stresses. Since the column has same strength, so to satisfy the condition, the X-sectional area must increase as we move down

Let area at distance x be a_x and in length dx

$$\text{wt, added} = \rho g a_x dx$$

But stress has to remain constant



$$d_w = a_x . dx \rho g$$

$$\Rightarrow P_0 . a_x + a_x . \rho g\,(dx) = P_0(a_x + da_x)$$

So $\quad da_x\, P_0 = \rho g a_x dx$

$$\int \frac{da_x}{a_x} = \int \frac{\rho g}{P_0} dx$$

$$ln\, a_x = \frac{\rho g}{P_0} x + C$$

at $\quad x = 0,\ a_x = A$

$$C = ln\, A$$

$$ln \frac{a_x}{A} = \frac{\rho g x}{P_0}$$

at $\quad x = H,\ ln \frac{a_H}{A} = \frac{\rho g H}{P_0}$

$$\frac{a_H}{A} = e^{\rho g H/P_0}$$

$$\Rightarrow \quad a_H = Ae^{\rho g H/P_0}$$

9. (b) Poisson's ratio,

$$\mu = -\frac{\text{Lateral strain}}{\text{Longitudinal strain}}$$

$$= -\frac{(-0.0045/30)}{0.09/200} = \frac{1}{3}$$

10. (a) In ductile material failure is due to shear which in case of torsion occurs at 90° to the axis.

11. (a) Modulus of resilience = Energy stored upto elastic limit per unit volume

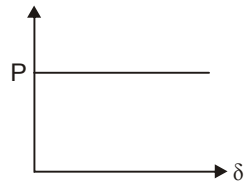
$$= \frac{1}{2} \times \text{stress} \times \text{stress}$$

$$= \frac{1}{2} \times 200 \times \frac{2}{2000} = 0.1 \text{ units}$$

12. (b) Endurance limit is the stress level below which even large no. of stress cycle cannot produce fatigue failure.

13. (a) Energy stored in body = $\frac{\sigma^2 AL}{2E}$

Load is applied suddenly



$$\frac{\sigma^2 AL}{2E} = P.\delta L \Rightarrow \frac{\sigma^2 AL}{2E} = \frac{P\sigma L}{E}$$

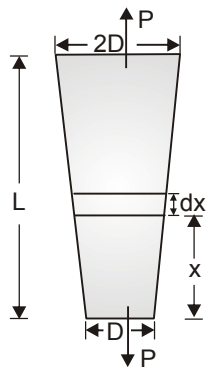
$$\Rightarrow \quad \sigma = \frac{2P}{A}$$

$$\Rightarrow \quad \delta L = \frac{\sigma}{E} \cdot L = \frac{2PL}{AE}$$

$$= \frac{2 \times 60 \times 10^3 \times 4000}{\frac{\pi}{4} \times 50^2 \times 2.06 \times 10^5} = 1.19 \text{ mm}$$

Instantansis elongation is double that under static loading.

14. (a) Diameter at a distance *x*



$$D_x = D + \frac{D}{L} x$$

Extension of bar due to load P

$$\int d\Delta = \int_{d_1}^{d_2} \frac{P dx}{\frac{\pi D_x^2}{4} . E}$$

Note: Extension of circular bar having varying diameter from d_1 to d_2 due to load P.

$$\Delta = \frac{PL}{\left(\frac{\pi d_1 d_2}{4}\right) E}$$

When taking average diameter extension of bar is

$$\Delta_{av} = \frac{PL}{AE} = \frac{PL}{\frac{\pi}{4}\left(\frac{D + 2D}{2}\right)^2 E}$$

$$= \frac{16}{9} \frac{PL}{\pi D^2 E}$$

$$\% \text{ error} = \frac{\frac{2PL}{\pi D^2 E} - \frac{16}{9}\frac{PL}{\pi D^2 E}}{\frac{2PL}{\pi D^2 E}} = 11.11\%$$

15. (b) Stress developed in a bar due to temperature

$$\sigma = \frac{E}{L}(\text{Deformation prevented})$$

$$= \frac{E}{L} \times L\alpha\Delta t = E\alpha\Delta t$$

$$\frac{\sigma_A}{\sigma_B} = \frac{(E\alpha\Delta t)_A}{(E\alpha\Delta t)_B} = \frac{2E \cdot 2\alpha\Delta t}{E\alpha\Delta t} = 4$$

16. (a) A = Volumetric strain

$$\frac{\Delta V}{V} = \frac{(\sigma_x + \sigma_y + \sigma_z)}{E}(1-2\mu)$$

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

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

B = Strain energy per unit volume

$$B = \frac{1}{2}\text{stress} \times \text{strain} = \frac{p^2}{2E}$$

C : $E = 3K(1-2\mu)$

$$\frac{E}{K} = 3(1-2\mu)$$

D : $E = 2G(1+\mu)$

17. (b) Elongation of bar due to it's own weight

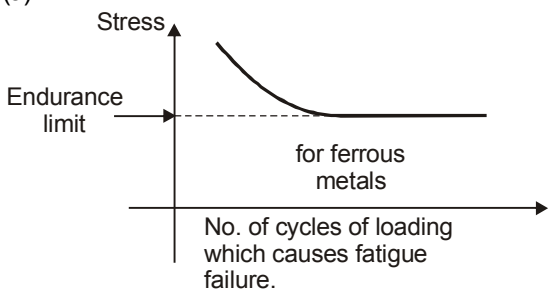
$$\Delta_{initial} = \frac{wL}{2AE} = \frac{(a \times a \times L) \times L}{2 \times (a \times a) \times E} \cdot \gamma = \frac{L^2\gamma}{2E}$$

When all the dimensions are doubled

$$\Delta_{final} = \frac{wL}{2AE} = \frac{(2a \times 2a \times 2L) \times 2L}{2 \times (2a \times 2a) \times E} \cdot \gamma = \frac{4L^2\gamma}{2E}$$

$$= 4\,\Delta_{initial}$$

18. (a)



19. (b) Assertion is correct because strain is the fundamental behaviour but stress is a derived concept because strain can be measured with some instrument and is a fundamental quantity however stress can only be derived, it cannot be measured.

Reasoning is also correct but A does not follow from R.

20. (a) If the material is homogeneous & isotropic, magnitude of deformation will be same if E & μ are same in all direction.

$$\varepsilon_x = \frac{\sigma_x}{E} - \frac{\mu\sigma_y}{E} - \frac{\mu\sigma_z}{E} \quad \text{... (i)}$$

$$\varepsilon_x = \frac{-\sigma_x}{E} - \frac{\mu(-\sigma_y)}{E} - \frac{\mu(-\sigma_z)}{E} \quad \text{... (ii)}$$

Magnitude of ε_x in (i) as well as (ii) is same.

21. (a) Shear is maximum at 45° to the direction of the applied tensile force and mild steel is weak in shear so failure takes place in the direction of maximum shear stress, in cup and cone shape fracture mode.

22. (a) Elongation due to tensile force P

$$\delta = \frac{\Sigma PL}{AE} = \frac{PL_1}{A_1E} + \frac{PL_2}{A_2E}$$

$$= \frac{10 \times 1000 \times 20}{\frac{\pi \times 10^2}{4} \times 2 \times 10^6} + \frac{10 \times 1000 \times 20}{\frac{\pi \times 8^2}{4} \times 2 \times 10^6}$$

$$= \frac{1}{10\pi}\left[\frac{1}{25} + \frac{1}{16}\right] \text{cm}$$

23. (d) Stress induced in the bar due to rise in temperature

$$\sigma = \frac{E}{L} \times (\text{Deflection prevented})$$

$$= \frac{E}{L}(L\,\alpha\,\Delta t - 0.01)$$

$$= \frac{10^6}{25}[25 \times 20 \times 10^{-6} \times 100 - 0.01]$$

$$= 1600 = 16 \times 10^2 \text{ kg/cm}^2$$

24. (c) $E = 2G(1+\mu)$

$$\frac{E}{G} = 2(1+\mu) = 2 \times (1 + 0.25)$$

$$= 2.5$$

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