CIVIL ENGINEERING
ESE TOPICWISE OBJECTIVE SOLVED
PAPER-I

FROM 1995-2018

UPSC Engineering Services Examination,
State Engineering Service Examination & Public Sector Examination.

Regd. office : F-126, (Lower Basement), Katwaria Sarai, New Delhi-110016  Phone : 011-26522064
Mobile : 8010009955, 9711853908  E-mail: info@iesmasterpublications.com, info@iesmaster.org
Web : iesmasterpublications.com, iesmaster.org
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 immensely 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
Genius Batch for ESE GATE PSUs

Start Date
28th May & 14th June

A Classroom Program for SMART LEARNERS

Call 80 1000 9955, 011 4101 3406

Register Now
CONTENTS

1. Strength of Material --------------------------------- 001 – 214
2. Structure Analysis ---------------------------------- 215 – 340
3. Steel Structure ------------------------------------- 341 – 458
4. RCC and Prestressed Concrete ------------------------ 459 – 586
5. PERT CPM ------------------------------------------ 587 – 680


Contents

<table>
<thead>
<tr>
<th>Chapter No.</th>
<th>Topic</th>
<th>Page No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Strength of Materials</td>
<td>01 – 36</td>
</tr>
<tr>
<td>2.</td>
<td>Shear Force and Bending Moment</td>
<td>37 – 72</td>
</tr>
<tr>
<td>3.</td>
<td>Deflection of Beams</td>
<td>73 – 96</td>
</tr>
<tr>
<td>4.</td>
<td>Transformation of Stress and Strain</td>
<td>97 – 123</td>
</tr>
<tr>
<td>5.</td>
<td>Combined Stresses</td>
<td>124 – 136</td>
</tr>
<tr>
<td>6.</td>
<td>Bending Stress in Beams</td>
<td>137 – 159</td>
</tr>
<tr>
<td>7.</td>
<td>Shear Stress in Beams</td>
<td>160 – 170</td>
</tr>
<tr>
<td>8.</td>
<td>Torsion of Circular Shafts</td>
<td>171 – 187</td>
</tr>
<tr>
<td>9.</td>
<td>Columns</td>
<td>188 – 201</td>
</tr>
<tr>
<td>10.</td>
<td>Springs</td>
<td>202 – 206</td>
</tr>
<tr>
<td>11.</td>
<td>Thick and Thin Cylinders/Spheres</td>
<td>207 – 212</td>
</tr>
<tr>
<td>12.</td>
<td>Moment of Inertia</td>
<td>213 – 214</td>
</tr>
</tbody>
</table>

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.
1. Given that for an element in a body of homogeneous isotropic material subjected to plane stress; \( \varepsilon_x, \varepsilon_y \) and \( \varepsilon_z \) are normal strains in x, y, z directions respectively and \( \mu \) is the Poisson's ratio, the magnitude of unit volume change of the element is given by
   \[
   (a) \varepsilon_x + \varepsilon_y + \varepsilon_z \\
   (b) \varepsilon_x - \mu (\varepsilon_y + \varepsilon_z) \\
   (c) \mu (\varepsilon_x + \varepsilon_y + \varepsilon_z) \\
   (d) \frac{1}{\varepsilon_x} + \frac{1}{\varepsilon_y} + \frac{1}{\varepsilon_z}
   \]

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 \( \rho \) and the modulus of elasticity is \( E \), then the total elongation of the bar due to its own weight is
   \[
   (a) \frac{\rho L}{2E} \\
   (b) \frac{\rho L^2}{2E} \\
   (c) \frac{\rho E}{2L} \\
   (d) \frac{\rho E}{2L^2}
   \]

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
   \[
   \begin{array}{cc}
   \text{(a)} & \text{(b)} \\
   \text{Stress} & \text{Strain} \\
   \text{Strain} & \text{Stress}
   \end{array}
   \]

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 \( 1.33 \times 10^6 \) kg/sq. cm. The volumetric change is
   \[
   (a) 8 \text{ cc} \\
   (b) 6 \text{ cc} \\
   (c) 0.8 \text{ cc} \\
   (d) 10^{-3} \text{ cc}
   \]

6. In terms of bulk modulus (\( K \)) and modulus of rigidity (\( G \)), the Poisson's ratio can be expressed as
   \[
   (a) \frac{3K - 4G}{6K + 4G} \\
   (b) \frac{3(K+4G)}{6K - 4G} \\
   (c) \frac{3K - 2G}{6K + 2G} \\
   (d) \frac{3K + 2G}{6K - 4G}
   \]

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
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 ‘P₀’ 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) \( \frac{H P₀}{\rho g} \)  
(b) \( \frac{-\rho g H}{P₀} \)  
(c) \( \frac{\rho g H}{P₀} \)  
(d) \( \frac{H + g P₀}{\rho} \)

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 in diameter is 0.0045 mm. The Poisson’s ratio will be

(a) \( \frac{1}{4} \)  
(b) \( \frac{1}{3} \)  
(c) \( \frac{1}{4.5} \)  
(d) \( \frac{1}{2} \)

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 mm² extends 2 mm under a limiting axial stress of 200 N/mm². 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 \( E = 2.06 \times 10^5 \) N/mm², 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

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 \( \mu \) and subjected to axial stress ‘p’. Match List-I with List-II and select the correct answer using the codes given below the lists:

<table>
<thead>
<tr>
<th>List-I</th>
<th>List-II</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Volumetric strain</td>
<td>1. ( 2(1 + \mu) )</td>
</tr>
<tr>
<td>B. Strain energy per unit volume</td>
<td>2. ( 3(1 - 2\mu) )</td>
</tr>
<tr>
<td>C. Ratio of Young’s modulus to bulk modulus</td>
<td>3. ( \frac{P}{E(1-2\mu)} )</td>
</tr>
<tr>
<td>D. Ratio of Young’s modulus to modulus of rigidity</td>
<td>4. ( \frac{p^2}{2E} )</td>
</tr>
<tr>
<td></td>
<td>5. ( 2(1 - \mu) )</td>
</tr>
</tbody>
</table>
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.

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  
\[ \frac{4 \times 10^8}{10 \pi} \left( \frac{1}{25} + \frac{1}{16} \right) \text{ cm} \]
(a) 10 cm  
(b) 20 cm  
(c) 30 cm  
(d) 40 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 \( \alpha_c = 20 \times 10^{-6}/\text{°C} \) & \( E_c=1 \times 10^6 \text{kg/cm}^2 \) will be
(a) 2 \times 10^2 \text{ kg/cm}^2  
(b) 4 \times 10^2 \text{ kg/cm}^2  
(c) 8 \times 10^2 \text{ kg/cm}^2  
(d) 16 \times 10^2 \text{ 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 cm² is subjected to axial loads as shown in the given figure.
SUBJECT-WISE IMPROVEMENT PROGRAM
Expert guidance and quality material within your reach

SESSION 2018-2019
ESE/GATE/PSUs

for ME, EE, ECE

Call 80 1000 9955, 011 4101 3406

Enrol Now
Choose any package & get admission in GS Batch for FREE

Batches start from 12th March

Register Now
<p>| | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>(a)</td>
<td>24.</td>
<td>(c)</td>
<td>47.</td>
<td>(b)</td>
<td>70.</td>
<td>(c)</td>
</tr>
<tr>
<td>2.</td>
<td>(b)</td>
<td>25.</td>
<td>(c)</td>
<td>48.</td>
<td>(b)</td>
<td>71.</td>
<td>(a)</td>
</tr>
<tr>
<td>3.</td>
<td>(c)</td>
<td>26.</td>
<td>(d)</td>
<td>49.</td>
<td>(a)</td>
<td>72.</td>
<td>(c)</td>
</tr>
<tr>
<td>4.</td>
<td>(c)</td>
<td>27.</td>
<td>(a)</td>
<td>50.</td>
<td>(a)</td>
<td>73.</td>
<td>(c)</td>
</tr>
<tr>
<td>5.</td>
<td>(a)</td>
<td>28.</td>
<td>(d)</td>
<td>51.</td>
<td>(a)</td>
<td>74.</td>
<td>(a)</td>
</tr>
<tr>
<td>6.</td>
<td>(c)</td>
<td>29.</td>
<td>(a)</td>
<td>52.</td>
<td>(b)</td>
<td>75.</td>
<td>(a)</td>
</tr>
<tr>
<td>7.</td>
<td>(d)</td>
<td>30.</td>
<td>(b)</td>
<td>53.</td>
<td>(a)</td>
<td>76.</td>
<td>(d)</td>
</tr>
<tr>
<td>8.</td>
<td>(c)</td>
<td>31.</td>
<td>(a)</td>
<td>54.</td>
<td>(b)</td>
<td>77.</td>
<td>(c)</td>
</tr>
<tr>
<td>9.</td>
<td>(b)</td>
<td>32.</td>
<td>(c)</td>
<td>55.</td>
<td>(b)</td>
<td>78.</td>
<td>(a)</td>
</tr>
<tr>
<td>10.</td>
<td>(a)</td>
<td>33.</td>
<td>(d)</td>
<td>56.</td>
<td>(a)</td>
<td>79.</td>
<td>(b)</td>
</tr>
<tr>
<td>11.</td>
<td>(a)</td>
<td>34.</td>
<td>(c)</td>
<td>57.</td>
<td>(c)</td>
<td>80.</td>
<td>(b)</td>
</tr>
<tr>
<td>12.</td>
<td>(b)</td>
<td>35.</td>
<td>(a)</td>
<td>58.</td>
<td>(c)</td>
<td>81.</td>
<td>(c)</td>
</tr>
<tr>
<td>13.</td>
<td>(a)</td>
<td>36.</td>
<td>(a)</td>
<td>59.</td>
<td>(c)</td>
<td>82.</td>
<td>(a)</td>
</tr>
<tr>
<td>14.</td>
<td>(a)</td>
<td>37.</td>
<td>(d)</td>
<td>60.</td>
<td>(c)</td>
<td>83.</td>
<td>(a)</td>
</tr>
<tr>
<td>15.</td>
<td>(b)</td>
<td>38.</td>
<td>(a)</td>
<td>61.</td>
<td>(b)</td>
<td>84.</td>
<td>(a)</td>
</tr>
<tr>
<td>16.</td>
<td>(a)</td>
<td>39.</td>
<td>(d)</td>
<td>62.</td>
<td>(d)</td>
<td>85.</td>
<td>(d)</td>
</tr>
<tr>
<td>17.</td>
<td>(b)</td>
<td>40.</td>
<td>(b)</td>
<td>63.</td>
<td>(b)</td>
<td>86.</td>
<td>(c)</td>
</tr>
<tr>
<td>18.</td>
<td>(a)</td>
<td>41.</td>
<td>(a)</td>
<td>64.</td>
<td>(c)</td>
<td>87.</td>
<td>(b)</td>
</tr>
<tr>
<td>19.</td>
<td>(b)</td>
<td>42.</td>
<td>(a)</td>
<td>65.</td>
<td>(d)</td>
<td>88.</td>
<td>(b)</td>
</tr>
<tr>
<td>20.</td>
<td>(a)</td>
<td>43.</td>
<td>(d)</td>
<td>66.</td>
<td>(c)</td>
<td>89.</td>
<td>(d)</td>
</tr>
<tr>
<td>21.</td>
<td>(a)</td>
<td>44.</td>
<td>(a)</td>
<td>67.</td>
<td>(c)</td>
<td>90.</td>
<td>(d)</td>
</tr>
<tr>
<td>22.</td>
<td>(a)</td>
<td>45.</td>
<td>(d)</td>
<td>68.</td>
<td>(b)</td>
<td>91.</td>
<td>(b)</td>
</tr>
<tr>
<td>23.</td>
<td>(d)</td>
<td>46.</td>
<td>(b)</td>
<td>69.</td>
<td>(c)</td>
<td>92.</td>
<td>(c)</td>
</tr>
<tr>
<td>24.</td>
<td>(c)</td>
<td>25.</td>
<td>(c)</td>
<td>47.</td>
<td>(b)</td>
<td>70.</td>
<td>(c)</td>
</tr>
<tr>
<td>25.</td>
<td>(c)</td>
<td>26.</td>
<td>(d)</td>
<td>48.</td>
<td>(b)</td>
<td>71.</td>
<td>(a)</td>
</tr>
<tr>
<td>26.</td>
<td>(a)</td>
<td>27.</td>
<td>(a)</td>
<td>49.</td>
<td>(a)</td>
<td>72.</td>
<td>(c)</td>
</tr>
<tr>
<td>27.</td>
<td>(c)</td>
<td>28.</td>
<td>(d)</td>
<td>50.</td>
<td>(a)</td>
<td>73.</td>
<td>(c)</td>
</tr>
<tr>
<td>28.</td>
<td>(c)</td>
<td>29.</td>
<td>(a)</td>
<td>51.</td>
<td>(a)</td>
<td>74.</td>
<td>(a)</td>
</tr>
<tr>
<td>29.</td>
<td>(c)</td>
<td>30.</td>
<td>(a)</td>
<td>52.</td>
<td>(b)</td>
<td>75.</td>
<td>(a)</td>
</tr>
<tr>
<td>30.</td>
<td>(b)</td>
<td>31.</td>
<td>(b)</td>
<td>53.</td>
<td>(a)</td>
<td>76.</td>
<td>(d)</td>
</tr>
<tr>
<td>31.</td>
<td>(b)</td>
<td>32.</td>
<td>(c)</td>
<td>54.</td>
<td>(b)</td>
<td>77.</td>
<td>(c)</td>
</tr>
<tr>
<td>32.</td>
<td>(a)</td>
<td>33.</td>
<td>(d)</td>
<td>55.</td>
<td>(b)</td>
<td>78.</td>
<td>(a)</td>
</tr>
<tr>
<td>33.</td>
<td>(d)</td>
<td>34.</td>
<td>(c)</td>
<td>56.</td>
<td>(a)</td>
<td>79.</td>
<td>(b)</td>
</tr>
<tr>
<td>34.</td>
<td>(c)</td>
<td>35.</td>
<td>(a)</td>
<td>57.</td>
<td>(c)</td>
<td>80.</td>
<td>(b)</td>
</tr>
<tr>
<td>35.</td>
<td>(a)</td>
<td>36.</td>
<td>(a)</td>
<td>58.</td>
<td>(c)</td>
<td>81.</td>
<td>(c)</td>
</tr>
<tr>
<td>36.</td>
<td>(a)</td>
<td>37.</td>
<td>(d)</td>
<td>59.</td>
<td>(c)</td>
<td>82.</td>
<td>(a)</td>
</tr>
<tr>
<td>37.</td>
<td>(d)</td>
<td>38.</td>
<td>(a)</td>
<td>60.</td>
<td>(c)</td>
<td>83.</td>
<td>(a)</td>
</tr>
<tr>
<td>38.</td>
<td>(a)</td>
<td>39.</td>
<td>(d)</td>
<td>61.</td>
<td>(b)</td>
<td>84.</td>
<td>(a)</td>
</tr>
<tr>
<td>39.</td>
<td>(d)</td>
<td>40.</td>
<td>(b)</td>
<td>62.</td>
<td>(d)</td>
<td>85.</td>
<td>(d)</td>
</tr>
<tr>
<td>40.</td>
<td>(b)</td>
<td>41.</td>
<td>(a)</td>
<td>63.</td>
<td>(b)</td>
<td>86.</td>
<td>(c)</td>
</tr>
<tr>
<td>41.</td>
<td>(a)</td>
<td>42.</td>
<td>(a)</td>
<td>64.</td>
<td>(c)</td>
<td>87.</td>
<td>(b)</td>
</tr>
<tr>
<td>42.</td>
<td>(a)</td>
<td>43.</td>
<td>(d)</td>
<td>65.</td>
<td>(d)</td>
<td>88.</td>
<td>(b)</td>
</tr>
<tr>
<td>43.</td>
<td>(d)</td>
<td>44.</td>
<td>(a)</td>
<td>66.</td>
<td>(c)</td>
<td>89.</td>
<td>(d)</td>
</tr>
<tr>
<td>44.</td>
<td>(a)</td>
<td>45.</td>
<td>(d)</td>
<td>67.</td>
<td>(c)</td>
<td>90.</td>
<td>(d)</td>
</tr>
<tr>
<td>45.</td>
<td>(d)</td>
<td>46.</td>
<td>(b)</td>
<td>68.</td>
<td>(b)</td>
<td>91.</td>
<td>(b)</td>
</tr>
<tr>
<td>46.</td>
<td>(b)</td>
<td>69.</td>
<td>(c)</td>
<td>92.</td>
<td>(c)</td>
<td>93.</td>
<td>(c)</td>
</tr>
<tr>
<td>47.</td>
<td>(b)</td>
<td>70.</td>
<td>(c)</td>
<td>94.</td>
<td>(a)</td>
<td>116.</td>
<td>(b)</td>
</tr>
<tr>
<td>48.</td>
<td>(b)</td>
<td>71.</td>
<td>(a)</td>
<td>95.</td>
<td>(b)</td>
<td>117.</td>
<td>(c)</td>
</tr>
<tr>
<td>49.</td>
<td>(a)</td>
<td>72.</td>
<td>(c)</td>
<td>96.</td>
<td>(b)</td>
<td>118.</td>
<td>(a)</td>
</tr>
<tr>
<td>50.</td>
<td>(a)</td>
<td>73.</td>
<td>(c)</td>
<td>97.</td>
<td>(d)</td>
<td>119.</td>
<td>(b)</td>
</tr>
<tr>
<td>51.</td>
<td>(a)</td>
<td>74.</td>
<td>(a)</td>
<td>98.</td>
<td>(d)</td>
<td>120.</td>
<td>(d)</td>
</tr>
<tr>
<td>52.</td>
<td>(b)</td>
<td>75.</td>
<td>(a)</td>
<td>99.</td>
<td>(c)</td>
<td>121.</td>
<td>(d)</td>
</tr>
<tr>
<td>53.</td>
<td>(a)</td>
<td>76.</td>
<td>(d)</td>
<td>100.</td>
<td>(a)</td>
<td>122.</td>
<td>(b)</td>
</tr>
<tr>
<td>54.</td>
<td>(b)</td>
<td>77.</td>
<td>(c)</td>
<td>101.</td>
<td>(d)</td>
<td>123.</td>
<td>(c)</td>
</tr>
<tr>
<td>55.</td>
<td>(b)</td>
<td>78.</td>
<td>(a)</td>
<td>102.</td>
<td>(a)</td>
<td>124.</td>
<td>(c)</td>
</tr>
<tr>
<td>56.</td>
<td>(a)</td>
<td>79.</td>
<td>(b)</td>
<td>103.</td>
<td>(a)</td>
<td>125.</td>
<td>(b)</td>
</tr>
<tr>
<td>57.</td>
<td>(c)</td>
<td>80.</td>
<td>(b)</td>
<td>104.</td>
<td>(d)</td>
<td>126.</td>
<td>(d)</td>
</tr>
<tr>
<td>58.</td>
<td>(c)</td>
<td>81.</td>
<td>(c)</td>
<td>105.</td>
<td>(d)</td>
<td>127.</td>
<td>(a)</td>
</tr>
<tr>
<td>59.</td>
<td>(c)</td>
<td>82.</td>
<td>(a)</td>
<td>106.</td>
<td>(c)</td>
<td>128.</td>
<td>(c)</td>
</tr>
<tr>
<td>60.</td>
<td>(c)</td>
<td>83.</td>
<td>(a)</td>
<td>107.</td>
<td>(c)</td>
<td>129.</td>
<td>(a)</td>
</tr>
<tr>
<td>61.</td>
<td>(b)</td>
<td>84.</td>
<td>(a)</td>
<td>108.</td>
<td>(c)</td>
<td>130.</td>
<td>(b)</td>
</tr>
<tr>
<td>62.</td>
<td>(d)</td>
<td>85.</td>
<td>(d)</td>
<td>109.</td>
<td>(a)</td>
<td>131.</td>
<td>(b)</td>
</tr>
<tr>
<td>63.</td>
<td>(b)</td>
<td>86.</td>
<td>(c)</td>
<td>110.</td>
<td>(a)</td>
<td>132.</td>
<td>(a)</td>
</tr>
<tr>
<td>64.</td>
<td>(c)</td>
<td>87.</td>
<td>(b)</td>
<td>111.</td>
<td>(b)</td>
<td>133.</td>
<td>(*)</td>
</tr>
<tr>
<td>65.</td>
<td>(d)</td>
<td>88.</td>
<td>(b)</td>
<td>112.</td>
<td>(b)</td>
<td>134.</td>
<td>(b)</td>
</tr>
<tr>
<td>66.</td>
<td>(c)</td>
<td>89.</td>
<td>(d)</td>
<td>113.</td>
<td>(d)</td>
<td>136.</td>
<td>(c)</td>
</tr>
<tr>
<td>67.</td>
<td>(c)</td>
<td>90.</td>
<td>(d)</td>
<td>114.</td>
<td>(d)</td>
<td>136.</td>
<td>(c)</td>
</tr>
<tr>
<td>68.</td>
<td>(b)</td>
<td>91.</td>
<td>(b)</td>
<td>115.</td>
<td>(a)</td>
<td>137.</td>
<td>(b)</td>
</tr>
<tr>
<td>69.</td>
<td>(c)</td>
<td>92.</td>
<td>(c)</td>
<td>116.</td>
<td>(b)</td>
<td>138.</td>
<td>(a)</td>
</tr>
</tbody>
</table>
1. (a) Unit volume change,
\[
\frac{\Delta V}{V} = \frac{\text{Final volume} - \text{Initial volume}}{\text{Initial volume}}
\]
\[
\frac{\Delta V}{V} = (1 + \varepsilon_x)(1 + \varepsilon_y)(1 + \varepsilon_z) - 1
\]
\[
= 1 + \varepsilon_x + \varepsilon_y + \varepsilon_z + \varepsilon_x\varepsilon_y + \varepsilon_x\varepsilon_z + \varepsilon_y\varepsilon_z - 1
\]
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
\[
d\delta = \frac{Pdx}{AE}
\]
for a force of \(P\) on element (\(dx\))
\[
\int d\delta = \int_0^L \frac{\gamma x^2}{2E} dx
\]
\[
\delta = \frac{\gamma L^2}{2E}
\]

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 \(B\)
\[
F_B = K_B \delta_B
\]

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

5. (a) Bulk modulus = \(\frac{-P}{\Delta V / V}\)
\[
1.33 \times 10^6 = \frac{-1330}{\Delta V / 8000}
\]
\[
\Delta V = -8 \text{ cc}
\]

6. (c) We know,
\[
E = 2G (1 + \mu) \quad \ldots (i)
\]
\[
E = 3K (1 - 2\mu) \quad \ldots (ii)
\]
(where \(\mu\) is poisson’s ratio)
Equation (i) ÷ (ii)
\[
1 = \frac{2G}{3K} \left( \frac{1 + \mu}{1 - 2\mu} \right)
\]
\[
3K - 6K\mu = 2G + 2G\mu
\]
\[
\mu = \frac{3K - 2G}{6K + 2G}
\]

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

\[d\sigma_y = a_x \, dx \rho g\]

\[\Rightarrow P_0 \cdot a_x + a_x \rho g (dx) = P_0 (a_x + da_x)\]

So

\[da_x = \frac{\rho g \, dx}{P_0}\]

\[\ln a_x = \frac{\rho g x + C}{P_0}\]

at \(x = 0, a_x = A\)
\[C = \ln A\]
\[\ln \frac{a_x}{A} = \frac{\rho g x}{P_0}\]

at \(x = H, \ln \frac{a_H}{A} = \frac{\rho g H}{P_0}\)
\[\Rightarrow \frac{a_H}{A} = e^{\frac{\rho g H}{P_0}}\]
\[\Rightarrow a_H = A e^{\frac{\rho g H}{P_0}}\]

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 \(90^\circ\) to the axis.

11. (a) Modulus of resilience = Energy stored upto elastic limit per unit volume
\[= \frac{1}{2} \times \text{stress} \times \text{stress}\]

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 = \(\frac{\sigma^2AL}{2E}\)
Load is applied suddenly

\[\frac{\sigma^2}{2E} = P \delta L \Rightarrow \frac{\sigma^2}{2E} = \frac{P \delta L}{E}\]

\[\Rightarrow \sigma = \frac{2P}{A}\]
\[\Rightarrow \delta L = \frac{\sigma}{E} = \frac{2PL}{AE} = \frac{2 \times 60 \times 10^3 \times 4000}{\pi \times 50^2 \times 2.06 \times 10^5} = 1.19 \text{ mm}\]

Instantaneous elongation is double that under static loading.

14. (a) Diameter at a distance \(x\)
\[D_z = D + \frac{D}{L} x\]

Extension of bar due to load \(P\)
\[\Delta = \int_0^\delta P d\delta = \frac{P d\delta}{4} \frac{\pi D^2}{E}\]

\[\text{Note:} \text{ Extension of circular bar having varying diameter from } \frac{d_1}{4} \text{ to } \frac{d_2}{4} \text{ due to load } P\]
\[\Delta = \frac{PL}{\pi d_d \frac{d}{4} E}\]

When taking average diameter extension of bar is
\[\Delta_{av} = \frac{PL}{AE} = \frac{PL}{\pi \left(\frac{D + 2D}{2}\right)^2 E}\]
\[= \frac{16 \times PL}{9 \, \pi D^2 E}\]
15. (b) Stress developed in a bar due to temperature
\[ \sigma = \frac{E}{L} (\text{Deformation prevented}) = \frac{E \times L \alpha \Delta t}{L} = E \alpha \Delta t \]
\[ \frac{\sigma_A}{\sigma_B} = \frac{(E \alpha \Delta t)_A}{(E \alpha \Delta t)_B} = \frac{2E \cdot 2 \alpha \Delta t}{E \alpha \Delta t} = 4 \]

16. (a) Volumetric strain
\[ \frac{\Delta V}{V} = \left( \frac{\sigma_x + \sigma_y + \sigma_z}{E} \right) (1 - 2\mu) = \frac{p}{E} (1 - 2\mu) \]
\[ B = \text{Strain energy per unit volume} = \frac{1}{2} \text{stress} \times \text{strain} = \frac{p^2}{2E} \]

17. (b) Elongation of bar due to its own weight
\[ \Delta_{\text{final}} = \frac{wL}{2AE} = \frac{(a \times a \times L) \times L \gamma}{2(a \times a) \times E \gamma} = \frac{L^2 \gamma}{2E} \]
When all the dimensions are doubled
\[ \Delta_{\text{final}} = \frac{wL}{2AE} = \frac{(2a \times 2a \times 2L) \times 2L}{2(2a \times 2a) \times 2E \gamma} = \frac{4L^2 \gamma}{2E} \]
\[ = 4 \Delta_{\text{initial}} \]

18. (a) Stress vs. Endurance limit
No. of cycles of loading which causes fatigue failure.

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.
\[ \varepsilon_x = \frac{\sigma_x - \mu \sigma_y}{E} \]
\[ \varepsilon_y = \frac{-\sigma_y - \mu \sigma_x}{E} \]
Magnitude of \( \varepsilon_x \) 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
\[ \delta = \frac{\sum P L}{AE} = \frac{P L}{A E} = \frac{P L}{A_1 E} + \frac{P L}{A_2 E} \]
\[ = \frac{10 \times 1000 \times 20}{\pi \times 10^2} + \frac{10 \times 1000 \times 20}{\pi \times 8^2} \times 2 \times 10^6 \]
\[ = \frac{1}{10 \pi} \left[ \frac{1}{20} + \frac{1}{16} \right] \text{cm} \]

23. (d) Stress induced in the bar due to rise in temperature
\[ \sigma = \frac{E}{L} (\text{Deflection prevented}) = \frac{E}{L} (L \alpha \Delta t - 0.01) \]
\[ = \frac{10^6}{25} [25 \times 20 \times 10^{-6} \times 100 - 0.01] \]
\[ = 1600 = 16 \times 10^3 \text{ kg/cm}^2 \]

24. (c) Endurance limit
\[ E = 2G (1+\mu) \]
\[ = 2 \times (1 + 0.25) = 2.5 \]