30 Years
Previous Solved Papers

GATE 2026

Civil Engineering

- Fully solved with explanations
- Analysis of previous papers
- Topicwise presentation
- Thoroughly revised & updated

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GATE - 2026

Civil Engineering

Topicwise Previous GATE Solved Papers (1996-2025)

Editions

1st Edition	:	2008
2nd Edition	:	2009
3rd Edition	:	2010
4th Edition	:	2011
5th Edition	:	2012
6th Edition	:	2013
7th Edition	:	2014
8th Edition	:	2015
9th Edition	:	2016
10th Edition	:	2017
11th Edition	:	2018
12th Edition	:	2019
13th Edition	:	2020
14th Edition	:	2021
15th Edition	:	2022
16th Edition	:	2023
17th Edition	:	2024
18th Edition	**:**	**2025**

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Preface

B. Singh (Ex. IES)

Over the period of time the GATE examination has become more challenging due to increasing number of candidates. Though every candidate has ability to succeed but competitive environment, in-depth knowledge, quality guidance and good source of study is required to achieve high level goals.

The new edition of **GATE 2026 Solved Papers : Civil Engineering** has been fully revised, updated and edited. The whole book has been divided into topicwise sections.

At the beginning of each subject, analysis of previous papers are given to improve the understanding of subject.

I have true desire to serve student community by way of providing good source of study and quality guidance. I hope this book will be proved an important tool to succeed in GATE examination. Any suggestions from the readers for the improvement of this book are most welcome.

B. Singh (Ex. IES)
Chairman and Managing Director
MADE EASY Group

GATE-2026

Civil Engineering

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Solid Mechanics

UNIT

I

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Solid Mechanics

Syllabus

Bending moment and shear force in statically determinate beaM; Simple stress and strain relationships; Simple bending theory, flexural and shear stresses, shear centre; Uniform torsion, Transformation of stress; buckling of column, combined and direct bending stresses.

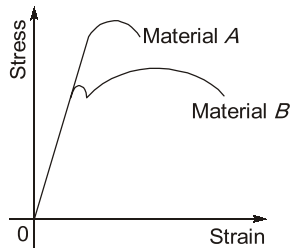
Analysis of Previous GATE Papers

Exam Year	1 Mark Ques.	2 Marks Ques.	Total Marks
1996	3	–	3
1997	2	–	2
1998	–	1	2
1999	4	–	4
2000	7	–	7
2001	1	–	1
2002	2	1	4
2003	2	5	12
2004	1	6	13
2005	2	3	8
2006	3	9	21
2007	3	5	13
2008	–	8	16
2009	2	5	12
2010	5	1	7
2011	1	3	7
2012	4	2	8
2013	4	2	8
2014 Set-1	1	3	7
2014 Set-2	1	5	11
2015 Set-1	1	2	5
2015 Set-2	2	3	8

Exam Year	1 Mark Ques.	2 Marks Ques.	Total Marks
2016 Set-1	–	3	6
2016 Set-2	–	3	6
2017 Set-1	2	2	6
2017 Set 2	1	4	9
2018 Set-1	2	3	8
2018 Set-2	–	1	2
2019 Set-1	2	1	4
2019 Set-2	2	1	4
2020 Set-1	1	2	5
2020 Set-2	2	2	6
2021 Set-1	2	1	4
2021 Set-2	3	1	5
2022 Set-1	2	–	2
2022 Set-2	2	1	4
2023 Set-1	1	2	5
2023 Set-2	2	4	10
2024 Set-1	1	3	7
2024 Set-2	2	1	4
2025 Set-1	–	3	6
2025 Set-2	–	2	4

1 Properties of Metals, Stress & Strain

1.1 The stress-strain diagram for two materials *A* and *B* is shown below:



The following statements are made based on this diagram:

I. Material *A* is more brittle than material *B*.

II. The ultimate strength of material *B* is more than that of *A*.

With reference to the above statements, which of the following applies?

(a) Both the statements are false
(b) Both the statements are true
(c) I is true but II is false
(d) I is false but II is true **[2000 : 1 M]**

1.2 The dimensions for the flexural rigidity of a beam element in mass (*M*), length (*L*) and time (*T*) is given by

(a) MT^{-2} (b) ML^3T^{-2}
(c) $ML^{-1}T^{-2}$ (d) $ML^{-1}T^2$

[2000 : 1 M]

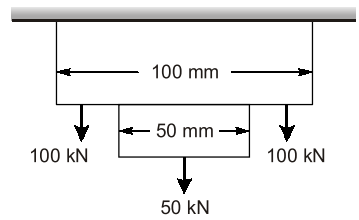
1.3 The shear modulus (*G*), modulus of elasticity (*E*) and the Poisson's ratio (ν) of a material are related as

(a) $G = \dfrac{E}{[2(1+\nu)]}$ (b) $E = \dfrac{G}{[2(1+\nu)]}$

(c) $G = \dfrac{E}{[2(1-\nu)]}$ (d) $G = \dfrac{E}{[2(\nu-1)]}$

[2002 : 1 M]

1.4 A bar of varying square cross-section is loaded symmetrically as shown in the figure. Loads shown are placed on one of the axes of symmetry of cross-section. Ignoring self weight, the maximum tensile stress in N/mm^2 anywhere is



(a) 16.0 (b) 20.0
(c) 25.0 (d) 30.0 **[2003 : 1 M]**

1.5 For linear elastic systeM, the type of displacement function for the strain energy is

(a) linear (b) quadratic
(c) cubic (d) quartic **[2004 : 1 M]**

1.6 The symmetry of stress tensor at a point in the body under equilibrium is obtained from

(a) conservation of mass
(b) force equilibrium equations
(c) moment equilibrium equations
(d) conservation of energy **[2005 : 1 M]**

1.7 For an isotropic material, the relationship between the Young's modulus (*E*), shear modulus (*G*) and Poisson's ratio (μ) is given by

(a) $G = \dfrac{E}{2(1+\mu)}$ (b) $E = \dfrac{G}{2(1+\mu)}$

(c) $G = \dfrac{E}{(1+2\mu)}$ (d) $G = \dfrac{E}{2(1-2\mu)}$

[2007 : 1 M]

1.8 A metal bar of length 100 mm is inserted between two rigid supports and its temperature is increased by 10°C. If the coefficient of thermal expansion is 12×10^{-6} per °C and the Young's modulus is 2×10^5 MPa, the stress in the bar is

(a) zero (b) 12 MPa
(c) 24 MPa (d) 2400 MPa

[2007 : 2 M]

1.9 A rigid bar is suspended by three rods made of the same material. The area and length of the central rod are 3A and L, respectively while that of the two outer rods are 2A and 2L, respectively. If a downward force of 50 kN is applied to the rigid bar, the forces in the central and each of the outer rods will be

(a) 16.67 kN each (b) 30 kN and 15 kN
(c) 30 kN and 10 kN (d) 21.4 kN and 14.3 kN

[2007 : 2 M]

1.10 U_1 and U_2 are the strain energies stored in a prismatic bar due to axial tensile forces P_1 and P_2, respectively. The strain energy U stored in the same bar due to combined action of P_1 and P_2 will be

(a) $U = U_1 + U_2$ (b) $U = U_1 U_2$
(c) $U < U_1 + U_2$ (d) $U > U_1 + U_2$

[2007 : 2 M]

1.11 A mild steel specimen is under uniaxial tensile stress. Young's modulus and yield stress for mild steel are 2×10^5 MPa and 250 MPa respectively. The maximum amount of strain energy per unit volume that can be stored in this specimen without permanent set is

(a) 156 Nmm/mm^3 (b) 15.6 Nmm/mm^3
(c) 1.56 Nmm/mm^3 (d) 0.156 Nmm/mm^3

[2008 : 1 M]

1.12 A vertical rod PQ of length L is fixed at its top end P and has a flange fixed to the bottom end Q. A weight W is dropped vertically from a height h ($<L$) on to the flange. The axial stress in the rod can be reduced by

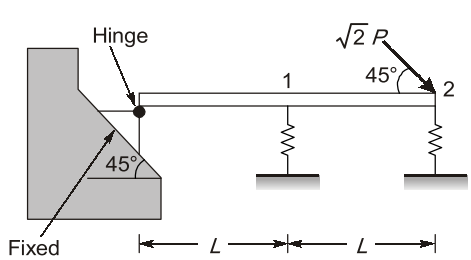
(a) increasing the length of the rod
(b) decreasing the length of the rod
(c) decreasing the area of cross-section of the rod
(d) increasing the modulus of elasticity of the material [2008 : 2 M]

1.13 The number of independent elastic constants for a linear elastic isotropic and homo-geneous material is

(a) 4 (b) 3
(c) 2 (d) 1 [2010 : 1 M]

Linked Answer Questions 1.14 and 1.15:

A rigid beam is hinged at one end and supported on linear elastic springs (both having a stiffness of 'k') at points '1' and '2', and an inclined load acts at '2', as shown.



1.14 Which of the following options represents the deflections δ_1 and δ_2 at points '1' and '2'?

(a) $\delta_1 = \frac{2}{5}\left(\frac{2P}{k}\right)$ and $\delta_2 = \frac{4}{5}\left(\frac{2P}{k}\right)$

(b) $\delta_1 = \frac{2}{5}\left(\frac{P}{k}\right)$ and $\delta_2 = \frac{4}{5}\left(\frac{P}{k}\right)$

(c) $\delta_1 = \frac{2}{5}\left(\frac{P}{\sqrt{2}k}\right)$ and $\delta_2 = \frac{4}{5}\left(\frac{P}{\sqrt{2}k}\right)$

(d) $\delta_1 = \frac{2}{5}\left(\frac{\sqrt{2}P}{k}\right)$ and $\delta_2 = \frac{4}{5}\left(\frac{\sqrt{2}P}{k}\right)$

[2011 : 2 M]

1.15 If the load P equals 100 kN, which of the following options represents forces R_1 and R_2 in the springs at points '1' and '2'?

(a) R_1 = 20 kN and R_2 = 40 kN
(b) R_1 = 50 kN and R_2 = 50 kN
(c) R_1 = 30 kN and R_2 = 60 kN
(d) R_1 = 40 kN and R_2 = 80 kN [2011 : 2 M]

1.16 The Poisson's ratio is defined as

(a) $\left|\frac{\text{axial stress}}{\text{lateral stress}}\right|$ (b) $\left|\frac{\text{lateral strain}}{\text{axial strain}}\right|$

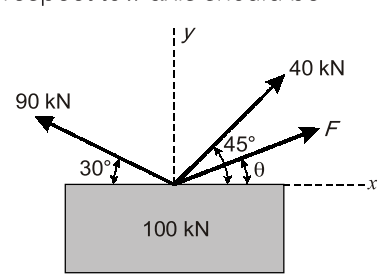
(c) $\left|\frac{\text{lateral stress}}{\text{axial stress}}\right|$ (d) $\left|\frac{\text{axial strain}}{\text{lateral strain}}\right|$

[2012 : 1 M]

1.17 Creep strains are

(a) caused due to dead load only
(b) caused due to live load only
(c) caused due to cyclic load only
(d) independent of load [2013 : 1 M]

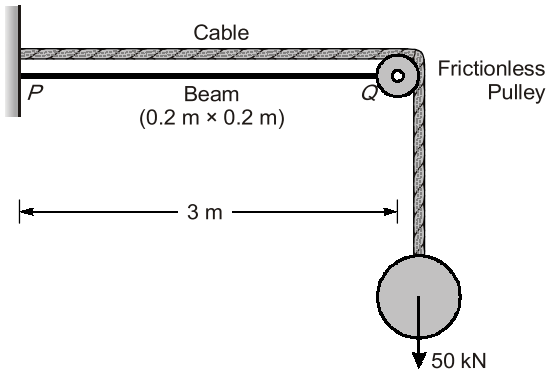
1.18 A box of weight 100 kN shown in the figure is to be lifted without swinging. If all forces are coplanar, the magnitude and direction (θ) of the force (F) with respect to x-axis should be



(a) F = 56.389 kN and θ = 28.28°
(b) F = – 56.389 kN and θ = – 28.28°
(c) F = 9.055 kN and θ = 1.414°
(d) F = – 9.055 kN and θ = – 1.414°

[2014 : 2 M, Set-I]

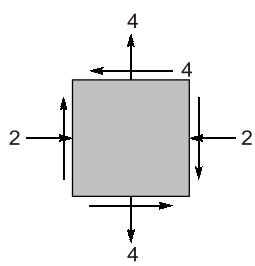
1.19 The values of axial stress (σ) in kN/m^2, bending moment (M) in kNm, and shear force (V) in kN acting at point P for the arrangement shown in the figure are respectively



(a) 1000, 75 and 25 (b) 1250, 150 and 50
(c) 1500, 225 and 75 (d) 1750, 300 and 100

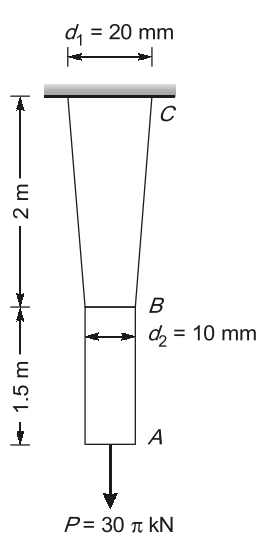
[2014 : 2 M, Set-II]

1.20 For the state of stresses (in MPa) shown in the figure below, the maximum shear stress (in MPa) is _____.



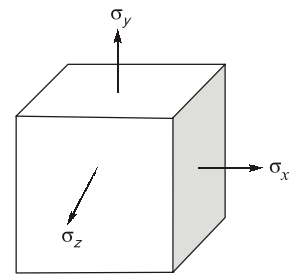
[2014 : 2 M, Set-II]

1.21 A tapered circular rod of diameter varying from 20 mm to 10 mm is connected to another uniform circular rod of diameter 10 mm as shown in the following figure. Both bars are made of same material with the modulus of elasticity, $E = 2 \times 10^5$ MPa. When subjected to a load $P = 30\pi$ kN, the deflection at point A is ____ mm.



[2015 : 2 M, Set-I]

1.22 An elastic isotropic body is in a hydrostatic state of stress as shown in the figure. For no change in the volume to occur, what should be its Poisson's ratio?



(a) 0.00 (b) 0.25
(c) 0.50 (d) 1.00

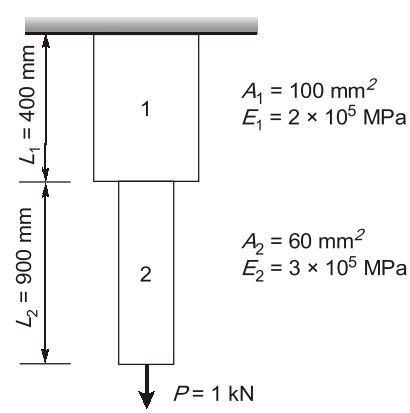
[2016 : 2 M, Set-II]

1.23 An elastic bar of length L, uniform cross-sectional area A, coefficient of thermal expansion α, and Young's modulus E is fixed at the two ends. The temperature of the bar is increased by T, resulting in an axial stress σ. Keeping all other parameters unchanged, if the length of the bar is doubled, the axial stress would be

(a) σ (b) 2σ
(c) 0.5σ (d) 0.25σ

[2017 : 1 M, Set-I]

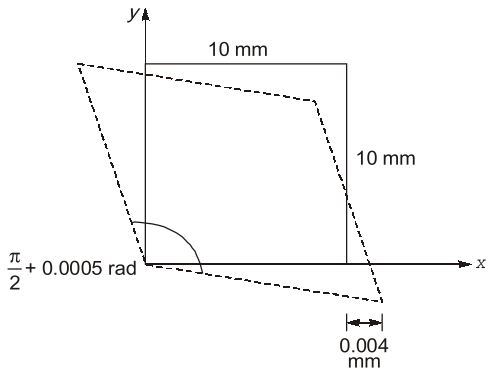
1.24 Consider the stepped bar made with a linear elastic material and subjected to an axial load of 1 kN, as shown in the figure.



Segments 1 and 2 have cross-sectional area of 100 mm^2 and 60 mm^2. Young's modulus of 2×10^5 MPa and 3×10^5 MPa, and length of 400 mm and 900 mm, respectively. The strain energy (in N-mm upto one decimal place) in the bar due to the axial load is _____.

[2017 : 2 M, Set-I]

1.25 In a material under a state of plane strain, a 10 × 10 mm square centered at a point gets deformed as shown in the figure.

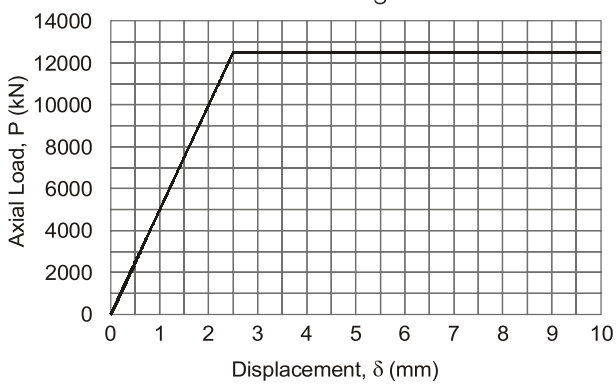


If the shear strain γ_{xy} at this point is expressed as 0.001 k (in rad), the value of k is

(a) 0.50 (b) 0.25
(c) –0.25 (d) –0.50

[2017 : 1 M, Set-II]

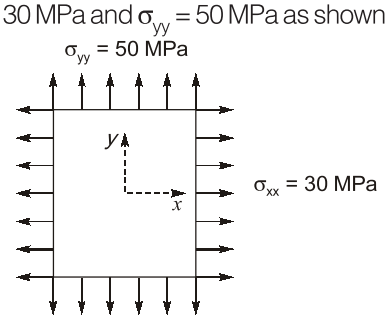
1.26 A 2 m long, axially loaded mild steel rod of 8 mm diameter exhibits the load-displacement (P-δ) behavior as shown in the figure.



Assume the yield stress of steel as 250 MPa. The complementary strain energy (in N-mm) stored in the bar up to its linear elastic behaviour will be _____.

[2017 : 2 M, Set-II]

1.27 A plate in equilibrium is subjected to uniform stresses along its edges with magnitude σ_{xx} = 30 MPa and σ_{yy} = 50 MPa as shown in the figure

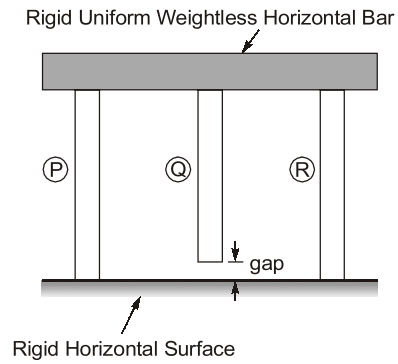


The Young's modulus of the material is 2×10^{11} N/m^2 and the Poisson's ratio is 0.3. If σ_{zz} is negligibly small and assumed to be zero, then the strain ε_{zz} is

(a) -120×10^{-6} (b) -60×10^{-6}
(c) 0.0 (d) 120×10^{-6}

[2018 : 2 M, Set-I]

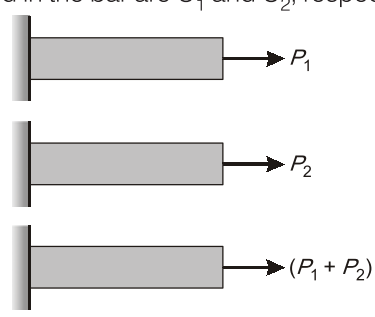
1.28 A rigid, uniform, weightless, horizontal bar is connected to three vertical members P, Q and R as shown in the figure (not drawn to the scale). All three members have identical axial stiffness of 10 kN/mm. The lower ends of bars P and R rest on a rigid horizontal surface. When NO load is applied, a gap of 2 mm exists between the lower end of the bar Q and the rigid horizontal surface. When a vertical load W is placed on the horizontal bar in the downward direction, the bar still remains horizontal and gets displaced by 5 mm in the vertically downward direction.



The magnitude of the load W (in kN, round off to the nearest integer), is _____.

[2020 : 2 M, Set-I]

1.29 A prismatic linearly elastic bar of length, L, cross-sectional area A, and made up of a material with Young's modulus E, is subjected to axial tensile force as shown in the figures. When the bar is subjected to axial tensile force P_1 and P_2, the strain energies stored in the bar are U_1 and U_2, respectively.

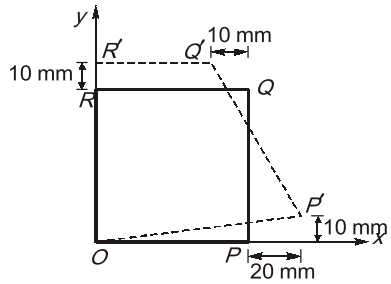


If U is the strain energy stored in the same bar when subjected to an axial tensile force $(P_1 + P_2)$, the correct relationship is

(a) $U = U_1 - U_2$ (b) $U = U_1 + U_2$
(c) $U < U_1 + U_2$ (d) $U > U_1 + U_2$

[2020 : 2 M, Set-II]

1.30 A square plate O-P-Q-R of a linear elastic material with sides 1.0 m is loaded in a state of plane stress. Under a given stress condition, the plate deforM to a new configuration O-P′-Q′-R′ as shown in the figure (not to scale). Under the given deformation, the edges of the plate remain straight.



The horizontal displacement of the point (0.5 m, 0.5 m) in the plate O-P-Q-R (in mm, round off to one decimal place) is _____.

[2021 : 2 M, Set-I]

1.31 Strain hardening of structural steel means

(a) strengthening steel member externally for reducing strain experienced

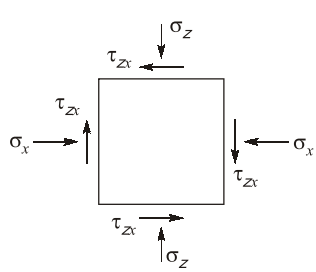
(b) experiencing higher stress than yield stress with increased deformation

(c) strain occurring before plastic flow of steel material

(d) decrease in the stress experienced with increasing strain

[2021 : 1 M, Set-II]

1.32 Stresses acting on an infinitesimal soil element are shown in the figure (with $\sigma_z > \sigma_x$). The major and minor principal stresses are σ_1 and σ_3, respectively. Considering the compressive stresses as positive,which one of the following expressions correctly represents the angle between the major principal stress plane and the horizontal plane?



(a) $\tan^{-1}\left(\dfrac{\tau_{Zx}}{\sigma_1+\sigma_3}\right)$ (b) $\tan^{-1}\left(\dfrac{\tau_{Zx}}{\sigma_3-\sigma_x}\right)$

(c) $\tan^{-1}\left(\dfrac{\tau_{Zx}}{\sigma_1-\sigma_x}\right)$ (d) $\tan^{-1}\left(\dfrac{\tau_{Zx}}{\sigma_1+\sigma_x}\right)$

[2022 : 1 M, Set-II]

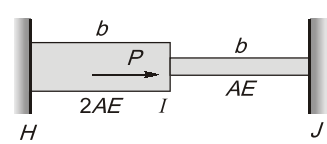
1.33 For a linear elastic and isotropic material, the correct relationship among Young's modulus of elasticity (E), Poisson's ratio (v), and shear modulus (G) is

(a) $G=\dfrac{E}{2(1+v)}$ (b) $G=\dfrac{E}{(1+2v)}$

(c) $E=\dfrac{G}{2(1+v)}$ (d) $E=\dfrac{G}{(1+2v)}$

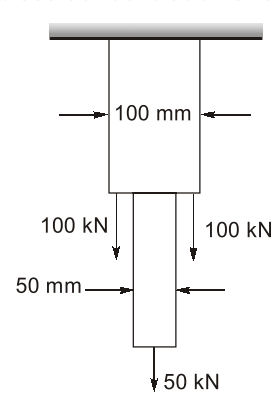
[2022 : 2 M, Set-II]

1.34 Consider two linearly elastic rods HI and IJ. each of length b, as shown in the figure. The rods are co-linear, and confined between two fixed supports at if and J. Both the rods are initially stress free, The coefficient of linear thermal expansion is a for both the rods. The temperature of the rod IJ is raised by ΔT. whereas the temperature of rod HI remains unchanged. An external horizontal force P is now applied at node I. It is given that a = 10^{-6} °C^{-1}, ΔT = 50° C, b = 2m, AE = 10^6N. The axial rigidities of the rods HI and U are 2 AE and AE, respectively. To make the axial force in rod HI equal to zero, the value of the external force P (in N) is ____ . (rounded off to the nearest integer).



[2022 : 1 M, Set-II]

1.35 A hanger is made of two bars of different sizes. Each bar has a square cross-section. The hanger is loaded by three-point loads in the mid vertical plane as shown in the figure. Ignore the self-weight of the hanger. What is the maximum tensile stress in N/mm^2 anywhere in the hanger without considering stress concentration effects?



(a) 15.0 (b) 25.0

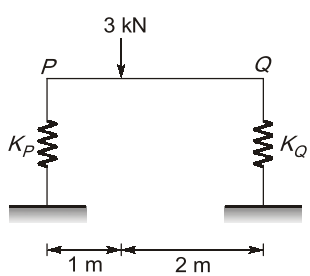
(c) 35.0 (d) 45.0

[2023 : 1 M, Set-I]

1.36 A 2D thin plate with modulus of elasticity, E =1.0 N/m^2, and Poisson's ratio, μ = 0.5, is in plane stress condition. The displacement field in the plate is given by $u = Cx^2y$. and $v = 0$, where u and v are displacements (in m) along the X and Y directions, respectively, and C is a constant (in m^{-2}). The distances x and y along X and Y, respectively, are in m. The stress in the X direction is $\sigma_{XX} = 40xy$ N/m^2, and the shear stress is $\tau_{XY} = \alpha x^2$ N/m^2. What is the value of α (in N/m^4, in integer)? _____

[2023 : 2 M, Set-II]

1.37 A 3 m long, horizontal, rigid, uniform bean PQ has negligible mass. The beam is subjected to a 3kN concentrated vertically downward force at 1 m from P, as shown in the figure. The beam is resting on vertical linear springs at the ends P and Q. For the spring at the end P, the spring constant K_P = 100 kN/m.



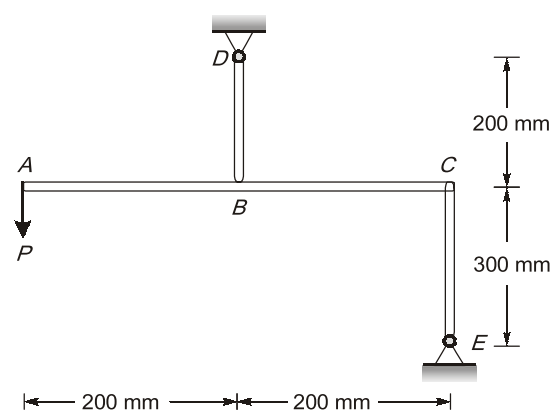
(Figure NOT to scale)

If the beam DOES NOT rotate under the application of the force and displaces only vertically, the value of the spring constant K_Q (in kN/m) for the spring at the end Q

(a) 200 (b) 50
(c) 100 (d) 150

[2024 : 1 M, Set-II]

1.38 Consider the rigid bar ABC supported by the pin-jointed links BD and CE and subjected to a load P at the end A, as shown in the figure. The axial rigidities of BD and CE are 22500 kN and 15000 kN, respectively. If CE elongates by 5 mm due to the load P, the magnitude of the downward deflection (in mm) of the end A would be ____ (rounded off to the nearest integer).



[2025 : 2 M, Set-I]

Answers Properties of Metals, Stress & Strain

1.1 (c)	1.2 (b)	1.3 (a)	1.4 (c)	1.5 (b)	1.6 (c)	1.7 (a)
1.8 (c)	1.9 (c)	1.10 (d)	1.11 (d)	1.12 (a)	1.13 (c)	1.14 (b)
1.15 (d)	1.16 (b)	1.17 (a)	1.18 (a)	1.19 (b)	1.20 (5.0)	1.21 (15)
1.22 (c)	1.23 (a)	1.24 (35)	1.25 (d)	1.26 (15625000)		1.27 (a)
1.28 (130)	1.29 (d)	1.30 (2.5)	1.31 (b)	1.32 (c)	1.33 (a)	1.34 (50)
1.35 (b)	1.36 (5)	1.37 (b)	1.38 (14)			

Explanations Properties of Metals, Stress & Strain

1.1 (c)

Since strain in material B is more, hence it is more ductile than material A i.e., material A is more brittle than material B. Hence **statement I is true**. Material A can reach upto higher stress level hence ultimate strength of material A is more than that of material B. Hence **statement II is false**.

1.2 (b)

Flexural regidity = $EI = ML^{-1}T^{-2} \times L^4 = ML^3T^{-2}$

1.3 (a)

For isotropic and homogenous materials,

$$E = 2G(1 + \mu)$$
$$E = 3k(1 - 2\mu)$$

1.4 (c)

Method-I

The stress in lower bar

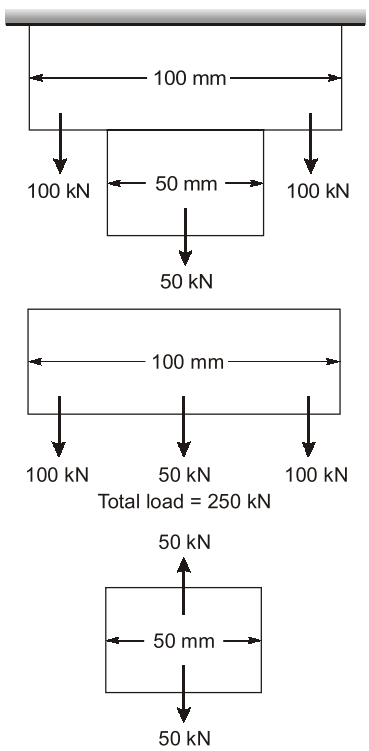
$$= \frac{50 \times 1000}{50 \times 50} = 20 \text{ N/mm}^2$$

The stress in upper bar

$$= \frac{250 \times 1000}{100 \times 100} = 25 \text{ N/mm}^2$$

Thus the maximum tensile stress any where in the bar is 25 N/mm^2.

Method-II



Stress in upper bar

$$= \frac{250 \times 1000}{100 \times 100} = 25 \text{ N/mm}^2$$

Stress in lower bar $= \dfrac{50 \times 10^3}{50 \times 50} = 20 \text{ N/mm}^2$

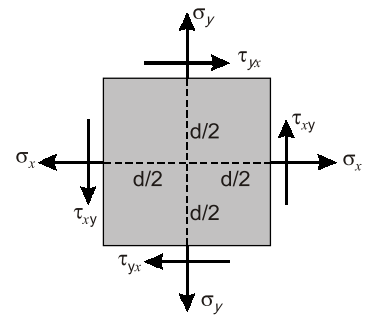
So, maximum tensile stress = 25 N/mm^2

1.5 (b)

Strain Energy $= \dfrac{1}{2} \times \sigma \times \varepsilon = \dfrac{1}{2} E\varepsilon^2$

Since strain is directly proportional to displacement so strain energy is directly proportional to quadratic equation of displacement.

1.6 (c)



Taking moment equilibrium about the centre, we get,

$$\tau_{yx} \times \frac{d}{2} + \tau_{yx} \times \frac{d}{2} = \tau_{xy} \times \frac{d}{2} + \tau_{xy} \times \frac{d}{2}$$

$$\therefore \quad \tau_{xy} = \tau_{yx}$$

1.7 (a)

For isotropic and homogenous materials,

$$E = 2G(1 + \mu)$$
$$E = 3k(1 - 2\mu)$$

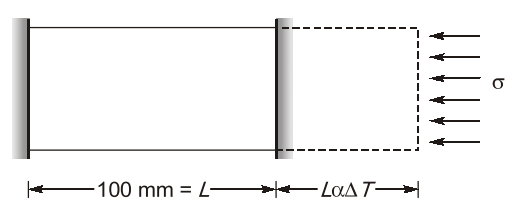
1.8 (c)

Method-I

Temperature stress

$$= \alpha TE$$
$$= 12 \times 10^{-6} \times 10 \times 2 \times 10^5$$
$$= 24 \text{ MPa}$$

Method-II



Due to temperature,

$$\Delta L = L\alpha\Delta T$$

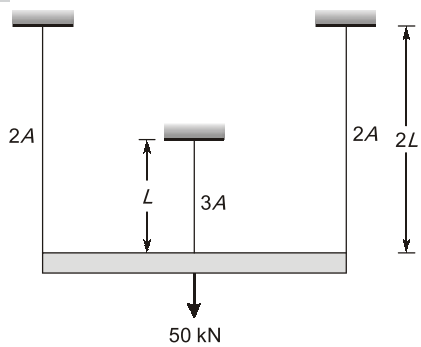
But since support in fixed so, expansion is not allowed so stress is developed in the bar which is compressive in nature.

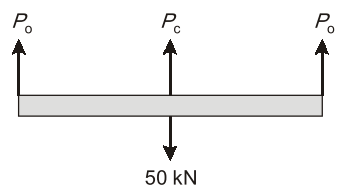
Now, Expansion due to temperature = Compression due to stress

$$L\alpha\Delta T = \frac{\sigma}{E} \times L$$

$$\sigma = E\alpha\Delta T = 1 \times 10^5 \times 12 \times 10^{-6} \times 10$$
$$= 24 \text{ MPa}$$

1.9 (c)





From symmetry, the force in each of outer rods is P_0 and force in the central rod is P_C, then,

$$2P_0 + P_C = 50 \quad \text{...(i)}$$

Also, the elongation of central rod and outer rods is same.

Since all the rods are connected by rigid bar. So, deflection in each rod will be same

$$\therefore \quad \frac{P_0 L_0}{A_0 E} = \frac{P_C L_C}{A_C E}$$

$$\Rightarrow \quad \frac{P_0 \times 2L}{2A} = \frac{P_C \times L}{3A}$$

$$\Rightarrow \quad P_C = 3P_0 \quad \text{...(ii)}$$

Solving (i) and (ii), we get,

$P_C = 30$ kN and $P_0 = 10$ kN

1.10 (d)

Strain energy stored in a prismatic bar due to axial load P_1,

$$U_1 = \frac{P_1^2 L}{2AE}$$

Strain energy stored in a prismatic bar due to axial load, P_2,

$$U_2 = \frac{P_2^2 L}{2AE}$$

Strain energy stored in a prismatic bar due to combined action of P_1 and P_2,

$$U = \frac{(P_1 + P_2)^2 L}{2AE}$$

$$U = \frac{P_1^2 L}{2AE} + \frac{P_2^2 L}{2AE} + \frac{P_1 P_2 L}{AE}$$

$$U = U_1 + U_2 + \frac{P_1 P_2 L}{AE}$$

$$\Rightarrow \quad U > U_1 + U_2$$

1.11 (d)

The strain energy per unit volume may be given as

$$U = \frac{1}{2} \times \text{Stresses} \times \text{Strain}$$

$$U = \frac{1}{2} \times \frac{\sigma_y^2}{E} = \frac{1}{2} \times \frac{(250)^2}{2 \times 10^5} = 0.156 \text{ N-mm/mm}^3$$

1.12 (a)

The kinetic energy of the weight (W) at flange level will be transformed in the form of strain energy in the rod.

We know that,

$U = \sigma^2/2E \times$ Area of cross-section of rod $\times$ length of rod.

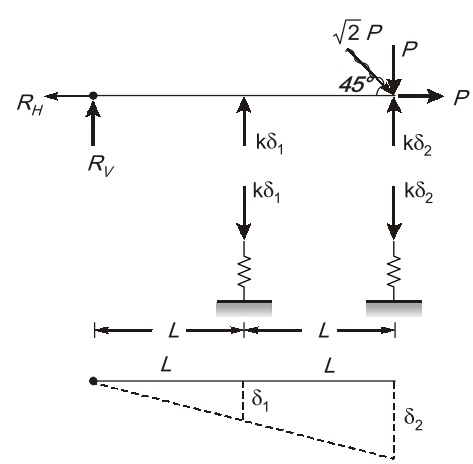
Since, energy remains constant, hence to reduce the axial stress in the rod, the length of the rod should be increased or area of cross-section of the rod should be increased or modulus of elasticity should be decreased.

1.13 (c)

Type of material	Number of independent elastic constants
Isotropic	2
Orthotropic	9
Antisotropic	21

1.14 (b)

The free diagram of the beam is shown below,



From similar triangles, we get,

$$\frac{L}{\delta_1} = \frac{2L}{\delta_2}$$

$\Rightarrow \quad \delta_2 = 2\delta_1 \quad$ ...(i)

Taking moments about hinge, we get,

$P \times 2L - k\delta_2 \times 2L - k\delta_1 \times L = 0$

$\Rightarrow 2P - k(2\delta_2 + \delta_1) = 0 \quad$ [∴ from (i)]

$\Rightarrow 2P - k(4\delta_1 + \delta_1) = 0$

$\Rightarrow \quad \delta_1 = \frac{2P}{5k}$

From (i), we get,

$$\delta_2 = 2 \times \frac{2P}{5k} = \frac{4P}{5k}$$

1.15 (d)

$$R_1 = k\delta_1 = k \times \frac{2P}{5k} = \frac{2 \times 100}{5} = 40 \text{ kN}$$

$$R_2 = k\delta_2 = k \times \frac{4P}{5k} = \frac{4 \times 100}{5} = 80 \text{ kN}$$

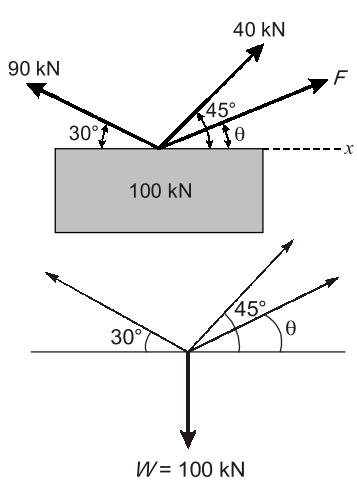
1.16 (b)

$$\mu = \left| \frac{\text{Lateral strain}}{\text{Axial strain}} \right|$$

1.17 (a)

Creep strains occur with time at a constant level of stress. So they occur due to permanent load i.e., Dead Load.

1.18 (a)



For no swinging force should be balanced i.e.,

$\Sigma F_H = 0$

$\Sigma F_V = 0$

$\Sigma F_{horizontal} = 0$

$90 \cos 30° = 40 \cos 45° + F \cos \theta$

$77.94 = 28.28 + F \cos \theta$

or $\quad F \cos\theta = 49.66 \text{ kN} \quad$ ...(i)

$\Sigma F_{vertical} = 100$

$90 \sin 30° + 40 \sin 45° + F \sin \theta = W$

$45 + 28.28 + F \sin \theta = 100$

or $\quad F \sin\theta = 26.72 \text{ kN} \quad$ ...(ii)

Dividing eq. (ii) by eq. (i), we get

$$\tan \theta = \frac{26.72}{49.66} = 0.5380$$

or $\quad \theta = \tan^{-1}(0.5380) = 28.28°$

Substituting $\theta = 28.28$ in eq. (i), we get

$F \cos 28.28° = 49.66$

or $\quad F = \frac{49.66}{\cos 28.28°} = \frac{49.66}{0.88} = 56.43 \text{ kN}$

1.19 (b)

Loading after removing the cable,

$$\text{Axial stress} = \frac{50}{0.2 \times 0.2} = 1250 \text{ kN/m}^2$$

Bending moment = 50 × 3 = 150 kNm

Shear force = 50 kN

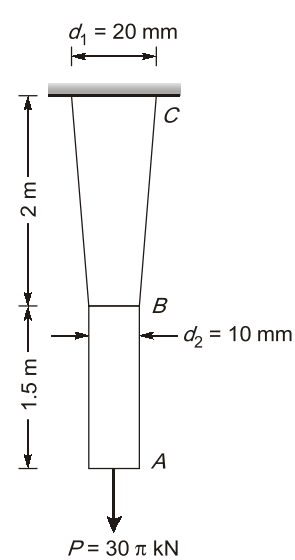
1.20 Sol.

$$\tau_{max} = \frac{\sigma_1 - \sigma_2}{2} = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2} = 5.0 \text{ MPa}$$

NOTE: In this case σ_{P1} = +ve

So it can be found out by Mohr circle, otherwise always check for absolute shear stress.

1.21 Sol.



Total elongation,
AB is uniform

So, $\Delta = \dfrac{PL}{AE}$

BC is tapered

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

$$\Delta = \Delta_{AB} + \Delta_{BC}$$

$$= \frac{PL}{AE} + \frac{4PL}{\pi d_1 d_2 E}$$

$$= \frac{30\pi \times 10^3 \times 1.5 \times 10^3}{\frac{\pi}{4} \times (10)^2 \times 10^5}$$

$$+ \frac{30\pi \times 10^3 \times 2 \times 10^3}{\frac{\pi}{4} \times 10 \times 20 \times 2 \times 10^5}$$

$= (9 + 6)$ mm = 15 mm

1.22 (c)

Volumetric strain,

$$\epsilon_V = \left(\frac{\sigma_x + \sigma_y + \sigma_z}{3}\right)(1 - 2\mu)$$

$$\Rightarrow \quad \frac{\delta V}{V} = \left(\frac{\sigma_x + \sigma_y + \sigma_z}{3}\right)(1 - 2\mu)$$

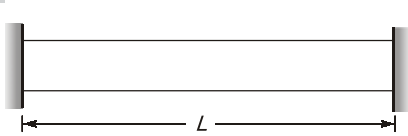
As $\Delta V = 0$

$\Rightarrow$ Either $\sigma_x + \sigma_y + \sigma_z = 0$ or $1 - 2\mu = 0$

$\Rightarrow$ $1 - 2\mu = 0$

$\mu = 0.5$

1.23 (a)



$\sigma = \alpha T E$

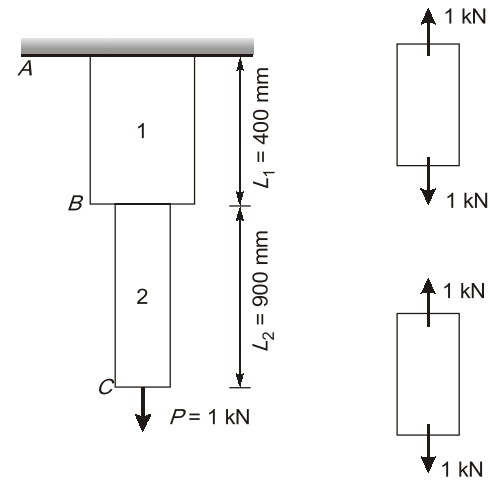
$\therefore$ Length have no effect on thermal stress.

$\therefore$ Axial stress is only 'σ'.

1.24 Sol.

$A_1 = 100$ mm^2, $EI = 2 \times 10^5$ MPa

$A_2 = 60$ mm^2, $EI = 3 \times 10^5$ MPa



$$\Delta_{AC} = \Delta_{AB} + \Delta_{BC}$$

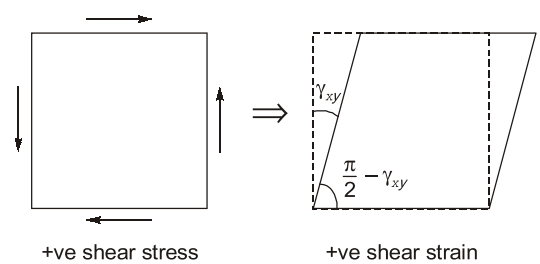
$$= \frac{1 \times 10^3 \times 400}{100 \times 2 \times 10^5} + \frac{1 \times 10^3 \times 900}{60 \times 3 \times 10^5}$$

$= 0.02 + 0.05 = 0.07$ mm

$$U = \frac{1}{2} \times P \times \Delta = \frac{1}{2} \times 1 \times 1000 \times 0.07 = 35 \text{ N-mm}$$

1.25 (d)

According to the sign convention,



In question since angle has been increase therefore shear strain should be negative.

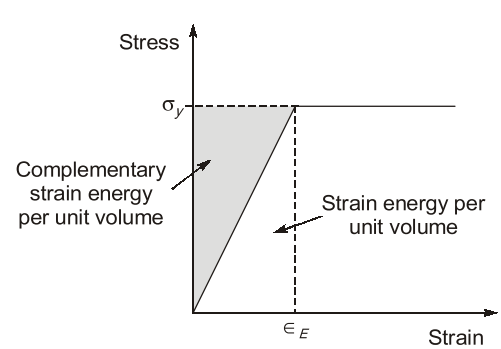
$\therefore \quad \gamma_{xy} = -0.0005$ rad

$= 0.001k$

$-0.0005 = 0.001k$

$\Rightarrow \quad k = -0.50$

1.26 Sol.



Elastic strain, $\epsilon_E = \frac{\Delta L}{L} = \frac{2.5}{2000} = 1.25 \times 10^{-2}$

$\therefore$ Elastic strain energy $= \frac{1}{2}\sigma_y \epsilon_E AL$

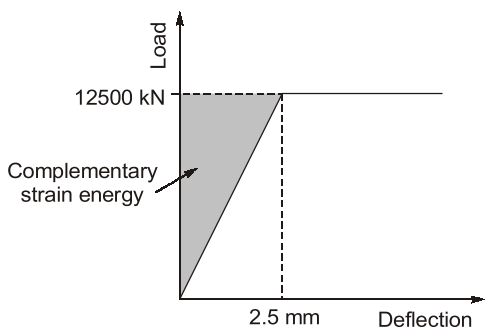
$= \frac{1}{2} \times 250 \times 1.25 \times 10^{-3} \times \frac{\pi}{4} \times 8^2 \times 2000$

= 15707.96 Nmm

Note: For linear elastic material both complementary energy and strain energy is same.

OR

By considering given graph in question, between Axial Load and Displacement the solution will be as follows:



Complementary stain energy,

$U = \frac{1}{2}P\delta = \frac{1}{2}\left(12500 \times 10^3\right) \times 2.5$

= 15625000 Nmm

It means there is some error in the given data.

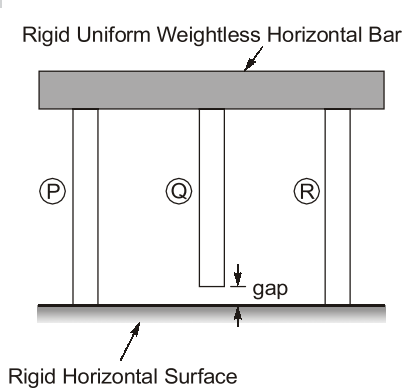
1.27 (a)

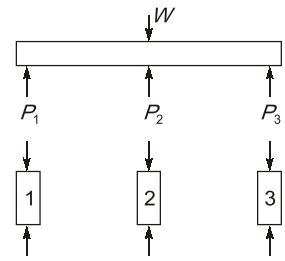
σ_{xx} = 30 MPa, σ_{yy} = 50 MPa, σ_{zz} = 0

$$\varepsilon_{zz} = \frac{\sigma_{zz}}{E} - \mu\frac{\sigma_{xx}}{E} - \mu\frac{\sigma_{yy}}{E} = -\frac{\mu}{E}\left(\sigma_{xx} + \sigma_{yy}\right)$$

$$= -\frac{0.3}{2 \times 10^5}(30 + 50) = -120 \times 10^{-6}$$

1.28 Sol.





$P_1 + P_1 + P_2 = W$ ...(i)

$P_1 = P_3$

$\delta_1 = 5 \text{ mm} = \frac{P_1 L}{AE}$ $\quad \frac{AE}{L} = 10 \frac{\text{kN}}{\text{mm}}$

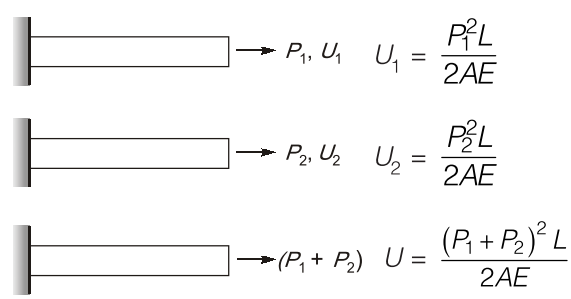
$\delta_2 = 3 \text{ mm} = \frac{P_2 L}{AE}$

So, $P_1 = 10 \times 5 = 50$ kN

$P_2 = 10 \times 3 = 30$ kN

$W = 2(50) + 30 = 130$ kN

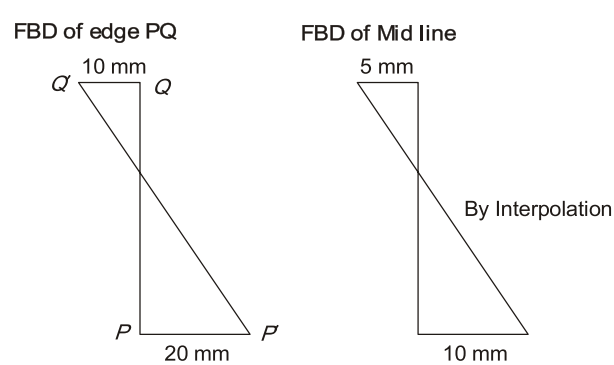
1.29 (d)



$$(P_1 + P_2)^2 > P_1^2 + P_2^2$$

$$U > U_1 + U_2$$

1.30 Sol.



So horizontal displacement of the point (0.5 m, 0.5 m)

= –2.5 mm + 5 mm = 2.5 mm

1.31 (c)

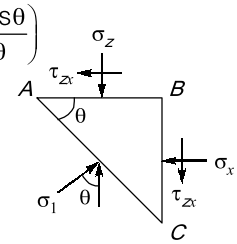
In strain hardening region, further addition of stress gives additional strain. However, strain inceases with faster rate in this region. The material in this range in this region. The material in this range undergoes changes in its crystalline structure, resulting in increased resistance to further deformation.

1.32 (c)

$$\Sigma F_x = 0$$

$$\Rightarrow -\sigma_x(BC) - \tau_Z \times (AB) + \sigma_1 \sin\theta = 0$$

$$\Rightarrow \sigma_x\left(\frac{AC\sin\theta}{\cos\theta}\right) + \tau_{Zx}\left(\frac{AC\cos\theta}{\cos\theta}\right)$$



$$= \sigma_1 \frac{\sin\theta \times AC}{\cos\theta}$$

$$\Rightarrow \sigma_x \tan\theta + \tau_{zx} = \sigma_1 \tan\theta$$

$$\Rightarrow \tan\theta\,(\sigma_1 - \sigma_x) = \tau_{zx}$$

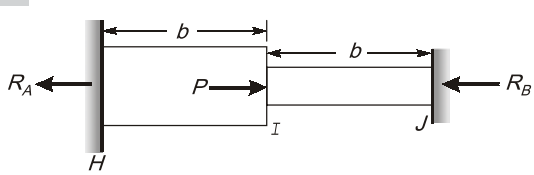
$$\Rightarrow \tan\theta = \left(\frac{\tau_{Zx}}{\sigma_1 - \sigma_x}\right)$$

1.33 (a)

$E = 2G(1 + \mu)$; G = Shear modulus

μ = Poission's ratio; E = Young's modulus

1.34 Sol.

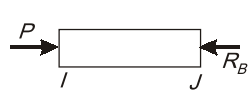


For horizontal force equilibrium,

$$R_A + R_B = P$$

Since there is no axial force in rod HI, thereore $R_A = 0$.

Now check for rod IJ,



$\therefore \quad R_B = P$

Now, as rod IJ is fixed from both end, so net deflection due to increase in temperature will be 0.

$$\therefore b\alpha T + \left[-\frac{Pb}{AE}\right] = 0$$

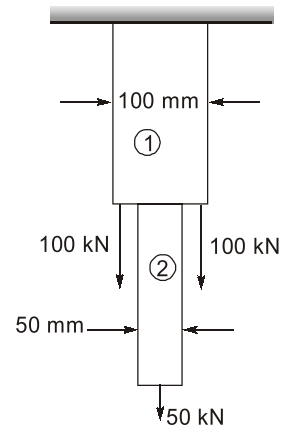
$$\Rightarrow b\alpha T = \frac{Pb}{AE}$$

$$\Rightarrow P = AE\alpha T$$

$$\Rightarrow P = 10^6 \times 10^{-6} \times 50$$

$$\Rightarrow P = 50 \text{ N}$$

1.35 (b)



Stress in member (1),

$$(\sigma_1) = \frac{P_1}{A_1} = \frac{250 \times 10^3}{100 \times 100} = 25 \text{ N/mm}^2$$

Stress in member (2),

$$(\sigma_2) = \frac{P_2}{A_2} = \frac{50 \times 10^3}{50 \times 50} = 20 \text{ N/mm}^2$$

$$\therefore \quad \sigma_{max} = 25 \text{ N/mm}^2$$

1.36 Sol.

We know that,

$$\sigma_x = \frac{E}{(1-\mu^2)}(\epsilon_x + \mu\,\epsilon_y)$$

$$\Rightarrow \sigma_x = \frac{E}{(1-\mu^2)}\left(\frac{\partial u}{\partial x} + \mu\frac{\partial v}{\partial y}\right)$$

$$\Rightarrow \sigma_x = \frac{E}{(1-\mu^2)}(2Cxy + 0)$$

$$\Rightarrow \sigma_x = \frac{2ECxy}{(1-\mu^2)}$$

Given, $\sigma_x = 40xy$ N/m^2

$$\Rightarrow \frac{2EC\cancel{xy}}{(1-\mu^2)} = 40\cancel{xy}$$

$$\Rightarrow C = \frac{40(1-\mu^2)}{2E} = \frac{40(1-0.5^2)}{2 \times 1} = 15$$

Now, $\gamma_{xy} = \dfrac{\partial u}{\partial y} + \dfrac{\partial v}{\partial x}$

$$\gamma_{xy} = Cx^2 + 0$$

Also, $G = \dfrac{E}{2(1+\mu)} = \dfrac{\tau_{xy}}{\gamma_{xy}}$

$$\Rightarrow \tau_{xy} = \frac{Cx^2 \times 1}{2(1+0.5)} = \left(\frac{15}{2 \times 1.5}\right)x^2 = 5x^2$$

On comparing with $\tau_{xy} = \alpha x^2$, the value of α is 5.