30 Years
Previous Solved Papers

GATE 2021

Civil Engineering

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

B. Singh (Ex. IES)
CMD, MADE EASY Group

MADE EASY Publications

MADE EASY Publications

Corporate Office: 44-A/4, Kalu Sarai (Near Hauz Khas Metro Station), New Delhi-110016
E-mail: infomep@madeeasy.in
Contact: 011-45124660, 8860378007
Visit us at: www.madeeasypublications.org

GATE - 2021 : Civil Engineering Topicwise Previous GATE Solved Papers (1991-2020)

First Edition : 2008
Second Edition : 2009
Third Edition : 2010
Fourth Edition : 2011
Fifth Edition : 2012
Sixth Edition : 2013
Seventh Edition : 2014
Eighth Edition : 2015
Ninth Edition : 2016
Tenth Edition : 2017
Eleventh Edition : 2018
Twelveth Edition : 2019
Thirteenth Edition: 2020

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 2021 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

Contents

Unit . I

Solid Mechanics

Contents

UNIT I

Solid Mechanics

Syllabus : Bending moment and shear force in statically determinate beams; Simple stress and strain relationships; Theories of failures; Simple bending theory, flexural and shear stresses, shear centre; Uniform torsion, buckling of column, combined and direct bending stresses.

Analysis of Previous GATE Papers

Exam Year	1 Mark Ques.	2 Marks Ques.	Total Marks
1991	5	1	**7**
1992	3	2	**7**
1993	1	1	**3**
1994	2	2	**6**
1995	2	–	**2**
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**

Exam Year	1 Mark Ques.	2 Marks Ques.	Total Marks
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**
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**

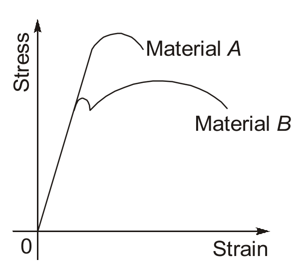
1 Properties of Metals, Stress & Strain

1.1 The maximum value of Poisson's ratio for an elastic material is
(a) 0.25 (b) 0.5
(c) 0.75 (d) 0.1
[1991 : 1 Mark]

1.2 A cantilever beam of tubular section consists of two materials, copper as outer cylinder and steel as inner cylinder. It is subjected to a temperature rise of 20°C and $\alpha_{copper} > \alpha_{steel}$. The stresses developed in the tubes will be
(a) compression in steel and tension in copper
(b) tension in steel and compression in copper
(c) no stress in both
(d) tension in both the materials
[1991 : 1 Mark]

1.3 The material that exhibits the same elastic properties in all directions at a point is said to be
(a) homogeneous (b) orthotropic
(c) viscoelastic (d) isotropic
[1995 : 1 Mark]

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

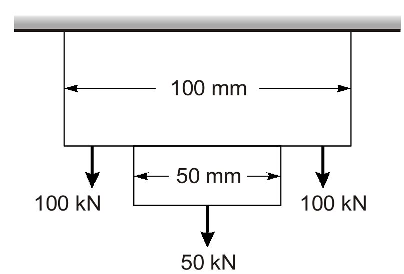


The following statements are made based on this diagram:
I. Material *A* is more brittle than material *B*.
II. The ultimate strength of material *B* is more than that of *A*.
With reference to the above statements, which of the following applies?
(a) Both the statements are false
(b) Both the statements are true
(c) I is true but II is false
(d) I is false but II is true
[2000 : 1 Mark]

1.5 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 Mark]

1.6 The shear modulus (*G*), modulus of elasticity (*E*) and the Poisson's ratio (ν) of a material are related as
(a) $G = \frac{E}{[2(1+\nu)]}$ (b) $E = \frac{G}{[2(1+\nu)]}$
(c) $G = \frac{E}{[2(1-\nu)]}$ (d) $G = \frac{E}{[2(\nu-1)]}$
[2002 : 1 Mark]

1.7 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 Mark]

1.8 For linear elastic systems, the type of displacement function for the strain energy is
(a) linear (b) quadratic
(c) cubic (d) quartic
[2004 : 1 Mark]

1.9 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 Mark]

1.10 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 Mark]

1.11 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 Marks]

1.12 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 Marks]

1.13 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 Marks]

1.14 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 Mark]

1.15 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 Marks]

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

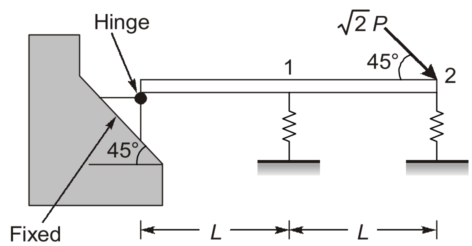
(a) 4 (b) 3

(c) 2 (d) 1

[2010 : 1 Mark]

Linked Answer Questions 1.17 and 1.18:

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.



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

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

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

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

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

[2011 : 2 Marks]

1.18 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 Marks]

1.19 The Poisson's ratio is defined as

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

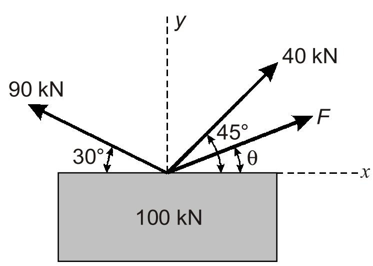
(c) $\left|\frac{\text{lateral stress}}{\text{axial stress}}\right|$ (d) $\left|\frac{\text{axial strain}}{\text{lateral strain}}\right|$

[2012 : 1 Mark]

1.20 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 Mark]

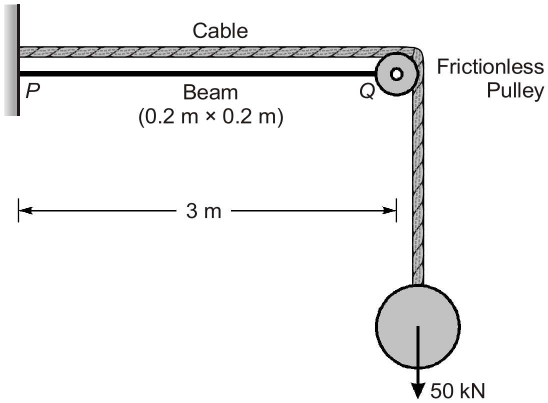
1.21 A box of weight 100 kN shown in the figure is to be lifted without swinging. If all forces are coplanar, the magnitude and direction (θ) of the force (F) with respect to x-axis should be



(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 Marks, Set-I]

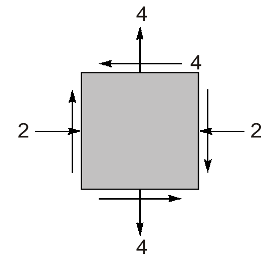
1.22 The values of axial stress (σ) in kN/m^2, bending moment (M) in kNm, and shear force (V) in kN acting at point P for the arrangement shown in the figure are respectively



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

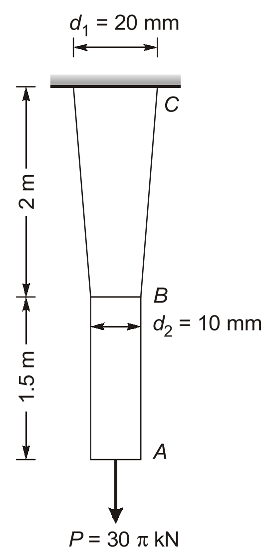
[2014 : 2 Marks, Set-II]

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



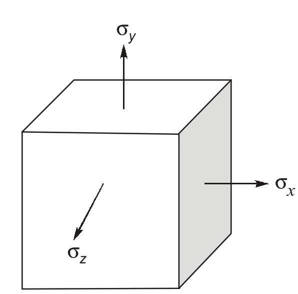
[2014 : 2 Marks, Set-II]

1.24 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 Marks, Set-I]

1.25 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

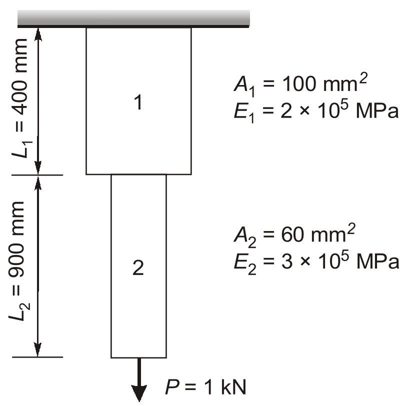
[2016 : 2 Marks, Set-II]

1.26 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 Mark, Set-I]

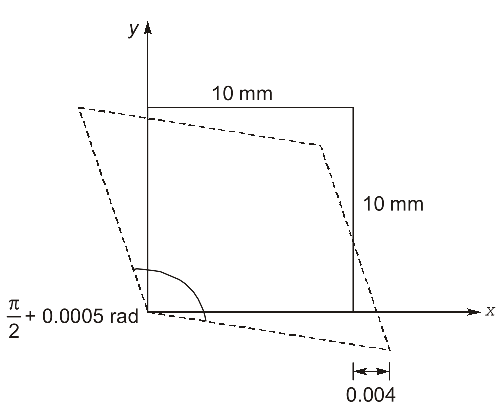
1.27 Consider the stepped bar made with a linear elastic material and subjected to an axial load of 1 kN, as shown in the figure.



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 Marks, Set-I]

1.28 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.

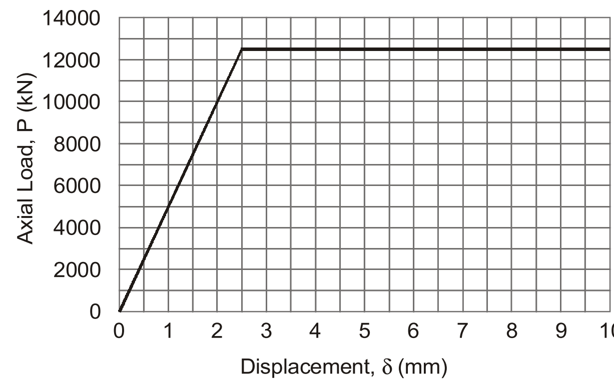


If the shear strain γ_{xy} at this point is expressed as 0.001 k (in rad), the value of k is

(a) 0.50 (b) 0.25
(c) –0.25 (d) –0.50

[2017 : 1 Mark, Set-II]

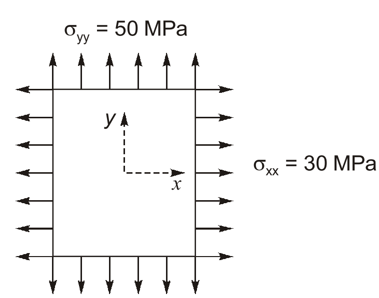
1.29 A 2 m long, axially loaded mild steel rod of 8 mm diameter exhibits the load-displacement (P-δ) behavior as shown in the figure.



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 Marks, Set-II]

1.30 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

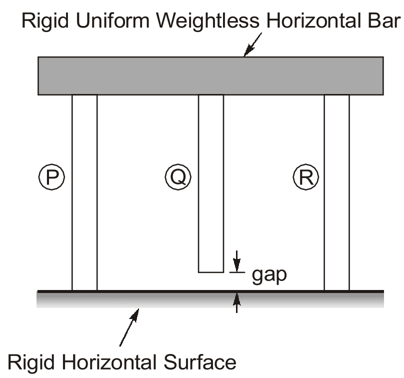


The Young's modulus of the material is 2×10^{11} N/m^2 and the Poisson's ratio is 0.3. If σ_{zz} is negligibly small and assumed to be zero, then the strain ε_{zz} is

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

[2018 : 2 Marks, Set-I]

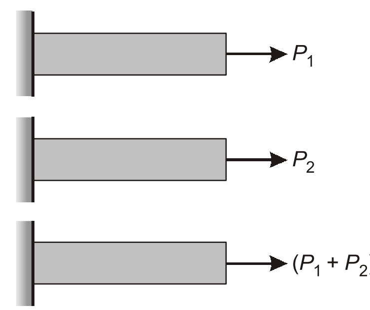
1.31 A rigid, uniform, weightless, horizontal bar is connected to three vertical members P, Q and R as shown in the figure (not drawn to the scale). All three members have identical axial stiffness of 10 kN/mm. The lower ends of bars P and R rest on a rigid horizontal surface. When NO load is applied, 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 Marks, Set-I]

1.32 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 Marks, Set-II]

■■■■

Answers Properties of Metals, Stress & Strain

1.1	(b)	1.2	(b)	1.3	(d)	1.4	(c)	1.5	(b)	1.6	(a)	1.7	(c)	1.8	(b)	1.9	(c)
1.10	(a)	1.11	(c)	1.12	(c)	1.13	(d)	1.14	(d)	1.15	(a)	1.16	(c)	1.17	(b)	1.18	(d)
1.19	(b)	1.20	(a)	1.21	(a)	1.22	(b)	1.25	(c)	1.26	(a)	1.28	(d)	1.30	(a)	1.32	(d)

Explanations Properties of Metals, Stress & Strain

1.1 (b)

The range of Poisson's ratio (μ) is,

$$0 \le \mu \le 0.5$$

1.2 (b)

Method-I

The magnitude of extension in the beam due to change in temperature is *L* a *T*.

where, L = length of the beam

α = coefficient of thermal expansion

T = change in temperature

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

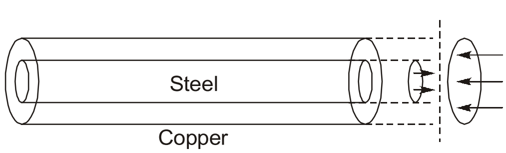
$\therefore (\Delta l)_{copper} > (\Delta l)_{steel}$

As free extension in copper is more than steel, so equilibrium will develop compressive stress in copper and will develop tensile stress in steel.

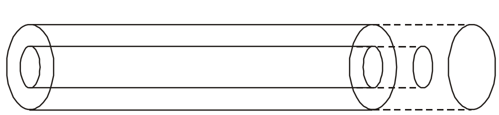
Note: As it is not given whether the two material form a composite sectionor not, so we will treat them to be connected together.

Method-II

If assumed connected:



If assumed independent free expansion:



1.3 (d)

The material that exhibits the same elastic properties in all directions at a point is said to be **isotropic**.

If the material exhibits different properties in different directions, then it is said to be **Anisotropic**.

1.4 (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**.

1.5 (b)

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

1.7 (c)

Method-I

The stress in lower bar

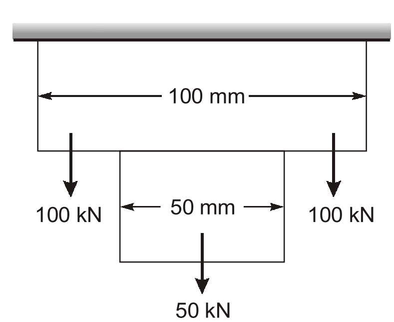
$$= \frac{50 \times 1000}{50 \times 50} = 20 \text{ N/mm}^2$$

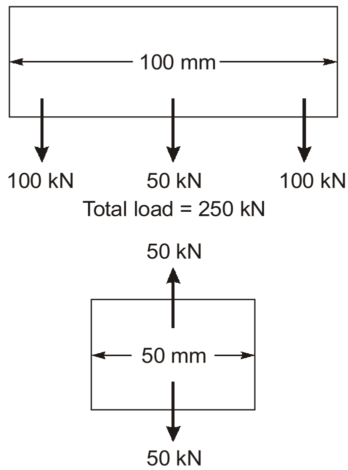
The stress in upper bar

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

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

$$= \frac{50 \times 10^3}{50 \times 50} = 20 \text{ N/mm}^2$$

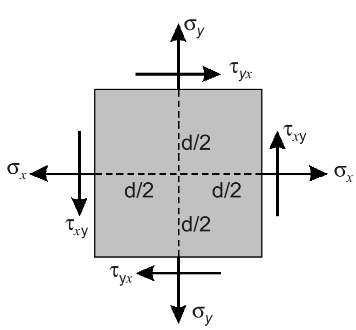
So maximum = 25 kN/mm^2

1.8 (b)

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

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

1.9 (c)



Taking moment equilibrium about the centre, we get,

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

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

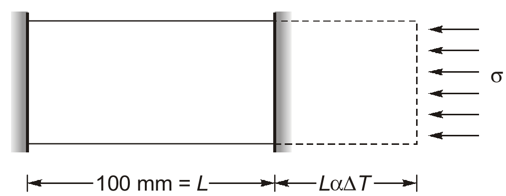
1.11 (c)

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 teh bar which is compressive in nature.

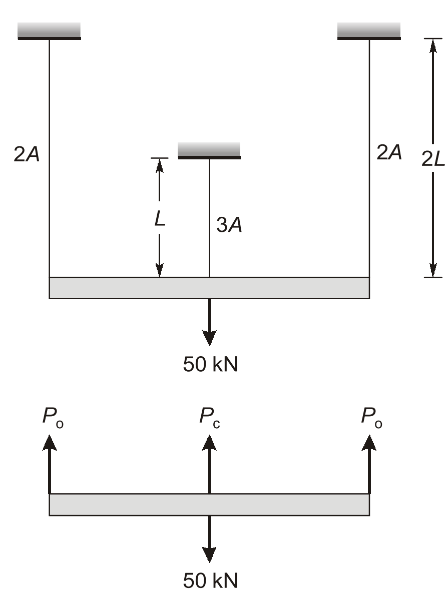
Now,

Expansion due to temperature = Compression due to stress

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

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

1.12 (c)



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

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

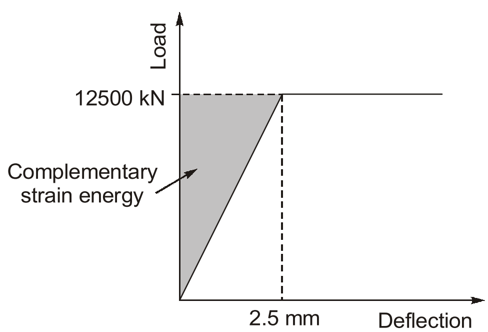
$$= \frac{1}{2} \times 250 \times 1.25 \times 10^{-3} \times \frac{\pi}{4} \times 8^2 \times 2000$$

$$= 15707.96 \text{ Nmm}$$

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,

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

$$= 15625000 \text{ Nmm}$$

It means there seems some error in the given data.

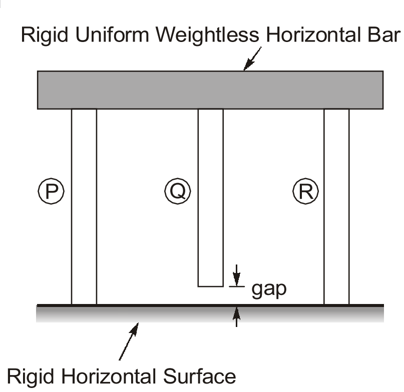
1.30 (a)

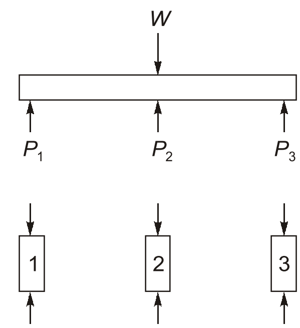
$$\sigma_{xx} = 30 \text{ MPa}, \ \sigma_{yy} = 50 \text{ MPa}, \ \sigma_{zz} = 0$$

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

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

1.31 Sol.





$$P_1 + P_1 + P_2 = W \quad \text{...(i)}$$

$$P_1 = P_3$$

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

$$\frac{AE}{L} = 10 \text{ kN/mm}$$

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

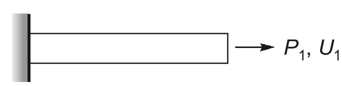
So,

$$P_1 = 10 \times 5 = 50 \text{ kN}$$

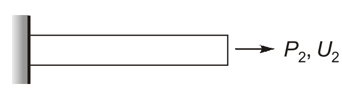
$$P_2 = 10 \times 3 = 30 \text{ kN}$$

$$W = 2(50) + 30 = 130 \text{ kN}$$

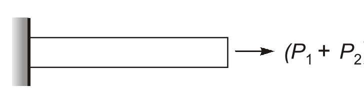
1.32 (d)



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



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



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

$$\left(P_1 + P_2\right)^2 > P_1^2 + P_2^2$$

$$U > U_1 + U_2$$

■■■■