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# CIVIL ENGINEERING GATE 2019


CIVIL ENGINEERING GATE-2019

32 YEARS SOLUTION

# GATE SOLUTIONS

## CIVIL ENGINEERING

From (1987 - 2018)

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# PREFACE

It is an immense pleasure to present topic wise previous years solved paper of GATE Exam. This booklet has come out after long observation and detailed interaction with the students preparing for GATE 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.

GATE exam now a days has become more important because it not only opens the door for higher education in institutes like IIT, IISC, NIT's but also many of the PSUs have started inducting students on the basis of GATE score. In PSU's, which are not inducting through GATE route, the questions in their exams are asked from GATE previous year papers. Thus, availability of authentic solutions to the students is the need of the day. Towards this end this booklet becomes indispensable.

I am thankful to IES master team without whose support, I don't think, this book could have been flawlessly produced.

Every care has been taken to bring an error free book. However comments for future improvement are most welcome.

Mr. Kanchan Kumar Thakur
**Director Ex-IES**

# CONTENTS

Unit 1

# Strength of Materials

**Syllabus**

*Bending moment and shear force in statically determinate beams. Simple stress and strain relationship: Stress and strain in two dimensions, principal stresses, stress transformation. Mohr's circle. Simple bending theory, flexural and shear stresses, unsymmetrical bending, shear centre. Thin walled pressure vessels, uniform torsion, buckling of column. Combined and direct bending stresses.*

# Contents

CHAPTER

# 1

# Strength of Materials

## One Mark Questions

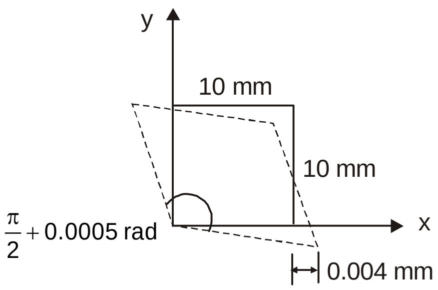
**1.** An elastic bar of length L, uniform cross sectional area A, coefficient of thermal expansion $\alpha$ and Young's modulus E is fixed at the two ends. The temperature of the bar is increased by T, resulting in an axial stress $\sigma$. Keeping all other parameters unchanged, if the length of the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

(a) $\sigma$ (b) $2\sigma$

(c) $0.5\sigma$ (d) $0.25\ \alpha\sigma$

***[GATE–2017, SET-I]***

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




If the shear strain $\gamma_{xy}$ 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

***[GATE–2017, SET-II]***

**3.** The creep strains are

(a) caused due to dead loads only

(b) caused due to live loads only

(c) caused due to cyclic loads only

(d) independent of loads

***[GATE–2013]***

**4.** 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) $\left|\frac{\text{axial strain}}{\text{lateral strain}}\right|$

***[GATE–2012]***

**5.** The number of independent elastic constant for a linear elastic isotropic and homogeneous material is

(a) 4 (b) 3

(c) 2 (d) 1

***[GATE–2010]***

**6.** A mild steel specimen is under uniaxial tensile stress. Young's modulus and yield stress for mild steel are $2 \times 10^5$ 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 $Nmm/mm^3$

***[GATE–2008]***

**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) $G = \frac{E}{(1+\mu)}$ (b) $G = \frac{E}{2(1+\mu)}$

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

**[GATE–2007]**

**8.** The necessary and sufficient condition for a surface to be called as a free surface is

(a) no stress should be acting on it

(b) tensile stress acting on it must be zero

(c) shear stress acting on it must be zero

(d) no point on it should be under any stress

**[GATE–2006]**

**9.** The components of strain tensor at a point in the plane strain case can be obtained by measuring longitudinal strain in following directions8

(a) along any two arbitrary directions

(b) along any three arbitrary directions

(c) along two mutually orthogonal directions

(d) along any arbitrary direction

**[GATE–2005]**

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

(a) conservation of mass

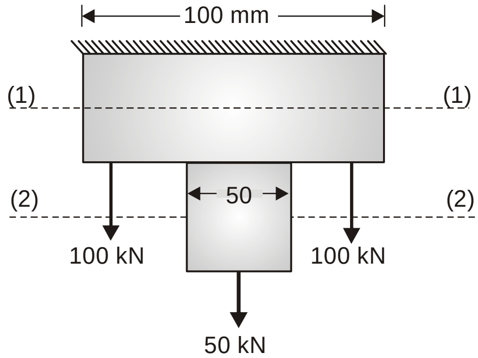
(b) force equilibrium equations

(c) moment equilibrium equations

(d) conservation of energy

**[GATE–2005]**

**11.** 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

**[GATE–2003]**

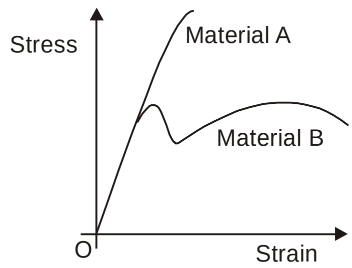
**12.** The shear modulus (G), modulus of elasticity (E) and the Poisson's ratio (v) of a material are related as,

(a) G = E/[2(1 + v)] (b) E = G/[2(1 + v)]

(c) G = E/[2(1 – v)] (d) G = E/[2(1 – v)]

**[GATE–2002]**

**13.** 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

**[GATE–2000]**

**14.** In a linear elastic structural element

(a) Stiffness is directly proportional to flexibility

(b) Stiffness is inversely proportional to flexibility

(c) Stiffness is equal to flexibility

(d) Stiffness and flexibility are not related

**[GATE–1991]**

**15.** A cantilever beam of tubular section consists of 2 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 is steel and tension in copper
(b) Tension in steel and compression in copper
(c) No stress in both
(d) Tension in both the materials

**[GATE–1991]**

**16.** The maximum value of Poisson's ratio for an elastic material is

(a) 0.25 (b) 0.5
(c) 0.75 (d) 1.0

**[GATE–1991]**

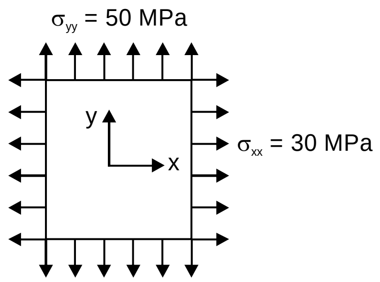
**17.** The principle of superposition is made use of in structural computations when:

(a) The geometry of the structure changes by a finite amount during the application of the loads
(b) The changes in the geometry of the structure during the application of the loads is too small and the strains in the structure are directly proportional to the corresponding stresses.
(c) The strain in the structure are not directly proportional to the corresponding stresses, even though the effect of changes in geometry can be neglected.
(d) None of the above conditions are met.

**[GATE–1990]**

## Two Marks Questions

**18.** A plate in equilibrium is subjected to uniform stresses along its edges with magnitude $\sigma_{xx} = 30$ MPa and $\sigma_{yy} = 50$ MPa as shown in the figure.

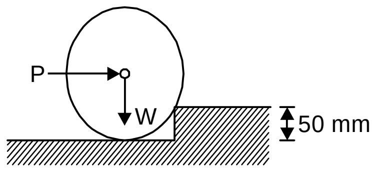



The Young's modulus of the material is $2 \times 10^{11}$ N/m$^2$ and the Poisson's ratio is 0.3. If $\sigma_{zz}$ is negligibly small and assumed to be zero, then the strain $\varepsilon_{zz}$ is

(a) $-120 \times 10^{-6}$ (b) $-60 \times 10^{-6}$
(c) 0.0 (d) $120 \times 10^{-6}$

**[GATE–2018, SHIFT-I]**

**19.** A cylinder of radius 250 mm and weight, W = 10 kN is rolled up an obstacle of height 50 mm by applying a horizontal force P at its centre as shown in the figure.

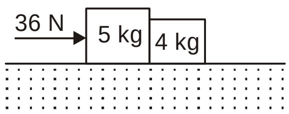



All interfaces are assumed frictionless. The minimum value of P is

(a) 4.5 kN (b) 5.0 kN
(c) 6.0 kN (d) 7.5 kN

**[GATE–2018, SHIFT-I]**

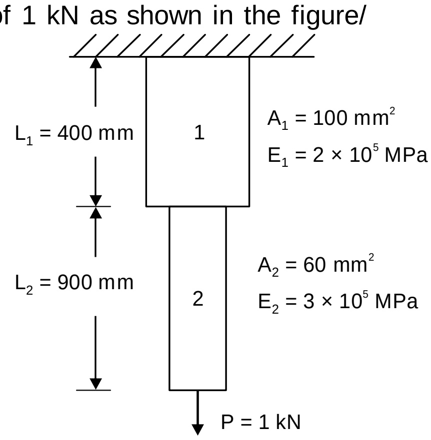
**20.** Two rigid bodies of mass 5 kg and 4 kg are at rest on a frictionless surface until acted upon by a force of 36 N as shown in the figure. The contact force generated between the two bodies is




(a) 4.0 N (b) 7.2 N
(c) 9.0 N (d) 16.0 N

**[GATE–2018, SHIFT-II]**

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



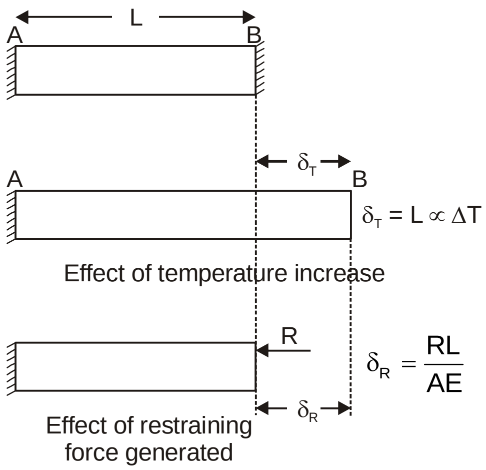
## ANSWERS

| -: 1 Mark :- | | | | -: 2 Marks :- | | |
|---|---|---|---|---|---|---|
| **1.** (a) | **6.** (d) | **11.** (c) | **16.** (b) | **18. (a)** | **23.** (c) | **28.** (c) |
| **2.** (d) | **7.** (b) | **12.** (a) | **17.** (b) | **19. (d)** | **24.** (15) | **29.** (c) |
| **3.** (a) | **8.** (c) | **13.** (c) | | **20. (d)** | **25.** (a) | **30.** (c) |
| **4.** (b) | **9.** (b) | **14.** (b) | | **21.** (35) | **26.** (1200 kN/m$^2$) | **31.** (c) |
| **5.** (c) | **10.** (c) | **15.** (c) | | **22.** (15707.96) | **27.** (a) | |

# SOLUTION...

## One Mark Solutions

**1.** (a)




From compatibility

$$\delta_T = \delta_R = 0$$

$$\Rightarrow \quad L\propto\Delta T = \frac{RL}{AE}$$

$$\Rightarrow \quad \sigma = \frac{R}{A} = \text{Stress}$$

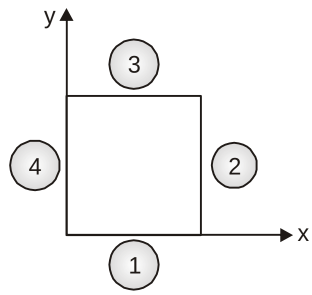
$$= E\propto\Delta T$$

Hence stress is independent of length of bar.

**2.** (d)

Shear strain in an element is positive when the angle between two positive faces (or two negative faces) is reduced.

The strain is negative when the angle between two positive (or two negative) faces increase.




Face (2) & (3) are +ve face

Face (1) & (4) are –ve face.

Angle between (1) & (4) is increased by 0.0005 rad.

$\therefore \quad \gamma_{xy} = -0.0005 = 0.001\ K$

$\therefore \quad K = -0.5$

**3.** (a) Creep strains are those which occur with time at a contant level of stress. Thus, these occur due to permanent load i.e., Dead load.

**4.** (b) Poissons ratio, $\mu = -\dfrac{\text{Lateral strain}}{\text{Longitudinal strain}}$

The poisson's ratio of a stable, isotropic, linear elastic material cannot be less than –1.0 and nor greater than 0.5 due to the requirement that Young's modulus, shear modulus and bulk modulus have positive values.

*Note :* Rubber has a poisson ratio close to 0.5 and is therefore almost incompressible Cork, on the other hand, has a Poisson ratio close to zero. This makes cork function well as a bottle stopper, since an axial loaded cork will not swell laterally to resist bottle insertion.

**5.** (c)

| Material | No. of independent elastic constants |
|---|---|
| Isotropic | 2 |
| Orthotropic (wood) | 9 |
| Anisotropic | 21 |

**6.** (d) Young's modulus, $E = 2 \times 10^5$ MPa

Yield stress, $f_y = 250$ MPa

Strain energy per unit volume

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

$$= \frac{1}{2} f_y \times \frac{f_y}{E}$$

$$= \frac{1}{2} \times \frac{(250)^2}{2\times10^5}$$

$$= 0.156\ \text{N/mm}^2$$

$$= 0.156\ \text{Nmm/mm}^3$$

**7.** (b) The relation between elastic constants is –

1. $E = 2G\ (1 + \mu)$
2. $E = 3K\ (1 - 2\mu)$
3. $E = \dfrac{9KG}{3K+G}$
4. $\mu = \dfrac{3K-2G}{6K+2G}$

**8.** (c)

**9.** (b) In plane strain case, component of strain tensor at a point are $\in_x, \in_y, \gamma_{xy}$

We have three unknown so we require 3 equations to find them. These unknowns are related to longitudinal strain by the equation.

$$\in_1 = \in_x \cos^2\theta_1 + \in_y \sin^2\theta_1 + \frac{\gamma_{xy}}{2}\sin 2\theta_1$$

$$\in_2 = \in_x \cos^2\theta_2 + \in_y \sin^2\theta_2 + \frac{\gamma_{xy}}{2}\sin 2\theta_2$$

$$\in_3 = \in_x \cos^2\theta_3 + \in_y \sin^2\theta_3 + \frac{\gamma_{xy}}{2}\sin 2\theta_3$$

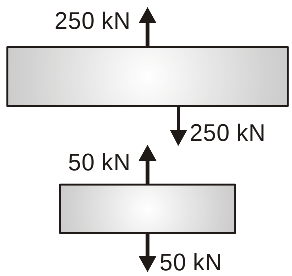
Hence to find out component of strain tensor we measure longitudinal strain ($\in_1$, $\in_2$, $\in_3$,) along any three arbitrary direction.

**10.** (c)

Symmetry of stress tensor at a point in a body under equilibrium is obtained from moment equilibrium equation.

**11.** (c)

Tensile stress at 1 –1 $= \dfrac{\text{Force}}{\text{Area}}$




$$= \frac{250\times1000}{100\times100} = 25\ \text{N/mm}^2$$

Tensile stress at

$$2-2 = \frac{F}{A} = \frac{50\times1000}{50\times50}$$

$$= 20\ \text{N/mm}^2$$

Hence, max tensile stress = 25 N/mm$^2$

**12.** (a) The relation between elastic constants is–

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

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

3. $E = \dfrac{9KG}{3K + G}$

4. $\mu = \dfrac{3K - 2G}{6K + 2G}$

**13.** (c) Strain in material B is more, hence is more ductile than A or in other words, Material A is more brittle than B. Material A can reach upto higher stress level hence ultimate strength of material A is more than that of B.

Hence, statement (I) is true and II is false.

**14.** (b) Stiffness is defined as the force required for a unit displacement. Flexibility is defined as displacement caused by a unit force. Both are inverse of one another.

**15.** (c) As it is not given whether the two material form a composite section or not i.e., they are connected to each other or not, we will treat them to be not connected. Hence as cantilever beam is fixed at one end and free at other. The two will act independently and stress in both of them will be zero.

**16.** (b) Poisson's ratio, $\mu = -\dfrac{\text{Lateral strain}}{\text{Longitudinal strain}}$

The poisson's ratio of a stable, isotropic, linear elastic material cannot be less than –1.0 and nor greater than 0.5 due to the requirement that Young's modulus, shear modulus and bulk modulus have positive values.

*Note:* Rubber has a Poisson's ratio close to 0.5 and is therefore almost incompressible. Cork, on the other hand, has a Poisson ratio close to zero. This makes cork function well as a bottle stopper, since an axial loaded cork will not swell laterally to resist bottle insertion.

**17.** (b) The principle of superposition is stated as- 'the deflection at a given point in a structure produced by several loads acting simultaneously on the structure can be found by superposing deflections at the same point produced by loads acting individually.

The principle of superposition can be applied only when–

1. stress-strain relationship is linear.
2. the geometry of the structure doesn't change with the application of load. i.e., strains are small

Hence answer is option (b).

## Two Marks Solutions

**18. (a)**

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

$E = 2 \times 10^{11}\text{ N/m}^2 = 2\times 10^5\text{ N/mm}^2$

$= 2 \times 10^5\text{ MPa}$

Poisson ratio, $\mu = 0.3$

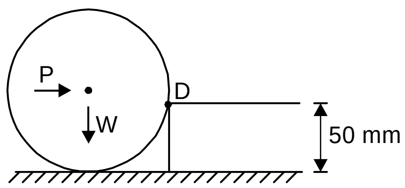
$\sigma_{zz} = 0$

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

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

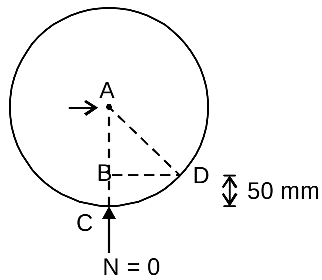
$$= -120 \times 10^{-6}$$

**19. (d)**




$W = 10\text{ kN}$

$\Sigma M_D = 0$




For rolling, the normal reaction should be zero when the cylinder just starts to roll.

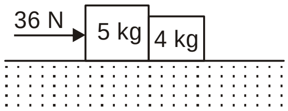
$$BD = \sqrt{AD^2 - AB^2} = \sqrt{(250)^2 - (200)^2}$$

$$= BD = 150 \text{ mm}$$

$$P \times 200 - W \times 150 = 0$$

$$P = \frac{10 \times 150}{200} = 7.5 \text{ kN}$$

**20. (d)**



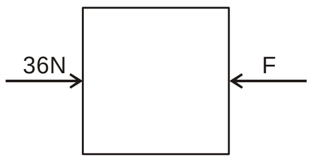

Net force = Net mass × acceleration

$\Rightarrow$ 36 = 9 × a

$\Rightarrow$ a = 4 $ms^{-2}$

Now, considering 5 kg weight only

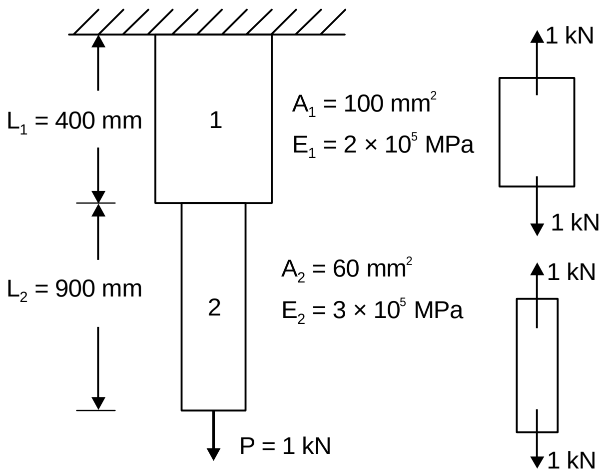
force on 5 kg = 5 × 4 N = 20 N




$\Rightarrow$ 36N – F = 20N

$\Rightarrow$ F = 16N

**21. 35**

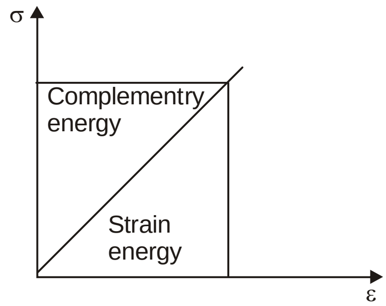



$$U = \sum \frac{P^2 L_1}{2A_1E_1}$$

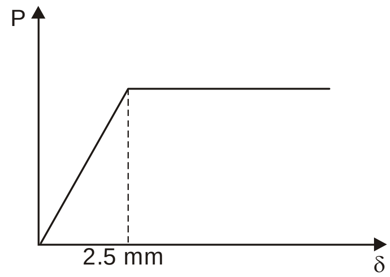
$$= \frac{(1000)^2 \times 400}{2 \times 100 \times 2 \times 10^5} + \frac{(1000)^2 \times 900}{2 \times 60 \times 3 \times 10^5}$$

= 10 + 25 = 35 Nmm

**22. (15707.96)**




The area enclosed by the inclined line and the vertical axis is called complementary strain energy




$$\in = \frac{\delta}{l} = \frac{2.5}{2000} = \frac{1}{800}$$

$$\sigma_y = 250 \text{ MPa}$$

Complementry strain energy = strain energy

$$= \frac{1}{2} \times \sigma_y \times \varepsilon \times \text{vol. of bar}$$

$$= \frac{1}{2} \times 250 \times \frac{1}{800} \times \frac{\pi}{4} \times 8^2 \times 2000$$

= 15707.96 Nmm

**23. (c)**

$\Delta V = 0$

$$\Rightarrow \quad \varepsilon_V = 0 = \frac{\sigma}{E} - 2\mu\frac{\sigma}{E} = \frac{\sigma}{E}(1 - 2\mu) = 0$$

$$\Rightarrow \quad \boxed{\mu = 0.5}$$

**24. (15)**

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