

For 2024 (IES, Gate & PSUs)

Strength of Materials

(Only Questions & Answers)

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S K Mondal

Ministry of Railways (AIR-12, General Category)

- GATE Topper, IES Topper
- Ex. NTPC
- BARC selected
- IISc Selected
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- Co-Author of Hydro Power Familiarization, NTPC
- 15 free online publications of mechanical engineering for GATE, ESE, PSUs and State exams.



NOTE
“Asked Objective Questions”
is the total collection of questions from

30 yrs.	IES	(2023-1992)	[UPSC-Engineering Service Examination]
31 yrs.	GATE	(2023-1992)	[Mechanical Engineering]
21 yrs.	GATE	(2023-2003)	[Civil Engineering]
2 yrs.	GATE	(2023-2022)	[Engineering Science-XE]
and 14 yrs. IAS (Prelim.) [UPSC-Civil Service Preliminary]			

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Every effort has been made to see that there are no errors (typographical or otherwise) in the material presented. However, it is still possible that there may be a few errors (serious or otherwise).

OBJECTIVE QUESTIONS (GATE, IES, IAS)

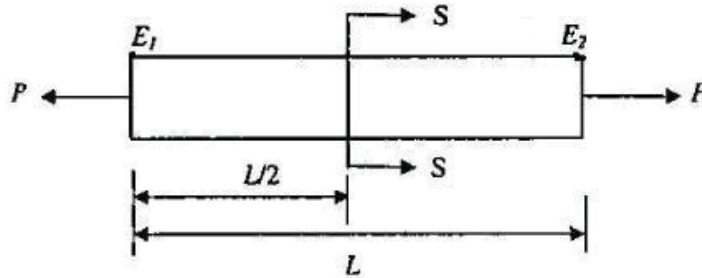
Previous 30-Years' GATE Questions

Stress in a bar

GATE-1. Two identical circular rods of same diameter and same length are subjected to same magnitude of axial tensile force. One of the rods is made out of mild steel having the modulus of elasticity of 206 GPa. The other rod is made out of cast iron having the modulus of elasticity of 100 GPa. Assume both the materials to be homogeneous and isotropic and the axial force causes the same amount of uniform stress in both the rods. The stresses developed are within the proportional limit of the respective materials. Which of the following observations is correct? [GATE-2003]

- (a) Both rods elongate by the same amount
- (b) Mild steel rod elongates more than the cast iron rod
- (c) Cast iron rod elongates more than the mild steel rod
- (d) As the stresses are equal strains are also equal in both the rods

GATE-1(i). A rod of length L having uniform cross-sectional area A is subjected to a tensile force P as shown in the figure below. If the Young's modulus of the material varies linearly from E_1 to E_2 along the length of the rod, the normal stress developed at the section-SS is [GATE-2013]



- (a) $\frac{P}{A}$
- (b) $\frac{P(E_1 - E_2)}{A(E_1 + E_2)}$
- (c) $\frac{PE_2}{AE_1}$
- (d) $\frac{PE_1}{AE_2}$

GATE-2. A steel bar of $40 \text{ mm} \times 40 \text{ mm}$ square cross-section is subjected to an axial compressive load of 200 kN. If the length of the bar is 2 m and $E = 200 \text{ GPa}$, the elongation of the bar will be: [GATE-2006]

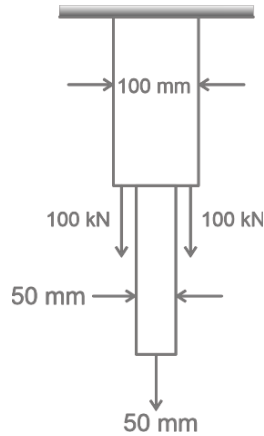
- (a) 1.25 mm
- (b) 2.70 mm
- (c) 4.05 mm
- (d) 5.40 mm

GATE-2a. A 300 mm long copper wire of uniform cross-section is pulled in tension so that a maximum tensile stress of 270 MPa is developed within the wire. The entire deformation of the wire remains linearly elastic. The elastic modulus of copper is 100 GPa. The resultant elongation (in mm) is _____. [PI: GATE-2006]

GATE-2b. 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? [GATE : CE 2023]

I would be thankful to the readers if they are brought to my attention at the following e-mail address:
swapan_mondal_01@yahoo.co.in

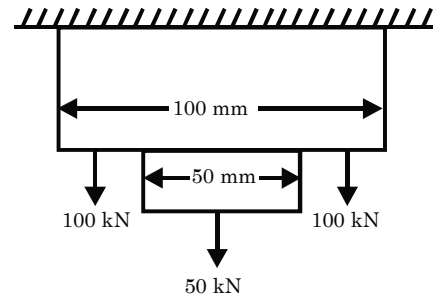
S K Mondal(Ex.IES)



- (a) 15.0 (b) 25.0 (c) 35.0 (d) 45.0

GATE-2bi. 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

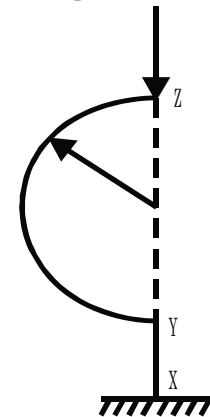
- (a) 16.0 (b) 20.0
(c) 25.0 (d) 30.0



[CE: GATE-2003]

GATE-2c. A curved member with a straight vertical leg carrying a vertical load at Z. As shown in the figure. The stress resultants in the XY segment

- (a) bending moment, shear force and axial force
(b) bending moment and axial force only
(c) bending moment and shear force only
(d) axial force only



[CE: GATE-2003]

GATE-2d. A metallic rod of 500 mm length and 50 mm diameter, when subjected to a tensile force of 100 kN at the ends, experiences an increase in its length by 0.5 mm and a reduction in its diameter by 0.015 mm. The Poisson's ratio of the rod material is

[GATE-2014]

True stress and true strain

GATE-3. The ultimate tensile strength of a material is 400 MPa and the elongation up to maximum load is 35%. If the material obeys power law of hardening, then the true stress-true strain relation (stress in MPa) in the plastic deformation range is:

- (a) $\sigma = 540\varepsilon^{0.30}$ (b) $\sigma = 775\varepsilon^{0.30}$ (c) $\sigma = 540\varepsilon^{0.35}$ (d) $\sigma = 775\varepsilon^{0.35}$ [GATE-2006]

Elasticity and Plasticity

GATE-4. An axial residual compressive stress due to a manufacturing process is present on the outer surface of a rotating shaft subjected to bending. Under a given bending

load, the fatigue life of the shaft in the presence of the residual compressive stress is: [GATE-2008]

- (a) Decreased
- (b) Increased or decreased, depending on the external bending load
- (c) Neither decreased nor increased
- (d) Increased

GATE-5. A static load is mounted at the centre of a shaft rotating at uniform angular velocity. This shaft will be designed for [GATE-2002]

- (a) The maximum compressive stress (static)
- (b) The maximum tensile stress (static)
- (c) The maximum bending moment (static)
- (d) Fatigue loading

GATE-6. Fatigue strength of a rod subjected to cyclic axial force is less than that of a rotating beam of the same dimensions subjected to steady lateral force because

- (a) Axial stiffness is less than bending stiffness [GATE-1992]
- (b) Of absence of centrifugal effects in the rod
- (c) The number of discontinuities vulnerable to fatigue are more in the rod
- (d) At a particular time the rod has only one type of stress whereas the beam has both the tensile and compressive stresses.

Relation between the Elastic Moduli

GATE-7. The number of independent elastic constants required to define the stress-strain relationship for an isotropic elastic solid is [GATE-2014]

GATE-7(i). A rod of length L and diameter D is subjected to a tensile load P . Which of the following is sufficient to calculate the resulting change in diameter?

- (a) Young's modulus
- (b) Shear modulus [GATE-2008]
- (c) Poisson's ratio
- (d) Both Young's modulus and shear modulus

GATE-7ii. If the Poisson's ratio of an elastic material is 0.4, the ratio of modulus of rigidity to Young's modulus is [GATE-2014]

GATE-8. In terms of Poisson's ratio (μ) the ratio of Young's Modulus (E) to Shear Modulus (G) of elastic materials is [GATE-2004]

- (a) $2(1 + \mu)$
- (b) $2(1 - \mu)$
- (c) $\frac{1}{2}(1 + \mu)$
- (d) $\frac{1}{2}(1 - \mu)$

GATE-9. The relationship between Young's modulus (E), Bulk modulus (K) and Poisson's ratio (μ) is given by: [GATE-2002]

- (a) $E = 3K(1 - 2\mu)$
- (b) $K = 3E(1 - 2\mu)$
- (c) $E = 3K(1 - \mu)$
- (d) $K = 3E(1 - \mu)$

GATE-9(i) For an isotropic material, the relationship between the Young's modulus (E), shear modulus (G) and Poisson's ratio (μ) is given by [CE: GATE-2007; PI: GATE-2014]

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

GATE-9(ii) For a linear elastic and isotropic material, the correct relationship among Young's modulus of elasticity (E), Poisson's ratio (ν), and shear modulus (G) is

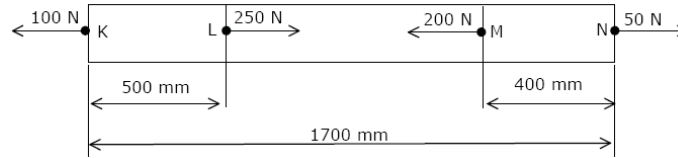
[CE: GATE-2022 set - 2]

- (a) $G = \frac{E}{2(1 + \nu)}$
- (b) $G = \frac{E}{1 + 2\nu}$
- (c) $E = \frac{G}{2(1 + \nu)}$
- (d) $E = \frac{G}{1 + 2\nu}$

GATE-10. A rod is subjected to a uni-axial load within linear elastic limit. When the change in the stress is 200 MPa, the change in the strain is 0.001. If the Poisson's ratio of the rod is 0.3, the modulus of rigidity (in GPa) is _____ [GATE-2015]

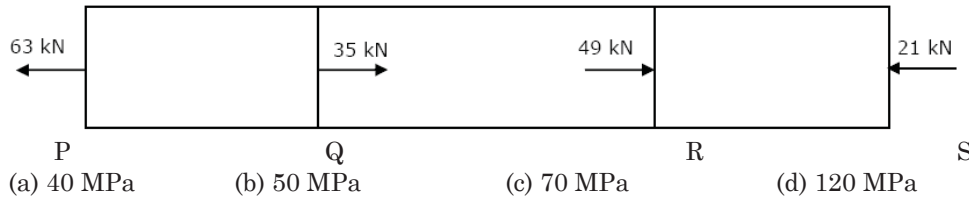
Stresses in compound strut

GATE-11. The figure below shows a steel rod of 25 mm^2 cross sectional area. It is loaded at four points, K, L, M and N. [GATE-2004, IES 1995, 1997, 1998]

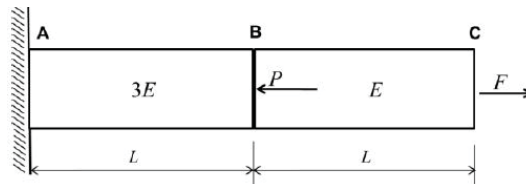


Assume $E_{\text{steel}} = 200 \text{ GPa}$. The total change in length of the rod due to loading is:
 (a) $1 \mu\text{m}$ (b) $-10 \mu\text{m}$ (c) $16 \mu\text{m}$ (d) $-20 \mu\text{m}$

GATE-12. A bar having a cross-sectional area of 700 mm^2 is subjected to axial loads at the positions indicated. The value of stress in the segment QR is: [GATE-2006]



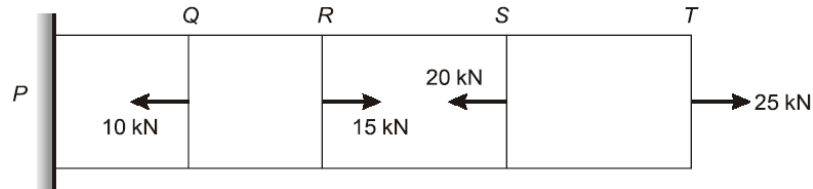
GATE-13. A horizontal bar with a constant cross-section is subjected to loading as shown in the figure. The Young's moduli for the sections AB and BC are $3E$ and E , respectively.



[GATE-2016]

For the deflection at C to be zero, the ratio P/F is _____

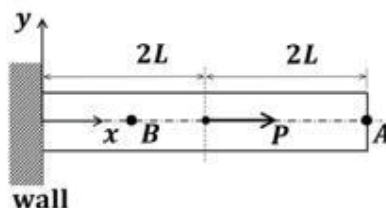
GATE-13a. A prismatic bar PQRST is subjected to axial loads as shown in the figure. The segments having maximum and minimum axial stresses, respectively, are



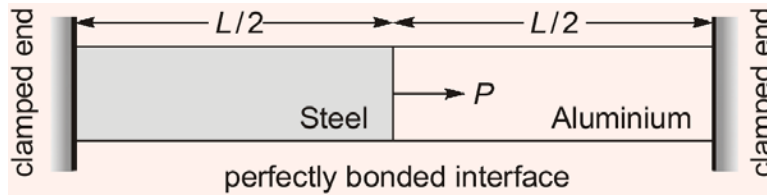
[GATE-2021]

(a) ST and PQ (b) QR and PQ (c) ST and RS (d) QR and RS

GATE-13b. A uniform elastic rod of constant cross-section is fixed at its left end as shown in the figure. An axial force P is acting as shown. Assume that plane sections remain plane during deformation. The ratio of axial displacements at point A ($x = 4L$) to that at point B ($x = L$) is _____ (rounded off to one decimal place) [XE: GATE-2022]



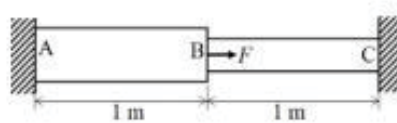
- GATE-13c. A bimetallic cylindrical bar of cross sectional area 1 m^2 is made by bonding Steel (Young's modulus = 210 GPa) and Aluminium (Young's modulus = 70 GPa) as shown in the figure. To maintain tensile axial strain of magnitude 10^{-6} Steel bar and compressive axial strain of magnitude 10^{-6} Aluminium bar, the magnitude of the required force P (in kN) along the indicated direction is



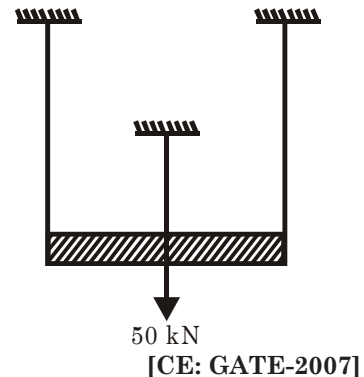
[GATE-2018]

- (a) 70 (b) 140 (c) 210 (d) 280
- GATE-13d. The stepped rod of length 2 m , shown in the figure, is fixed at both ends (A and C). The area of cross-section of portion AB is 200 mm^2 and that of portion BC is 100 mm^2 . Force F is applied at section B such that the section is displaced by 0.1 mm in the direction of the force. Young's modulus of the rod is 200 GPa . The applied force F in N is _____ (round off to the nearest integer)

[XE: GATE-2022]



- GATE-14. A rigid bar is suspended by three rods made of the same material as shown in the figure. 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



[CE: GATE-2007]

Stresses due to self-weight

- GATE-14a. A right solid circular cone standing on its base on a horizontal surface is of height H and base radius R . The cone is made of a material with specific weight w and elastic modulus E . The vertical deflection at the mid-height of the cone due to self-weight is given by

[GATE-2021]

- (a) $\frac{wRH}{8E}$ (b) $\frac{wH^2}{8E}$ (c) $\frac{wRH}{6E}$ (d) $\frac{wH^2}{6E}$

Thermal Effect

- GATE-15. A uniform, slender cylindrical rod is made of a homogeneous and isotropic material. The rod rests on a frictionless surface. The rod is heated uniformly. If the radial and longitudinal thermal stresses are represented by σ_r and σ_z , respectively, then

[GATE-2005]

- (a) $\sigma_r = 0, \sigma_z = 0$ (b) $\sigma_r \neq 0, \sigma_z = 0$ (c) $\sigma_r = 0, \sigma_z \neq 0$ (d) $\sigma_r \neq 0, \sigma_z \neq 0$

GATE-16. A solid steel cube constrained on all six faces is heated so that the temperature rises uniformly by ΔT . If the thermal coefficient of the material is α , Young's modulus is E and the Poisson's ratio is ν , the thermal stress developed in the cube due to heating is

(a) $-\frac{\alpha(\Delta T)E}{(1-2\nu)}$ (b) $-\frac{2\alpha(\Delta T)E}{(1-2\nu)}$ (c) $-\frac{3\alpha(\Delta T)E}{(1-2\nu)}$ (d) $-\frac{\alpha(\Delta T)E}{3(1-2\nu)}$ [GATE-2012]

GATE-16a. A solid cube of side 1 m is kept at a room temperature of 32°C . The coefficient of linear thermal expansion of the cube material is $1 \times 10^{-5}/^\circ\text{C}$ and the bulk modulus is 200 GPa. If the cube is constrained all around and heated uniformly to 42°C , then the magnitude of volumetric (mean) stress induced due to heating is _____ MPa. [GATE-2019]

GATE-17. 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 $^\circ\text{C}$ 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 [CE: GATE-2007]

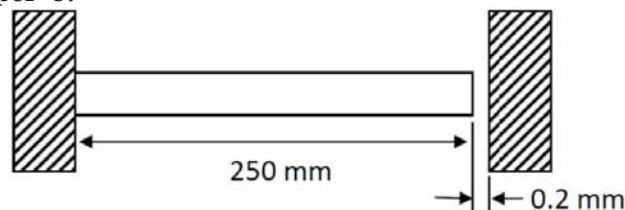
GATE-18. A 200 mm long, stress free rod at room temperature is held between two immovable rigid walls. The temperature of the rod is uniformly raised by 250°C . If the Young's modulus and coefficient of thermal expansion are 200 GPa and $1 \times 10^{-5}/^\circ\text{C}$, respectively, the magnitude of the longitudinal stress (in MPa) developed in the rod is [GATE-2014]

GATE-19. A circular rod of length 'L' and area of cross-section 'A' has a modulus of elasticity 'E' and coefficient of thermal expansion ' α '. One end of the rod is fixed and other end is free. If the temperature of the rod is increased by ΔT , then [GATE-2014]
(a) stress developed in the rod is $E \alpha \Delta T$ and strain developed in the rod is $\alpha \Delta T$
(b) both stress and strain developed in the rod are zero
(c) stress developed in the rod is zero and strain developed in the rod is $\alpha \Delta T$
(d) stress developed in the rod is $E \alpha \Delta T$ and strain developed in the rod is zero

GATE-20. A steel cube, with all faces free to deform, has Young's modulus, E, Poisson's ratio, ν , and coefficient of thermal expansion, α . The pressure (hydrostatic stress) developed within the cube, when it is subjected to a uniform increase in temperature, ΔT , is given by [GATE-2014]

(a) 0 (b) $\frac{\alpha(\Delta T)E}{1-2\nu}$ (c) $-\frac{\alpha(\Delta T)E}{1-2\nu}$ (d) $\frac{\alpha(\Delta T)E}{3(1-2\nu)}$

GATE-20a. A circular metallic rod of length 250 mm is placed between two rigid immovable walls as shown in the figure. The rod is in perfect contact with the wall on the left side and there is a gap of 0.2 mm between the rod and the wall on the right side. If the temperature of the rod is increased by 200°C , the axial stress developed in the rod is _____ MPa. [GATE-2016]
Young's modulus of the material of the rod is 200 GPa and the coefficient of thermal expansion is 10^{-5} per $^\circ\text{C}$.



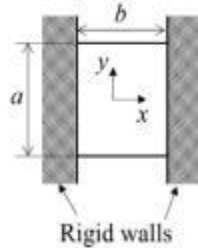
GATE-20b. A steel bar is held by two fixed supports as shown in the figure and is subjected to an increase of temperature $\Delta T = 100^\circ\text{C}$. If the coefficient of thermal expansion and

Young's modulus of elasticity of steel are $11 \times 10^{-6}/^{\circ}\text{C}$ and 200 GPa, respectively, the magnitude of thermal stress (in MPa) induced in the bar is _____. [GATE-2017]



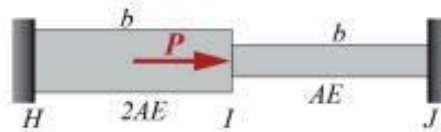
GATE-20c. A horizontal bar, fixed at one end ($x = 0$), has a length of 1 m, and cross-sectional area of 100 mm^2 . Its elastic modulus varies along its length as given by $E(x) = 100 e^{-x}$ GPa, where x is the length coordinate (in m) along the axis of the bar. An axial tensile load of 10 kN is applied at the free end ($x = 1$). The axial displacement of the free end is _____ mm. [GATE-2017]

GATE-20d. A rectangular plate of uniform thickness having initial length a and width b is placed between two rigid immovable walls. The temperature of the plate is increased by ΔT . The plate is free to expand along the y and z directions. The mid-surface of the plate remains in the xy -plane. The Poisson's ratio is ν and the coefficient of thermal expansion is α . Assuming that the plate is initially free of stresses, the change in length of the plate after the increase in temperature is given by [XE: GATE-2022]



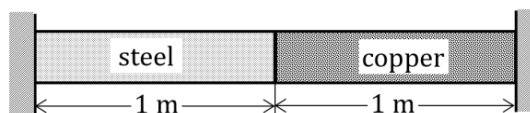
- (a) $a(1 - \nu)\alpha\Delta T$ (b) $a(1 + \nu)\alpha\Delta T$ (c) $a\alpha\Delta T$ (d) $2a\alpha\Delta T$

GATE-20e. 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 H and J. Both the rods are initially stress free. The coefficient of linear thermal expansion is α 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 $\alpha = 10^{-6} ^{\circ}\text{C}^{-1}$, $\Delta T = 50 ^{\circ}\text{C}$, $b = 2 \text{ m}$, $AE = 10^6 \text{ N}$. The axial rigidities of the rods HI and IJ are $2AE$ and AE , respectively. [CE: GATE-2022 set - 2]



To make the axial force in rod HI equal to zero, the value of the external force P (in N) is _____. (round off to the nearest integer)

GATE-20f. A composite rod made of steel and copper is fixed immovably at its ends as shown in the figure. The length of each portion of the rod is 1 m as shown. The cross-sections of both portions are the same. The moduli of elasticity of steel and copper are 200 GPa and 100 GPa, respectively. The coefficients of thermal expansion of steel and copper are $12 \times 10^{-6} /^{\circ}\text{C}$ and $18 \times 10^{-6} /^{\circ}\text{C}$, respectively. The composite rod is initially stress free. Then, the temperature of the composite rod is increased by 100°C . The magnitude of axial stress (in MPa) developed in the steel rod is _____ (rounded off to one decimal place). [GATE : XE 2023]



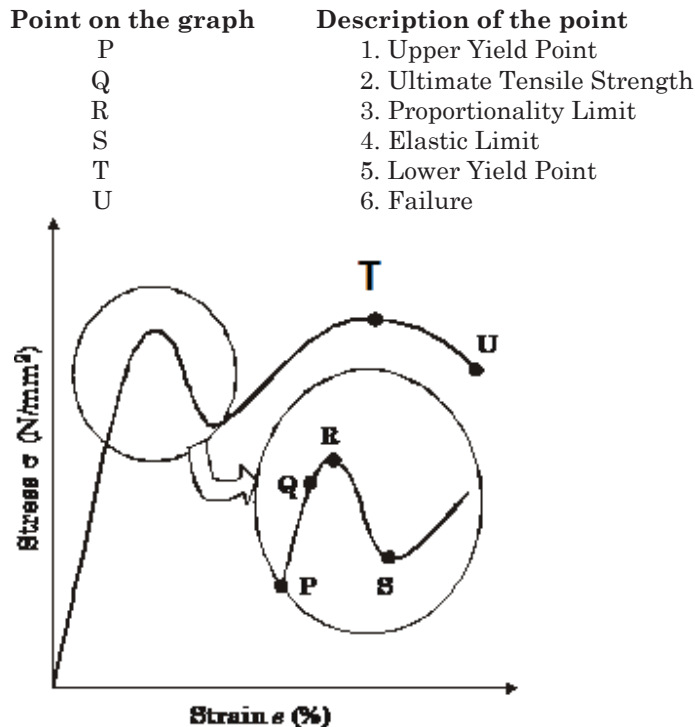
Fatigue, Creep

- GATE-21. The creep strains are [CE: GATE-2013]
 (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-21.a Creep of mild steel at elevated temperature involves GATE 2023 (PI)
 (a) elastic deformation under constant load
 (b) elastic deformation under dynamic load
 (c) plastic deformation under constant load
 (d) plastic deformation under dynamic load

Tensile Test

- GATE-22. The stress-strain curve for mild steel is shown in the figure given below. Choose the correct option referring to both figure and table. [GATE-2014]



- | | | | | | | | | | | | | |
|-----|---|---|---|---|---|---|---|---|---|---|---|---|
| | P | Q | R | S | T | U | P | Q | R | S | T | U |
| (a) | 1 | 2 | 3 | 4 | 5 | 6 | 3 | 1 | 4 | 2 | 6 | 5 |
| (c) | 3 | 4 | 1 | 5 | 2 | 6 | 4 | 1 | 5 | 2 | 3 | 6 |

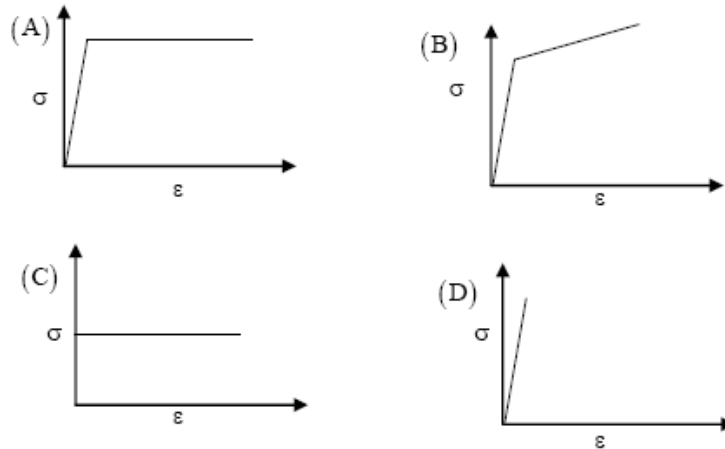
- GATE-22a. In the engineering stress-strain curve for mild steel, the Ultimate Tensile Strength (UTS) refers to [GATE-2017]
 (a) Yield stress (b) Proportional limit
 (c) Maximum Stress (d) Fracture stress

- GATE-22b. The elastic modulus of a rigid perfectly plastic solid is [PI: GATE-2016]
 (a) 0 (b) 1 (c) 100 (d) infinity

- GATE-22c. Which one of the following is the definition of ultimate tensile strength (UTS) obtained from a stress-strain test on a metal specimen?
- Stress value where the stress-strain curve transitions from elastic to plastic behavior
 - The maximum load attained divided by the original cross-sectional area
 - The maximum load attained divided by the corresponding instantaneous cross-sectional area
 - Stress where the specimen fractures
- [GATE- 2022 Set-2]

- GATE-23. A test specimen is stressed slightly beyond the yield point and then unloaded. Its yield strength will
- [GATE-1995]
- Decrease
 - Increase
 - Remains same
 - Becomes equal to ultimate tensile strength

- GATE-23a. Which one of the following types of stress-strain relationship best describes the behavior of brittle materials, such as ceramics and thermosetting plastics, σ = stress; ϵ = strain
- [GATE-2015]



- GATE-23b. In a linearly hardening plastic material, the true stress beyond initial yielding
- [GATE-2018]
- increases linearly with the true strain
 - decreases linearly with the true strain
 - first increases linearly and then decreases linearly with the true strain
 - remain constant

- GATE-23c. Consider the stress-strain curve for an ideal elastic-plastic strain hardening metal as shown in the figure. The metal was loaded in uniaxial tension starting from O . Upon loading, the stress-strain curve passes through initial yield point at P , and then strain hardens to point Q , where the loading was stopped. From point Q , the specimen was unloaded to point R , where the stress is zero. If the same specimen is reloaded in tension from point R , the value of stress at which the material yields again is ____MPa.
- [GATE-2019]

