# CHAPTER 26

# OBJECTIVE TYPE QUESTIONS

## 26.1. OBJECTIVE TYPE QUESTIONS GENERALLY ASKED IN COMPETITIVE EXAMINATIONS

**Tick mark (√) the most appropriate answer of the multiple choices.**

1. Within elastic limit in a loaded material, stress is
   (*a*) inversely proportional to strain
   (*b*) directly proportional to strain
   (*c*) equal to strain
   (*d*) none of the above.
2. The ratio of linear stress to linear strain is known as
   (*a*) Poisson's ratio
   (*b*) bulk modulus
   (*c*) modulus of rigidity
   (*d*) modulus of elasticity.
3. The ratio of lateral strain to longitudinal strain is called
   (*a*) Poisson's ratio
   (*b*) bulk modulus
   (*c*) modulus of rigidity
   (*d*) modulus of elasticity.
4. The ratio of shear stress to shear strain is called
   (*a*) Poisson's ratio
   (*b*) bulk modulus
   (*c*) modulus of rigidity
   (*d*) modulus of elasticity.
5. The ratio of normal stress of each face of a solid cube to volumetric strain is called
   (*a*) Poisson's ratio
   (*b*) bulk modulus
   (*c*) modulus of rigidity
   (*d*) modulus of elasticity.
6. Hooke's law holds good upto
   (*a*) proportional limit
   (*b*) yield point
   (*c*) elastic limit
   (*d*) plastic limit.
7. The property of a material by virtue of which a body returns to its original shape after removal of the load is known as
   (*a*) ductility
   (*b*) plasticity
   (*c*) elasticity
   (*d*) resilience.
8. A tensile force ($P$) is acting on a body of length ($L$) and area of cross-section ($A$). The change in length would be
   (*a*) $\frac{P}{LAE}$
   (*b*) $\frac{PE}{AL}$
   (*c*) $\frac{PL}{AE}$
   (*d*) $\frac{AL}{PE}$.

**9.** The modulus of elasticity ($E$) and modulus of rigidity ($C$) are related by

($a$) $C = \dfrac{mE}{3(m-2)}$

($b$) $C = \dfrac{mE}{2(m+1)}$

($c$) $C = \dfrac{3(m-2)}{mE}$

($d$) $C = \dfrac{2(m+1)}{mE}$

where $\dfrac{1}{m}$ = Poisson's ratio.

**10.** The modulus of elasticity ($E$) and bulk modulus ($K$) are related by

($a$) $K = \dfrac{mE}{3(m-2)}$

($b$) $K = \dfrac{mE}{2(m+1)}$

($c$) $K = \dfrac{3(m-2)}{mE}$

($d$) $K = \dfrac{2(m+1)}{mE}$

where $\dfrac{1}{m}$ = Poisson's ratio.

**11.** The elongation produced in a rod (by its own weight) of length ($l$) and diameter ($d$) rigidly fixed at the upper end and hanging is equal to

($a$) $\dfrac{wl}{2E}$

($b$) $\dfrac{wl^2}{2E}$

($c$) $\dfrac{wl^3}{2E}$

($d$) $\dfrac{wl^4}{2E}$

where $w$ = weight per unit volume of the rod,
$E$ = modulus of elasticity.

**12.** The ratio of modulus of rigidity to modulus of elasticity for a Poisson's ratio of 0.25 would be

($a$) 0.5
($b$) 0.4
($c$) 0.3
($d$) 1.0.

**13.** The ratio of bulk modulus to modulus of elasticity for a Poisson's ratio of 0.25 would be

($a$) 2/3
($b$) 1/3
($c$) 4/3
($d$) 1.0.

**14.** The relation between modulus of elasticity ($E$), modulus of rigidity ($C$) and bulk modulus ($K$) is given by

($a$) $E = \dfrac{3KC}{C+9K}$

($b$) $E = \dfrac{9KC}{C+3K}$

($c$) $E = \dfrac{C+9K}{3KC}$

($d$) $E = \dfrac{C+3K}{9KC}$.

**15.** The ratio of modulus of rigidity to bulk modulus for a Poisson's ratio of 0.25 would be

($a$) 2/3
($b$) 2/5
($c$) 3/5
($d$) 1.0.

**16.** The work done in producing strain on a material per unit volume is called

($a$) resilience
($b$) ductility
($c$) elasticity
($d$) plasticity.

17. The property by virtue of which a metal can be beaten into plates is called
(a) ductility
(b) malleability
(c) resilience
(d) plasticity.

18. Choose the wrong statement
(a) Elongation produced in a rod (by its own weight) which is rigidly fixed at the upper end and hanging is equal to that produced by a load half its weight applied at the end.
(b) The stress at any section of a rod on account of its own weight is directly proportional to the distance of the section from the lower end.
(c) Modulus of elasticity is having the same unit as stress.
(d) If a material expands freely due to heating, it will develop thermal stresses.

19. A rod of length ($l$) tapers uniformly from a diameter $D_1$ to a diameter $D_2$ and carries an axial tensile load $P$. The extension of the rod would be
(a) $\frac{\pi Pl}{4ED_1D_2}$
(b) $\frac{4Pl}{\pi ED_1D_2}$
(c) $\frac{\pi EPl}{4D_1D_2}$
(d) $\frac{4PEl}{\pi D_1D_2}$.

20. If in question 19, the rod is of uniform diameter ($D$), then extension would be
(a) $\frac{\pi Pl}{4ED^2}$
(b) $\frac{4Pl}{\pi ED^2}$
(c) $\frac{\pi EPl}{4D^2}$
(d) $\frac{4PEl}{\pi D^2}$.

21. A rod of length $l$ and cross-sectional area $A$ rotates about an axis passing through one end of the rod. The extension produced in the bar due to centrifugal forces would be
(a) $\frac{w\omega l^2}{3E}$
(b) $\frac{w\omega^2 l^3}{gE}$
(c) $\frac{w\omega^2 l^3}{3gE}$
(d) $\frac{3gE}{w\omega^2 l^3}$.

22. For the bars of composite section,
(a) the load carried by different materials is the same as the total external load
(b) the extension in different materials is different
(c) the total external load is equal to the total sum of the loads carried by different materials
(d) strain in all materials is equal
(e) both (c) and (d).

23. Two materials are having modulus of elasticities, modulus of rigidities and bulk modulus as ($E_1$, $E_2$); ($C_1$, $C_2$) and ($K_1$, $K_2$). The modulus ratio is given by
(a) $\frac{E_1}{C_2}$
(b) $\frac{E_1}{K_2}$
(c) $\frac{E_1}{E_2}$
(d) $\frac{C_1}{K_2}$.

24. For uniform strength, a bar which is fixed at the upper end and is subjected to an external load $P$ at the lower end, the area ($A$) at any section at a distance $x$ from the lower end is given by

(a) $A_2\, e^{\frac{w}{\sigma x}}$ (b) $A_2\, e^{\frac{\sigma}{wx}}$

(c) $A_2\, e^{\frac{wx}{\sigma}}$ (d) $A_2 \times \frac{\sigma}{wx}$

where $A_2$ = area at the lower end, $w$ = weight per unit volume

$\sigma$ = uniform stress intensity in the bar.

25. The thermal stress is given by

(a) $E\alpha T$ (b) $\frac{ET}{\alpha}$

(c) $\frac{E\alpha}{T}$ (d) $\frac{1}{E\alpha T}$

where $\alpha$ = co-efficient of linear expansion,

$T$ = rise in temperature.

26. The proof resilience is given by

(a) $\frac{2\sigma^2}{E}$ (b) $\frac{2E}{\sigma^2}$

(c) $\frac{\sigma^2}{2E}$ (d) $\frac{E}{2\sigma^2}$

where $\sigma$ = stress at the elastic limit.

27. If $D$ is the diameter of a sphere, then volumetric strain is equal to

(a) two times the strain of diameter (b) 1.5 times the strain of diameter

(c) three times the strain of diameter (d) the strain of diameter.

28. If $l$ be the length and $D$ be the diameter of a cylindrical rod, then volumetric strain of the rod is equal to

(a) strain of length plus strain of diameter

(b) strain of diameter

(c) strain of length + twice the strain of diameter

(d) strain of length.

29. The extension per unit length of the rod due to suddenly applied load as compared to the same load gradually applied to the same rod is

(a) same (b) double

(c) three times (d) half.

30. The stress due to suddenly applied load as compared to the stress due to the same load gradually applied to the same rod is

(a) half (b) same

(c) double (d) three times.

31. The tensile force at a distance $y$ from support in a vertical hanging bar of length $l$ which carries a load $P$ at the bottom is equal to

(a) $P$ (b) $P + wl$
(c) $P + w(l - y)$ (d) $P + wy$

where $w$ = weight per unit length.

32. The normal stress on an oblique plane at an angle $\theta$ to the cross-section of a body which is subjected to a direct tensile stress ($\sigma$) is equal to

(a) $\frac{\sigma}{2} \sin 2\theta$ (b) $\sigma \cos \theta$
(c) $\sigma \cos^2 \theta$ (d) $\sigma \sin^2 \theta$.

33. In question 32, the normal stress on the oblique plane will be maximum when $\theta$ is equal to

(a) 90° (b) 45°
(c) 0° (d) 30°.

34. The tangential or shear stress on an oblique plane at an angle $\theta$ to the cross-section of a body which is subjected to a direct tensile stress ($\sigma$) is equal to

(a) $\frac{\sigma}{2} \sin 2\theta$ (b) $\sigma \cos \theta$
(c) $\sigma \cos^2 \theta$ (d) $\sigma \sin^2 \theta$.

35. In question 34, the tangential or shear stress on the oblique plane will be maximum when $\theta$ is equal to

(a) 90° (b) 45°
(c) 0° (d) 30°.

36. The resultant stress on an oblique plane at an angle $\theta$ to the cross-section of a body which is subjected to a direct tensile stress is

(a) $\sigma/2 \sin 2\theta$ (b) $\sigma \cos \theta$
(c) $\sigma \cos^2 \theta$ (d) $\sigma \sin^2 \theta$.

37. If a member is subjected to an axial tensile load, the plane normal to the axis of loading carries

(a) minimum normal stress (b) maximum normal stress
(c) maximum shear stress (d) none of the above.

38. If a member is subjected to an axial tensile load, the plane inclined at 45° to the axis of loading carries

(a) minimum shear stress (b) maximum normal stress
(c) maximum shear stress (d) none of the above.

39. The maximum shear stress induced in a member which is subjected to an axial load is equal to

(a) maximum normal stress (b) half of maximum normal stress
(c) twice the maximum normal stress (d) thrice the maximum normal stress.

40. If a member, whose tensile strength is more than two times the shear strength, is subjected to an axial load upto failure, the failure of the member will occur by

(a) maximum normal stress (b) maximum shear stress
(c) normal stress or shear stress (d) none of the above.

41. The elongation of a conical bar due to its own weight is equal to

(a) $\frac{wl}{2E}$ (b) $\frac{wl^2}{6E}$

(c) $\frac{wl^3}{6E}$ (d) $\frac{wl^4}{6E}$

where $l$ = length of bar and $w$ = weight per unit volume.

42. If a beam is fixed at both its ends, it is called a

(a) fixed beam (b) built-in beam

(c) encastered beam (d) any one of the above

(e) none of the above.

43. If a beam is supported on more than two supports, it is called a

(a) built-in beam (b) continuous beam

(c) simply supported beam (d) encastered beam.

44. Choose the wrong statement

(a) The shear force at any section of a beam is equal to the total sum of the forces acting on the beam on any one side of the section.

(b) The magnitude of the bending moment at any section of a beam is equal to the vector sum of the moments (about the section) due to the forces acting on the beam on any one side of the section.

(c) A diagram which shows the values of shear forces at various sections of structural member is called a shear force diagram.

(d) A simply supported beam is one which is supported on more than two supports.

45. A simply supported beam of span ($l$) carries a point load ($W$) at the centre of the beam. The bending moment diagram will be a

(a) parabola with maximum ordinate at the centre of the beam

(b) parabola with maximum ordinate at one end of the beam

(c) triangle with maximum ordinate at the centre of the beam

(d) triangle with maximum ordinate at one end of the beam.

46. A simply supported beam of span ($l$) carries a uniformly distributed load ($w$ N per unit length) over the whole span. The bending moment diagram will be a

(a) parabola with maximum ordinate at the centre of the beam

(b) parabola with maximum ordinate at one end of the beam

(c) triangle with maximum ordinate at the centre of the span

(d) triangle with maximum ordinate at one end of the beam.

47. A cantilever of length ($l$) carries a point load ($W$) at the free end. The bending moment diagram will be a

(a) parabola with maximum ordinate at the centre of the beam

(b) parabola with maximum ordinate at the cantilever end

(c) triangle with maximum ordinate at the free end

(d) triangle with maximum ordinate at the cantilever end.

48. A cantilever of length ($l$) carries a uniformly distributed load over the whole length. The bending moment diagram will be

(*a*) parabola with maximum ordinate at the centre

(*b*) parabola with maximum ordinate at the cantilever end

(*c*) triangle with maximum ordinate at the free end

(*d*) triangle with maximum ordinate at the cantilever end.

49. A simply supported beam of span ($l$) carries a point load ($W$) at the centre of the beam. The shear force diagram will be

(*a*) a rectangle (*b*) a triangle

(*c*) two equal and opposite rectangles (*d*) two equal and opposite triangles.

50. A simply supported beam of span ($l$) carries a uniformly distributed load over the whole span. The shear force diagram will be

(*a*) a rectangle (*b*) a triangle

(*c*) two equal and opposite rectangles (*d*) two equal and opposite triangles.

51. A cantilever of length ($l$) carries a point load ($W$) at the free end. The shear force diagram will be

(*a*) two equal and opposite rectangles (*b*) a rectangle

(*c*) two equal and opposite triangles (*d*) a triangle.

52. A cantilever of length ($l$) carries a uniformly distributed load over the whole length. The shear force diagram will be

(*a*) two equal and opposite rectangles (*b*) a rectangle

(*c*) two equal and opposite triangles (*d*) a triangle.

53. The bending moment on a section is maximum where shearing force is

(*a*) minimum (*b*) maximum

(*c*) zero (*d*) equal

(*e*) changing sign (*f*) none of the above.

54. The point of zero bending moment, where the continuous curve of bending moment changes sign, is called

(*a*) the point of contraflexure (*b*) the point of inflation

(*c*) the point of virtual hinge (*d*) all of the above.

55. The point of contraflexure occurs only in

(*a*) continuous beams (*b*) cantilever beams

(*c*) overhanging beams (*d*) simply supported beams

(*e*) all of the above (*f*) none of the above.

56. The bending moment at a section, where shear force is zero, will be

(*a*) zero (*b*) maximum

(*c*) minimum (*d*) either minimum or maximum

(*e*) none of the above.

57. A beam of uniform strength is one which has same

(*a*) bending stress at every section (*b*) deflection throughout the beam

(*c*) bending moment throughout the beam (*d*) shear force throughout the beam.

**58.** The shear force and bending moment are zero at the free end of a cantilever, if it carries a

(*a*) point load at the free end

(*b*) uniformly distributed load over the whole length

(*c*) point load in the middle of its length

(*d*) none of the above.

**59.** A simply supported beam carries a uniformly distributed load of $w$ N per unit length over the whole span ($l$). The shear force at the centre is

(*a*) $\frac{wl}{2}$ (*b*) $\frac{wl^2}{8}$

(*c*) $\frac{wl}{4}$ (*d*) zero.

**60.** For the question 59, the shear force at the supported ends will be

(*a*) $\pm\frac{wl}{2}$ (*b*) $\frac{wl^2}{8}$

(*c*) $\frac{wl}{4}$ (*d*) zero.

**61.** For the question 59, the bending moment at the supported ends will be

(*a*) $\pm\frac{wl}{2}$ (*b*) $\frac{wl^2}{8}$

(*c*) $\frac{wl}{4}$ (*d*) zero.

**62.** For the question 59, the bending moment at the centre will be

(*a*) $\pm\frac{wl}{2}$ (*b*) $\frac{wl^2}{8}$

(*c*) $\frac{wl}{4}$ (*d*) zero.

**63.** For the question 59, the point of contraflexure is at

(*a*) the supported end (*b*) the middle of the beam

(*c*) a distance $\frac{l}{4}$ from the supported ends (*d*) none of the above.

**64.** A cantilever of length ($l$) carries a uniformly distributed load $w$ N per unit length for the whole length. The shear force at the free end will be

(*a*) $wl$ (*b*) $\frac{wl^2}{2}$

(*c*) $\frac{wl}{2}$ (*d*) zero.

**65.** In question 64, the shear force at the fixed end will be

(*a*) $wl$ (*b*) $\frac{wl^2}{2}$

(*c*) $\frac{wl}{2}$ (*d*) zero.

**66.** In a tensile test of a specimen, the ratio of maximum load to the original cross-sectional area of the test piece is called

(*a*) yield stress (*b*) ultimate stress
(*c*) safe stress (*d*) breaking stress.

**67.** A short column of rectangular section carries a vertical point load $W$ axially. The stress on the section of the column will be

(*a*) uniform
(*b*) zero at one end and maximum at the other end
(*c*) zero at the axis and maximum on the outer ends
(*d*) tensile on one end and compressive on the other.

**68.** If in question 67, the short column carries a vertical point load eccentrically, then the stress on the section will be

(*a*) uniform
(*b*) zero at the axis and maximum on the outer ends
(*c*) zero at one end and maximum at the other end
(*d*) tensile on one end and compressive on the other
(*e*) non-uniform and will depend upon the amount of eccentricity.

**69.** A solid circular shaft of diameter $D$ carries an axial load $W$. If the same load is applied axially on a hollow circular shaft of inner diameter as $\frac{D}{2}$, the ratio of stresses in a solid shaft to that of hollow shaft would be

(*a*) $\frac{1}{2}$ (*b*) $\frac{1}{4}$
(*c*) $\frac{4}{3}$ (*d*) $\frac{3}{4}$.

**70.** If in question 69, the inner diameter of hollow shaft is $D/3$, then the ratio of stress in a solid shaft to that of hollow shaft would be

(*a*) $\frac{1}{2}$ (*b*) $\frac{1}{4}$
(*c*) $\frac{8}{9}$ (*d*) $\frac{9}{8}$.

**71.** Under tensile test, a test piece of a material is having 40% elongation whereas another test piece of the same dimensions but of different material is having 25% elongation. Then the ductility of the first material as compared to that of second material is

(*a*) less (*b*) same
(*c*) more (*d*) none of the above.

**72.** The diameter of a cast iron round bar, on which tensile test is performed, at fracture will

(*a*) increase (*b*) decrease
(*c*) be approximately same (*d*) none of the above.

**73.** The diameter of a mild steel round bar, on which tensile test is performed, at fracture will

(*a*) increase (*b*) decrease
(*c*) be same (*d*) none of the above.

**74.** If a member is subjected to a uniform bending moment ($M$), the radius of curvature of the deflected form of the member is given by

(a) $\frac{M}{R} = \frac{E}{I}$ (b) $\frac{M}{I} = \frac{E}{R}$

(c) $\frac{M}{I} = \frac{R}{E}$ (d) $\frac{M}{E} = RI$.

**75.** Which one of the following equations is correct

(a) $\frac{1}{R} = \frac{d^2y}{dx^2} = \frac{EI}{M}$ (b) $\frac{1}{R} = \frac{d^2y}{dx^2} = \frac{M}{EI}$

(c) $R = \frac{d^2y}{dx^2} = \frac{M}{EI}$ (d) $R = \frac{d^2y}{dx^2} = \frac{EI}{M}$

where $R$ = radius of curvature and $M$ = bending moment.

**76.** The expression $EI\frac{d^2y}{dx^2}$ at a section of a member represents

(a) shearing force (b) rate of loading

(c) bending moment (d) slope.

**77.** The expression $EI\frac{d^3y}{dx^3}$ at a section of a member represents

(a) shearing force (b) rate of loading

(c) bending moment (d) slope.

**78.** The expression $EI\frac{d^4y}{dx^4}$ at a section of a member represents

(a) shearing force (b) rate of loading

(c) bending moment (d) slope.

**79.** A cantilever of length ($l$) carries a point load ($W$) at the free end. The downward deflection at the free end is equal to

(a) $\frac{Wl^3}{8EI}$ (b) $\frac{Wl^3}{3EI}$

(c) $\frac{5Wl^3}{384EI}$ (d) $\frac{Wl^3}{48EI}$.

**80.** In question 79, the slope at the free end will be

(a) $\frac{Wl^2}{6EI}$ (b) $\frac{Wl^2}{2EI}$

(c) $\frac{Wl^2}{24EI}$ (d) $\frac{Wl^2}{16EI}$.

**81.** A cantilever of length ($l$) carries a uniformly distributed load $w$ per unit length over the whole length. The downward deflection at the free end will be

(a) $\frac{Wl^3}{8EI}$ (b) $\frac{Wl^3}{3EI}$

(c) $\frac{5Wl^3}{384EI}$ (d) $\frac{Wl^3}{48EI}$

where $W = w \times l$ = total load.

82. In question 81, the slope at the free end will be

(a) $\frac{Wl^2}{6EI}$ (b) $\frac{Wl^2}{2EI}$

(c) $\frac{Wl^2}{24EI}$ (d) $\frac{Wl^2}{16EI}$

where $W$ = total load = $w \times l$.

83. A uniform simply supported beam of span ($l$) carries a point load ($W$) at the centre. The downward deflection at the centre will be

(a) $\frac{Wl^3}{8EI}$ (b) $\frac{Wl^3}{3EI}$

(c) $\frac{5Wl^3}{384EI}$ (d) $\frac{Wl^3}{48EI}$.

84. In question 83, the slope at the support will be

(a) $\frac{Wl^2}{6EI}$ (b) $\frac{Wl^2}{2EI}$

(c) $\frac{Wl^2}{24EI}$ (d) $\frac{Wl^2}{16EI}$.

85. A uniformly simply supported beam of span ($l$) carries a uniformly distributed load $w$ per unit length over the whole span. The downward deflection at the centre will be

(a) $\frac{Wl^3}{8EI}$ (b) $\frac{Wl^3}{3EI}$

(c) $\frac{5Wl^3}{384EI}$ (d) $\frac{Wl^3}{48EI}$

where $W = w \times l$ = total load.

86. A simply supported beam is of rectangular section. It carries a uniformly distributed load over the whole span. The deflection at the centre is $y$. If the depth of the beam is doubled, the deflection at the centre would be

(a) $2y$ (b) $4y$

(c) $\frac{y}{2}$ (d) $\frac{y}{8}$.

87. A simply supported beam carries a uniformly distributed load over the whole span. The deflection at the centre is $y$. If the distributed load per unit length is doubled and also depth of the beam is doubled, then the deflection at the centre would be

(a) $2y$ (b) $4y$

(c) $\frac{y}{2}$ (d) $\frac{y}{4}$.

88. The slope at the free end of a cantilever of length 1 m is 1°. If the cantilever carries a uniformly distributed load over the whole length, then the deflection at the free end will be

(a) 1 cm (b) 1.309 cm

(c) 2.618 cm (d) 3.927 cm.

**89.** A cantilever of length ($l$) carries a point load ($W$) at a distance $x$ from the fixed end, then the deflection at the free end will be

(a) $\frac{Wx^3}{3EI} + \frac{Wx^2}{2EI} \times l$ (b) $\frac{Wl^3}{3EI}$

(c) $\frac{Wx^3}{3EI} + \frac{Wx^2}{2EI}(l - x)$ (d) $\frac{Wx^2}{2EI} + \frac{Wx^3}{3EI}(l - x)$.

**90.** A cantilever of length ($l$) carries a uniformly distributed load of $w$ per unit length for a distance $x$ from the fixed end, then the deflection at the free end will be

(a) $\frac{Wx^4}{8EI} + \frac{Wx^3}{6EI} \times l$ (b) $\frac{Wx^4}{8EI}$

(c) $\frac{Wl^4}{8EI}$ (d) $\frac{Wx^4}{8EI} + \frac{Wx^3}{6EI} \times (l - x)$.

**91.** A cantilever of length ($l$) carries a distributed load whose intensity varies from zero at the free end to $w$ per unit length at the fixed end. The deflection at the free end will be

(a) $\frac{wl^4}{3EI}$ (b) $\frac{wl^4}{8EI}$

(c) $\frac{11}{120}\frac{wl^4}{EI}$ (d) $\frac{wl^4}{30EI}$.

**92.** A cantilever of length ($l$) carries a distributed load whose intensity varies uniformly from zero at the fixed end to $w$ per unit length at the free end. The deflection at the free end will be

(a) $\frac{wl^4}{3EI}$ (b) $\frac{wl^4}{8EI}$

(c) $\frac{11}{120}\frac{wl^4}{EI}$ (d) $\frac{wl^4}{30EI}$.

**93.** The statement that 'the deflection at any point in a beam subjected to any load system is equal to the partial derivative of the total strain energy stored with respect to the load acting at the point in the direction in which deflection is desired' is called

(a) Bettle's law (b) the first theorem of Castigliano

(c) Clapeyron's theorem (d) Maxwell's law.

**94.** A laminated spring 1 m long carries a central point load of 2000 N. The spring is made up of plates each 5 cm wide and 1 cm thick. The bending stress in the plates is limited to 10 N/mm$^2$. The number of plates required, will be

(a) 3 (b) 5

(c) 6 (d) 8.

**95.** In question 94, if $E = 2 \times 10^5$ N/mm$^2$ the deflection under the given load of 2000 N will be

(a) 1 cm (b) 1.25 cm

(c) 1.3 cm (d) 1.40 cm.

**96.** A fixed beam is a beam whose end supports are such that the end slopes

(a) are maximum (b) are minimum

(c) are zero (d) none of the above.

97. A fixed beam of length ($l$) carries a point load ($W$) at the centre. The deflection at the centre is
(a) same as for a simply supported beam
(b) half of the deflection for a simply supported beam
(c) one-fourth of the deflection for a simply supported beam
(d) double the deflection for a simply supported beam.

98. For the question 97, the number of points of contraflexure
(a) is one
(b) are two
(c) are three
(d) is none.

99. For the question 97, the points of contraflexure lies at
(a) the fixed ends
(b) the middle of the beam
(c) $\frac{l}{4}$ from the ends
(d) none of the above.

100. For the question 97, the bending moment at the centre is
(a) same as for a simply supported beam
(b) half of the bending moment for a simply supported beam
(c) one-fourth of the bending moment for a simply supported beam
(d) double the bending moment for a simply supported beam.

101. For the question 97, the bending moment at the fixed ends is
(a) zero
(b) $\frac{Wl}{4}$
(b) $\frac{Wl}{8}$
(d) $\frac{Wl}{2}$.

102. A fixed beam of span ($l$) carries a uniformly distributed load of $w$ per unit length over the whole span. The deflection at the centre is
(a) equal to the central deflection of a simply supported beam
(b) half of the central deflection for a simply supported beam
(c) one-fourth of the central deflection for a simply supported beam
(d) one-fifth of the central deflection of the simply supported beam.

103. For the question 102, the points of contraflexure lies at
(a) the fixed ends
(b) the middle of the beam
(c) $\frac{l}{4}$ from the ends
(d) $\frac{l}{2\sqrt{3}}$ from the centre of the span.

104. For the solution of problems on fixed beam, the condition is
(a) area of free B.M. diagram = area of fixed B.M. diagram
(b) the distance of the centroid of the free B.M. diagram from an end should be equal to the distance of the centroid of fixed B.M. diagram from the same end
(c) both (a) and (b)
(d) none of the above.

105. In question 102, the end moments are each equal to
(a) $\frac{wl^2}{8}$
(b) $\frac{wl^2}{6}$
(c) $\frac{wl^2}{12}$
(d) $\frac{wl^2}{4}$.

**106.** The load on a circular column of diameter ($d$) for keeping the stress wholly compressive may be applied anywhere within a concentric circle of diameter

(a) $\frac{d}{8}$ (b) $\frac{d}{4}$

(c) $\frac{d}{3}$ (d) $\frac{d}{2}$.

**107.** Three beams of circular, square, rectangular (with depth twice the width) sections and of same length are subjected to the same maximum bending moment. If allowable stress is the same then the section which will require maximum weight of the same material will be

(a) rectangular (b) square

(c) circular (d) none of the above.

**108.** For the question 107, the section which will require minimum weight of the same material will be

(a) rectangular (b) square

(c) circular (d) none of the above.

**109.** For the question 107, the ratios of weight of circular beam, weight of rectangular beam and weight of square beam is

(a) 1 : 0.7938 : 1.118 (b) 0.7938 : 1 : 1.118

(c) 1.118 : 0.7938 : 1 (d) 0.7938 : 1.118 : 1.

**110.** Kernel or core of a section is the figure within which load may be placed so as

(a) to produce tensile stress at one end and compressive stress at the other end

(b) to produce tensile stress at both the ends of the section

(c) to produce tensile stress in the middle of the section

(d) not to produce tensile stress anywhere in the section.

**111.** The ratio of moment of inertia about the neutral axis to the distance of the most distance point of the section from the neutral axis is called

(a) moment of inertia (b) section modulus

(c) polar moment of inertia (d) modulus of rigidity.

**112.** The relation between maximum stress ($\sigma$) offered by a section, moment of resistance ($M$) and section modulus ($Z$) is given by

(a) $M = \frac{\sigma}{Z}$ (b) $M = \frac{Z}{\sigma}$

(c) $M = \sigma \times Z$ (d) $M = \frac{1}{\sigma \times Z}$.

**113.** Choose the correct statement

(a) Section modulus of a hollow circular section of external diameter $D$ and internal diameter $d$ is equal to $\frac{\pi(D^4 - d^4)}{64D}$.

(b) Section modulus of a circular section of diameter $D$ is $\frac{\pi D^4}{32}$.

(c) Section modulus of a rectangular section is $\frac{bd^2}{6}$.

(d) Section modulus of a square section $b \times b$ is $\frac{b^4}{12}$.

114. A beam of uniform strength can be designed by
(a) varying the depth of the beam but maintaining constant width
(b) varying the width of the beam but maintaining constant depth
(c) varying width and depth
(d) any one of the above
(e) none of the above.

115. For a beam of uniform strength having constant depth, the width at a distance $x$ from the support varries with
(a) $\sqrt{x}$
(b) $x$
(c) $x^{1/4}$
(d) $x^{3/4}$.

116. For a beam of uniform strength having constant width, the depth of the beam at a distance $x$ from the support varies with
(a) $\sqrt{x}$
(b) $x$
(c) $x^{1/4}$
(d) $x^{3/4}$.

117. Flitched beam means a
(a) continuous beam
(b) fixed beam
(c) beam of composite section consisting of a wooden beam strengthened by mild steel plates
(d) none of the above.

118. The shear stress required to cause plastic deformation of solid metal is called
(a) proof stress
(b) flow stress
(c) rupture stress
(d) ultimate stress.

119. The stress which will cause a specified permanent deformation in a material (usually 0.01% or less) is called
(a) proof stress
(b) flow stress
(c) rupture stress
(d) ultimate stress.

120. The stress obtained by dividing the load at the moment of incipient fracture, by the area supporting that load is called
(a) proof stress
(b) flow stress
(c) rupture stress
(d) ultimate stress.

121. The statement that 'If unit loads rest upon a beam at the two points $A$ and $B$, then the deflection at $A$ due to unit load at $B$ is equal to the deflection at $B$ due to unit load at $A$' is given by
(a) Mohr
(b) Castigliano
(c) Maxwell
(d) Rankine.

122. A short column of rectangular section carries a point load ($W$) acting with an eccentricity ($e$). The shape of Kernel area would be
(a) square
(b) rectangle
(c) circle
(d) rhombus.

**123.** If in question 122, the column is of circular section then the shape of Kernel area would be

(*a*) square (*b*) rectangle

(*c*) circle (*d*) rhombus.

**124.** Every cross-section of a shaft, which is subjected to a twisting moment, is under

(*a*) compressive stress (*b*) shear stress

(*c*) tensile stress (*d*) bending stress.

**125.** The shear stress at any point of a shaft, subjected to twisting moment, is

(*a*) proportional to its distance from the central axis of the shaft

(*b*) inversely proportional to its distance from the central axis of the shaft

(*c*) proportional to the square of its distance from the central axis of the shaft

(*d*) none of the above.

**126.** When a shaft is subjected to torsion, the relation between maximum shear stress ($\tau$), modulus of rigidity of the shaft ($C$) and angle of twist ($\theta$) is given by

(*a*) $\frac{C\theta}{\tau} = \frac{R}{L}$ (*b*) $\frac{C\theta}{L} = \frac{\tau}{R}$

(*c*) $\frac{C\theta}{R} = \frac{\tau}{L}$ (*d*) $\frac{C}{L\theta} = \frac{\tau}{R}$

where $L$ = length of shaft and $R$ = radius of shaft.

**127.** A solid shaft of diameter $D$ transmits the torque equal to

(*a*) $\frac{\pi}{32} \tau D^3$ (*b*) $\frac{\pi}{64} \tau D^3$

(*c*) $\frac{\pi}{16} \tau D^3$ (*d*) $\frac{\pi}{8} \tau D^3$

where $\tau$ = maximum allowable shear stress.

**128.** The torque transmitted by a hollow shaft of external diameter ($D$) and internal diameter ($d$) is equal to

(*a*) $\frac{\pi}{32} \tau [D^3 - d^3]$ (*b*) $\frac{\pi}{16} \tau [D^3 - d^3]$

(*c*) $\frac{\pi}{16} \tau \left[\frac{D^4 - d^4}{D}\right]$ (*d*) $\frac{\pi}{32} \tau \left[\frac{D^4 - d^4}{D}\right]$.

**129.** Polar moment of inertia of a solid circular shaft of diameter $D$ is equal to

(*a*) $\frac{\pi D^3}{32}$ (*b*) $\frac{\pi D^4}{32}$

(*c*) $\frac{\pi D^3}{64}$ (*d*) $\frac{\pi D^4}{64}$.

**130.** Polar moment of inertia of a hollow circular shaft is equal to

(*a*) $\frac{\pi}{32} [D^3 - d^3]$ (*b*) $\frac{\pi}{32} [D^4 - d^4]$

(*c*) $\frac{\pi}{64} [D^3 - d^3]$ (*d*) $\frac{\pi}{64} [D^4 - d^4]$.

131. Torsional rigidity of a shaft is equal to
(a) product of modulus of rigidity and polar moment of inertia
(b) sum of modulus of rigidity and polar moment of inertia
(c) difference of modulus of rigidity and polar moment of inertia
(d) ratio of modulus of rigidity and polar moment of inertia.

132. Polar modulus of a shaft section is equal to
(a) product of polar moment of inertia and maximum radius of the shaft
(b) ratio of polar moment of inertia to maximum radius of the shaft
(c) sum of polar moment of inertia and maximum radius of the shaft
(d) difference of polar moment of inertia and maximum radius of the shaft.

133. The torsional rigidity of a shaft is defined as the torque required to produce
(a) maximum twist in the shaft
(b) maximum shear stress in the shaft
(c) minimum twist in the shaft
(d) a twist of one radian per unit length of the shaft.

134. The flexural rigidity for the deflection of beams is expressed as
(a) $\frac{I}{E}$
(b) $\frac{E}{I}$
(c) $EI$
(d) $\frac{1}{EI}$
where $E$ = modulus of elasticity and $I$ = moment of inertia.

135. The greatest twisting moment which a given shaft section can resist is equal to
(a) polar modulus $\times f$
(b) polar modulus/$\tau$
(c) $\tau$/polar modulus
(d) none of the above.

136. Choose the correct statement
(a) Shafts of the same material and length having the same polar modulus have the same strength.
(b) For a shaft of a given material, the magnitude of polar modulus is a measure of its strength in resisting torsion.
(c) From a number of shafts of the same length and material, the shaft with greatest polar modulus will resist the maximum twisting moment.
(d) all of the above.
(e) none of the above.

137. Two shafts, one solid and the other hollow, are made of the same materials and are having same length and weight. The hollow shaft as compared to solid shaft is
(a) more strong
(b) less strong
(c) having same strength
(d) none of the above.

138. Two shafts, one solid and the other hollow, are of same length and material. They are subjected to the same torque and attain the same permissible maximum shear stress at the same time. The weight of hollow shaft will be
(a) more
(b) less
(c) same as of solid shaft
(d) none of the above.

139. The torque transmitted, by a solid shaft of diameter 40 mm if the shear stress is not to exceed 400 N/cm$^2$, would be
(a) $1.6 \times \pi$ N-m
(b) $16 \times \pi$ N-m
(c) $0.8 \times \pi$ N-m
(d) $0.4 \times \pi$ N-m.

**140.** If in question 139, the diameter of the solid shaft is doubled, then torque transmitted would be

(*a*) same (*b*) double

(*c*) four times (*d*) eight times.

**141.** If in question 139, the diameter of the solid shaft is made 20 mm, then torque transmitted would be

(*a*) same (*b*) one-half

(*c*) one-eight (*d*) one-fourth.

**142.** The torsion equation is given by

(*a*) $\dfrac{T}{J} = \dfrac{\tau}{R} = \dfrac{L}{C\theta}$ (*b*) $\dfrac{T}{R} = \dfrac{\tau}{J} = \dfrac{C\theta}{L}$

(*c*) $\dfrac{T}{J} = \dfrac{\tau}{R} = \dfrac{C\theta}{L}$ (*d*) $\dfrac{T}{\tau} = \dfrac{R}{J} = \dfrac{C\theta}{L}$.

**143.** The assumption made, while determining the shear stress in a circular shaft subjected to torsion, is that

(*a*) the material of the shaft is uniform (*b*) the twist along the shaft is uniform

(*c*) cross-sections of the shaft is plane and circular before and after the twist

(*d*) all of the above (*e*) none of the above.

**144.** When a shaft of diameter ($d$) is subjected to combined twisting moment ($T$) and bending moment ($M$), the maximum shear stress ($\tau$) is equal to

(*a*) $\dfrac{R}{J}\sqrt{M^2 + T^2}$ (*b*) $\dfrac{J}{R}\sqrt{(M^2 + T^2)}$

(*c*) $\dfrac{R}{J}(M^2 + T^2)$ (*d*) $\dfrac{J}{R}(M^2 + T^2)$

where $J$ = polar moment of inertia of the shaft.

**145.** In question 144, the maximum normal stress is given by

(*a*) $\dfrac{16}{\pi d^3}(M - \sqrt{M^2 + T^2})$ (*b*) $\dfrac{16}{\pi d^3}(M + \sqrt{M^2 + T^2})$

(*c*) $\dfrac{16}{\pi d^3}(M - \sqrt{M^2 - T^2})$ (*d*) $\dfrac{16}{\pi d^3}(M + \sqrt{M^2 - T^2})$.

**146.** A cylindrical vessel is said to be thin if the ratio of its internal diameter to the wall thickness is

(*a*) less than 20 (*b*) equal to 20

(*c*) more than 20 (*d*) none of the above.

**147.** The hoop or circumferential stress in a thin cylindrical shell of diameter ($D$), length ($L$) and thickness ($t$), when subjected to an internal pressure ($p$) is equal to

(*a*) $\dfrac{pD}{4t}$ (*b*) $\dfrac{pD}{2t}$

(*c*) $\dfrac{2pD}{t}$ (*d*) $\dfrac{4pD}{t}$.

**148.** The longitudinal or axial stress in a thin cylindrical shell of diameter ($D$), length ($L$) and thickness ($t$), when subjected to an internal pressure ($p$) is equal to

(a) $\frac{pD}{4t}$ (b) $\frac{pD}{2t}$

(c) $\frac{2pD}{t}$ (d) $\frac{4pD}{t}$.

**149.** The maximum shear stress in a thin cylindrical shell, when subjected to an internal pressure ($p$) is equal to

(a) $\frac{pD}{4t}$ (b) $\frac{pD}{8t}$

(c) $\frac{pD}{2t}$ (d) $\frac{pD}{t}$.

**150.** The maximum shear stress in a thin spherical shell, when subjected to an internal pressure ($p$) is equal to

(a) $\frac{pD}{4t}$ (b) $\frac{pD}{8t}$

(c) $\frac{pD}{2t}$ (d) zero.

**151.** The hoop or circumferential stress in a thin spherical shell, when subjected to an internal pressure ($p$) is equal to

(a) $\frac{pD}{4t}$ (b) $\frac{pD}{2t}$

(c) $\frac{pD}{8t}$ (d) $\frac{2pD}{t}$.

**152.** The hoop or circumferential stress in a riveted cylindrical shell, when subjected to an internal pressure ($p$) is equal to

(a) $\frac{pD}{4t\,\eta_l}$ (b) $\frac{pD}{4t\,\eta_c}$

(c) $\frac{pD}{2t\,\eta_l}$ (d) $\frac{pD}{2t\,\eta_c}$

where $D$ = internal diameter, $\eta_l$ = efficiency of longitudinal joint and $\eta_c$ = efficiency of circumferential joint.

**153.** The longitudinal stress in a riveted cylindrical shell, when subjected to internal pressure ($p$) is equal to

(a) $\frac{pD}{4t\,\eta_l}$ (b) $\frac{pD}{4t\,\eta_c}$

(c) $\frac{pD}{2t\,\eta_l}$ (d) $\frac{pD}{2t\,\eta_c}$

where $\eta_l$ = efficiency of longitudinal joint and

$\eta_c$ = efficiency of circumferential joint.

**154.** Choose the correct statement.

(a) The hoop stress in a thin cylindrical shell is compressive stress.

(b) The shear stress in a thin spherical shell is more than that of in a thin cylindrical shell.

(*c*) The design of thin cylindrical shell is based on hoop stress.

(*d*) The ratio of hoop stress to longitudinal stress for a thin cylindrical shell is 1/2.

**155.** A water main 1 m in diameter contains a fluid having pressure 1 N/mm$^2$. If the maximum permissible tensile stress in the metal is 20 N/mm$^2$, the thickness of the metal required would be

(*a*) 2 cm (*b*) 2.5 cm

(*c*) 1 cm (*d*) 0.5 cm.

**156.** The circumferential strain in case of thin cylindrical shell, when subjected to internal pressure ($p$), is equal to

(*a*) $\frac{pd}{2tE}\left(\frac{1}{2}-\frac{1}{m}\right)$ (*b*) $\frac{pd}{2tE}\left(1-\frac{1}{2m}\right)$

(*c*) $\frac{pd}{4tE}\left(1-\frac{1}{m}\right)$ (*d*) $\frac{3pd}{4tE}\left(1-\frac{1}{m}\right)$.

**157.** The longitudinal strain in case of thin cylindrical shell, when subjected to internal pressure ($p$), is equal to

(*a*) $\frac{pd}{2tE}\left(\frac{1}{2}-\frac{1}{m}\right)$ (*b*) $\frac{pd}{2tE}\left(1-\frac{1}{2m}\right)$

(*c*) $\frac{pd}{4tE}\left(1-\frac{1}{m}\right)$ (*d*) $\frac{3pd}{4tE}\left(1-\frac{1}{m}\right)$.

**158.** The strain in any direction in case of a thin spherical shell, when subjected to internal pressure ($p$), is equal to

(*a*) $\frac{pd}{2tE}\left(\frac{1}{2}-\frac{1}{m}\right)$ (*b*) $\frac{pd}{2tE}\left(1-\frac{1}{2m}\right)$

(*c*) $\frac{pd}{4tE}\left(1-\frac{1}{m}\right)$ (*d*) $\frac{3pd}{4tE}\left(1-\frac{1}{m}\right)$.

**159.** The volumetric strain in case of thin spherical shell, when subjected to internal pressure ($p$), is equal to

(*a*) $\frac{pd}{2tE}\left(\frac{1}{2}-\frac{1}{m}\right)$ (*b*) $\frac{pd}{2tE}\left(1-\frac{1}{2m}\right)$

(*c*) $\frac{pd}{4tE}\left(1-\frac{1}{m}\right)$ (*d*) $\frac{3pd}{4tE}\left(1-\frac{1}{m}\right)$.

**160.** The circumferential strain in case of thin cylindrical shell, when subjected to internal pressure ($p$), is

(*a*) more than diametral strain (*b*) less than diametral strain

(*c*) equal to diametral strain (*d*) none of the above.

**161.** In the assembly of pulley, key and shaft

(*a*) key is made strongest link

(*b*) key is made weaker link

(*c*) all the three are designed for the same strength

(*d*) pulley is made weaker.

162. A coil is having stiffness $k$. It is cut into two halves, then the stiffness of the cut coils will be

(a) same
(b) half
(c) double
(d) one-fourth.

163. The hoop stress in case of thick cylinders across the thickness

(a) is uniformly distributed
(b) varies from maximum at the outer circumference to minimum at inner circumference
(c) varies from maximum at the inner circumference to minimum at outer circumference
(d) is zero.

164. The longitudinal stress in case of thick cylinders

(a) is uniformly distributed
(b) varies from maximum at the outer circumference to minimum at inner circumference
(c) varies from maximum at the inner circumference to minimum at outer circumference
(d) none of the above.

165. In case of thick cylinders, at any point the three principal stresses, *i.e.*, radial, circumferential and longitudinal

(a) are all tensile stresses
(b) are all compressive stresses
(c) are all shear stresses
(d) none of the above.

166. In case of cylinders which have to carry high internal fluid pressure, the method adopted is to

(a) wind strong steel wire under tension on the cylinder
(b) shrink one cylinder over the other
(c) both (a) and (b)
(d) none of the above.

167. The radial stress, at any radius $x$ in case of a thick spherical shell subjected to internal fluid pressure $p$, is equal to

(a) $\left(\frac{2b}{x^3}\right) - a$
(b) $\left(\frac{b}{x^3}\right) + a$
(c) $\left(\frac{x^3}{2b}\right) - a$
(d) $\left(\frac{x^3}{b}\right) + a$

where $a$ and $b$ are constants.

168. The circumferential stress, at any radius $x$ in case of a thick spherical shell subjected to internal fluid pressure $p$, is equal to

(a) $\left(\frac{2b}{x^3}\right) - a$
(b) $\left(\frac{b}{x^3}\right) + a$
(c) $\left(\frac{x^3}{2b}\right) - a$
(d) $\left(\frac{x^3}{b}\right) + a$.

169. Choose the correct statement.

(a) When a thick cylinder is subjected to internal fluid pressure, the circumferential stress is maximum at the outer surface of the cylinder.
(b) In case of thick cylinders, the difference of circumferential stress and radial stress is constant.

(c) In case of thick cylinders, the minimum value of radial stress is equal to internal fluid pressure.

(d) The single thick cylinder withstands high internal fluid pressure as compared to compound cylinder.

**170.** When a thick cylinder is subjected to internal fluid pressure ($p_i$), the maximum value of circumferential stress is

(a) $\dfrac{2p_i\, R_i^2}{R_o^2 - R_i^2}$ (b) $p_i$

(c) 0 (d) $\left(\dfrac{R_o^2 + R_i^2}{R_o^2 - R_i^2}\right) \times p_i$.

**171.** The shearing strength per pitch length in case of butt joint is equal to

(a) $n \times \dfrac{\pi}{4} d^2 \times \tau$ (b) $2n \times \dfrac{\pi}{4} d^2 \times \tau$

(c) $3n \times \dfrac{\pi}{4} d^2 \times \tau$ (d) $4n \times \dfrac{\pi}{4} d^2 \times \tau$

where $n$ = number of rivets per pitch length

$\tau$ = shear stress.

**172.** The tearing strength per pitch length of a riveted joint is equal to

(a) $(p - d) \times t \times \sigma_c$ (b) $(p - d) \times t \times \sigma_t$

(c) $(p - d) \times t \times \tau$ (d) $(p - 2d) \times t \times \sigma_t$

where $p$ = pitch

$d$ = diameter of rivet

$t$ = thickness of plates and

$\sigma_c$, $\sigma_t$ and $\tau$ = safe crushing, tensile and shear stresses respectively.

**173.** The bearing or crushing strength per pitch length of a riveted joint is equal to

(a) $\dfrac{\pi}{4} d^2 \times \sigma_c \times n$ (b) $\pi d \times t \times \sigma_c \times n$

(c) $d \times t \times \sigma_c \times n$ (d) $p \times t \times \sigma_c \times n$

where $n$ = number of rivets per pitch length

$\sigma_c$ = safe crushing stress.

**174.** In case of riveted joint 'margin' is the distance between the

(a) centres of two consecutive rivets in a row

(b) centre of rivet hole to the nearest edge of plate

(c) centres of rivets in adjacent rows

(d) none of the above.

**175.** If the margin in case of riveted joint is at least 1.5 $d$, there will be

(a) tearing off the plate between the rivet hole and edge of the plate

(b) tearing off the plates between rivets

(c) no tearing off the plate between the rivet hole and edge of the plate

(d) no crushing of the joint.

176. The expression $p \times t \times \sigma_t$ in case of a riveted joint is called
(*a*) tearing strength
(*b*) bearing strength
(*c*) crushing strength
(*d*) strength of solid plate.

177. If $P_t$, $P_s$ and $P_c$ are the maximum load per pitch length for a riveted joint from tearing, shearing and crushing considerations respectively, then efficiency of the joint is equal to
(*a*) $\dfrac{P_t}{\text{strength of solid plate}}$
(*b*) $\dfrac{P_s}{\text{strength of solid plate}}$
(*c*) $\dfrac{P_c}{\text{strength of solid plate}}$
(*d*) $\dfrac{\text{least of } P_t, P_s \text{ and } P_c}{\text{strength of solid plate}}$
(*e*) $\dfrac{\text{maximum of } P_t, P_s \text{ and } P_c}{\text{strength of solid plate}}$
(*f*) none of the above.

178. In riveted joint the tensile, shearing and crushing stresses are based on the
(*a*) diameter of drilled hole
(*b*) diameter of rivet
(*c*) mean of the diameter of rivet and drilled hole
(*d*) none of the above.

179. Generally a rivet joint fails by
(*a*) shearing of rivets
(*b*) crushing of rivets
(*c*) tearing of the plate across the row of rivets
(*d*) all of the above
(*e*) any one of the above.

180. A welded joint as compared to riveted joint, has
(*a*) less strength
(*b*) more strength
(*c*) same strength
(*d*) none of the above.

181. In the diamond-riveted arrangement, the nine rivets have been arranged in four rows with one rivet in the first row, two rivets in the second row, three rivets in the third row and three rivets in the fourth row. The weakest section is the section passing through
(*a*) fourth row
(*b*) third row
(*c*) second row
(*d*) one rivet hole in the first row.

182. The efficiency of a diamond-riveted joint, having width of the plate as $b$ and diameter of hole as $d$, is equal to
(*a*) $\dfrac{d}{b}$
(*b*) $\dfrac{b+d}{b}$
(*c*) $\dfrac{b-d}{b}$
(*d*) $\dfrac{b-d}{d}$.

183. The material, of which rivets are made, should be
(*a*) hard
(*b*) malleable
(*c*) ductile
(*d*) tough.

184. Strut is defined as a
(*a*) member of a structure which carries a tensile load
(*b*) member of a structure which carries an axial compressive load
(*c*) vertical member of a structure which carries a tensile load
(*d*) none of the above.

**185.** Column is defined as a

(*a*) member of a structure which carries a tensile load

(*b*) member of a structure which carries an axial compressive load

(*c*) vertical member of a structure which carries a tensile load

(*d*) vertical member of a structure which carries an axial compressive load.

**186.** The maximum axial compressive load which a column can take without failure by lateral deflection is called

(*a*) critical load (*b*) buckling load

(*c*) crippling load (*d*) any one of the above.

**187.** Slenderness ratio is defined as the ratio of

(*a*) equivalent length of the column to the minimum radius of gyration

(*b*) length of the column to the minimum radius of gyration

(*c*) length of the column to the area of cross-section of the column

(*d*) minimum radius of gyration to the area of cross-section of the column.

**188.** Buckling factor is defined as the ratio of

(*a*) equivalent length of a column to the minimum radius of gyration

(*b*) length of the column to the minimum radius of gyration

(*c*) length of the column to the area of cross-section of the column

(*d*) none of the above.

**189.** A loaded column is having the tendency to deflect. On account of this tendency, the critical load

(*a*) decreases with the decrease in length

(*b*) decreases with the increase in length

(*c*) first decreases then increases with the decrease in length

(*d*) first increases then decreases with the decrease in length.

**190.** A loaded column fails due to

(*a*) stress due to direct load (*b*) stress due to bending

(*c*) both (*a*) and (*b*) (*d*) none of the above.

**191.** The crippling load, according to Euler's theory of long columns, when both ends of the column are hinged, is equal to

(*a*) $\frac{4\pi^2 EI}{l^2}$ (*b*) $\frac{\pi^2 EI}{l^2}$

(*c*) $\frac{\pi^2 EI}{4l^2}$ (*d*) $\frac{2\pi^2 EI}{l^2}$

where $l$ = length of column.

**192.** The crippling load, according to Euler's theory of long column when one end of the column is fixed and other end is free, is equal to

(*a*) $\frac{4\pi^2 EI}{l^2}$ (*b*) $\frac{\pi^2 EI}{l^2}$

(*c*) $\frac{\pi^2 EI}{4l^2}$ (*d*) $\frac{2\pi^2 EI}{l^2}$.

193. The crippling load, according to Euler's theory of long column when both ends of the column are fixed, is equal to

(a) $\frac{4\pi^2 EI}{l^2}$ (b) $\frac{\pi^2 EI}{l^2}$

(c) $\frac{\pi^2 EI}{4l^2}$ (d) $\frac{2\pi^2 EI}{l^2}$.

194. The crippling load, according to Euler's theory of long column when one end of the column is fixed and the other end is hinged, is equal to

(a) $\frac{4\pi^2 EI}{l^2}$ (b) $\frac{\pi^2 EI}{l^2}$

(c) $\frac{\pi^2 EI}{4l^2}$ (d) $\frac{2\pi^2 EI}{l^2}$.

195. The ratio of crippling load, for a column of length ($l$) with both ends fixed to the crippling load of the same column with both ends hinged, is equal to

(a) 2.0 (b) 4.0

(c) 0.25 (d) 0.50.

196. The ratio of crippling load, for a column of length ($l$) with both ends fixed to the crippling load of the same column with one end fixed and other end free, is equal to

(a) 2.0 (b) 4.0

(c) 8.0 (d) 16.0.

197. The ratio of crippling load, for a column of length ($l$) with both ends fixed to the crippling load of the same column with one end fixed and other end hinged, is equal to

(a) 2.0 (b) 4.0

(c) 8.0 (d) 16.0.

198. The equivalent length of a given column with given end conditions is the length of a column of the same material and section with hinged ends having crippling load equal to

(a) two times that of the given column (b) half that of given column

(c) four times that of the given column (d) that of the given column.

199. The equivalent length is equal to actual length of a column with

(a) one end fixed and other end free (b) both ends fixed

(c) one end fixed and other end hinged (d) both ends hinged.

200. The equivalent length is twice the actual length of a column with

(a) one end fixed and other end free (b) both ends fixed

(c) one end fixed and other end hinged (d) both ends hinged.

201. The equivalent length is equal to half of the actual length of a column with

(a) one end fixed and other end free (b) both ends fixed

(c) one end fixed and other end hinged (d) both ends hinged.

202. The equivalent length is equal to actual length divided by $\sqrt{2}$ for a column with

(a) one end fixed and other end free (b) both ends fixed

(c) one end fixed and other end hinged (d) both ends hinged.

**203.** The equivalent length is equal to four times the actual length of a column with

(*a*) one end fixed and other end free

(*b*) both ends fixed

(*c*) one end fixed and other end hinged

(*d*) both ends hinged

(*e*) none of the above.

**204.** Choose the wrong statement

(*a*) Column is a vertical member of a structure which carries an axial compressive load.

(*b*) The ratio of length of a column to its minimum radius of gyration is called slenderness ratio.

(*c*) A column tends to buckle in the direction of the minimum moment of inertia.

(*d*) The equivalent length of a column with one end fixed and other end free is half of its actual length.

**205.** Choose the correct statement

(*a*) Euler's formula holds good only for short columns.

(*b*) A short column is one which has the ratio of its length to least radius of gyration more than 100.

(*c*) A column with both ends fixed has minimum equivalent (or effective) length.

(*d*) The equivalent length of a column with one end fixed and other end hinged is half of its actual length.

**206.** Rankine's formula is an empirical formula which is used for

(*a*) long columns

(*b*) short columns

(*c*) both long and short columns

(*d*) none of the above.

**207.** The crippling load by Rankine's formula is

(*a*) $\dfrac{\sigma_c A}{1+a\left(\dfrac{l}{k}\right)^2}$

(*b*) $\dfrac{\sigma_c A}{1+a\left(\dfrac{l_e}{k}\right)^2}$

(*c*) $\dfrac{\sigma_c A}{1-a\left(\dfrac{l}{k}\right)^2}$

(*d*) $\dfrac{\sigma_c A}{1-a\left(\dfrac{l_e}{k}\right)^2}$

where $A$ = area of cross-section of the column

$\sigma_c$ = crushing stress

$a$ = Rankine's constant

$k$ = least radius of gyration

$l$ = actual length of column

$l_e$ = equivalent length of column.

**208.** The Rankine's constant ($a$) in Rankine's formula is equal to

(*a*) $\dfrac{\pi^2 E}{\sigma_c}$

(*b*) $\dfrac{\pi^2}{E\sigma_c}$

(*c*) $\dfrac{E\sigma_c}{\pi^2}$

(*d*) $\dfrac{\sigma_c}{\pi^2 E}$.

209. The Rankine's constant ($a$) for a given material of a column depends upon the
(*a*) length of column
(*b*) diameter of the column
(*c*) length and diameter
(*d*) none of the above.

210. The expression $\dfrac{(\sigma_c A)}{\left(1+b\left(\dfrac{l_e}{d}\right)^2\right)}$ is known as
(*a*) Rankine's formula
(*b*) Gordon's formula
(*c*) Straight line of formula
(*d*) Johnson's parabolic formula
where $d$ = least diameter or width of the section
$b$ = constant and $l_e$ = equivalent length.

211. A cantilever of length ($l$) carries a load whose intensity varies uniformly from zero at the free end to $w$ per unit length at the fixed end, the bending moment diagram will be a
(*a*) straight line curve
(*b*) parabolic curve
(*c*) cubic curve
(*d*) combination of (*a*) and (*b*).

212. A simply supported beam is overhanging equally on both sides and carries a uniformly distributed load of $w$ per unit length over the whole length. The length between the supports is ($l$) and length of overhang to one side is '$a$'. If $l > 2a$ then the number of points of contra-flexure will be
(*a*) zero
(*b*) one
(*c*) two
(*d*) three.

213. If in question 212, $l = 2a$, the number of points of contraflexure will be
(*a*) zero
(*b*) one
(*c*) two
(*d*) three.

214. If in question 212, $l < 2a$, the number of points of contraflexure will be
(*a*) zero
(*b*) one
(*c*) two
(*d*) three.

215. In question 212, the shear force diagram will consists of
(*a*) two triangles
(*b*) two rectangles
(*c*) four triangles
(*d*) four rectangles.

216. For the same loading, the maximum bending moment for a fixed beam as compared to simply supported beam is
(*a*) more
(*b*) less
(*c*) same
(*d*) none of the above.

217. For the same loading, the maximum deflection for a fixed beam as compared to simply supported beam is
(*a*) more
(*b*) same
(*c*) less
(*d*) none of the above.

218. In a fixed beam, temperature variation produces
(*a*) large stresses
(*b*) small stresses
(*c*) zero stress
(*d*) none of the above.

219. In a simply supported beam, the temperature variation produces
(*a*) large stresses
(*b*) small stresses
(*c*) zero stress
(*d*) none of the above.

## 26.2. ANSWERS OF OBJECTIVE TYPE QUESTIONS

| | | | | | |
|---|---|---|---|---|---|
| 1. (*b*) | 2. (*d*) | 3. (*a*) | 4. (*c*) | 5. (*b*) | 6. (*a*) |
| 7. (*c*) | 8. (*c*) | 9. (*b*) | 10. (*a*) | 11. (*b*) | 12. (*b*) |
| 13. (*a*) | 14. (*b*) | 15. (*c*) | 16. (*a*) | 17. (*b*) | 18. (*d*) |
| 19. (*b*) | 20. (*b*) | 21. (*b*) | 22. (*e*) | 23. (*c*) | 24. (*c*) |
| 25. (*a*) | 26. (*c*) | 27. (*c*) | 28. (*c*) | 29. (*b*) | 30. (*c*) |
| 31. (*c*) | 32. (*c*) | 33. (*c*) | 34. (*a*) | 35. (*b*) | 36. (*b*) |
| 37. (*b*) | 38. (*c*) | 39. (*b*) | 40. (*b*) | 41. (*b*) | 42. (*d*) |
| 43. (*b*) | 44. (*d*) | 45. (*c*) | 46. (*a*) | 47. (*d*) | 48. (*b*) |
| 49. (*c*) | 50. (*d*) | 51. (*b*) | 52. (*d*) | 53. (*e*) | 54. (*d*) |
| 55. (*c*) | 56. (*d*) | 57. (*a*) | 58. (*b*) | 59. (*d*) | 60. (*a*) |
| 61. (*d*) | 62. (*b*) | 63. (*d*) | 64. (*d*) | 65. (*a*) | 66. (*b*) |
| 67. (*a*) | 68. (*e*) | 69. (*d*) | 70. (*c*) | 71. (*c*) | 72. (*c*) |
| 73. (*b*) | 74. (*b*) | 75. (*b*) | 76. (*c*) | 77. (*a*) | 78. (*b*) |
| 79. (*b*) | 80. (*b*) | 81. (*a*) | 82. (*a*) | 83. (*d*) | 84. (*d*) |
| 85. (*c*) | 86. (*d*) | 87. (*d*) | 88. (*b*) | 89. (*c*) | 90. (*d*) |
| 91. (*d*) | 92. (*c*) | 93. (*b*) | 94. (*c*) | 95. (*b*) | 96. (*c*) |
| 97. (*c*) | 98. (*b*) | 99. (*c*) | 100. (*b*) | 101. (*c*) | 102. (*d*) |
| 103. (*d*) | 104. (*c*) | 105. (*c*) | 106. (*b*) | 107. (*c*) | 108. (*a*) |
| 109. (*c*) | 110. (*d*) | 111. (*b*) | 112. (*c*) | 113. (*c*) | 114. (*d*) |
| 115. (*b*) | 116. (*a*) | 117. (*c*) | 118. (*b*) | 119. (*a*) | 120. (*c*) |
| 121. (*c*) | 122. (*d*) | 123. (*c*) | 124. (*b*) | 125. (*a*) | 126. (*b*) |
| 127. (*c*) | 128. (*c*) | 129. (*b*) | 130. (*b*) | 131. (*a*) | 132. (*b*) |
| 133. (*d*) | 134. (*c*) | 135. (*a*) | 136. (*d*) | 137. (*a*) | 138. (*b*) |
| 139. (*a*) | 140. (*d*) | 141. (*c*) | 142. (*c*) | 143. (*d*) | 144. (*a*) |
| 145. (*b*) | 146. (*c*) | 147. (*b*) | 148. (*a*) | 149. (*b*) | 150. (*d*) |
| 151. (*a*) | 152. (*c*) | 153. (*b*) | 154. (*c*) | 155. (*b*) | 156. (*b*) |
| 157. (*a*) | 158. (*c*) | 159. (*d*) | 160. (*c*) | 161. (*b*) | 162. (*c*) |
| 163. (*c*) | 164. (*a*) | 165. (*d*) | 166. (*c*) | 167. (*a*) | 168. (*b*) |
| 169. (*b*) | 170. (*a*) | 171. (*b*) | 172. (*b*) | 173. (*c*) | 174. (*b*) |
| 175. (*c*) | 176. (*d*) | 177. (*d*) | 178. (*a*) | 179. (*e*) | 180. (*b*) |
| 181. (*d*) | 182. (*c*) | 183. (*c*) | 184. (*b*) | 185. (*d*) | 186. (*d*) |
| 187. (*b*) | 188. (*a*) | 189. (*b*) | 190. (*c*) | 191. (*b*) | 192. (*c*) |
| 193. (*a*) | 194. (*d*) | 195. (*b*) | 196. (*d*) | 197. (*a*) | 198. (*d*) |
| 199. (*d*) | 200. (*a*) | 201. (*b*) | 202. (*c*) | 203. (*e*) | 204. (*d*) |
| 205. (*c*) | 206. (*c*) | 207. (*b*) | 208. (*d*) | 209. (*d*) | 210. (*b*) |
| 211. (*c*) | 212. (*c*) | 213. (*b*) | 214. (*a*) | 215. (*c*) | 216. (*b*) |
| 217. (*c*) | 218. (*a*) | 219. (*c*). | | | |

## 26.3. OBJECTIVE TYPE QUESTIONS FROM COMPETITIVE EXAMINATIONS

1. For the state of plane stress shown in Fig. 1, the maximum and minimum principal stresses are :

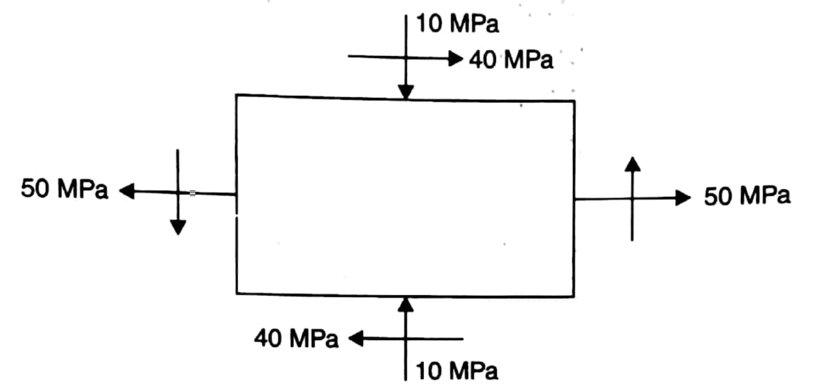



Fig. 1

(*a*) 60 MPa and 30 MPa (*b*) 50 MPa and 10 MPa
(*c*) 40 MPa and 20 MPa (*d*) 70 MPa and 30 MPa.

2. Which of the following is true ($\mu$ = Poisson's ratio)

(*a*) $0 < \mu < -\frac{1}{2}$ (*b*) $1 < \mu < 0$
(*c*) $1 < \mu < -1$ (*d*) $\infty < \mu < -\infty$.

3. For most brittle materials, the ultimate strength in compression is much large than the ultimate strength in tension. This is mainly due to
(*a*) presence of flaws and microscopic cracks or cavities.
(*b*) necking in tension
(*c*) severity of tensile stress as compared to compressive stress
(*d*) non-linearity of stress-strain diagram.

4. Bending moment $M$ and torque $T$ is applied on a solid circular shaft. If the maximum bending stress equals to maximum shear stress developed, then $M$ is equal to

(*a*) $\frac{T}{2}$ (*b*) $T$
(*c*) $2T$ (*d*) $4T$.

5. When bending moment $M$ and torque $T$ is applied on a shaft then equivalent torque is

(*a*) $M + T$ (*b*) $\sqrt{M^2 + T^2}$
(*c*) $\frac{1}{2}\sqrt{M^2 + T^2}$ (*d*) $\frac{1}{2}(M + \sqrt{M^2 + T^2})$.

**6.** The bending moment diagram for the case shown in Fig. 2 below will be as shown in figure

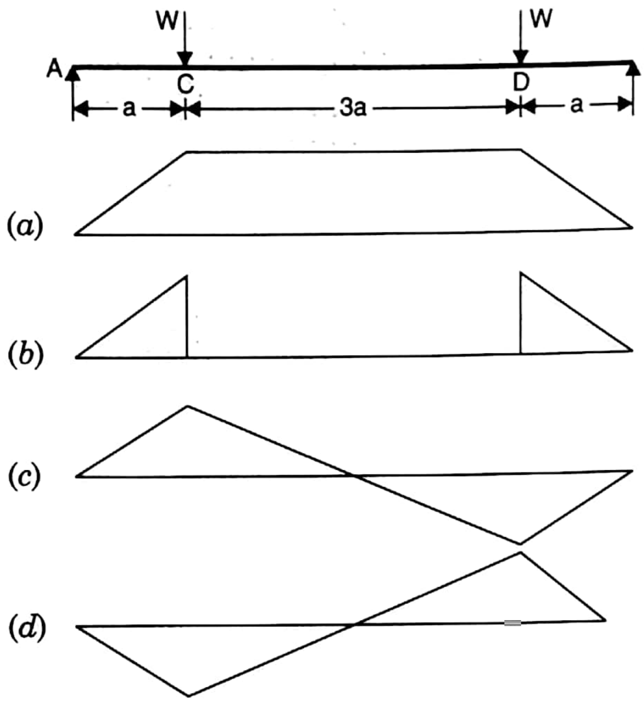



Fig. 2

**7.** If a prismatic bar be subjected to an axial tensile stress $\sigma$, the shear stress induced at a plane inclined at $\theta$ with the axis will be

(a) $\frac{\sigma}{2}\sin 2\theta$ (b) $\frac{\sigma}{2}\cos 2\theta$

(c) $\frac{\sigma}{2}\cos^2\theta$ (d) $\frac{\sigma}{2}\sin^2\theta$.

**8.** A vertical hanging bar of length $L$ and weighing $w$ N/unit length carries a load $W$ at the bottom as shown in Fig. 3. The tensile force in the bar at a distance $y$ from the support will be given by

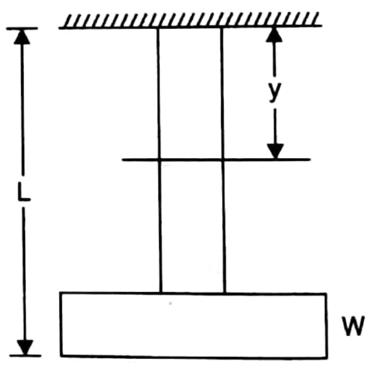



Fig. 3

(a) $W + w \times L$ (b) $W + w(L - y)$

(c) $(W + w) \times \frac{y}{L}$ (d) $W + \frac{W}{w}(L - y)$.

**9.** In case of bi-axial state of normal stresses, the normal stress on 45° plane is equal to

(a) sum of normal stresses (b) difference of normal stresses

(c) half the sum of normal stresses (d) half the difference of normal stresses.

**10.** The temperature stress is a function of

1. Co-efficient of linear expansion
2. Temperature rise
3. Modulus of elasticity.

The correct answer is

(a) 1 and 2 only (b) 1 and 3 only

(c) 2 and 3 only (d) 1, 2 and 3 only.

11. When two springs of equal lengths are arranged to form a cluster spring then which of the following statements are true :

1. Angle of twist in both the springs will be equal
2. Deflection of both the springs will be equal
3. Load taken by each spring will be half the total load
4. Shear stress in each spring will be equal

(*a*) 1 and 2 only (*b*) 2 and 3 only
(*c*) 3 and 4 only (*d*) 1, 2 and 4 only.

12. When $\sigma$ and Young's modulus of elasticity $E$ remains constant, the energy absorbing capacity of part subjected to dynamic forces, is a function of its

(*a*) length (*b*) cross-section
(*c*) volume (*d*) none of the above.

13. If the principal stresses corresponding to a two-dimensional state of stress are $\sigma_1$ and $\sigma_2$ when $\sigma_1$ is greater than $\sigma_2$ and both are tensile, then which one of the following would be correct criterion for failure by yielding, according to maximum shear stress theory ?

(*a*) $\dfrac{\sigma_1 - \sigma_2}{2} = \pm \dfrac{\sigma_{yp}}{2}$ (*b*) $\dfrac{\sigma_1}{2} = \pm \dfrac{\sigma_{yp}}{2}$

(*c*) $\dfrac{\sigma_2}{2} = \pm \dfrac{\sigma_{yp}}{2}$ (*d*) $\sigma_1 = \pm 2\sigma_{yp}$.

14. The buckling load will be maximum for a column, if

(*a*) one end of the column is clamped and other end is free
(*b*) both ends of the column are clamped
(*c*) both ends of the column are hinged
(*d*) one end of the column is hinged and other end is free.

15. A length of 10 mm diameter steel wire is coiled to a close-coiled helical spring having 8 coils of 75 mm mean diameter, and the spring has a stiffness $k$. If the same length of the wire is coiled to 10 coils of 60 mm mean diameter, then the spring stiffness will be

(*a*) $k$ (*b*) 1.25 $k$ (*c*) 1.56 $k$ (*d*) 1.95 $k$.

16. A metal pipe of 1 m diameter contains a fluid having a pressure of 100 N/cm$^2$. If the permissible tensile stress in the metal is 2 kN/cm$^2$, then the thickness of the metal required for making the pipe would be

(*a*) 5 mm (*b*) 10 mm (*c*) 20 mm (*d*) 25 mm.

17. Circumferential and longitudinal strains in cylindrical boiler under internal steam pressure, are $e_1$ and $e_2$ respectively. Change in volume of the boiler cylinder per unit volume will be

(*a*) $e_1 + 2e_2$ (*b*) $e_1 e_2^2$ (*c*) $2e_1 + e_2$ (*d*) $e_1^2 e_2$.

18. In the assembly of pulley, key and shaft

(*a*) pulley is made the weakest
(*b*) key is made the weakest
(*c*) key is made the strongest
(*d*) all the three are designed for equal strength.

**19.** Shear stress distribution diagram of a beam of rectangular cross-section, subject to transverse loading will be

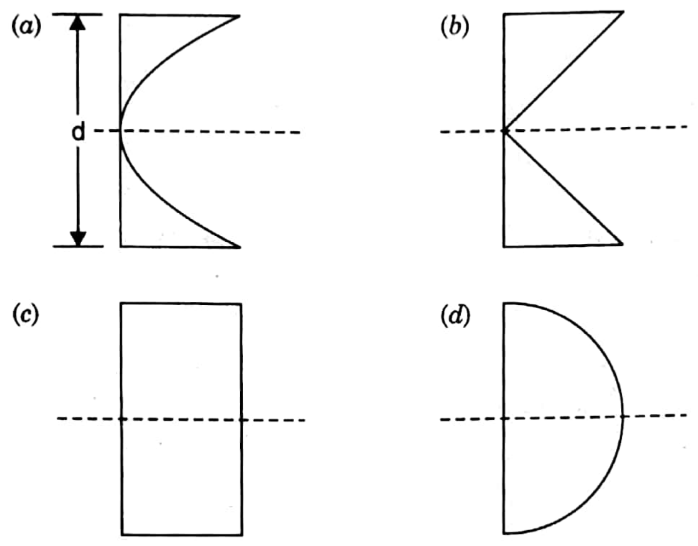



Fig. 4

**20.** A horizontal beam with square cross-section is simply supported with sides of the square horizontal and vertical and carries a distributed loading that produces maximum bending stress $\sigma$ in the beam. When the beam is placed with one of the diagonals horizontal, the maximum bending stress will be

(*a*) $\frac{\sigma}{\sqrt{2}}$ (*b*) $\sigma$ (*c*) $\sqrt{2} \times \sigma$ (*d*) $2\sigma$.

**21.** A shaft was initially subjected to bending moment and then was subjected to torsion. If the magnitude of the bending moment is found to be the same as that of the torque, then the ratio of maximum bending stress to shear stress would be

(*a*) 0.25 (*b*) 0.50 (*c*) 2.0 (*d*) 4.0.

**22.** A simply supported beam of rectangular section 4 cm by 6 cm carries a mid-span concentrated load such that 6 cm side lies parallel to the line of action of loading ; deflection under the load is $\delta$. If the beam is now supported with the 4 cm side parallel to the line of action of loading, the deflection under the load will be

(*a*) $0.44 \times \delta$ (*b*) $0.67 \times \delta$ (*c*) $1.50 \times \delta$ (*d*) $2.25 \times \delta$.

**23.** A beam *AB* is hinge-supported at its ends and is loaded by a couple $P \times C$ as shown in Fig. 5. The magnitude of shearing force at a section $x$ of the beam is

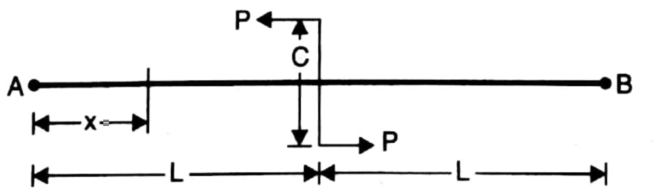



Fig. 5

(*a*) 0 (*b*) $P$ (*c*) $\frac{P}{2L}$ (*d*) $\frac{P \times C}{2L}$.

24. The frictional torque for square thread at mean radius ($R$) while raising load ($W$) is given by
(*a*) $WR \times \tan(\phi - \alpha)$
(*b*) $WR \times \tan(\phi + \alpha)$
(*c*) $WR \times \tan\alpha$
(*d*) $WR \times \tan\phi$
where $\phi$ = angle of friction and $\alpha$ = Helix angle.

25. Design of shafts made of brittle materials is based on
(*a*) Guest's theory
(*b*) Rankine's theory
(*c*) St. Venant's theory
(*d*) Von Mises theory.

26. Principal stresses at a point in plane stressed element are $\sigma_x = \sigma_y = 5000$ N/cm$^2$. Normal stress on the plane inclined at 45° to the $x$-axis will be
(*a*) 0
(*b*) 5000 N/cm$^2$
(*c*) 7070 N/cm$^2$
(*d*) 10000 N/cm$^2$.

27. State of stress in plane element is shown in Fig. 6. Which one of the following figures shown in Fig. 7 is the correct sketch of Mohr's circle of the state of stress ?

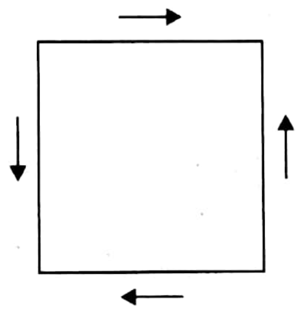


Fig. 6

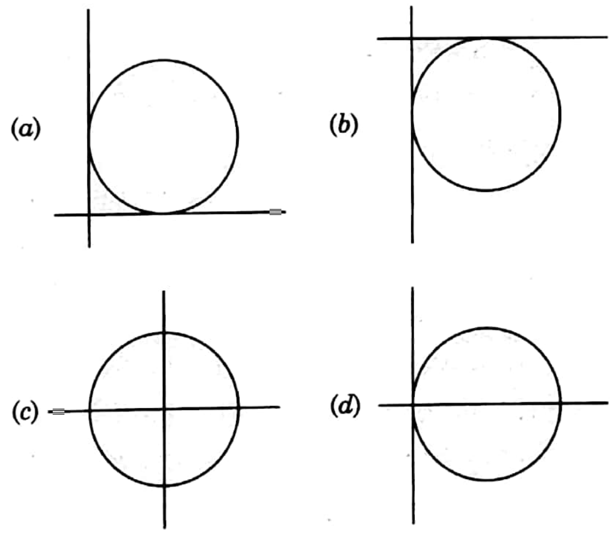



Fig. 7

28. A steel rod of 1 sq. cm cross-sectional area is 100 cm long and has a Young's modulus of elasticity $20 \times 10^6$ N/cm$^2$. It is subjected to an axial pull of 20 kN. The elongation of the rod will be
(*a*) 0.05 cm
(*b*) 0.1 cm
(*c*) 0.15 cm
(*d*) 0.20 cm.

29. If the area of cross-section of a wire is circular and if the radius of this wire decreases to half its original value due to stretch to the wire by a load, then modulus of elasticity of the wire be

(*a*) one-fourth of its original value (*b*) halved
(*c*) doubled (*d*) unaffected

E depends upon the material. It is independent of area, load etc.

**30.** Match list I with list II and select the correct answer using codes given below the lists :

| *List I* (*Material properties*) | *List II* (*Test to determine material properties*) |
|---|---|
| *A*. Ductility | 1. Impact test |
| *B*. Toughness | 2. Fatigue test |
| *C*. Endurance limit | 3. Tension test |
| *D*. Resistance to penetration | 4. Hardness test |

| **Codes :** | *A* | *B* | *C* | *D* |
|---|---|---|---|---|
| (*a*) | 3 | 2 | 1 | 4 |
| (*b*) | 4 | 2 | 1 | 3 |
| (*c*) | 3 | 1 | 2 | 4 |
| (*d*) | 4 | 1 | 2 | 3 |

**31.** If a material had a modulus of elasticity of $21 \times 10^6$ N/cm$^2$ and a modulus of rigidity of $8 \times 10^6$ N/cm$^2$, then approximate value of the Poisson's ratio of the material would be

(*a*) 0.26 (*b*) 0.31 (*c*) 0.47 (*d*) 0.5.

**32.** A shaft can safely transmit 90 kW while rotating at a given speed. If this shaft is replaced by a shaft of diameter double the previous one and rotated at half the speed of the previous, the power that can be transmitted by the new shaft is

(*a*) 90 kW (*b*) 180 kW (*c*) 360 kW (*d*) 720 kW.

**33.** A cold rolled steel shaft is designed on the basis of maximum shear stress theory. The principal stresses induced at its critical section are 60 MPa and – 60 MPa respectively. If the yield stress for the shaft material is 360 MPa, the factor of safety of the design is

(*a*) 2 (*b*) 3 (*c*) 4 (*d*) 5.

**34.** An eccentrically loaded riveted joint is shown in Fig. 8 with 4 rivets at *P*, *Q*, *R* and *S*. Which of the rivets are the most loaded ?

(*a*) *P* and *Q* (*b*) *Q* and *R* (*c*) *R* and *S* (*d*) *S* and *P*.

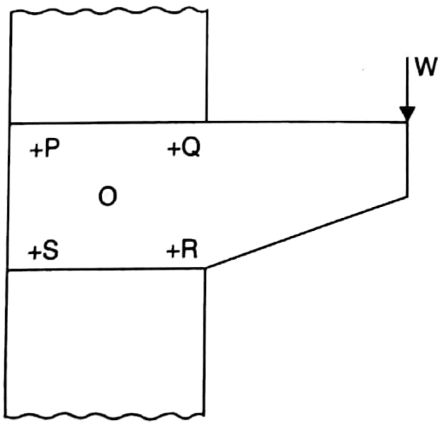



Fig. 8

**35.** When a helical compression spring is cut into two equal halves, the stiffness of each of the resulting springs will be

(*a*) unaltered (*b*) double (*c*) one-half (*d*) one-fourth.

**36.** While calculating the stress induced in a close-coiled helical spring, Wahl's factor must be considered to account for

(*a*) the curvature and stress concentration effect

(*b*) shock loading

(*c*) poor service conditions

(*d*) fatigue loading.

**37.** A straight bar is fixed at the edges *A* and *B* as shown in Fig. 9. Its elastic modulus is *E* and cross-section is *A*. There is a load $P = 120$ N acting at *C*. Determine the reactions at the ends

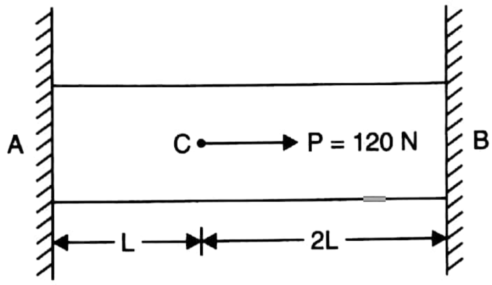



Fig. 9

(*a*) 60 N at *A*, 60 N at *B* (*b*) 30 N at *A*, 90 N at *B*

(*c*) 40 N at *A*, 80 N at *B* (*d*) 80 N at *A*, 40 N at *B*.

**38.** For a material, the modulus of rigidity is 100 G Pa and Poisson's ratio is 0.25. The value of modulus of elasticity in G Pa is

(*a*) 125 (*b*) 150 (*c*) 200 (*d*) 250.

**39.** A rigid beam of negligible weight is supported in a horizontal position by two rods of steel and aluminium 2 m and 1 m long having values of cross-sectional areas 1 cm² and 2 cm² and *E* of 200 G Pa and 100 G Pa respectively. A load *P* is applied as shown in Fig. 10 :

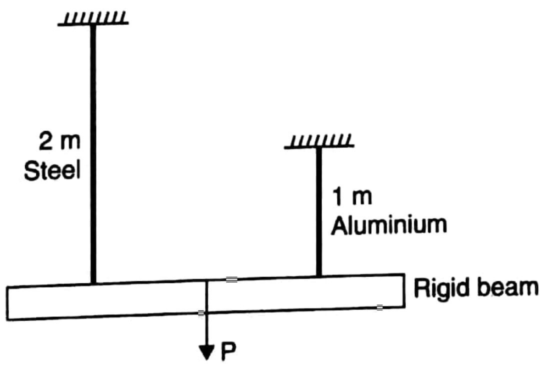



Fig. 10

If the rigid beam is to remain horizontal, then

(*a*) the load on both rods should be equal

(*b*) the load on aluminium rod should be twice the load on steel

(*c*) the load on the steel rod should be twice the load on aluminium

(*d*) the load $P$ must be applied at the centre of the beam.

**40.** A thin cylinder of radius $r$ and thickness $t$ when subjected to an internal hydrostatic pressure $p$ causes a radial displacement $u$, then the tangential strain caused is

(*a*) $\dfrac{du}{dr}$ (*b*) $\dfrac{1}{r} \cdot \dfrac{du}{dr}$ (*c*) $\dfrac{u}{r}$ (*d*) $\dfrac{2u}{r}$.

**41.** Determine the stiffness of the beam shown in Fig. 11 given below :

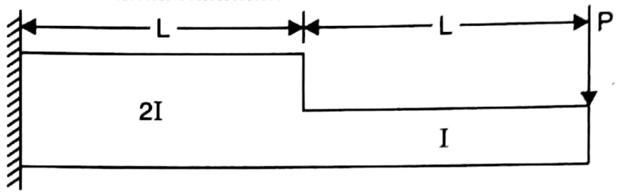



Fig. 11

When : $I = 375 \times 10^{-4}$ m$^4$

$L = 0.5$ m

$E = 200$ GPa

The stiffness is given by

(*a*) $12 \times 10^{10}$ N/m (*b*) $10 \times 10^{10}$ N/m

(*c*) $4 \times 10^{10}$ N/m (*d*) $8 \times 10^{10}$ N/m.

**42.** The strain energy stored in a body of volume $V$ subjected to uniform stress $\sigma$ is

(*a*) $\dfrac{\sigma \times E}{V}$ (*b*) $\dfrac{\sigma E^2}{V}$ (*c*) $\dfrac{\sigma \times V^2}{E}$ (*d*) $\dfrac{\sigma^2}{2E} \times V$.

**43.** For the same internal diameter, wall thickness, material and internal pressure, the ratio of maximum stress, induced in a thin cylindrical and in a thin spherical vessel will be

(*a*) 2 (*b*) $\dfrac{1}{2}$ (*c*) 4 (*d*) $\dfrac{1}{4}$.

**44.** Two identical springs labelled as 1 and 2 are arranged in series and subjected to force $F$ as shown in Fig. 12.

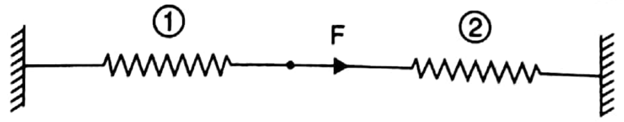



Fig. 12

Assume that each spring constant is $k$. The strain energy stored in spring 1 is

(*a*) $\dfrac{F^2}{2k}$ (*b*) $\dfrac{F^2}{4k}$ (*c*) $\dfrac{F^2}{8k}$ (*d*) $\dfrac{F^2}{16k}$.

45. A rod having cross-sectional area $100 \times 10^{-6}$ m$^2$ is subjected to a tensile load. Based on the Tresca failure criterion, if the uniaxial yield stress of the material is 200 M Pa, the failure load is

(*a*) 10 kN (*b*) 20 kN (*c*) 100 kN (*d*) 200 kN.

46. Wire diameter, mean coil diameter and number of turns of a closely-coiled steel spring are $d$, $D$ and $N$ respectively and stiffness of the spring is $k$. A second spring is made of the same steel but with wire diameter, mean coil diameter and number of turns as $2d$, $2D$ and $2N$ respectively. The stiffness of the new spring is

(*a*) $k$ (*b*) $2k$ (*c*) $4k$ (*d*) $8k$.

47. If the diameter of a long column is reduced by 20%, the percentage of reduction in Euler's buckling load is

(*a*) 4 (*b*) 36 (*c*) 49 (*d*) 59.

48. With one fixed end and other free end, a column of length $L$ buckles at load $P_1$. Another column of same length and same cross-section fixed at both ends buckles at load $P_2$. Then $P_2 / P_1$ is

(*a*) 1 (*b*) 2 (*c*) 4 (*d*) 16.

49. The principal stresses $\sigma_1$, $\sigma_2$ and $\sigma_3$ at a point respectively are 80 MPa, 30 MPa and – 40 MPa. The maximum shear stress is

(*a*) 25 MPa (*b*) 35 MPa (*c*) 55 MPa (*d*) 60 MPa.

50. The Poisson's ratio of a material which has Young's modulus of 120 GPa and shear modulus of 50 GPa, is

(*a*) 0.1 (*b*) 0.2 (*c*) 0.3 (*d*) 0.4.

## 26.4. ANSWERS WITH EXPLANATIONS

| | | | | | |
|---|---|---|---|---|---|
| 1. (*d*) | 2. (*a*) | 3. (*a*) | 4. (*a*) | 5. (*b*) | 6. (*a*) |
| 7. (*a*) | 8. (*b*) | 9. (*c*) | 10. (*d*) | 11. (*c*) | 12. (*c*) |
| 13. (*b*) | 14. (*b*) | 15. (*c*) | 16. (*d*) | 17. (*c*) | 18. (*b*) |
| 19. (*d*) | 20. (*c*) | 21. (*c*) | 22. (*d*) | 23. (*d*) | 24. (*b*) |
| 25. (*b*) | 26. (*b*) | 27. (*c*) | 28. (*b*) | 29. (*d*) | 30. (*c*) |
| 31. (*b*) | 32. (*c*) | 33. (*b*) | 34. (*d*) | 35. (*b*) | 36. (*a*) |
| 37. (*d*) | 38. (*d*) | 39. (*b*) | 40. (*c*) | 41. (*c*) | 42. (*d*) |
| 43. (*a*) | 44. (*c*) | 45. (*b*) | 46. (*a*) | 47. (*d*) | 48. (*d*) |
| 49. (*d*) | 50. (*b*). | | | | |

## EXPLANATIONS

1. Here $\sigma_x = 50$ MPa

$\sigma_y = -10$ MPa

$\tau_{xy} = 40$ MPa

The principal stresses $\sigma_1$ and $\sigma_2$ are given as

$$\sigma_1, \sigma_2 = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^{\ 2}}$$

$$= \frac{50 + (-10)}{2} \pm \sqrt{\left[\frac{50 - (-10)}{2}\right]^2 + 40^2}$$

$$= 20 \pm \sqrt{30^2 + 40^2}$$

$$= 20 \pm 50,$$

$\therefore$ $\sigma_1 = 20 + 50 = 70$ MPa

and $\sigma_2 = 20 - 50 = -30$ MPa = **30 MPa. (compressive)** **Ans.**

2. $\mu$ = Poisson's ratio = $\dfrac{\text{Lateral strain}}{\text{Longitudinal strain}}$

The lateral strain is opposite to longitudinal strain. This means if longitudinal strain is tensile, then lateral strain is compressive. Hence $\mu$ is negative. For most of the material $\mu$ lies between $-0.25$ to $-0.40$.

4. Bending stress, $\sigma_b = \dfrac{M}{I} \times y$

$\therefore$ $(\sigma_b)_{max} = \dfrac{M}{I} \times \dfrac{d}{2}$ where $I = \dfrac{\pi}{64} d^4$

$$= \frac{M}{\frac{\pi}{64} d^4} \times \frac{d}{2} = \frac{32\,M}{\pi d^3}$$

$$T = \frac{\pi}{16} \times d^3 \times \tau_{max}$$

$\therefore$ $\tau_{max} = \dfrac{16\,T}{\pi d^3}$

$\therefore$ If $\sigma_{max} = \tau_{max}$

Then $\dfrac{32M}{\pi d^3} = \dfrac{16T}{\pi d^3}$ or $M = \dfrac{\mathbf{T}}{\mathbf{2}}$. **Ans.**

5. Due to bending moment ($M$), the bending stress will be produced in the shaft. This bending stress ($\sigma_b$) is given by

$$\sigma_b = \frac{32M}{\pi d^3}$$

Due to torque ($T$), the shear stress will be produced. This shear stress ($\tau$) is given by

$$\tau = \frac{16T}{\pi d^3}$$

$\therefore$ The principal stresses due to bending and shear stresses are

$$\sigma_1 \text{ and } \sigma_2 = \frac{\sigma_b}{2} \pm \sqrt{\left(\frac{\sigma_b}{2}\right)^2 + \tau^2}$$

$$= \frac{1}{2} \times \frac{32M}{\pi d^3} \pm \sqrt{\left(\frac{16M}{\pi d^3}\right)^2 + \left(\frac{16T}{\pi d^3}\right)^2}$$

For finding equivalent torque ($T_e$) when the shaft is subjected to bending moment and torque, we should determine the maximum shear produced by the principal stresses.

$\therefore$ Max. shear stress due to principal stresses is given by

$$\tau_{max} = \frac{\sigma_1 - \sigma_2}{2} \qquad \text{where} \quad \sigma_1 = \frac{16M}{\pi d^3} + \sqrt{\left(\frac{16M}{\pi d^3}\right)^2 + \left(\frac{16T}{\pi d^3}\right)^2}$$

$$= \sqrt{\left(\frac{16M}{\pi d^3}\right)^2 + \left(\frac{16T}{\pi d^3}\right)^2} \qquad \text{and} \quad \sigma_2 = \frac{16M}{\pi d^3} - \sqrt{\left(\frac{16M}{\pi d^3}\right)^2 + \left(\frac{16T}{\pi d^3}\right)^2}$$

$$= \frac{16}{\pi d^3}\sqrt{M^2 + T^2}$$

Equivalent torque is

$$T_e = \frac{\pi}{16} \times d^3 \times \tau_{max.}$$

$$= \frac{\pi}{16} \times d^3 \times \left[\frac{16}{\pi d^3} \times \sqrt{M^2 + T^2}\right] \qquad \left(\because \tau_{max} = \frac{16}{\pi d^3} \times \sqrt{M^2 + T^2}\right)$$

$$= \sqrt{\mathbf{M^2 + T^2}}. \quad \textbf{Ans.}$$

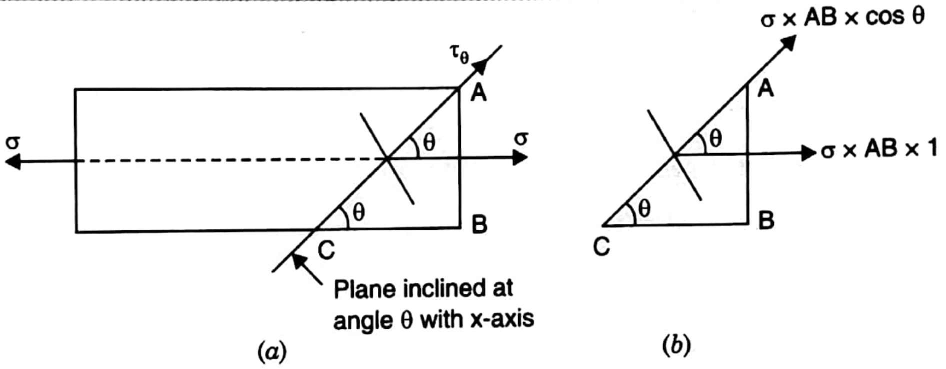
7. 


Fig. 13

Force on $AB = \sigma \times \text{Area}$

$= \sigma \times AB \times 1$ (Thickness = unity)

Force on $AC = (\sigma \times AB) \times \cos\theta$

$\therefore$ $\tau_\theta$ = Shear stress on the plane $AC$

$$= \frac{\text{Shear force}}{\text{Area}} = \frac{\sigma \times AB \times \cos\theta}{AC \times 1} = \sigma \times \sin\theta \times \cos\theta \qquad \left(\because \frac{AB}{AC} = \sin\theta\right)$$

$$= \frac{\sigma}{2} \times 2\sin\theta\cos\theta = \frac{\boldsymbol{\sigma}}{\mathbf{2}} \times \mathbf{\sin 2\theta}. \quad \textbf{Ans.}$$

8. The tensile force in the bar at a distance $y$ from the support

= Weight at the lower end + Weight of bar for a length $(L - y)$

= **W + w (L – y). Ans.**

9. The normal stress on the inclined plane in case of biaxial stress system is given by

$$\sigma_\theta = \frac{1}{2}(\sigma_x + \sigma_y) + \frac{1}{2}(\sigma_x - \sigma_y)\cos 2\theta$$

$$\therefore \quad \sigma_{45°} = \frac{1}{2}(\sigma_x + \sigma_y) + \frac{1}{2}(\sigma_x - \sigma_y)\cos 90°$$

$$= \frac{\mathbf{1}}{\mathbf{2}}(\boldsymbol{\sigma_x} + \boldsymbol{\sigma_y}). \quad \textbf{Ans.}$$

**10.** Temperature stress = $\alpha \times (\Delta t) + E$

where $\alpha$ = Co-efficient of linear expansion,

$\Delta t$ = Temperature rise, and

$E$ = Modulus of elasticity.

Hence temperature stress depends upon all the three and (*d*) is the answer.

**12.** The energy absorbed by a part subject to dynamic force is given by

$$U = \frac{\sigma^2}{2E} \times \text{volume}$$

when $\sigma$ and $E$ are constant then

$$U \propto \text{volume}$$

Hence (*c*) is the answer.

**13.** The criterion of failure according to maximum shear stress theory is

$$\frac{\sigma_1 - \sigma_2}{2} = \pm \frac{\sigma_{yp}}{2}$$ when the principal stresses $\sigma_1$ and $\sigma_2$ are opposite

*i.e.,* one is tensile then other is compressive

But if both are tensile (or compressive), then $\frac{\sigma_1 - \sigma_2}{2}$ will not represent the maximum shear stress. It will represent the stress less than maximum shear stress. But $\frac{\sigma_1}{2}$ will represent the maximum shear stress. Hence criterion of failure is

$$\frac{\sigma_1}{2} = \pm \frac{\sigma_{yp}}{2}.$$ **Ans.**

**14.** Buckling load for column with different end condition are :

$$P_E = \frac{\pi^2 EI}{L^2}$$ ...both ends hinged

$$= \frac{\pi^2 EI}{4L^2}$$ ...one end is fixed (or clamped) and other is hinged

$$= \frac{2\pi^2 EI}{L^2}$$ ...one end is fixed (clamped) and other is hinged

$$= \frac{4\pi^2 EI}{L^2}$$ ...both ends fixed (or clamped)

$\therefore$ When both ends are clamped, the buckling load is maximum.

**15.** The spring stiffness ($k$) for a close-coiled helical spring in terms of dia. of wire ($d$), mean radius of coil ($R$), no. of turns ($n$) and modulus of rigidity ($C$) is given by

$$k = \frac{W}{\delta} = \frac{Cd^4}{64R^3 \times n}$$

When the dia. of wire ($d$) and material of coil is same, then

$$k \propto \frac{1}{R^3 \times n}$$ [$\therefore$ For the same material, $C$ is constant]

$\therefore$ $$k \times R^3 \times n = \text{constant}$$

or $$k_1 \times R_1{}^3 \times n_1 = k_2 \times R_2{}^3 \times n_2$$

or $$k_2 = k_1 \times \left(\frac{R_1}{R_2}\right)^3 \times \left(\frac{n_1}{n_2}\right) = k_1 \times \left(\frac{D_1}{D_2}\right)^3 \times \left(\frac{n_1}{n_2}\right)$$

$$= k_1 \times \left(\frac{75}{60}\right)^3 \times \left(\frac{8}{10}\right) \qquad \left[\because \begin{array}{l} D_1 = 75 \text{ mm}, n_1 = 8 \\ D_2 = 60 \text{ mm}, n_2 = 10 \end{array}\right]$$

$= \mathbf{1.56\ k_1}$. **Ans.**

$\therefore$ Answer is (*c*).

**16.** Here $d = 1 \text{ m} = 100 \text{ cm}$

$p = 100 \text{ N/cm}^2$

Max. permissible tensile stress = 2 kN/cm² = 2000 N/cm²

For thin cylinder, the maximum stress is circumferential (or hoop) stress.

Hence here $\sigma_c = 2000 \text{ N/cm}^2$

Let $t$ = thickness.

Then $$\sigma_c = \frac{p \times d}{2t}$$ [Here $p$ and $\sigma_c$ should have same unit. Then $d$ and $t$ will have the same unit]

or $$t = \frac{p \times d}{2 \times \sigma_c} = \frac{100 \times 100}{2 \times 2000} = 2.5 \text{ cm} = \mathbf{25\ mm}.$$ **Ans.**

**17.** Original volume, $V = \frac{\pi}{4} D^2 \times L$

Change in volume, $dV$ will be obtained by taking differential as

$$dV = \frac{\pi}{4} D^2 \times dL + \frac{\pi}{4} Ld(2D^2)$$

$$= \frac{\pi}{4} D^2 \times dL + \frac{\pi}{4} L \times 2D\, d(D)$$

$\therefore$ Volumetric strain, $$\frac{dV}{V} = \frac{\frac{\pi}{4} D^2 \times dL + \frac{\pi}{4} L \times 2D \times d(D)}{\frac{\pi}{4} D^2 \times L}$$

$$= \frac{dL}{L} + \frac{2d(D)}{D}$$

$\frac{dL}{L}$ = Longitudinal strain = $e_2$

$\frac{d(D)}{D}$ = Circumferential strain $\left[\frac{\pi(D + dD) - \pi D}{\pi D} = \frac{dD}{D}\right]$

$= e_1$

$\therefore$ $$\frac{dV}{V} = e_2 + 2e_1 = 2e_1 + e_2 \qquad \left[\frac{dV}{V} = \text{Change in volume per unit volume}\right]$$

**18.** The part which is cheapest in overall cost and can be easily replaced when there is some damage, is made the weakest part. The key in comparison to pulley and shaft can be replaced easily.

**19.** The shear stress distribution in a beam of rectangular cross-section is parabolic and having maximum value at the neutral axis. Hence the answer is (*d*).

Shear stress is given by

$$\tau = \frac{FA \times \bar{y}}{I \times b} \qquad \text{where } A \times \bar{y} \text{ for rectangular section} = \frac{b}{2}\left(\frac{d^2}{4} - y^2\right)$$

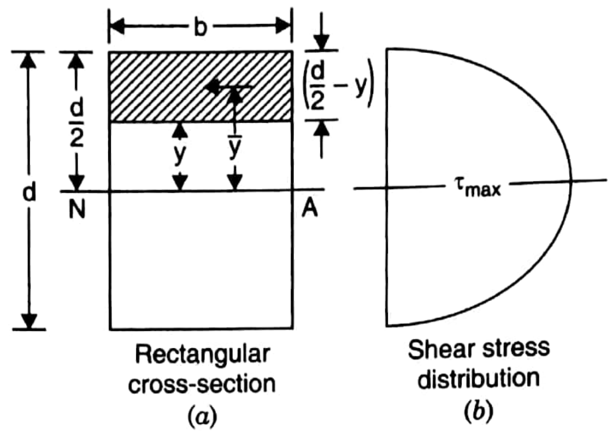



Fig. 14

where $A$ = shaded area $= b \times \left(\frac{d}{2} - y\right)$

$y$ = section where shear stress is $\tau$

$\bar{y}$ = distance of C.G. of shaded area from N.A. $= y + \frac{1}{2}\left(\frac{d}{2} - y\right)$

$I$ = M.O. Inertia

$b$ = width at section $y$ which is $b$ here.

$$\therefore \qquad \tau = \frac{F \times \frac{b}{2}\left(\frac{d^2}{4} - y^2\right)}{I \times b} = \frac{F}{2I}\left(\frac{d^2}{4} - y^2\right)$$

which is the equation of a parabola.

**20.** When beam is placed as shown in Fig. 15($a$) 1st position, then bending stress is given by

$$\sigma_b = \frac{M}{I} \times y$$

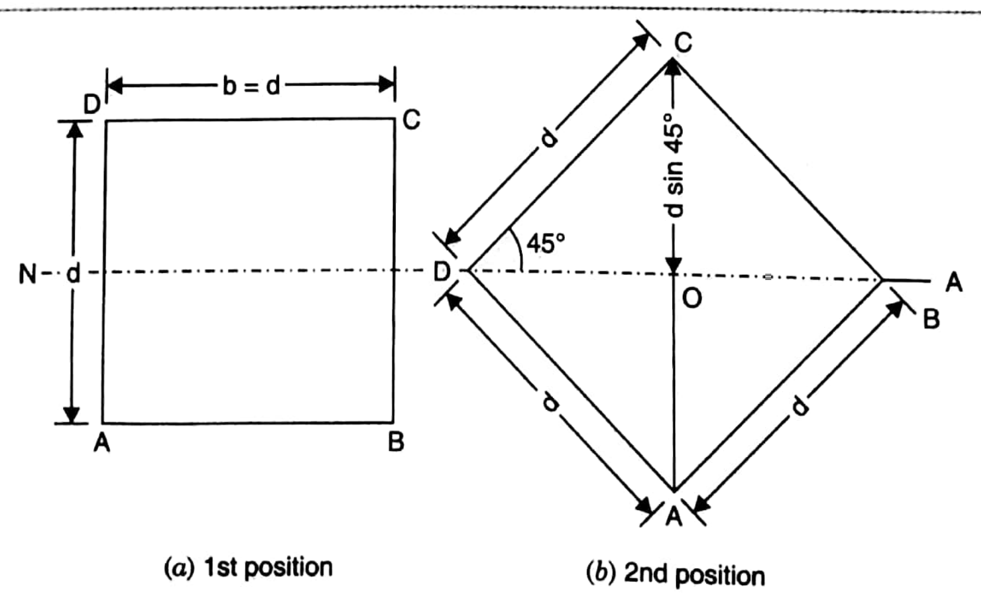



Fig. 15

and $$(\sigma_b)_{max} = \frac{M}{I} \times \frac{d}{2} = \frac{M}{\frac{bd^3}{12}} \times \frac{d}{2} \qquad \left[\because \; I = \frac{bd^3}{12} = \frac{d \times d^3}{12} = \frac{d^4}{12}\right]$$

$$= \frac{6M}{bd^2} = \frac{6M}{d \times d^2} = \frac{6M}{d^3} \qquad (\because \; b = d \text{ being square}) \quad ...(i)$$

The bending stress when beam is placed as shown in Fig. 15($b$) 2nd position is given by

$$(\sigma_b)^*_{max} = \frac{M}{I^*} \times y^*$$

where $y^*$ = Distance of top layer from N.A. *i.e.*, distance $OC$

= half of diagonal of the square = $OC$

$$= d \times \sin 45° = \frac{d}{\sqrt{2}}$$

$I^*$ = M.O.I. of 2nd position about N.A.

$$= 2 \times \frac{bh^3}{12} \quad \text{where} \quad b = BD = 2 \times \frac{d}{\sqrt{2}}$$

$$h = \frac{d}{\sqrt{2}} = \sqrt{2} \times d$$

$$= \frac{2 \times \sqrt{2}d \times \left(\frac{d}{\sqrt{2}}\right)^3}{12} = \frac{1}{6} \times \frac{d^4}{2} = \frac{d^4}{12}$$

$$= \frac{M}{\left(\frac{d^4}{12}\right)} \times \frac{d}{\sqrt{2}}$$

$$= \frac{12M}{d^3 \times \sqrt{2}}$$

$$\therefore \quad \frac{(\sigma_b)^*_{max}}{(\sigma_b)_{max}} = \frac{\left(\frac{12M}{d^3 \times \sqrt{2}}\right)}{\left(\frac{6M}{d^3}\right)}$$

$$= \frac{2}{\sqrt{2}} = \sqrt{2}$$

$$\therefore \quad (\sigma_b)^*_{max} = \sqrt{2} \times (\sigma_b)_{max}$$

Hence the answer is ($c$).

**21.** $$\sigma_b = \frac{M}{I} \times y = \frac{M}{\frac{\pi}{64} \times d^4} \times \frac{d}{2} = \frac{32\,M}{\pi d^3}$$

$$\therefore \quad T = \frac{\pi}{16} \times d^3 \times \tau$$

$$\therefore \quad \tau = \frac{16\,T}{\pi d^3}$$

$$\therefore \quad \frac{\sigma_b}{\tau} = \frac{32M}{\pi d^3} \times \frac{\pi d^3}{16T} = \frac{2M}{T} = 2. \qquad (\therefore \quad M = T)$$

**22.** For a simply supported beam carrying a point load at the centre, the deflection ($\delta$) is given by

$$\delta = \frac{PL^3}{48EI}$$

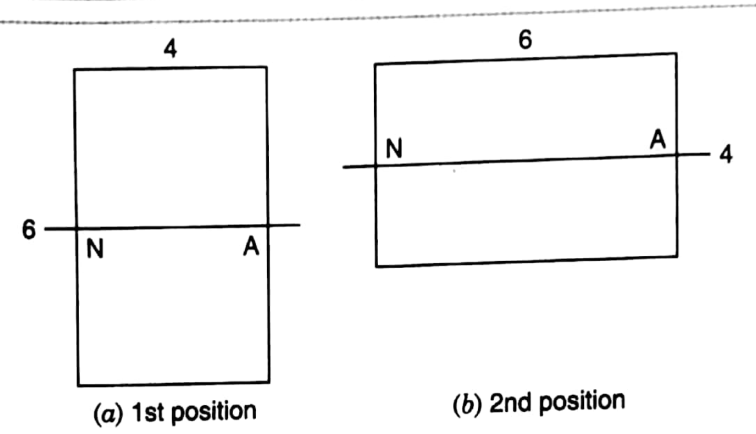



Fig. 16

Here load $P$, span of beam $L$ and $E$ is same for both positions,

$$\therefore \qquad \delta \propto \frac{1}{I} \qquad \text{or} \qquad \delta \times I = \text{constant}$$

$$\text{or} \qquad \delta_1 \times I_1 = \delta_2 \times I_2 \qquad \text{or} \qquad \delta_2 = \delta_1 \times \frac{I_1}{I_2}$$

Now $$I_1 = \frac{4 \times 6^3}{12} = 72$$

and $$I_2 = \frac{6 \times 4^3}{12} = 32$$

$$\therefore \qquad \delta_2 = \delta_1 \times \frac{72}{32} = \mathbf{2.25\ \delta_1}. \quad \textbf{Ans.}$$

Hence answer is (*d*).

**23.** Couple acting on beam = $P \times C$ anticlockwise moment at any point should be zero

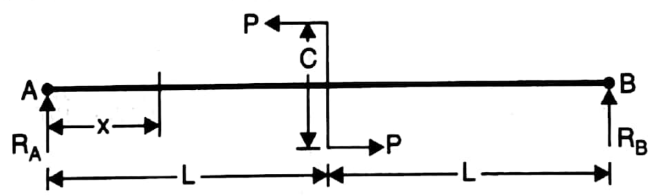



Fig. 17

$$\therefore \qquad M_A = 0$$

$$\text{or} \qquad R_B \times 2L + P \times C = 0$$

$$\text{or} \qquad R_B = \frac{-P \times C}{2L}$$ (–ve sign shows that reaction $R_B$ is acting downwards)

There is no load on the beam

$$\therefore \qquad R_A + R_B = 0 \qquad \text{or} \qquad R_A = -R_B = \frac{P \times C}{2L}$$

The reaction $R_A$ is acting upwards.

Shear force at $x$, $$F_x = R_A = \frac{\mathbf{P \times C}}{\mathbf{2L}}. \quad \textbf{Ans.}$$

**24.** Resolving forces along the inclined plane and normal to the plane, we get

$$P' \cos \alpha = \mu R_N + W \sin \alpha \qquad \text{...(1)}$$

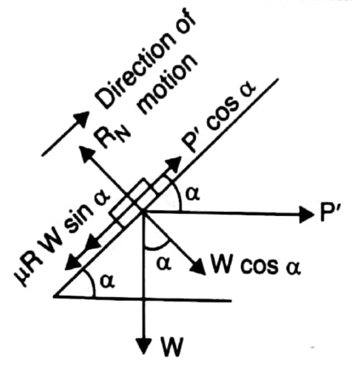



Fig. 18

$$R_N = W \cos \alpha + P' \sin \alpha \quad \text{...(2)}$$

Substituting the value of $R_N$ in (1), we get

$$P' \cos \alpha = \mu[W \cos \alpha + P' \sin \alpha] + W \sin \alpha$$

Taking $$\mu = \tan \phi = \frac{\sin \phi}{\cos \phi}$$

and substituting in the above equation and simplifying, we get

$$P' = W \tan (\alpha + \phi)$$

$\therefore$ Frictional torque at mean radius ($R$) is $= R \times P' = R \times W \tan (\alpha + \phi)$.

**26.**
$$\sigma_\theta = \frac{\sigma_x + \sigma_y}{2} + \frac{\sigma_x - \sigma_y}{2} \times \cos 2\theta$$

$$\sigma_{45^\circ} = \frac{\sigma_x + \sigma_y}{2} + \frac{\sigma_x - \sigma_y}{2} \times \cos 90^\circ$$

$$= \frac{\sigma_x + \sigma_y}{2}$$

$$= \frac{5000 + 5000}{2} = \mathbf{5000\ N/cm^2}. \quad \textbf{Ans.}$$

**27.** There is no normal stress either in $x$-direction or in $y$-direction.

$\therefore$ $\sigma_x = 0$ and $\sigma_y = 0$. While drawing Mohr's circle of stresses, $\sigma_x$ and $\sigma_y$ are taken along $x$-axis from origin and shear stress ($\tau$) along $y$-axis. Hence shear stress ($\tau$) will be taken on the origin of axis along $y$-direction upward and downwards.

Hence answer is ($c$).

**28.** $A = 1$ cm$^2$ ; $L = 100$ cm ; $E = 20 \times 10^6$ N/cm$^2$, $P = 20$ kN $= 20 \times 1000$ N

$$\frac{\delta L}{L} = \frac{\sigma}{E} = \frac{\left(\frac{P}{A}\right)}{E}$$

$\therefore$
$$\delta L = \frac{P}{AE} \times L = \frac{20{,}000 \times 100}{1 \times 20 \times 10^6} = \mathbf{0.1\ cm.} \quad \textbf{Ans.}$$

**29.** $A_1 = \pi r_1^2$, $A_2 = \pi\left(\frac{r_1}{2}\right)^2 = \frac{\pi r_1^2}{4}$

The modulus of elasticity for a material is independent of area and load applied etc. Hence with the increase or decrease of area (*i.e.*, radius), the modulus of elasticity will be unaffected. **Ans.**

**30.** To find the correct answer proceed as given below
Ductility is determined by tension test (3)
Toughness is determined by Impact test (1)
Endurance limit is determined by Fatigue Test (2)
Resistance to penetration is determined by Hardness test (4)
Hence the correct code is which contains 3, 1, 2, 4.
Hence the correct code is (*c*).

**31.**
$$E = 21 \times 10^6 \text{ N/cm}^2,\ C = 8 \times 10^6 \text{ N/cm}^2$$
$$E = 2C(1 + \mu)$$
$$\therefore \quad \mu = \frac{E}{2C} - 1$$
$$= \frac{21 \times 10^6}{2 \times 8 \times 10^6} - 1 = \frac{21}{16} - 1 = 1.3125 - 1 = \mathbf{0.3125}. \quad \textbf{Ans.}$$

**32.**
$$P = 2\pi NT, \text{ where} \qquad T = \frac{\pi}{16} \times d^3 \times \tau \quad \therefore \quad T_1 = \frac{\pi}{16} \times d_1^{\,3} \times \tau$$

$$N_2 = \frac{N_1}{2} \qquad T_2 = \frac{\pi}{6} \times (2d_1)^3 \times \tau = \frac{\pi}{16} \times 8 \times d_1^{\,3} \times \tau = 8 \times T_1$$

$$P_1 = 2\pi N_1 T_1$$
$$P_2 = 2\pi N_2 T_2$$
$$= 2\pi \times \left(\frac{N_1}{2}\right) \times T_1$$
$$= 2\pi N_1 \times T_1 \times 4$$
$$= P_1 \times 4 = 90 \times 4 = \mathbf{360\ kW}. \quad \textbf{Ans.}$$

**33.** According to maximum shear stress theory for design purpose, we have the equation
$$(\sigma_1 - \sigma_2) = \sigma_t \quad \text{where } \sigma_t = \text{Permissible stress in simple tension}$$
or $\quad 60 - (-60) = \sigma_t \quad$ or $\quad 60 + 60 = \sigma_t$

or $\quad \sigma_t = 120 \quad$ and safety factor $= \dfrac{\sigma_t^*}{\sigma_t} = \dfrac{360}{120} = \mathbf{3}.$ **Ans.**

**34.** Here each rivet is subjected to direct stress due to load $W$ and bending stress due to bending moment. Bending moment is equal to $W \times e$ where $e$ = eccentricity.
The value of $e$ is maximum for rivets $P$ and $S$. The direct stress is same for all the rivets, Bending stress is maximum when $e$ is maximum. Eccentricity is maximum for rivets $P$ and $S$. Hence rivets $P$ and $S$ are having maximum bending stress. Hence rivets $P$ and $S$ are most loaded. **Ans.**

**35.** The stiffness of a helical compression spring is given by,
$$k = \frac{Cd^4}{64\,R^3 \times n}$$
where $C$ = Modulus of rigidity
$d$ = dia. of wire
$n$ = no. of turns
$R$ = mean radius of coil.

When spring is cut into two equal halves, only no. of turns will be effected it will become half. Other value such as $C$, $d$ and $R$ will be same.

$$\therefore \quad k_2 = \frac{Cd^4}{64 \times R^3 \times \left(\frac{n}{2}\right)} = \frac{2Cd^4}{64R^3 \times n} = 2 \times \text{k}. \quad \textbf{Ans.}$$

**36.** For close-coiled helical spring,

$$\tau = \frac{16\,WR}{\pi d^3}$$

While deriving this equation, the effect of curvature of spring and stress concentration effect are neglected. Hence the correct expression for shear stress will be

$$\tau = \frac{16\,WR}{\pi d^3} \times K$$

where $K$ = Wahl's correction factor

$$= \frac{4S-1}{4S-4} + \frac{0.615}{S}$$

where $S = \text{spring index} = \frac{D}{d} = \frac{\text{mean dia. of coil}}{\text{dia. of wire}}$.

**37.** Free body diagram through $C$

$$R_1 + R_2 = 120 \text{ N} \quad \text{...}(i)$$

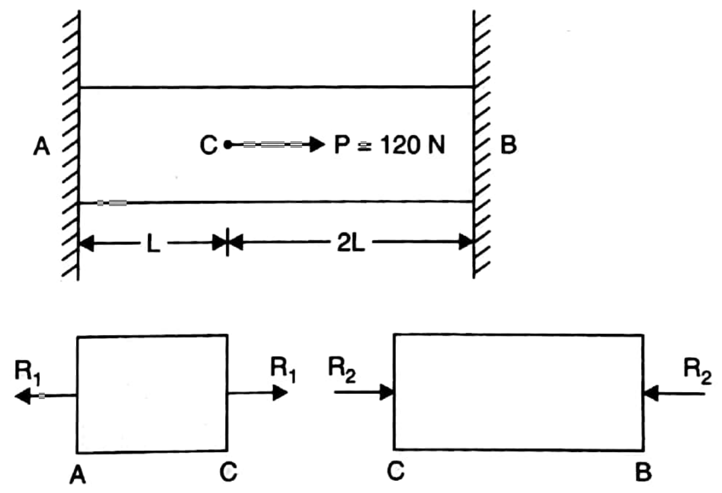



Fig. 19

Extension in $AC$ = Compression in $CB$

For $AC: \frac{\delta L_1}{L_1} = \frac{\sigma_1}{E}$ or $\delta L_1 = \frac{\sigma_1}{E} \times L_1 = \frac{R_1}{AE} \times L_1$ $\left(\because \sigma_1 = \frac{R_1}{A}\right)$

For $CB: \frac{\delta L_2}{L_2} = \frac{\sigma_2}{E}$ or $\delta L_2 = \frac{\sigma_2}{E} \times L_2 = \frac{R_2}{AE} \times L_2$ $\left(\because \sigma_2 = \frac{R_2}{A}\right)$

As $\delta L_1 = \delta L_2$

$\therefore \quad \frac{R_1 \times L_1}{AE} = \frac{R_2 \times L_2}{AE}$

or $R_1 \times L_1 = R_2 \times L_2$ But $L_1 = L$ and $L_2 = 2L$

$\therefore \quad R_1 \times L = R_2 \times 2L$

or $\quad R_1 = 2R_2$ ...(ii)

From (i) and (ii), $\quad 3R_2 = 120$ N $\quad \therefore \quad R_2 = \mathbf{40\ N.}$ **Ans.**

and $\quad R_1 = 120 - 40 = \mathbf{80\ N.}$ **Ans.**

**38.** $C = 100$ G Pa $= 100 \times 10^9$ N/m$^2$

$\mu = 0.25$

$$E = 2C(1 + \mu)$$
$$= 2 \times 100 \times 10^9 (1 + 0.25)$$
$$= 200 \times 1.25 \times 10^9$$
$$= 250 \times 10^9 \text{ N/m}^2 = \mathbf{250\ GPa.} \quad \textbf{Ans.}$$

**39.** Steel rod $\quad$ Aluminium rod

$L_1 = 2$ m $\quad L_2 = 1$ m

$A_1 = 1$ cm$^2$ $\quad A_2 = 2$ cm$^2$

$E_1 = 200$ GPa $\quad E_1 = 100$ GPa

The rigid beam will be horizontal if :

Extension of steel rod = Extension of aluminium rod

$$\delta L_1 = \delta L_2$$

$$\frac{P_1 \times L_1}{A_1 \times E_1} = \frac{P_2 \times L_2}{A_2 \times E_2}$$

or $$P_1 = P_2 \times \frac{A_1}{A_2} \times \frac{E_1}{E_2} \times \frac{L_2}{L_1} = P_2 \times \frac{1}{2} \times \frac{200}{100} \times \frac{1}{2} = \frac{P_2}{2}$$

or $\quad 2P_1 = P_2 \quad$ or $\quad \mathbf{P_2 = 2P_1.}$ **Ans.**

or $\quad$ load on aluminium rod = 2 times the load on steel rod.

**40.** Radial displacement $= u$

Initial radius $= r$

Final radius $= r + u$

$$\text{Tangential strain} = \text{Circumferential strain} = \frac{\text{Final circumference} - \text{Initial}}{\text{Initial circumference}}$$

$$= \frac{2\pi(r+u) - 2\pi r}{2\pi r} = \frac{2\pi u}{2\pi r} = \frac{\mathbf{u}}{\mathbf{r}}. \quad \textbf{Ans.}$$

**41.** $$\text{Stiffness} = \frac{\text{Load}}{\text{Deflection}} = \frac{P}{\text{Deflection under } P} \quad \text{...(i)}$$

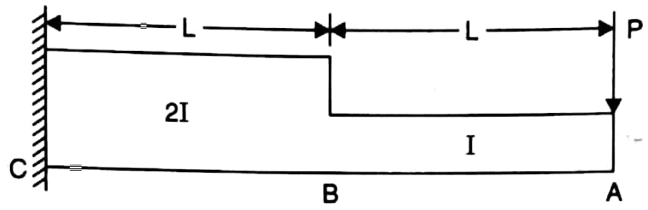
Let us find deflection under load $P$. This can be done by conjugate Beam Method. In this method, the beam carries the $\frac{M}{EI}$ load corresponding to actual load. The deflection at any section will be equal to B. M. at that section due the load carried by conjugate beam. Refer to Fig. 20 (b).

Load for conjugate beam is $\frac{M}{EI}$.

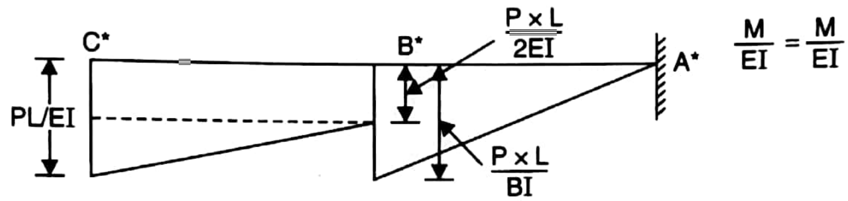
B.M. at $A = 0$, hence value of $\frac{M}{EI}$ at $A = 0$

B.M. at $C = P \times 2L$, hence value of $\frac{M}{EI}$ at $C = \frac{P \times 2L}{E \times (2I)} = \frac{PL}{EI}$

B.M. at $B = P \times L$, hence value of $\dfrac{M}{EI}$ at $B$ for $AB = \dfrac{P \times L}{EI}$, for $BC = \dfrac{P \times L}{E \times (2I)} = \dfrac{PL}{2EI}$




*(a)* Actual beam




*(b)* Conjugate beam

Fig. 20

Deflection (δ) at $A$ = B.M. at $A^*$ due to load carried by conjugate beam

$$= \left(\frac{1}{2} \times \frac{PL}{EI} \times L\right) \times \frac{2L}{3} + \left(\frac{PL}{2EI} \times L\right) \times 1.5L + \left(\frac{1}{2} \times \frac{PL}{2EL} \times L\right) \times \frac{5L}{3}$$

$$= \frac{PL^3}{EI}\left(\frac{1}{3} + 0.75 + \frac{5}{12}\right) = \frac{PL^3}{EI} \times \frac{18}{12} = \frac{1.5 \times PL^3}{EI}$$

$$\therefore \text{ Stiffness} = \frac{P}{\delta} = \frac{P}{\left(\dfrac{1.5 \times PL^3}{EI}\right)} = \frac{EI}{1.5 \times L^3} = \frac{(200 \times 10^9) \times (375 \times 10^{-6})}{1.5 \times (0.5)^3}$$

$$= \frac{200 \times 10^9 \times 375 \times 10^{-4} \times 10^3}{1.5 \times 125} = \mathbf{4 \times 10^{10}\ N/m.} \quad \textbf{Ans.}$$

**42.** The maximum stress induced in a thin cylinder is hoop stress ($\sigma_c$). It is given by

$$\sigma_c = \frac{p \times d}{2t}$$

The maximum hoop stress produced in spherical vessel $= \dfrac{p \times d}{4t}$

$$\therefore \frac{\text{Max. stress in cylindrical vessel}}{\text{Max. stress in spherical vessel}} = \frac{\dfrac{pd}{2t}}{\dfrac{p \times d}{4t}} = 2.0.$$

**44.**

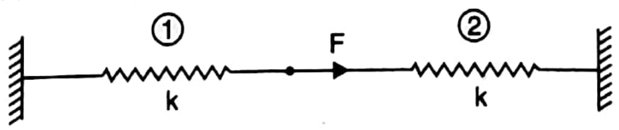



Fig. 21

Strain energy stored in spring 1,

$$U_1 = \frac{1}{2} \times F_1 \times \delta_1 \quad \text{where } F_1 = \text{force carried by spring 1}$$

$$= \frac{1}{2} \times \frac{F}{2} \times \frac{F}{2k}$$

$$= \frac{\mathbf{F^2}}{\mathbf{8k}}. \quad \textbf{Ans.}$$

$$= \frac{F}{2} \quad (\because \text{ both springs are identical})$$

$\delta_1$ = Deflection of spring 1.

$$= \frac{F_1}{k}$$

$$= \frac{F}{2k} \qquad \left(\because \; F_1 = \frac{F}{2}\right)$$

**45.** $A = 100 \times 10^{-6}$ m$^2$

Let $P$ = tensile load at failure

$\therefore$ For one-dimensional stress system, we have stresses as $\left(\frac{P}{A}, 0, 0\right)$

Tensile stress due to load $P$, $\sigma_1 = \frac{P}{A}$

This stress is in one-direction only *i.e.*, $(\sigma, 0, 0)$

Max. shear stress due to stress system $(\sigma_1, 0, 0) = \frac{1}{2}(\sigma_1 - 0) = \frac{\sigma_1}{2}$

Uniaxial yield stress, $\sigma_t^* = 200$ MPa $= 200 \times 10^6$ N/m$^2$.

$\therefore$ For uniaxial yield stress, we have stress system as $(\sigma_t^*, 0, 0)$

Max. shear stress due to uniaxial yield stress $= \frac{1}{2}(\sigma_t^* - 0) = \frac{\sigma_t^*}{2}$

According to Tresca failure criterion,

Max. shear stress developed = Max. shear due to yield stress

*i.e.*, $\quad \frac{\sigma_1}{2} = \frac{\sigma_t^*}{2} \quad$ or $\quad \sigma_1 = \sigma_t^*$

or $\quad \frac{P}{A} = 200 \times 10^6 \text{ N/m}^2 \qquad \left(\because \; \sigma_t^* = 200 \times 10^6 \text{ N/m}^2 \text{ and } \sigma_1 = \frac{P}{A}\right)$

or $\quad P = 200 \times 10^6 \times A$

$= (200 \times 10^6) \times (100 \times 10^{-6}) = 20000 =$ **20 kN. Ans.**

**46.** We know that stiffness of a close-coiled helical spring is given by

$$k = \frac{Cd^4}{64\, R^3 \times n}$$

1st case, $$k_1 = \frac{Cd^4}{64\left(\frac{D}{2}\right)^3 \times N} \qquad \left(\text{here } R = \frac{D}{2} \text{ and } n = N\right)$$

2nd case, $$k_2 = \frac{C(2d)^4}{64\left(\frac{2D}{2}\right)^3 \times 2N}$$

(here dia. of wire $= 2d$ ; Mean coil dia. $= 2D$ and number of turns $= 2N$)

$$= \frac{Cd^4 \times 16}{64 \times \left(\frac{D}{2}\right)^3 \times 8 \times 2N} = \frac{Cd^4}{64\left(\frac{D}{2}\right) \times N} = \mathbf{k_1} \qquad \left(\because \ k_1 = \frac{Cd^4}{64\left(\frac{D}{2}\right)^3 \times N}\right) \quad \textbf{Ans.}$$

**47.** Euler's buckling load,

$$P = \frac{\pi^2 EI}{L^2} \quad \text{where} \quad I = \frac{\pi}{64} d^4$$

For circular column when diameter is reduced by 20%, then dia. of new column = 0.8 $d$

$\therefore$ New moment of inertia, $I^* = \frac{\pi}{4} \times (0.8\,d)^4 = \frac{\pi}{4} \times d^4 \times (0.8)^4$

Initial buckling load, $$P = \frac{\pi^2 E}{L^2} \times \frac{\pi}{64} d^4$$

New buckling load, $$P^* = \frac{\pi^2 E}{L^2} \times \frac{\pi}{64} \times d^4 \times 0.8^4$$

$\therefore$ % reduction in load $$= \frac{P - P^*}{P} \times 100$$

$$= \frac{\left(\frac{\pi^2 E}{L^2} \times \frac{\pi}{64} d^4 - \frac{\pi^2 E}{L^2} \times \frac{\pi}{64} d^4 \times 0.8^4\right)}{\frac{\pi^2 E}{L^2} \times \frac{\pi}{4} d^4} \times 100$$

$$= \frac{1 - 0.8^4}{1} = (1 - 0.4096) \times 100 = \mathbf{59\%}. \quad \textbf{Ans.}$$

**48.** For a column of one end fixed and other free, the bucking load is

$$P_1 = \frac{\pi^2 EI}{4L^2}$$

For a second column of same length and same cross-sectional area when both ends are fixed, the buckling load is

$$P_2 = \frac{4\pi^2 EI}{L^2}$$

$$\therefore \quad \frac{P_2}{P_1} = \frac{\left(\frac{4\pi^2 EI}{L^2}\right)}{\left(\frac{\pi^2 EI}{4L^2}\right)} = 4 \times 4 = \mathbf{16}. \quad \textbf{Ans.}$$

**49.** $\sigma_{max} = \frac{1}{2}[\sigma_1 - \sigma_3] = \frac{1}{2}[80 - (-40)] = \mathbf{60\ MPa}.$ **Ans.**

**50.** $E = 2C(1 + \mu)$

$$\therefore \quad \mu = \frac{E}{2C} - 1 = \frac{120}{2 \times 50} - 1 = 1.2 - 1.0 = \mathbf{0.2}. \quad \textbf{Ans.}$$