KNOWLEDGE INSTITUTE OF TECHNOLOGY,SALEM.

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Question Bank

STRENGTH OF MATERIALS FOR MECHANICAL ENGINEERS

Department of Mechanical Engineering

Part A

Unit –I
STRESS, STRAIN AND DEFORMATION OF SOLIDS

1. **Define Hooke's law**. (Dec2003)(Dec 2010)(May 2009)(Dec2009)(May 2013)
   Within the elastic limit, the stress is directly proportional to the strain.
   $$\text{Stress} \propto \text{strain}$$
   $$\frac{\text{Stress}}{\text{Strain}} = \text{Constant of prortionality}$$
   The constants of proportionality are called elastic constants.

2. What are the three types of stresses? (May 2013)
   1. Tensile stress
   2. Compressive stress
   3. Tangential or shear stress

3. **Define limit of proportionality and yield stress.** (April2001)(May2013)
   - The load, within which the stress is directly proportional to the strain, is called limitof proportionality.
   - The load at which the material starts yielding and does not regains its original shapeon removal of load, is called yield stress.

4. **A steel rod 15 m long is at temperature of 15°C. Find the free expansion of the Length, when the temperature is raised to 65°C. If this expansion is prevented,find the stress in the material of the rod. Take E = 2. t X 105 *N/mm*2 and *a* = 12 x 10-6 per degree C.** (Dec 2012)

   Free expansion
   $$\delta l = \alpha t l = 12 \times 10^{-6} \times 50 \times 15000 = \mathbf{9\ mm.}\ \ \mathbf{Ans}$$
   Thermal stress developed in the bar
   $$\sigma = \alpha t E = 12 \times 10^{-6} \times 50 \times 2.1 \times 10^{5} = 126\ N/mm^2$$
   $$\boxed{\sigma = 126\ MPa.\ \ Ans.\ \ Ans}$$

5. **What do you mean by stiffness?** (May 2012)
   Stiffness is defined as the ability of the material to resist deformation under stress.The modulus of elasticity is the measure of stiffness.

6. **Define elasticity**. (May 2012)
   The property of certain materials of returning back to their original position, after removingthe external forceis known as elasticity.

7. **Calculate the force required for punching a hole of 10 mm diameter through a mildsteel plate of 5 mm thick. Take maximum shear strength of mild steel as *300 N/mm2.* Also find the compressive stress on the punch.**(May 2011)

Forcerequired for punching, $P = \text{Perimeter} \times \tau \times t$

$$= \pi \times 10 \times 300 \times 5 = 47.123 \times 10^3 \text{ N}$$

$$\boxed{P = 47.123 \text{ kN. Ans}}$$

Compressive stress on the punch,

$$\sigma_C = \frac{P}{A} = \frac{47.123 \times 10^3}{\frac{\pi}{4} \times 10^2} = 600 \text{ N}/mm^2$$

$$\boxed{\sigma_C = 600 \text{ MPa. Ans}}$$

8. **What is principle of super position?** (Dec 2010)
The resultant deformation of the body is equal to the algebraic sum of the deformation of the individual section. Such principle is called as principle of superposition.

9. **What is compound bar?**
A composite bar composed of two or more different materials joined together suchthat system is elongated or compressed in a single unit.

10. **Define- elastic limit.** (Dec2010)
The maximum applied load within which the material regains its original shape onremoval of load is called elastic limit of the material.

11. **What is thermal stress?** (May 2009)(May 2010)
The stress induced in the material due to prevention of thermal expansion is calledthermal stress.
This can be calculated by,

$$\boxed{\sigma = \alpha t E}$$

12. **Define - Young's modulus**. (Dec2009)
The ratio of tensile stress and tensile strain or compressive stress and compressive strain, within the elastic limit is called Young's modulus.

$$\boxed{E = \frac{\text{Tensile stess or compressive stress}}{\text{Tensile strain or compressive strain}}}$$

13. **The strain induced in an MS bar of rectangular section having width equal to twice the depth is 2.5 x 10-5• The bar is subjected to a tensile load of 4 kN. Find the section dimension of the bar. Take E = 0.2 X 106 *N/mm2.***(Dec 2008)

$$E = \frac{\sigma}{e}$$

$$\sigma = E \times e = 0.2 \times 10^6 \times 2.5 \times 10^{-5}$$

$$= \mathbf{5 \text{ N/mm}^2}$$

Load, $P = \text{Stress} \times \text{Area}$

$$4 \times 10^3 = 5 \times (b \times d) = 5 \times (2d \times d)$$

$$\boxed{\text{Depth, } d = 20 \text{ mm. Ans}}$$

$$\boxed{\text{Width, } b = 40 \text{ mm. Ans}}$$

14. A rod is 3 m long at temperature of 150 C. Find the expansion of the rod, when the temperature is raised to 950 C. If this expansion is prevented, find the stress in the material of the rod. Take E = 1 x 105 *N/mm2* and *u'* = 1.2 X 10-5 per degree C.(Dec 2008)

$t = 95°C - 15°C = 80°C$

The expansion of the rod,

$$\delta l = \alpha t l = 1.2 \times 10^{-5} \times 80 \times 3000$$

$$\boxed{\delta l = \mathbf{2.88\ mm.\quad Ans}}$$

The stress in the material of the rod,

$$\sigma = \alpha t E = 1.2 \times 10^{-5} \times 80 \times 2 \times 10^{5} = 192\ N/mm^2$$

$$\boxed{\sigma = \mathbf{192\ MPa.\quad Ans}}$$

15. **Explain the effect of change of temperature in a composite bar.**(Dec 2007)
Whenever there is some increase or decrease in the temperature of a bar,consisting of two or more different materials, it causes the bar to expand orcontract. On account of different coefficients of linear expansions, the twomaterials do not expand or contract by the same amount, but expand or contract bydifferent amounts.

$$\boxed{\mathbf{e_1 + e_2 = t(\alpha_1 - \alpha_2)}}$$

16. Write the concept used for finding stresses in composite bars. (May 2004) (May 2007)

- Extensions or contractions of the bar being equal, the deformation per unit length is also equal.

$$\boxed{\delta l_1 = \delta l_2}$$

- The total external load on the bar, is equal to the sum of the loads carried by the different materials.

$$\boxed{\mathbf{P = P_1 + P_2 = \sigma_1 A_2 + \sigma_1 A_2}}$$

17. Estimate the load carried by a bar if the axial stress is 10 *N/mm2* and thediameter of the bar is 10 mm.(Dec 2006)

$$\text{Load, P} = \text{Stress} \times \text{Area} = 10 \times \frac{\pi}{4} \times 10^2$$

$$\boxed{\mathbf{P = 785.4\ N.\quad Ans}}$$

18. A circular bar of 2 m long and 15 mm diameter is subjected to an axial tensile load of 30 kN. Find the elongation of the rod if the modulus of elasticity of the material of the rod is 120 kN/mm2. (May 2006)

$$\delta l = \frac{Pl}{AE} = \frac{30 \times 10^3 \times 2000}{\frac{\pi}{4} \times 15^2 \times 120 \times 10^3}$$

$$\boxed{\delta l = 2.83 \text{ mm.} \quad \textbf{Ans}}$$

19. A brass rod of 2 m long is fixed at both ends. If the thermal stress is not to exceed 76.5 *N/mm2*. Calculate the temperature through which the rod shouldbe heated. Take the values of αand E 17 x 10-6 /*K* and 90 GPa respectively. (May 2005)

$$\sigma = \alpha t E$$

$$76.5 = 17 \times 10^{-6} \times t \times 90 \times 10^3$$

$$\boxed{t = 50°C. \quad \textbf{Ans}}$$

20. A load of 2.5 kN is to be lifted by a steel wire. What should be the minimum diameter of the wire so that the stress in the wire may not exceed 100 *N/mm2?* (May 2004)

$$\text{Load, P} = \text{Stress} \times \text{Area}$$

$$2.5 \times 10^3 = 100 \times \frac{\pi}{4} \times d^2$$

$$\boxed{d = 5.64 \text{ mm say } \mathbf{6 \text{ mm.}} \quad \textbf{Ans}}$$

21. A wooden tie is 50 mm wide, 100 mm deep and 2 m long. It is subjected to an axial pull of 20 kN. The extension of the tie is found to be 0.75 mm. Find the modulus of elasticity ofthe tie material. (May 2004)

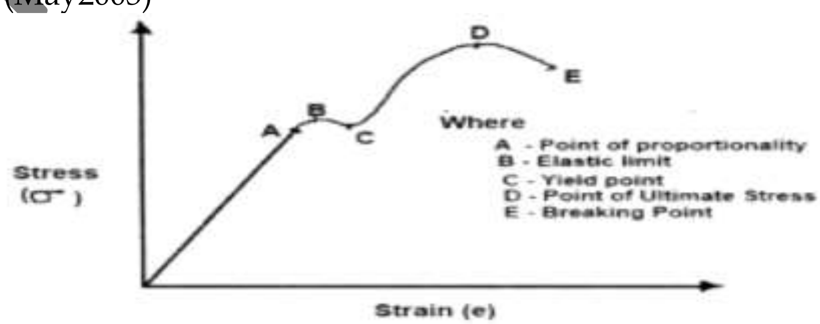
$$\delta l = \frac{Pl}{AE}$$

$$0.75 = \frac{20 \times 10^3 \times 2000}{(50 \times 100) \times E}$$

$$E = 10.667 \times 10^3 \text{ N/mm}^2$$

$$\boxed{E = 10.667 \text{ GPa.} \quad \textbf{Ans}}$$

22. Draw the stress - strain behavior of a ductile material showing all the salient points. (May2003)



23. A circular rod of 10 mm diameter elongates 0.25 mm over a length of 300 mm under a load of 11 kN. What is the E for the material of the rod? (May 2003)

$$\delta l = \frac{Pl}{AE}$$

$$0.25 = \frac{11 \times 10^3 \times 300}{\frac{\pi}{4} \times 10^2 \times E} = 168.06 \times 10^3\ \text{N/mm}^2$$

$$\boxed{E = \mathbf{168.06\ GPa.} \quad \textbf{Ans}}$$

24. Find the minimum diameter of a steel rod which is used to raise a load of 1OkN, if the stress in the rod is not to exceed 100 *N/mm2.* (Oct 2002)

$$\text{Load, } P = \text{Stress} \times \text{Area}$$

$$10 \times 10^3 = 100 \times \frac{\pi}{4} \times d^2$$

$$\boxed{d = 11.3\ \text{mm say } \mathbf{12\ mm.} \quad \textbf{Ans}}$$

25. A steel flat plate of 1cm thickness tapers uniformly from 10 cm to 5 cm within a length of 40 cm. Determine the elongation of the plate, if an axial tensileforce of 5000 N acts on it. Take E = 2 X 105 *N/mm2.* (Noy 2001)

Change in length of the rectangular plate,

$$\delta l = \frac{Pl}{Et(a-b)} \ln\left(\frac{a}{b}\right)$$

$$= \frac{5000 \times 400}{2 \times 10^5 \times 10 \times (100-50)} \ln\left(\frac{100}{50}\right)$$

$$\boxed{\delta l = \mathbf{0.0138\ mm.\ Ans}}$$

26. What do you mean by rigid body? (Oct 2001)

If the distance between any of the particles of a body remains constant on application of load, it is called rigid body.

27. Find the Young's modulus of a rod of diameter 30 mm and of length 300 mm which is subjected to a tensile load of 60 kN and the extension of the rod is equal to 0.4 mm. (Oct 2001)

$$\delta l = \frac{Pl}{AE}$$

$$0.4 = \frac{60 \times 10^3 \times 300}{\frac{\pi}{4} \times 30^2 \times E}$$

$$E = 63.66 \times 10^3\ \text{N/mm}^2$$

$$\boxed{E = \mathbf{63.66\ GPa.} \quad \textbf{Ans}}$$

28. Define working stress and factor of safety. (April 2001)

The permissible stress within which a material can be loadedis called working stress.

$$\text{Working stress} = \frac{\text{Ultimate stress}}{\text{Factor of safety}}$$

The ratio of ultimate stress to the permissible stress (working stress) is called factorof safety.

$$\text{Factor of safety} = \frac{\text{Ultimate stress}}{\text{Permissible stress}}$$

29. Define strain. (Qct 1997)

When a body is subjected to an external force, there is some change of dimension in the body.Numerically the strain is equal to the ratio of change in length to the original lengthof the body.

$$\text{Strain, e} = \frac{\text{Change in length}}{\text{Original length}} = \frac{\delta l}{l}$$

30. Define stress. (Oct 1997)

When an external force acts on a body, it undergoes deformation. At the same timethe body resists deformation. The magnitude of the resisting force is numericallyequal to the applied force. This internal resisting force per unit area is called stress.

$$\text{Stress, } \sigma = \frac{\text{Force}}{\text{Area}} = \frac{P}{A}$$

Unit is N/mm^2 or MPa.

31. A circular rod 2.5 m long tapers uniformly from 25 mm diameter to 12 mm diameter. Determine the extension of the rod under a pull of 30 kN. Assume modulus of elasticity of the rod is 200 *kN/mm2.* (Nov1996)

$$\delta l = \frac{4Pl}{\pi E d_1 d_2} = \frac{4 \times 30 \times 2500}{\pi \times 200 \times 25 \times 12}$$

$$\boxed{\delta l = \mathbf{1.6\ mm.} \quad \textbf{Ans}}$$

32. Define Poisson's ratio.(Oct 2001) (May 2003) (Dec2003)((May 2006)(Dec2007) (May 2009) (Dec 2010) (May 2013)

When a body is stressed, within its elastic limit, the ratio of lateral strain to the longitudinal strain is constant for a given material.

$$\text{Poisson's ratio}, \mu = \frac{\text{Lateral strain}}{\text{Linear strain}}$$

33. Define shear stress and shear strain.

When two equal and opposite force act tangentially on any cross sectional plane ofthe body, it tends to slide one part of the body over the other part. The stress induced is called shear stress and the corresponding strain is known as shear strain.

34. Define longitudinal strain and lateral strain. (May 2010)(Dec2012)

When a body is subjected to axial load P, the length of the body is increased. The axial deformation of the length of the body is called longitudinal strain.The strain right angle to the direction of the applied load is called lateral strain.

35. State the relationship between Young's Modulus and Modulus of Rigidity and bulk modulus.(April 2001)(May 2005)(May 2007)(May 2010)(Dec 2010)(May 2011)(Dec 2011)(May 2012)

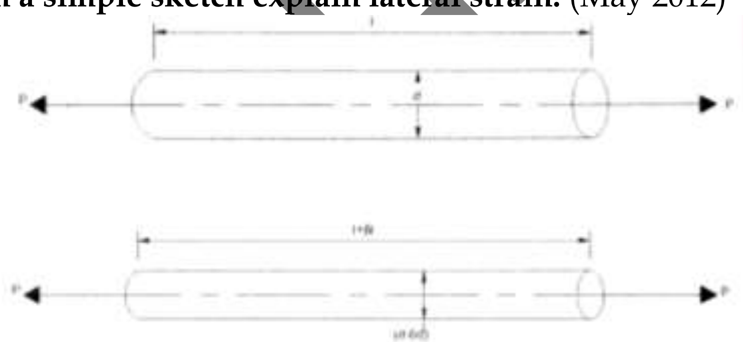
$$\boxed{E = 2G(1+\mu)}$$

$$\boxed{E = 3K(1-2\mu)}$$

$$\boxed{E = \frac{9KG}{3K+G}}$$

Where,
E - Young's Modulus
G - Modulus of rigidity
K - Bulk Modulus
μ - Poisson's ratio.

36. With a simple sketch explain lateral strain. (May 2012)



When a member is loaded axially in longitudinal direction, there will be adeformation along the loading direction followed by a corresponding deformationin the lateral dimension. The strain induced in the lateral dimension is called lateralstrain.

Lateral strain,

$$e_l = \frac{\text{Change in lateral dimension}}{\text{Original lateral dimension}} = \frac{\delta d}{d}$$

37. What is volumetric strain? (Dec1998)(Dec2011)

It is defined as the ratio of change in volume to the original volume of the body.

$$\text{Volumetric strain, } e_V = \frac{\text{Change in volume}}{\text{Original volume}} = \frac{\delta V}{V}$$

38. A circular bar of diameter 20 mm and length 400 mm is subjected to a tensile force of 50 kN. If the Young's modulus is 200 GPa, find the change in length and change in diameter of the **bar. Take Poisson's ratio as 0.3.** (Dec 2010)

$$\delta l = \frac{Pl}{AE} = \frac{50 \times 10^3 \times 400}{\frac{\pi}{4} \times 20^2 \times 200 \times 10^3}$$

$$\boxed{\delta l = 0.32 \text{ mm. Ans}}$$

$$\text{Linear strain, e} = \frac{\delta l}{l} = \frac{0.32}{400} = 800 \times 10^{-6}$$

$$\text{Lateral strain, } e_l = \mu \times e = 0.3 \times 800 \times 10^{-6} = 240 \times 10^{-6}$$

$$\text{Change in diameter, } \delta d = e_l \times d = 240 \times 10^{-6} \times 20$$

$$\boxed{\delta d = 0.005 \text{ mm. Ans}}$$

39. Calculate the instantaneous stress produced in a bar of cross sectional area 1000 mm ' **and 3 m long by the sudden application of a tensile load of unknownmagnitude, if the instantaneous extension is 1.5 mm. Also find the corresponding load. Take E = 200 GPa.** (May 2008)

Stress induced in the bar when the load is suddenly applied,

$$\sigma_{max} = 2 \times \frac{P}{1000} = 2 \times 10^{-3} P$$

$$1.5 = \frac{2 \times 10^{-3} P \times 3000}{200 \times 10^3} = 50000 \text{ N}$$

$$\boxed{P = 50 \text{ kN. Ans}}$$

$$\sigma_{max} = 2 \times 10^{-3} \times 50000 = 100 \text{ N/mm}^2$$

$$\boxed{\sigma_{max} = 100 \text{ MPa. Ans}}$$

41. The Young's modulus and the shear modulus of material are 120 GPa and 45 GPa respectively. What is its bulk modulus? (May 2008)

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

$$120 = \frac{9 \times K \times 45}{(3K + 45)}$$

$$360 K + 5400 = 405 K$$

$$\boxed{K = 120 \text{ GPa. Ans}}$$

42. Define bulk-modulus. (Oct 2000)(May 2006)(Dec 2007)

Within elastic limit, the ratio of direct stress to volumetric strain is called bulk modulus.

$$K = \frac{\text{Direct stress}}{\text{Volumetric strain}} = \frac{P}{e_V}$$

43. For a given material, the modulus of elasticity is 110 *kN/mm2* and modulus of rigidity is 43 *kN/mm2*. Find its bulk modulus. (May 2004)

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

$$110 = \frac{9 \times K \times 43}{(3K + 43)}$$

$$330\,K + 4730 = 387\,K$$

$$\boxed{K = \mathbf{83\ GPa.}\ \ \mathbf{Ans}}$$

44. What is stability? (Dec2003)

The stability is defined as an ability of a material to withstand high load without major deformation.

45. Define Modulus of rigidity. (Oct 2001) (May 2003)

Within elastic limit, the ratio of shear stress to shear strain is called shear modulusor modulus of rigidity.

$$G = \frac{\text{Shear stress}}{\text{Shear strain}} = \frac{\tau}{\phi}$$

46. The Young's modulus and Poisson's ratio of a material are 140 *kN/mm2* and 0.25espectively. Calculate its rigidity and bulk modulus. (Oct 2002)

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

$$G = \frac{140}{2(1 + 0.25)}$$

$$\boxed{G = \mathbf{56\ GPa.}\ \ \mathbf{Ans}}$$

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

$$K = \frac{140}{3(1 - 2 \times 0.25)}$$

$$\boxed{K = \mathbf{93.33\ GPa.}\ \ \mathbf{Ans}}$$

47. Define: Principal stress and Principal plane.

(Oct 2001) (May 2003) (May 2004) (May 2005) (Dec 2006) (Dec 2007) (Dec 2008) (Dec 2010) (May 2011) (Dec 2011) (May 20 12)

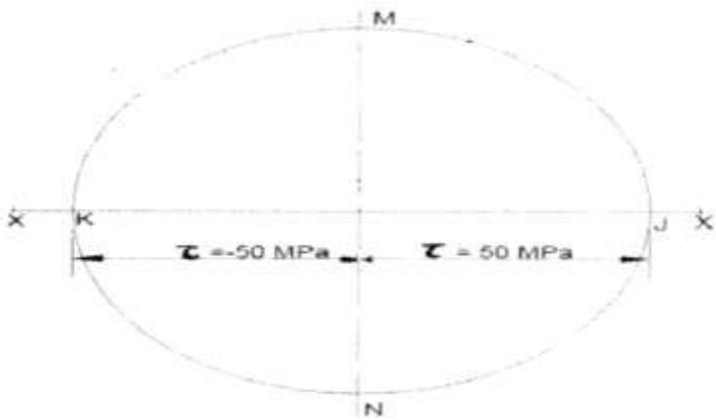
Principal stress: The magnitude of normal stress, acting on a principal plane known as principal stresses.

Principal plane: The planes which have no shear stress are known as principle planes.

48. What are the uses of a Mohr's circle? (Oct 1999)(Dec 20 11)(May 2012)

It is used to find out the normal, resultant and principal stresses and their planes

49. Draw a Mohr's circle for pure shear stress of 50 N/mm2 at a point. (Dec2002)



50. List the methods to find the stresses in oblique plane?

1. Analytical method
2. Graphical method

51. What is Mohr's circle method? (May 2009)

It is a graphical method to determine normal, tangential and resultant stresses on anyoblique planes and position and magnitude of principal stresses.

52. How will you find major principal stress and minor principal stress? Also mention how to locate the direction of principal planes. (May 2007)

$$\text{Major principal stress} = \frac{\sigma_1 + \sigma_2}{2} + \sqrt{\left[\frac{\sigma_1 - \sigma_2}{2}\right]^2 + \tau^2}$$

$$\text{Minor principal stress} = \frac{\sigma_1 + \sigma_2}{2} - \sqrt{\left[\frac{\sigma_1 - \sigma_2}{2}\right]^2 + \tau^2}$$

$$\text{Position of principal planes, } \tan 2\theta = \frac{2\tau}{\sigma_1 - \sigma_2}$$

53. The principal stress at a point is 100 N/mm2 (tensile) and 50 N/mm2 (compressive) respectively. Calculate the maximum shear stress at this point. (May 2006)

Maximum shear stress,

$$\tau_{max} = \frac{\sigma_{P_1} - \sigma_{P_2}}{2} = \frac{100 - (-50)}{2} = 75\ \text{N/mm}^2$$

$$\boxed{\tau_{max} = 75\ \text{MPa} \qquad \text{Ans}}$$

54. What is the radius of Mohr's circle? (Dec2003)

Radius of Mohrs circle is equal to the maximum shear stress.

55. State the expression for the principal plane.(Dec 2003)
Position of principal planes,

$$\tan 2\theta = \frac{2\tau}{\sigma_1 - \sigma_2}$$

56. The maximum principal stress at a point in a strained elastic material is 200MPa. If the maximum shear stress is limited to 50 MPa, determine the minor principal stress and the normal stress on maximum shear plane. (May 2003)

Solution:

Given data:

$\sigma_{P_1} = 200\ \text{N}/mm^2$

$\tau_{max} = 50\ \text{N}/\text{mm}^2$

$\sigma_{P_2} = ?$

$\sigma_n = ?$

$\theta = 90^\circ$ for maximum shear plane

$$\text{Maximum shear stress, } \tau_{Max} = \frac{\sigma_{P_1} - \sigma_{P_2}}{2}$$

$$50 = \frac{200 - \sigma_{P_2}}{2}$$

$$\boxed{\sigma_{P_2} = \mathbf{100\ MPa.\ \ Ans}}$$

$$\sigma_n = \frac{\sigma_1 + \sigma_2}{2} - \frac{\sigma_1 - \sigma_2}{2}\cos 2\theta = \frac{200 + 100}{2}$$

[since $\cos 90^\circ = 0$]

$$\boxed{\sigma_n = \mathbf{150\ MPa.\ \ Ans}}$$

57. The principal stress at a point is 120 N/mm2. Determine the normal stress on a plane inclined at 30° to the major principal plane. (Oct 2002)
Solution:
Given data:

$\sigma_P = 120\ \text{N}/\text{mm}^2$

$\theta = 30^\circ$ to the major principal plane

$\sigma_n = ?$

$$\sigma_n = \frac{\sigma_X}{2} - \frac{\sigma_X}{2}\cos 2\theta = \frac{120}{2} - \frac{120}{2}\cos(2 \times 30^\circ) = 60 - 60\cos 60^\circ$$

$$= 30\ \text{N}/\text{mm}^2$$

$$\boxed{\sigma_n = \mathbf{30\ MPa\ \ \ Ans}}$$

58. What are the planes along which the greatest shear stresses occur? (Dec2001)
Greatest shear stress occurs at the planes which is inclined at 45° to its normal

59. At a point in a strained material is subjected to a compressive stress of 100N/mm2 and shear stress of 60 N/mm2. Determine graphically or otherwise the principal stresses. (Nov 2001)

Principal stress, $\sigma_{p_{1,2}}$

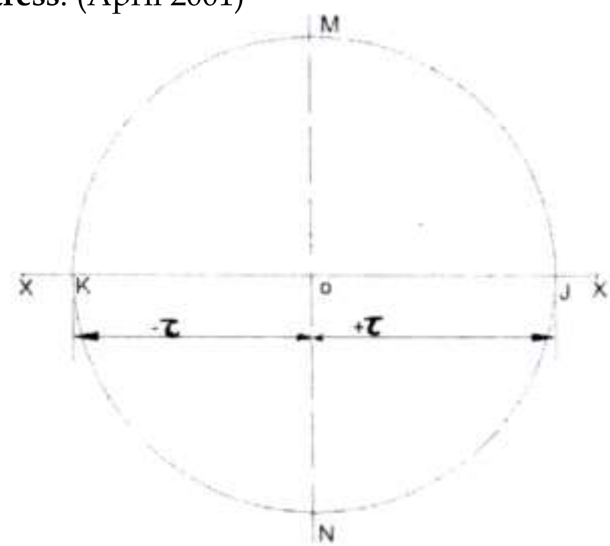
$$= \frac{\sigma_x}{2} \pm \sqrt{\left[\frac{\sigma_x}{2}\right]^2 + \tau_{xy}{}^2} = \frac{100}{2} \pm \sqrt{\left[\frac{100}{2}\right]^2 + 60^2}$$

$$= 50 \pm 78.1$$

$$\boxed{\sigma_{p1} = \mathbf{128.1\ MPa} \quad \mathbf{Ans}}$$

$$\boxed{\sigma_{p2} = \mathbf{-28.1\ MPa} \quad \mathbf{Ans}}$$

60. Sketch the Mohr's circle when an element is subjected to a state of pure shear stress. (April 2001)



61. Write the formulae to calculate stresses when a point in a member is subjected to direct stress in two mutually perpendicular directions accompanied by a simple shear stress(May 2000)

Normal stress, $\sigma_n = \frac{\sigma_x + \sigma_y}{2} - \frac{\sigma_x + \sigma_y}{2} \cos 2\theta - \tau_{xy} \sin 2\theta$

Shear stress or tangential stress, τ

$$= \frac{\sigma_x - \sigma_y}{2} \sin 2\theta - \tau_{xy} \cos 2\theta$$

Resultant stress, $\sigma_R = \sqrt{[\sigma_n{}^2 + \tau^2]}$

Maximum principal stress, σ_{p_1}

$$= \frac{\sigma_x + \sigma_y}{2} + \sqrt{\left[\frac{\sigma_x + \sigma_y}{2}\right]^2 + \tau_{xy}{}^2}$$

Minimum principal stress, σ_{p_2}

$$= \frac{\sigma_x + \sigma_y}{2} - \sqrt{\left[\frac{\sigma_x - \sigma_y}{2}\right]^2 + \tau_{xy}^2}$$

62. Write the formulae to calculate stresses when a point in a member subjected to direct stress in one direction. (Oct 1999)

Normal stress,

$$\sigma_n = \frac{\sigma}{2} - \frac{\sigma}{2}\cos 2\theta$$

$$\text{Shear stress, } \tau = \frac{\sigma}{2}\sin 2\theta$$

$$\text{Maximum shearstress, } \tau_{max} = \frac{\sigma}{2}$$

$$\text{Resultant stress, } \sigma_R = \sqrt{[\sigma_n^2 + \tau^2]}$$

63. A bar of cross sectional area 600 mm is subjected to a tensile load of 50 kN applied at each end. Determine the normal stress on a plane inclined at 30° to the direction of loading? (April 1999)

$$\sigma_x = \frac{P}{A} = \frac{50 \times 10^3}{600} = 83.33 \text{ N/mm}^2$$

$$\sigma_n = \frac{83.33}{2} - \frac{83.33}{2}\cos 60 = 20.92 \text{ N/mm}^2$$

$$\boxed{\sigma_n = \mathbf{20.92\ MPa.\ Ans}}$$

64. What is the radius of Mohr's circle? (April 1996)(Oct 1998)

Radius of Mohr's circle is equal to the maximum shear stress.

65. Give the expression for maximum shear stress in a two dimensional stress system. (April 1996)(April 1997)(Oct1998)

$$\text{Maximum shear stress, } \tau_{max} = \sqrt{\left[\frac{\sigma_x - \sigma_y}{2}\right]^2 + \tau_{xy}^2}$$

UNIT – II

TRANSVERSE LOADING ON BEAMS AND STRESSES IN BEAM

1. **Write down any four types of beams.** (Oct 2002)(Dec 2011)(May 2009)(May 2010)(Dec2011)(May 2012)(May2013)
   1. Cantilever beam
   2. Simply supported beam
   3. Fixed beam
   4. Continuous beam
   5. Over hanging beam

2. **Define point of contra flexure.** (April 1996)(Oct 1997)(Oct1998)(Oct 1999) (Oct 2001)(Nov 2001)(May 2008)(May 2011)(May 2012) (May 2013)
   Point at which Bending Moment (BM) changes to zero is point of contra flexure. It occurs inoverhanging beam.

3. **What is bending moment in a beam?** (Oct 1995)(Oct 1995)(Oct 1997)(Oct1999)(May 2002) (May 2000)(Dec2003)(Dec2009) (Dec20 12)
   Bending Moment (BM)at any cross section is defined as algebraic sum of the moments of all the forceswhich are placed either side from that point.

4. **Write the relationship between bending moment and shear force.**
   (April 1997)(April 2001)(May 2012)
   The rate of change of Bending Moment (BM)is equal to the shear force (SF) at that section.

$$\frac{dM}{dx} = -F$$

5. **A cantilever beam of length 6 m carries a uniformly distributed load of 3 kN/m over its entire length; draw shear force and bending moment diagram.**
   (May 2011)
   Shear force

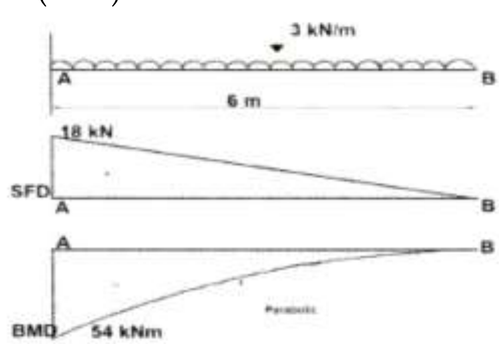
$F_B = 0$ kN

$F_A = 3 \times 6 = +18$ kN

Bending moment

$M_B = 0$ kN

$M_A = -(3 \times 6) \times 3 = -54$ kNm



6. **Derive the relationship between shear force and bending moment in a simply supported beam carrying UDL over entire span.** (Dec 2010)
The reaction at the support, A

$$R_A = R_B = \frac{wl}{2} = \mathbf{0.5wl}$$

Shear force at any section X at a distance x from A,

$$F_X = \mathbf{0.5wl - wx}$$

Bending moment at any section at a distance x from A,

$$M_X = R_A x - \frac{wx^2}{2} = \frac{wl}{2}x - \frac{wx^2}{2}$$

7. **What is the-maximum bending moment for a simply supported beam of span 'l' subjected to UDL of 'w' over entire span? Where it occurs?**
(April 1996)(May2010)

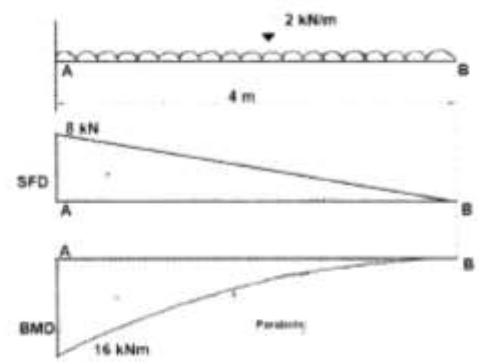
$$\boxed{\mathbf{M_{max}} = \frac{\mathbf{wl^2}}{\mathbf{8}}}$$

It occurs at the middle of the beam.

8. **What is shear force in a beam?** (Oct 1995)(Oct 1995)(Oct 1997)(Oct 1999)
(May 2000)(May2002)(Dec2003)(Dec2009)
SF at any cross section is defined as algebraic sum of all the forces acting either side of beam.

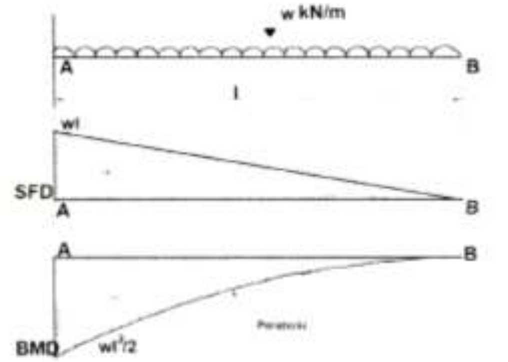
9. **Draw the shear force and bending moment diagram for a cantilever of span 4 m carrying a uniformly distributed load of 2 *kN/m* over the entire span.** (Dec2008)

Shear force:
$F_B = 0$ kN
$F_A = 2 \times 4 = +8$ kN

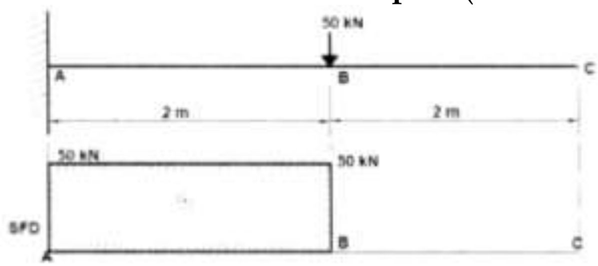


Bending moment
$M_B = 0$ kN
$M_A = -(2 \times 4) \times 2 = -16$ kNm

10. Sketch the bending moment diagram of a cantilever beam subjected to udl over the entire span. (Dec 2007)



11. Draw the shear force diagram for a cantilever beam of span 4 m and carrying a point load of 50 kN at mid span. (Dec 2006)



12. A cantilever beam of 3 m long carries a load of 20 kN at its free end. Calculate the shear force and bending moment at a section 2 m from the free end. (May 2006)

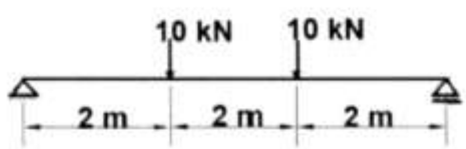
Shear force at any section X at a distance 2 m from free end A,

F_B = **20KN**

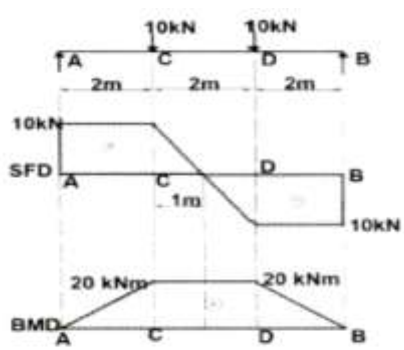
Bending moment at any section at a distance 2 m from free end A,

M_B= - 20 x 2 = **- 40kNm**

13. Draw shear force and bending moment diagram for the beam shown in figure.



(May 2004)



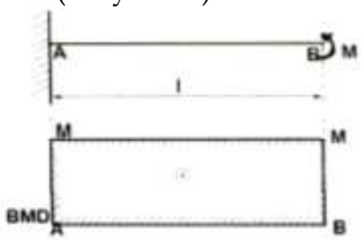
14. When is bending moment maximum?

BM will be maximum when shear force change its sign.

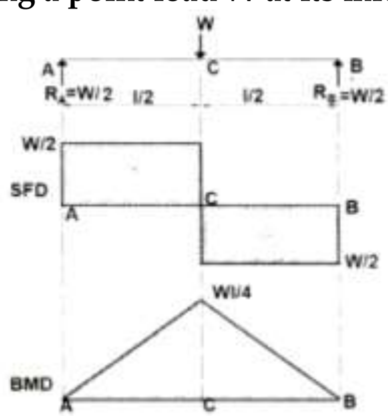
15. What is a point of inflexion? (May 2003)
The point where the bending moment is zero is called point of contra flexure or point of inflexion.

16. What is shear force and bending moment diagram? (April 1996)(April 1997) (May 2002)
The diagrams which show the variation of the shear force and bending moment along the length of the beam are called SF and BM diagrams.

17. Draw BMD for cantilever beam subjected to an anticlockwise moment at its free end. (May 2002)



18. Draw the S.F and B.M diagram for a simply supported beam of length 'l' carrying a point load W at its mid point. (Nov 2000)(Oct 2001)



19. Define beam? (Nov 2001)
BEAM is a structural member which is supported along the length and subjected toexternal loads acting transversely (i.e) perpendicular to the center line of the beam.

20. Calculate the BM at the fixed end of a cantilever beam subjected to a point load of 10 kN at 3 m from fixed end. (Oct 1999)

$$M_A = -10 \times 3$$
$$\boxed{M_A = -30 \text{ kNm. Ans}}$$

21. A cantilever beam of a pan 6 m is subjected to a point load of 10 kN at the free end. What is the maximum bending moment? (Oct 1998)
The maximum bending moment occurs at the fixed support.

$$M_{Max} = -10 \times 6$$
$$\boxed{M_{max} = -60 \text{ kNm. Ans}}$$

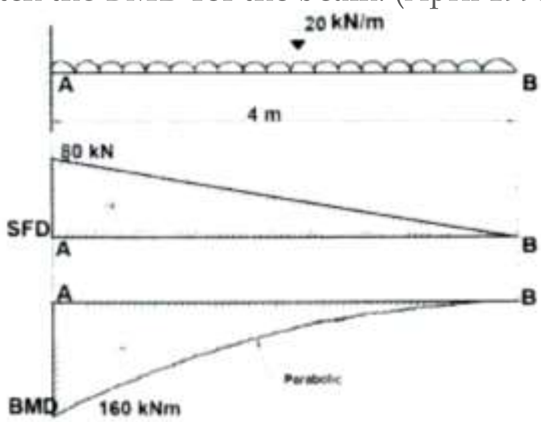
22. A simply supported beam AB of span 6 m is subjected to a udl of 10 *kN/m* over the entire span. What is the maximum bending moment? (Oct 1998)

The maximum bending moment occurs at the mid point.

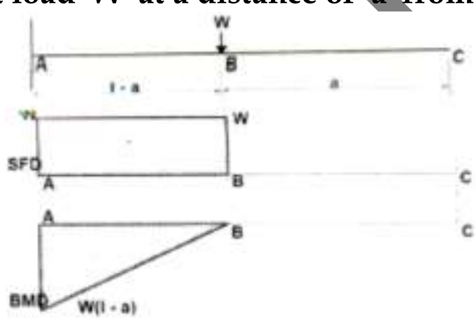
$$M_{max} = \frac{10 \times 6}{2} \times 3 - (10 \times 3) \times 1.5$$

$$\boxed{M_{max} = 45 \text{ kNm. Ans}}$$

23. A cantilever beam 4 m is subjected to a *udl*of 20 *kN/m* over its entire length. Sketch the BMD for the beam. (April 1998)



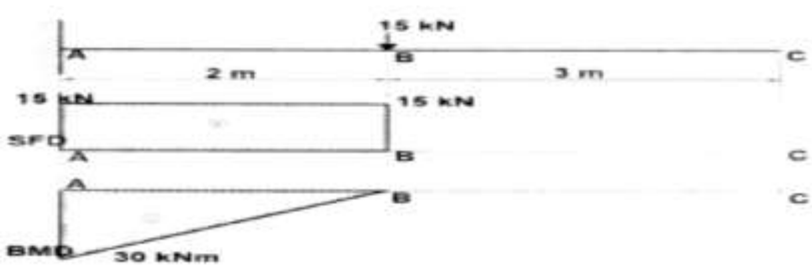
24. Draw the SF and BM diagram for a cantilever beam of span 'l' carrying apoint load 'W' at a distance of 'a' from free end. (Nov 1996)



25. In a simply supported beam how will you locate point of maximum bending moment? (Oct 1996)

The bending moment is maximum when SF is zero. Write SF equation at that point and equating to zero we can find out the distances 'x' from one end .then find maximum bending moment at that point by taking all moment on right or left handside of beam.

26. A cantilever beam of length 5 m is acted upon by a concentrated load of 15 kN at 3 m from the free end. Calculate the SF and BM at the free end.(April 1995)

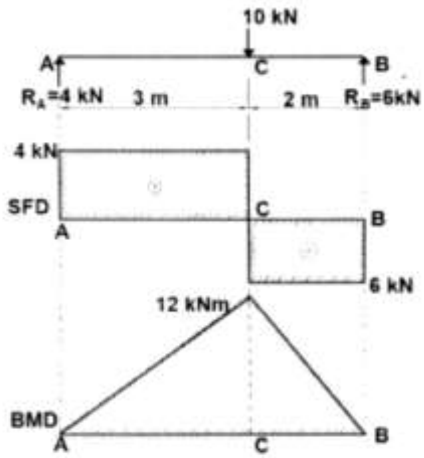


27. A cantilever beam of length 5 m is acted upon by a force couple moment of 100 kNm at the free end. What is the bending moment at the fixed end?(April 1995)

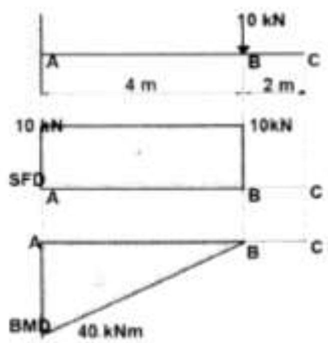
The bending moment at the fixed end,

$\boxed{M_A = -100 \text{ kNm. Ans}}$

28. A simply supported beam of 5 m span is subjected to a concentrated load of 10 kN at a distance of 3 m from the left support. Draw the bending moment diagram,



29. A cantilever beam of length 6 m is acted upon by a concentrated load of 10 kN at 2 m from the free end. Calculate the SF and BM at the free end.(April 1995)



The shear force at the free end C, Fc= 0

The bending moment at the free end C, Mc= 0

30. What are the types of loads?

1. Concentrated load or point load
2. Uniform distributed load
3. Uniform varying load

31. State the assumptions made in the theory of simple bending. (Nov 1996)(Oct 1997) (May 2007) (Dec2008)((Dec 2010) (May2011) (Dec 2011) (May 2012) (May 2013)

Assumptions made in the theory of simple bending:

1. The material is perfectly homogeneous and isotropic.
2. The value of Young's modulus is same in tension as well as in compression.

3. Transverse section which was plane before bending remains plane after bending.
4. The radius of curvature of the beam is very large compared to the cross sectionaldimension of the beam.
5. Each layer of the beam is free to expand or contract, independently of the layer,above or below it.
6. The resultant force on a transverse section of the beam is zero.

32. What is meant by neutral axis of a beam? (Dec2012)

It is the axis or layer of the beam where the bending stress is zero.

33. What is meant by section modulus? (Oct I997)(May 2012)

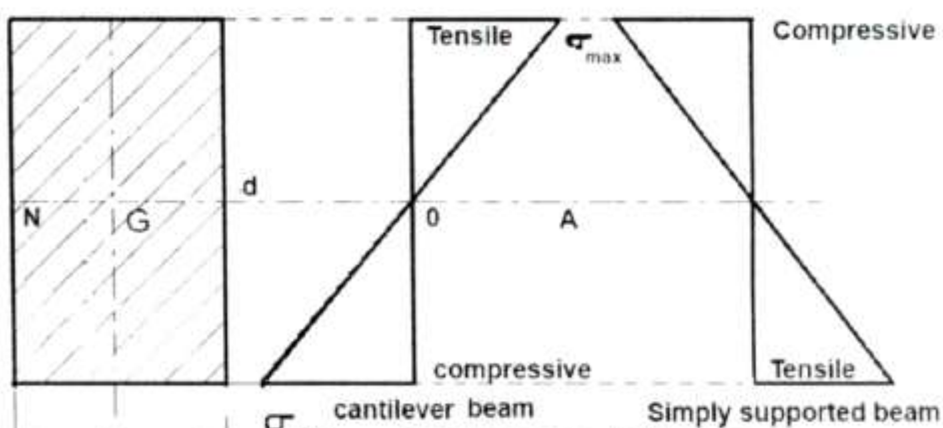
It is the ratio of moment of inertia of the section to the distance of the extreme layer from the neutral axis.

34. Write the theory of simple bending equation?

$$\boxed{\frac{M}{I} = \frac{\sigma}{Y} = \frac{E}{R}}$$

M - Maximum bending moment
I - Moment of inertia
F - Maximum stress induced
Y - Distance from the neutral axis
E - Young's modulus
R - Radius of Curvature

35. Sketch the bending stress distribution diagrams for the cantilever and simply supported beams of rectangular cross section under uniform loading.(May 2008) (May 2011)



Bending stress distribution

36. Write down the relation for maximum shear force and bending moment in case of a cantilever beam subjected to uniformly distributed load running over its entire span. (May 2007)

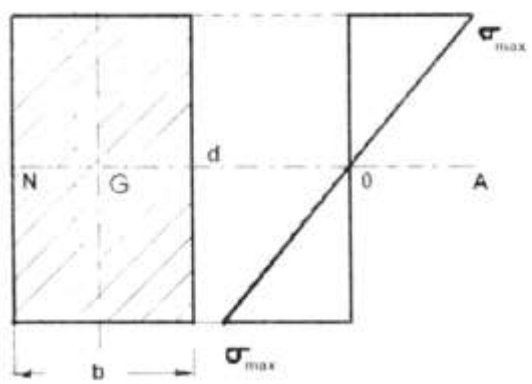
Maximum shear force,

$$\boxed{F_{max} = wl. \text{ Ans}}$$

Maximum bending moment,

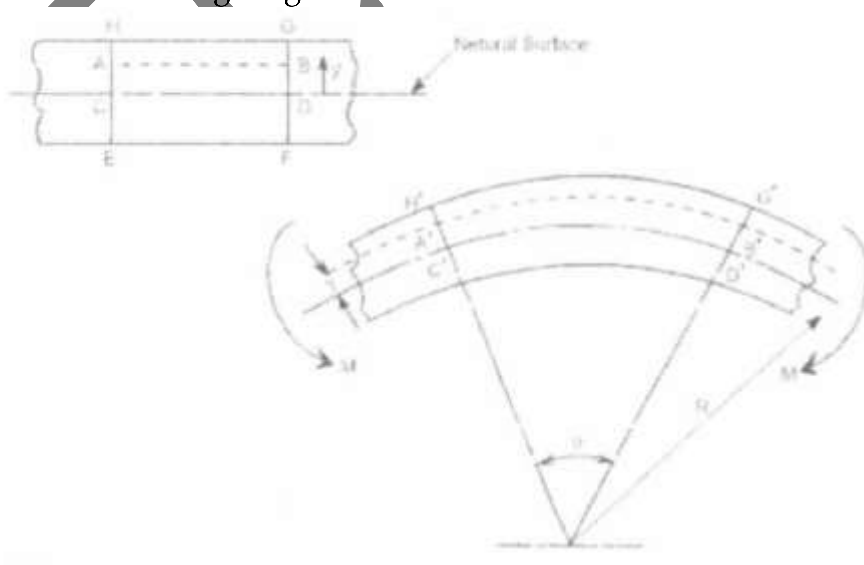
$$\boxed{M_{max} = \frac{wl^2}{2}. \text{ Ans}}$$

37. Sketch bending stress distribution for a beam of rectangular cross section. (Oct 2001) (May 2006)(Dec2006)



38. State the theory of simple bending. (April 1996)(Oct 1996)(May 2003)

When a beam is subjected to bending load, the bottom most layer is subjected to tensile stress and top most layer is subjected to compressive stress. The neutrallayer is subjected to neither compressive stress nor tensile stress. The stress at apoint in the section of the beam is directly proportional to its distance from theneutral axis.This isdepicted in the following diagram.



39. Calculate the sectional modulus of a circular section of diameter 200 mm. (Oct 2002)

Section modulus,

$$Z = \frac{I}{y} = \left(\frac{\pi}{64}d^4\right) \times \left(\frac{2}{d}\right) = \frac{\pi}{32}d^3 = \frac{\pi}{32} \times 200^3$$

$$\boxed{Z = 785.4 \times 10^3 \text{ mm}^3. \text{ Ans}}$$

40. Find the section modulus of a circular section of diameter 30 mm (April 1999)

Section modulus for a circular section,

$$Z = \frac{I}{y} = \frac{\pi}{64} \times d^4 \times \frac{2}{d} = \frac{\pi}{32}d^3 = \frac{\pi}{32} \times 30^3$$

$$\boxed{Z = 2650.7 \text{ mm}^3. \text{ Ans}}$$

41. A beam subjected to a bending stress of 5 *N/mm*2 and the section modulus is 3530 cm³. What is the moment of resistance of the beam? (Oct 1998)

$\sigma_b = 5 \text{ N/mm}^2$

$Z = \frac{I}{y} = 3530 \text{ cm}^3 = 3530 \times 10^3 \text{ mm}^3$

We know that the bending equation,

$$\boxed{\frac{M}{I} = \frac{\sigma}{Y} = \frac{E}{R}}$$

The moment of resistance

$$M = \frac{I}{y} \times \sigma_b = 3530 \times 10^3 \times 5 = 17.65 \times 10^6 \text{ N} - \text{mm}$$

$$\boxed{M_{max} = 17.65 \text{ k N} - \text{m}. \text{ Ans}}$$

42. What is the section modulus for a circular and hollow circular section? (Oct 1998)

Section modulus for a circular section,

$$Z = \frac{I}{y} = \frac{\pi}{64} \times d^4 \times \frac{2}{d}$$

$$\boxed{Z = \frac{\pi}{32}d^3. \text{ Ans}}$$

Section modulus for a hollow circular section,

$$Z = \frac{I}{y} = \frac{\pi}{64} \times [D^4 - d^4] \times \frac{2}{D}$$

$$\boxed{Z = \frac{\pi}{32}\left[\frac{D^4 - d^4}{D}\right]. \text{ Ans}}$$

43. Is bending stress a direct stress or shear stress?(Oct 1995)

Direct stress.

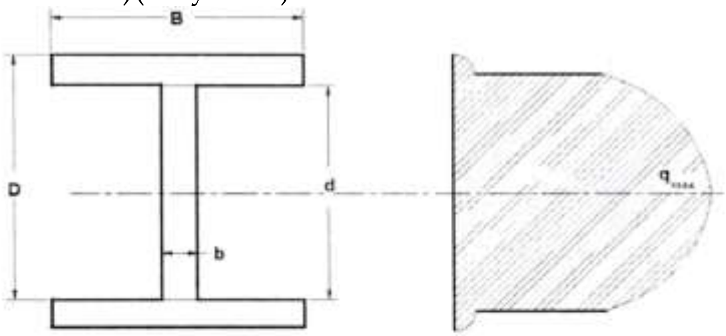
44. Define shear center. (Dec 2010) (Dec 2011)(May2013)

It is the point of intersection of the bending axis and the plane of transverse section. It is also known as center of twist.

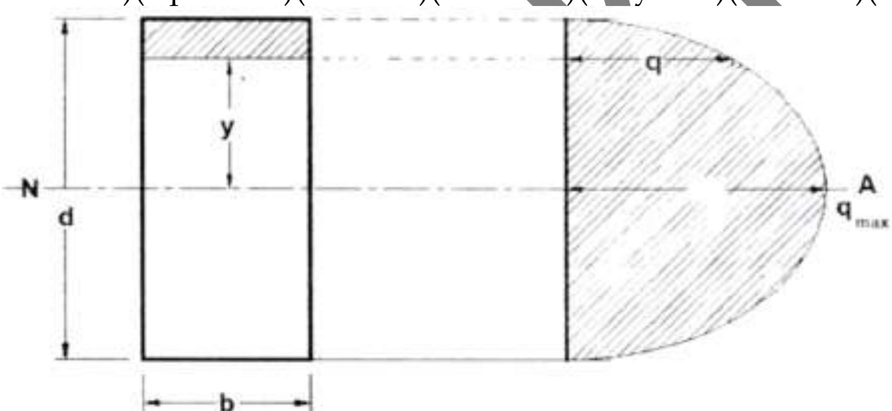
45. What is meant by shear flow? (Dec2010) (May 2013)

Shear flow is defined as the gradient of stress through the body.

46. Draw the shear stress distribution diagram for an I - section. (Nov 2001) (Dec 2011)(May 2013)



47. Draw the shear stress distribution diagram for a rectangular section. (April 1996) (Nov1996)(April1998)(Oct2001)(Nov2001)(May2006)(Dec2006)(Dec2011)(May2013)



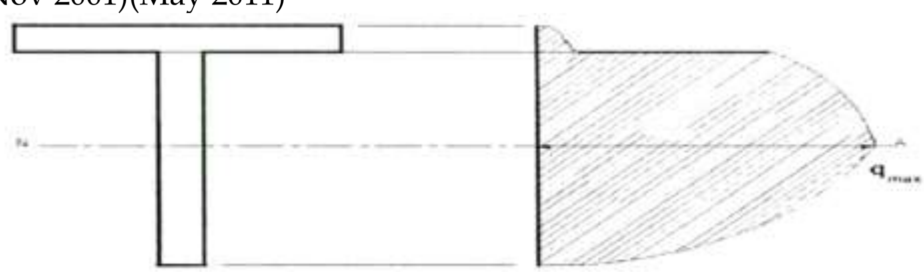
The shear stress distribution rectangular section is parabolic and is given by

$$q = \frac{F}{2I}\left[\frac{d^2}{4} - y^2\right]$$

d = Depth of the beam

y = Distance of the fiber from NA

48. Sketch the shear stress distribution diagram for a T - section. (Nov 2001)(May 2011)



49. Define shear stress. (May 2010)

The stress produced in a beam, which is subjected to shear force is known as shear stress.

50. A rectangular beam 150 mm wide and 200 mm deep is subjected to a shear force of 40 kN.Determine the average shear stress and maximum shear stress. (Dec 2008)

Average shear stress,

$$q_{av} = \frac{F}{A} = \frac{40 \times 10^3}{150 \times 200} = 1.33 \text{ N/mm}^2 = \mathbf{1.33\ MPa}$$

Maximum shear stress,

$$q_{max} = 1.5 q_{av} = 1.5 \times 1.33 \text{ N/mm}^2 = \mathbf{2\ MPa}$$

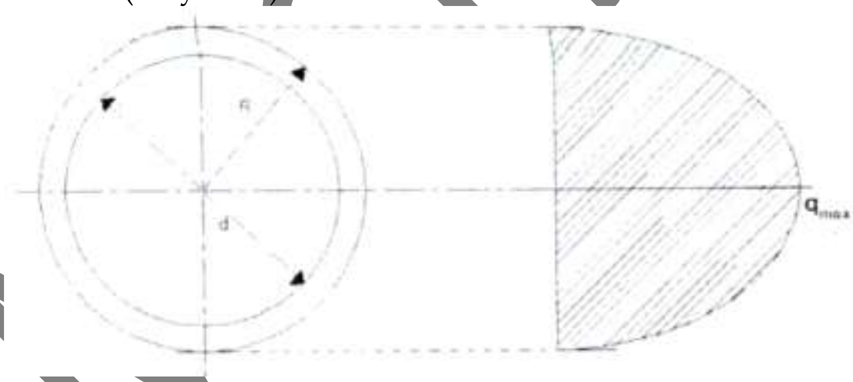
51. State the relationship between the average shear stress and maximum shear stress in a rectangular beam. (Dec 2003)

$$q_{max} = 1.5 \text{ X } \frac{F}{bd} = 1.5\, \tau_{av}$$

52. What is the ratio of maximum shear stress to the average shear stress for the rectangular section? (Dec2003)

q_{max} is 1.5 times the Q_{avg}.

53. Sketch the shear stress distribution in a beam made of hollow circular section. (May 2002)



54. Write down the expression for shear. stress distribution in a beam subjected to shear force F. (Oct 1998)

$$\text{Shear stress, } \tau = F \times \frac{A\bar{y}}{Ib}$$

55. What is the value of maximum shear stress in a rectangular cross section? (April 1996)

$$\tau_{max} = 1.5 \times \frac{F}{bd}$$

56. What arc the different sections in which the shear stress distribution is to be obtained?

- Rectangular section
- Circular section
- I- section
- T- section
- Miscellaneous section

57. Define: Shear stress distribution

The variation of shear stress along the depth of the beam is called shear stress distribution.

58. State the main assumptions while deriving the general formula for shear stresses.

The material is homogeneous, isotropic and elastic.
The modulus of elasticity in tension and compression are same. The shear stress is constant along the beam width.
The presence of shear stress does not affect the distribution of bending stress.

59. What is the shear stress distribution value of Flange portion of the I-section?

$$q = \frac{F}{2I}\left[\frac{D^2}{4} - y^2\right]$$

D-depth
y- distance from neutral axis

60. What is the shear stress distribution for I-section?

The shear stress distribution l-section is parabolic, but at the junction of web and flange, the shear stress changes abruptly. It changes from

$$\frac{F}{8I}[D^2 - d^2]$$

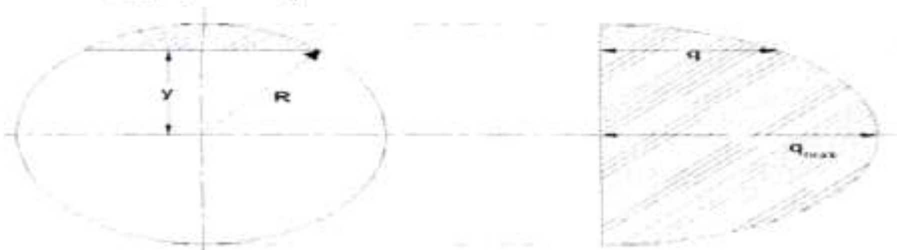
To

$$\frac{B}{b} \times \frac{F}{8I}[D^2 - d^2]$$

where
d = Depth of the web & b = Thickness of web
B = Over all width of the section.

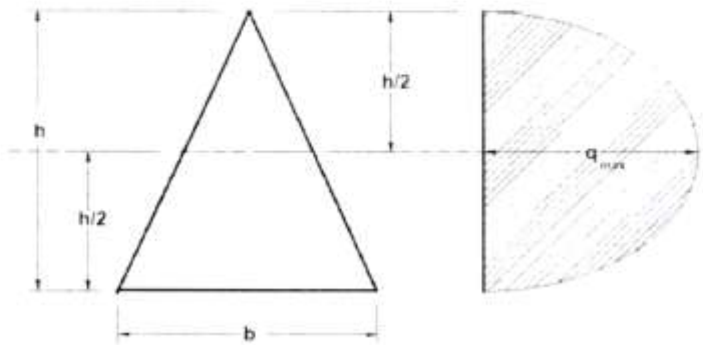
61. What is the shear stress distribution for circular section?

$$q = \frac{F}{3I}\left[\frac{R^2}{4} - y^2\right]$$



62. How will you obtained shear stress distribution for unsymmetrical section?
The shear stress distribution for unsymmetrical sections is obtained after calculating the position of NA.

63. Draw the shear stress distribution in the case of triangular section where the maximum shear stress occurs.

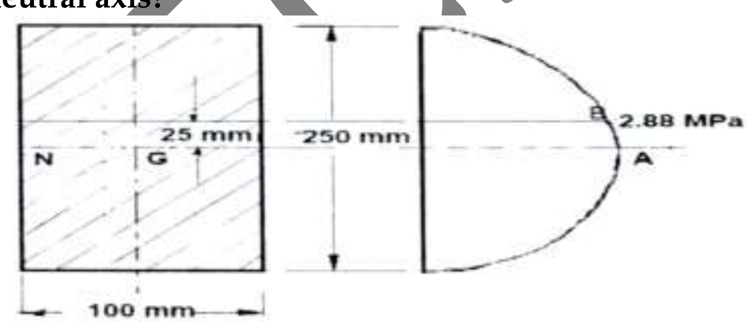


64. What is the formula to find a shear stress at a fiber in a section of a beam?
The shear stress at a fiber in a section of a beam is given by

$$\mathbf{q = \frac{F \times A\bar{y}}{I \times b}}$$

F = shear force acting at a section
A = Area of the section above the fiber
y = Distance of C G of the Area A from Neutral axis
I =Moment of Inertia of whole section about A
b = Actual width at the fiber

65. A rectangular beam 100 mm wide and 250 mm deep is subjected to a maximum shear force of 50 kN. What is the shear stress at a distance of 25 mmabove the neutral axis?



Shear stress,

$$\mathbf{q = F \times \frac{A\bar{y}}{Ib}}$$

$$= 50 \times 10^3 \times \frac{(100 \times 100) \times 75}{\left(\frac{100 \times 250^3}{12}\right) \times 100} = 2.88\ \text{N/mm}^2 = \mathbf{2.88\ MPa}$$

UNIT- III
TORSION AND SPRINGS

1. **List the loads normally acting on a shaft.** (Dec **2011**)(May20 13)
   Bending load.
   Torsional load or twisting load.
   Axial thrust.

2. **Write down the expression for the power transmitted by a shaft.** (Oct 2001) (May 2007) (May 2012)(May 2013)

   $$\boxed{P = \frac{2\pi NT}{60}}$$

   Where
   N-speed in rpm
   T- Torque in N-m
   P - Power transmitted in watts.

3. **Compute the torsional rigidity of a 100 mm diameter, 4 m length shaft G =** ***80kN/mm2.***(May 2013)
   Torsional rigidity,

   $$GJ = 80 \times 10^3 \times \frac{\pi}{32} \times 100^4$$

   $$\boxed{GJ = 7.854 \times 10^{11}\ N - mm^2.\ Ans}$$

4. **Write the polar modulus value of a rectangle.** (Dec2003)(May 2009)(May20 13)
   It is the ratio between the polar moment of inertia and distance of extreme layer of the shaft from neutral axis ..

   $$Z_p = \frac{\text{Polar moment of inertia}}{y} = \frac{J}{y} = \frac{I_{XX} + I_{YY}}{d/2} = \frac{\frac{bd^3}{12} + \frac{db^3}{12}}{d/2}$$

   $$\boxed{Z_p = \frac{bd^2 + b^3}{6}.\ \ Ans}$$

5. **Give torsion formula.** (May 2009)(Dec2011)(May2013)

   $$\boxed{\frac{T}{J} = \frac{G\theta}{l} = \frac{\tau}{R}}$$

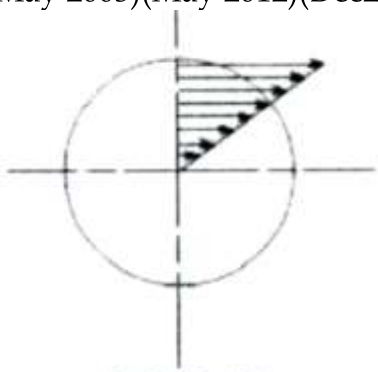
   T-Torque
   J- Polar moment of inertia
   G-Modulus of rigidity
   θ - angle of twist
   L- Length
   T- Shear stress
   R- Radius

6. **Define torsional rigidity** (Oct 2001) (May 2007)(May 2012)(May 2013)
Product of rigidity modulus and polar moment of inertia is called torsional rigidity

$$\boxed{\textbf{Torsional rigidity} = JG}$$

Where,
J = Polar moment of inertia.
G = Modulus of rigidity.

7. **Sketch the shear** stress **distribution on a solid circular shaft due to torsion.** (May 2003)(May 2012)(Dec2012)



(Solid Shaft)

8. **Define Torque.** (May 2011)
When a pair of forces of equal magnitude but opposite directions acting on body, it tends to twist the body. It is known as twisting moment or torsion moment or simplyas torque.Torque is equal to the product of the force applied and the distance between thepoint of application of the force and the axis of the shaft.

9. **A solid shaft is subjected to a torque 15 kN-m. Find the minimum diameter required for the shaft if the permissible shear stress is limited to 60 *N/mm2*.**(May 2011)

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

$$15 \times 10^6 = \frac{\pi}{16} \times 60 \times d^3$$

$$d = (1.273 \times 10^6)^{\frac{1}{3}}$$

$$\boxed{\mathbf{d = 108\ mm.\ Ans}}$$

10. **What is composite shaft?**
Sometimes a shaft is made up of composite section i.e. one type of shaft is sleeved over other types of shaft. At the time of sleeving, the two shafts are joined together, that the composite shaft behaves like a single shaft.

11. Find the expression for polar modulus for a solid and hollow shaft. (Dec 2010)

$$(Z_P)_{Solid} = \frac{J_S}{y} = \frac{\frac{\pi}{32} \times d^4}{\frac{d}{2}} = \frac{\pi}{16} d^3$$

$$\boxed{(Z_P)_{Solid} = \frac{\pi}{16} d^3.\ \textbf{Ans}}$$

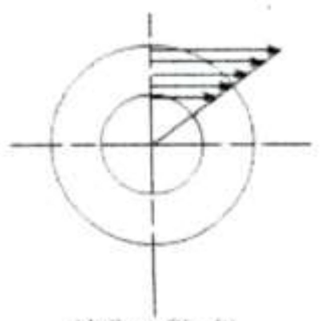
$$(Z_P)_{Hollow} = \frac{J_H}{y} = \frac{\frac{\pi}{32} \times [D_H^4 - d_H^4]}{\frac{D_H}{2}} = \frac{\pi}{16} \times \frac{[D_H^4 - d_H^4]}{D_H}$$

$$\boxed{(Z_P)_{Hollow} = \frac{\pi}{16} \times \frac{[D_H^4 - d_H^4]}{D_H}.\ \textbf{Ans}}$$

12. What do you mean by strength of a shaft? (Dec 2010)
The maximum torque that a shaft can transmit is called strength of the shaft.

13. What do you mean by the term shear flow? (Dec 2010)
It is defined as the gradient of shear stress through the body.

14. Sketch the variation of shear stress due to torsion in a hollow circular shaft. (Dec 2010)



(Hollow Shaft)

15. Determine the maximum torque developed in a shaft transmitting a power of 100 kW running at 150 rpm. The maximum torque is 20 % more than the mean torque. (Dec 2010)

$$100 \times 10^3 = \frac{2\pi \times 150 \times T_{mean}}{60}$$

$$T_{mean} = 6.366 \times 10^3\ N - m = 6.366\ kN - m$$

$$T_{max} = 1.2 \times 6.366\ kN - m$$

$$\boxed{T_{max} = 7.64\ k\,N - m}$$

16. A solid shaft of 150 mm diameter is used to transmit torque. Find the maximum torque transmitted by the shaft if the maximum shear stress induced to the shaft is 45 *N/mm2*. (May 2010)

$$T = \frac{\pi}{16} \times \tau \times d^3 = \frac{\pi}{16} \times 45 \times 150^3 = 29.82 \times 10^6 N - mm$$

$$\boxed{T_{max} = 23.873k\ N - m}$$

17. State any four assumptions involved in simple theory of torsion.
(Oct 2002)(Dec2009)(Dec2010)

1. The material of the shaft is homogeneous, perfectly elastic and obeys Hooke's law.
2. Twist is uniform along the length of the shaft
3. The stress does not exceed the limit of proportionality
4. The shaft circular in section remains circular after loading
5. Strain and deformations are small.

18. What is the maximum shear stress produced in a bolt diameter 20 mm when it is tightened by a spanner which exerts a force of 50 N with a radius of action of 150 mm? . (Dec 2008)

$$\text{Shearstress} = \frac{\text{Turning force}}{\text{Area}}$$

$$= \frac{50}{\frac{\pi}{4} \times 20^2} = 0.16\ N/mm^2$$

$$= \mathbf{0.16\ MPa\ \ Ans}$$

19. Define polar modulus or torsional section modulus of a section. (May 2008)
It is the ratio between polar moment of inertia and radius of the shaft.

$$\boxed{Z_p = \frac{J}{R}}$$

Where

Z_P = Polar Modulus

J = polar moment of inertia = J

R = Radius of the shaft

20. What is polar modulus value for a hollow circular section of 100 mm external diameter 40 mm internal diameter? (May 2008)

$$(Z_P)_{Hollow} = \frac{J_H}{y} = \frac{\frac{\pi}{32} \times [D_H{}^4 - d_H{}^4]}{\frac{D_H}{2}} = \frac{\pi}{16} \times \frac{[D_H{}^4 - d_H{}^4]}{D_H}$$

$$= \frac{\pi}{16} \times \frac{[100^4 - 40^4]}{100}$$

$$\boxed{(Z_P)_{Hollow} = \mathbf{191.323 \times 10^3\ mm^3.\ Ans}}$$

21. Express the strength of a solid shaft. (Dec 2007)

Strength of a solid shaft,

$$\boxed{T = \frac{\pi}{16} \times \tau \times d^3.\ \text{Ans}}$$

22. Find the minimum diameter of the shaft required to transmit a torque of 29820 Nm if the maximum shear stress is not to exceed 45 *N/mm2*.(Dec 2006)

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

$$29820 \times 10^3 = \frac{\pi}{16} \times 45 \times d^3$$

$$\boxed{d = 150\ \text{mm. Ans}}$$

23. Find the torque which a shaft of 50 mm diameter can transmit safely, if the allowable shear stress is 75 *N/mm2*.(May 2006)

$$T = \frac{\pi}{16} \times \tau \times d^3 = \frac{\pi}{16} \times 75 \times 50^3 = 1.84 \times 10^6\ \text{N} - \text{mm}$$

$$\boxed{T = 1.84\ \text{kN} - \text{m. Ans}}$$

24. Calculate the maximum torque that a shaft of 125 mm diameter can transmit, if the maximum angle of twist is 1° in a length of 1.5 m. Take G = 70 x10^3N/mm2. (May 2005)

$$\frac{T}{J} = \frac{G\theta}{l}$$

$$T = \frac{G\theta}{l} \times J = \frac{70 \times 10^3 \times 1 \times \frac{\pi}{180}}{1500} \times \frac{\pi}{32} \times 125^4$$

$$= 19.52 \times 10^6\ \text{N} - \text{mm}$$

$$\boxed{T = 19.52\ \text{kN} - \text{m. Ans}}$$

25. Write down the expression for torque transmitted by hollow shaft.

$$\boxed{T = \frac{\pi}{16} \times \tau \times \left[\frac{D^4 - d^4}{D}\right]}$$

Where

T- Torque transmitted
T- Shear stress
D- Outer diameter
d- Inner diameter

26. Define section modulus and what is its value for a circular section of diameter d? (May 2003)(May2005)

It is the ratio of moment of inertia of the section and the distance of extreme layer from the neutral axis.

$$Z = \frac{I}{y} = \frac{\frac{\pi}{64} \times d^4}{\frac{d}{2}} = \frac{\pi}{32} \times d^3$$

$$\boxed{Z = \frac{\pi}{32} \times d^3. \text{ Ans}}$$

27. Find the torque, which a shaft of 250 mm diameter can safely transmit, if the shear stress is not to exceed 50 *N/mm2*. (May 2004)

$$T = \frac{\pi}{16} \times \tau \times d^3 = \frac{\pi}{16} \times 50 \times 250^3 = 153.4 \times 10^6 \text{ N} - \text{mm}$$

$$\boxed{T = 153.4 \text{ kN} - \text{m. Ans}}$$

28. A solid shaft of 100 mm diameter and 2 m length is subjected to an external torque 10 kN-m. Find the relative angle of twist between its extreme cross section. Assume the modulus of rigidity 80 *kN/mm2.* (May 2004)

$$\frac{T}{J} = \frac{G\theta}{l}$$

$$\theta = \frac{Tl}{JG} = \frac{10 \times 10^6 \times 2000}{\frac{\pi}{32} \times 100^4 \times 80 \times 10^3} = 0.0255 \text{ rad}$$

$$\boxed{\theta = 1.46}$$

29. What do you mean by torsional stiffness? (April 2001)

Torsional rigidity or stiffness of the shaft is defined as the product of modulus of rigidity G and polar moment of inertia of the shaft.

Torsional rigidity = GJ = T x (L/θ)

30. Why are hollow circular shafts preferred when compared to solid circular shafts?

• The torque transmitted by the hollow shaft is greater than the solid shaft

• For same material, length and given torque, the weight of the hollow shaft will Beless compared to solid shaft.

31. What do you mean by equivalent twisting moment? Give the relation.

(April 2001)

When a shaft is subjected to twisting and bending moment, the resultant twisting moment is called equivalent twisting moment. It is denoted by Te.

Equivalent twisting moment

$$\boxed{T_e = \sqrt{T^2 + M^2}}$$

32. Differentiate between dose coiled and open coiled helical spring **and** state the **type of stress induced in each spring due to an** axial load.(April 2001) May 2006) (May 2009)((May 2012)(May 2013)

The spring wires are coiled very closely, each turn is nearly at right gap between the two consecutive turns	The wires are coiled such that there is a angles to the axis of helix
Helix angle is less than 10°	Helix angle is large (> 10°)

33. What are the two types of shear stresses induced in a helical spring? (Dec2012)

1. Shear stress
2. Bending stress

34. What are the uses of leaf springs? (Dec2010)(May 2012)

1. They are used in railway wagons, coaches and road vehicles.
2. They are used to absorb shocks which give unpleasant feeling to the passenger.

35. State any two functions of springs. (April 2004)(Dec 2006) (Dec 2010)(Dec 201I)

1 To measure forces in spring balance, meters and engine indicators.

2 To store energy.

36. What is a leaf spring? (May 2011)

The laminated carriage springs are called leaf springs.

They are two types, namely (i) Semi-elliptical type and (ii) quarter-elliptical type

37. State the expression for maximum shear stress and deflection of close coiled helical spring when subjected to axial load **W.** (May 2007)(Dec2007) (May 2011)

Torque,

$$\boxed{T = W.R = \frac{\pi}{16} \times \tau \times d^3. \textbf{ Ans}}$$

Shear stress,

$$\boxed{\tau = \frac{16\, W.R}{\pi \times d^3}. \textbf{ Ans}}$$

Deflection of the spring

$$\boxed{\delta = \frac{64WR^3n}{Gd^4}. \textbf{ Ans}}$$

38. What is meant by stiffness of spring (Spring rate)? (May 2003)(Dec2009) (Dec 2010)

The spring stiffness or spring constant is defined as the load required per unit deflection of the spring.

$$k = \frac{W}{\delta}$$

Where

W -load
δ– Deflection

39. Define spring. (May 2010)

A spring is an elastic member, which deflects. or distorts under the action of load and regains its original shape after the load is removed.

40. What are the various types of springs?(May 2010)

- Helical springs
- Spiral springs
- Leaf springs
- Disc spring or Belleville springs.
-

41. A close coiled helical spring of 10 mm in diameter having 10 complete turns, with mean diameter 120 mm is subjected to an axial load of 200 N. Determine the maximum shear stress and stiffness of the spring. Take G = 9 x 10" *N/mm2*. (Dec 2008)

$$\text{Maximum shear stress, } \tau = \frac{16\,W.R}{\pi \times d^3} = \frac{16 \times 200 \times 60}{\pi \times 10^3} = 61.1 \ \text{N/mm}^2$$

$$\boxed{\tau_{max} = \mathbf{61.1\ MPa.\ Ans}}$$

Deflection of the spring.

$$\delta = \frac{64WR^3n}{Gd^4} = \frac{64 \times 200 \times 60^3 \times 10}{9 \times 10^4 \times 10^4}$$

$$\boxed{\delta = \mathbf{30.72\ mm.\ Ans}}$$

42. A close coiled helical spring is to carry an axial load of 500 N. Its mean coil diameter is to be 10 times its wire diameter. Calculate this diameter if the maximum shear stress in the material is to be 80 MPa. (May 2008)

$$\text{Maximum shear stress, } \tau = \frac{16\,W.R}{\pi \times d^3}$$

$$80 = \frac{16 \times 500 \times \left(\frac{10d}{2}\right)}{\pi \times d^3}$$

$$d = 12.6 \text{ mm say } 13 \text{ mm}$$

$$\boxed{\mathbf{d = 13\ mm.\ Ans}}$$

43. Write the expression for stiffness of a close coiled helical spring. (Dec 2006)

Stiffness of the spring,

$$\boxed{s = \frac{W}{\delta} = \frac{Gd^4}{64R^3n}. \text{ Ans}}$$

44. Write down the formula for deflection of an open coiled spring subjected to an axial load 'W'. (May 2005)

$$\boxed{\delta = \frac{64WR^3n\sec\alpha}{d^4}\left[\frac{\cos^2\alpha}{G} + \frac{2\sin^2\alpha}{E}\right]. \text{ Ans}}$$

45. Name the two important types of helical springs. (Oct2001)

1. Close - coiled or tension helical spring.
2. Open -coiled or compression helical spring.

46. What is spring index (C)?

The ratio of mean or pitch diameter to the diameter of wire for the spring is called the spring index.

47. What is solid length?

The length of a spring under the maximum compression is called its solid length. It is the product of total number of coils and the diameter of wire.

$Ls = n_t \times d$

Where,

n_t = total number of coils.

d = diameter of the coil of the spring

48. Define pitch.

Pitch of the spring is defined as the axial distance between the adjacent coils in uncompressed state.

Mathematically

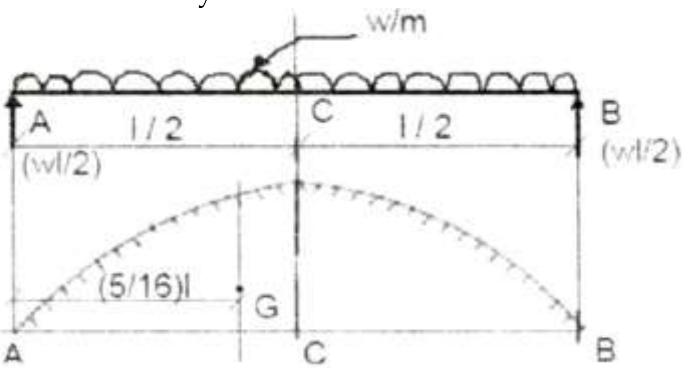
$$\text{Pitch} = \frac{\text{Free length}}{n-1}$$

49. Define helical springs.

The helical springs are made up of a wire coiled in the form of a helix and are primarily intended for compressive or tensile load.

Unit – IV
DEFLECTION OF BEAMS

1. **What is the maximum deflection of a simply supported beam subjected to Uniformly distributed load over the entire span? Where does it occur?**(May 2003) (May 2007)(Dec 2007) (May 2013)
   The maximum deflection occurs at mid-point.
   Itis calculated by area moment method:



Area of the BMD between A and C,

$$a = \frac{2}{3} \times b \times d = \frac{2}{3} \times \frac{l}{2} \times \frac{wl^2}{8} = \frac{\mathbf{w}\boldsymbol{l}^3}{\mathbf{24}}$$

Distance of centroid of the BMD between A and C from A

$$\bar{x} = \frac{5}{8} \times \frac{l}{2} = \frac{\mathbf{5}}{\mathbf{16}}\boldsymbol{l}$$

$$y_{max} = \frac{\text{Moment of the areaof BMD between A and C about A}}{EI}$$

$$y_{max} = \frac{1}{EI}[a\bar{x}] = \frac{1}{EI} \times \frac{wl^3}{24} \times \frac{5}{16}l$$

$$\boxed{y_{max} = \frac{5wl^3}{384EI}. \quad \text{Ans}}$$

2. **Write the relationship between intensity of load, shear force, bending moment, slope and deflection in a beam.** (Dec20 10) (Dec 2011)(May20 13)
   Deflection = Y

$$\text{Slope} = \frac{dy}{dx}$$

$$B.M = EI\frac{d^2y}{dx^2}$$

$$S.F = EI\frac{d^3y}{dx^3}$$

$$w = EI\frac{d^4y}{dx^4}$$

3. **Describe the double integration method.** (May 2013)

The bending moment at a point,

$$M = EI\frac{d^2y}{dx^2}$$

Integrating the above equation,

$$EI\frac{dy}{dx} = \int M$$

And integrating the above equation once again,

$$EI\,y = \iint M$$

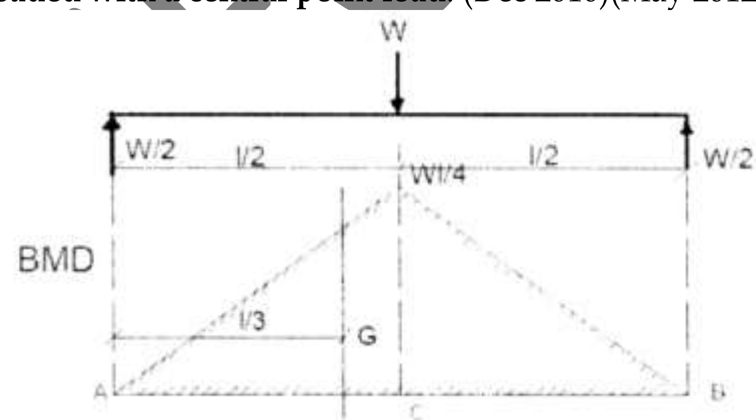
After first integration of the original differential equation, we get the value of slopeat any point. On further integration, we get the value of deflection at any point.While integrating twice the original differential equation, we will get two constantsC1and C2.The values of these constants may be found out by using the endconditions.

4. **Write down the boundary conditions for a cantilever beam to find out** the **equations for deflection and slope.** (Dec2012)

When $x = l$, $\quad \frac{dy}{dx} = 0$

When $x = l$, $\quad y = 0$

5. **Write down the equations for maximum deflection of a simply Supported beam loaded with a central point load**. (Dec 2010)(May 2012)



Area of the BMD between A and C,

$$a = \frac{1}{2} \times b \times d = \frac{1}{2} \times \frac{l}{2} \times \frac{Wl}{4} = \frac{Wl^2}{16}$$

Distance of centroid of the BMD between A and C from A

$$\bar{x} = \frac{2}{3} \times \frac{l}{2} = \frac{l}{3}$$

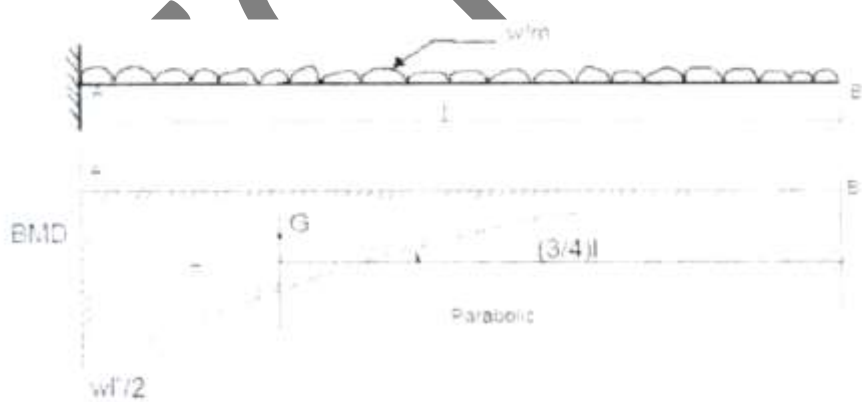
$$y_{max} = \frac{\text{Moment of the area of BMD between A and C about A}}{EI}$$

$$y_{max} = \frac{1}{EI}[a\bar{x}] = \frac{1}{EI} \times \frac{Wl^2}{16} \times \frac{l}{3}$$

$$\boxed{y_{max} = \frac{Wl^3}{48EI}. \quad \text{Ans}}$$

6. **How do you determine the maximum deflection in a simply supported beam**? (May 2012)
   The maximum deflection occurs where slope is zero. The position of the maximum deflection is found out by equating the slope equation zero. Then the value of x is substituted in the deflection equation to calculate the maximum deflection.

7. **State the expression for slope and deflection at the free end of a cantilever beam of length 'L' subjected to a uniformly distributed load of 'w' per unit length**. (Dec 2008)(Dec 2011)
   Slopeand deflections are calculated by area moment method.



Area of the BMD,

$$A = \frac{1}{3} \times l \times \frac{wl^2}{2} = \frac{wl^3}{6}$$

Distance of centroid of the BMD between A and B from B

$$\bar{x} = \frac{3}{4} \times l = \frac{3}{4}l$$

Slope of the cantilever beam at its free end,

$$i_B = \frac{\text{Area of the BMD between A and B}}{EI}$$

$$\boxed{i_B = \frac{wl^3}{6EI} \quad \textbf{Ans}}$$

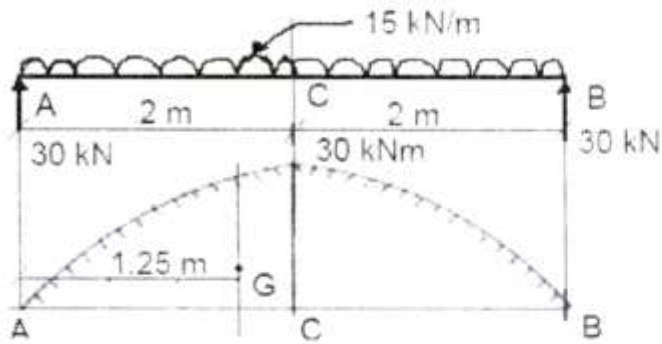
Deflection of the cantilever beam at its free end,

$$y_{max} = \frac{\text{Moment of area of the BMD between A and B about B}}{EI}$$

$$= \frac{1}{EI} \times a\bar{x} = \frac{1}{EI} \times \frac{wl^3}{6} \times \frac{3}{4}l$$

$$\boxed{y_{max} = \frac{wl^4}{8EI}. \quad \textbf{Ans}}$$

8. **A simply supported beam of length 4 meters carries a uniformly distributed load of 15 *kN/m* throughout its length. Determine the maximum deflection and slope in the beam. Take flexural rigidity El = 25000 kN m2**. (May 2011)
The maximum deflection occurs at mid-point.
It is calculated *by* area moment method:



$$y_{max} = \frac{\text{Moment of the area of BMD between A and C about A}}{EI}$$

Area of the BMD between A and C,

$$a = \frac{2}{3} \times b \times d = \frac{2}{3} \times 2 \times 30 = 40$$

Distance of centroid of the BMD between A and C from A

$$\bar{x} = \frac{5}{8} \times \frac{l}{2} = \frac{5}{8} \times 2 = 1.25$$

$$y_{max} = \frac{1}{EI}[a\bar{x}] = \frac{40 \times 1.25}{25000} = 0.002 \text{ m}$$

$$\boxed{y_{max} = 2 \text{ mm (downward)}. \quad \textbf{Ans}}$$

The maximum slope occurs at the supports.

$$i_A = \frac{\text{Area of BMD between A and C}}{\text{EI}} = \frac{40}{25000}$$

$$\boxed{i_A = \mathbf{0.0016\ rad\ \ (Clockwise).\ \ Ans}}$$

OR

Alternate method:

Double integration method:

$$y_{max} = \frac{5wl^4}{384EI} = \frac{5 \times 15 \times 4^4}{384 \times 25000} = 0.002\ m = \mathbf{2\ mm.\ Ans}$$

$$i_A = \frac{wl^3}{24EI} = \frac{15 \times 4^3}{24 \times 25000} = \mathbf{0.0016\ rad.\ Ans}$$

9. **To find slope and deflection of beams, which method is suitable for single load and which method is suitable for several loads**? (May 2011)
   Double integration method is suitable for beams with single load.
   Macaulays method, conjugate beam and area moment method are suitable for beams with single load.

10. **Determine the. slope of simply supported beam subjected to a point load at the center**. (Dec 2010)
   The BM at any section in AC at x from support A is given by

$$EI\frac{d^2y}{dx^2} = +\frac{W}{2}x \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(1)$$

Integrating once, we get

$$EI\frac{dy}{dx} = +\frac{Wx^2}{4} + C_1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Since the maximum deflection occurs at mid span C, the slope at C is zero.

At

$$x = \frac{l}{2}, \qquad \frac{dy}{dx} = 0$$

$$\frac{W}{4}\left(\frac{l}{2}\right)^2 + C_1 = 0$$

$$C_1 = -\frac{Wl^2}{16}$$

Substituting in (2),

$$EI\frac{dy}{dx} = \frac{Wx^2}{4} - \frac{Wl^2}{16} \ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

To find the slope at A, put x = 0 in (3)

$$EI.\,i_A = -\frac{Wl^2}{16}$$

$$\boxed{i_A = \frac{Wl^2}{16EI}\ (\textbf{Clockwise}).\quad \textbf{Ans}}$$

11. **State Mohr's theorems.** (April 2001) (Dec 2003)(May 2005)(Dec2010)
    Mohr's theorem I:
    The change of slope between any two points is equal to the net area of the bending moment diagram between these points divided by El.
    Mohr's theorem 11:
    The total deflection between any two points is equal to the moment of the area of the bending moment diagram between these two points about the reference line divided by El

12. What are the methods for finding out the slope and deflection at a section?
(Dec2010)
The important methods used for finding out the slope and deflection at a section in a loaded beam are
1. Double integration method
2. Moment area method
3. Macaulay's method

13. Write down the formula used to find the deflection of beam by Moment area method. (May 2010)
The change in deflection of the beam at between two sections,

$$= \frac{\text{Moment of the area of the BMD between these two points}}{\text{EI}}$$

14. Explain the theorem for conjugate beam method?
Theorem I : "The slope at any section of a loaded beam, relative to the original axis of the beam is equal to the shear in the conjugate beam at the corresponding section"
Theorem II: "The deflection at any given section of a loaded beam, relative to the original position is equal to the Bending moment at the corresponding section of the conjugate beam"

15. **What are the points to be worth for conjugate beam method**?
    This method can be directly used for simply supported beam
    In this method, for cantilevers and fixed beams, artificial constraints need to be supplied to the conjugate beam so that it is supported in a manner consistent with the constraints of the real beam.

16. Why is moment area method more useful, when compared with double integration?
Moment area method is more useful, as compared with double integration method because many problems which do not have a simple mathematical solution can be simplified by the ending moment area method.

17. State the relationship between slope, deflection, radius of curvature and bending moment. (Dec 2010)

Deflection. = y

$$\text{slope} = \frac{dy}{dx}$$

$$M = EI \times \frac{1}{R}$$

$$M = EI\frac{d^2y}{dx^2}$$

18. **What is deflection of a beam**? (Dec 2009)
Deflection is the vertical distance at a point between the elastic curve (deflected beam) to unloaded neutral axis (actualbeam)

19. **What is slope of a beam?** (Dcc2009)
Slope or a beam is the angle between detected beam to the actual beam at the same point.

20. A steel joist, simply supported over a span of 6 m carries a point load of 50 k at 1.2 m from the left end support. Find the position and the magnitude of the maximum deflection. Take El = 14 x 1012 N-mm2 (Dec 2009)

$l = 6$ m
$a = 1.2$ m
$b = 4.8$ m
$W = 50$ kN
$EI = 14 \times 10^{12}\ N - mm^2 = 14 \times 10^3\ kNm^2$
Position of the maximum deflection.

$$x = \sqrt{\left(\frac{l^2 - a^2}{3}\right)} \quad \text{when a} < \text{b}$$

$$= \sqrt{\left(\frac{6^2 - 1.2^2}{3}\right)} = \mathbf{1.96\ m} \text{ from the left support}$$

$$y_{max} = \frac{Wa}{9\sqrt{3}EIl}[l^2 - a^2]^{\frac{3}{2}} = \frac{50 \times 1.2}{9\sqrt{3} \times 14 \times 10^3 \times 6}[6^2 - 1.2^2]^{\frac{3}{2}}$$

$$= \frac{12190.23}{1.3094 \times 10^6} = 9.31 \times 10^{-3}\ \text{m}$$

$$\boxed{\mathbf{y_{max} = 9.31\ mm\ (downward).\quad Ans}}$$

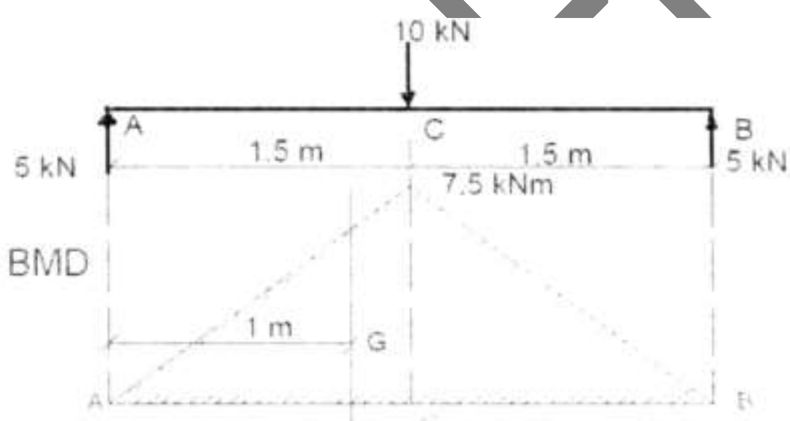
21. A simply supported beam of span 3 m is subjected to a central load of 10 kN. Find the maximum slope and deflection of the beam. Take I = 12 x 106 mm~ and E = 200 GPa. (Dec2009)

Area moment method:

$E = 200\ \text{GPa} = 200 \times 10^9\ \text{N/m}^2 = 200 \times 10^6\ \text{kN/m}^2$

$I = 12 \times 10^6\ \text{mm}^4 = 12 \times 10^{-6}\ \text{m}^4$

$EI = 200 \times 10^6 \times 12 \times 10^{-6} = 2400\ \text{kNm}^2$



$$y_{max} = \frac{\text{Moment of the area of BMD between A and C about A}}{EI}$$

Area of the BMD between A and C,

$$a = \frac{1}{2} \times b \times d = \frac{1}{2} \times 1.5 \times 7.5 = \mathbf{5.625}$$

Distance of centroid of the BMD between A and C from A

$$\bar{x} = \frac{2}{3} \times 1.5 = \mathbf{1m}$$

$$y_{max} = \frac{1}{EI} \times a\bar{x} = \frac{5.625 \times 1}{2400} = 0.00234 \text{ m}$$

$$\boxed{\mathbf{y_{max} = 2.34\ mm\ (downward).\quad Ans}}$$

Maximum slope occurs at supports
Slope at support A

$$i_A = \frac{\text{Area of BMD between A and C}}{EI} = \frac{a}{EI} = \frac{5.625}{2400}$$

$$\boxed{\mathbf{i_A = 0.00234\ rad.\quad Ans}}$$

OR

Alternate Method

Double integration method using formula:

$$y_{max} = \frac{Wl^3}{48EI} = \frac{10 \times 10^3 \times 3000^3}{48 \times 2.4 \times 10^{12}} = \mathbf{2.344\ mm\ \ Ans}$$

$$i_A = \frac{Wl^2}{16EI} = \frac{10 \times 10^3 \times 3000^2}{16 \times 2.4 \times 10^{12}} = \mathbf{0.00234\ rad.\ Ans}$$

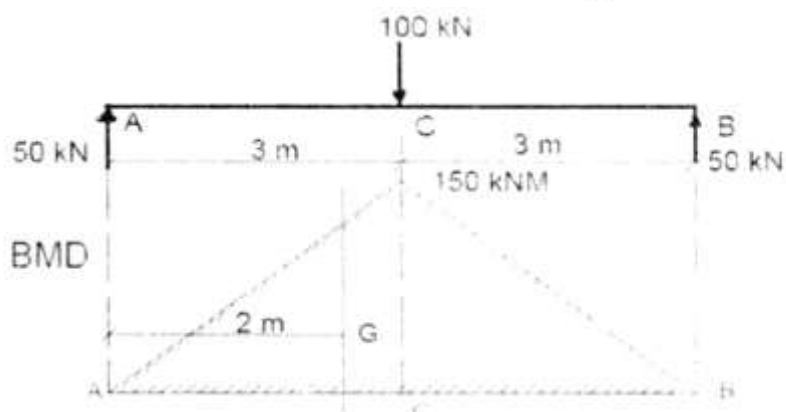
22. Calculate the maximum deflection of a simply supported beam carrying point load of 100 kN at mid span. Span = 6 m, EI = 20,000 kN/m2. (Dec 2010)
Area moment method:

$EI = 20000\ kNm^2$

Area of the BMD between A and C,

$$a = \frac{1}{2} \times b \times d = \frac{1}{2} \times 3 \times 150 = 225$$

$$y_{max} = \frac{\text{Moment of the area of BMD between A and C}}{EI}$$



Distance of centroid of the BMD between A and C from A

$$\bar{x} = \frac{2}{3} \times 3 = 2\text{m}$$

$$y_{max} = \frac{1}{EI} \times a\bar{x} = \frac{225 \times 2}{20000} = 0.0225 \text{ m}$$

$$\boxed{\mathbf{y_{max} = 22.5\ mm\ (downward).\quad Ans}}$$

OR

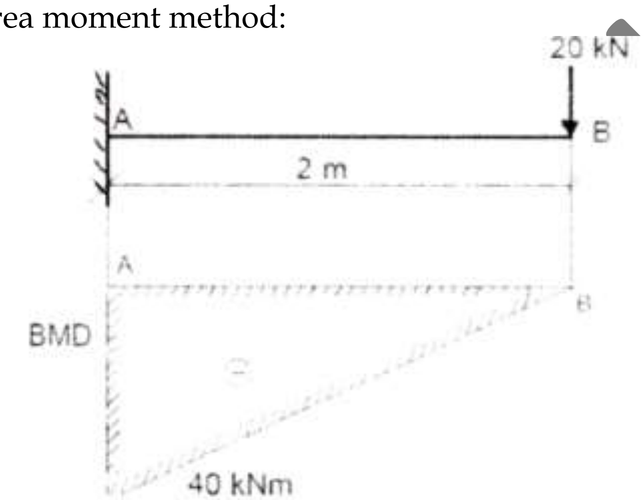
Alternate Method:

Double integration method using formula:

$$y_{max} = \frac{Wl^3}{48EI} = \frac{100 \times 10^3 \times 6000^3}{48 \times 20 \times 10^{12}} = \mathbf{22.5\ mm\ \ Ans}$$

23. A cantilever beam of span 2 m is carrying a point load of 20 kN at its free end. Calculate the slope at the free end. Assume El = 12 x 103 kN-m2. (May 2006)

Area moment method:



Slope at support A

$$i_A = \frac{\text{Area of BMD between A and B}}{EI}$$

$$= \frac{a}{EI} = \frac{0.5 \times 2 \times 40}{12 \times 10^3}$$

$$\boxed{\mathbf{i_A = 0.0033\ rad.\quad Ans}}$$

OR

Alternate Method:

Double integration method:

$$i_A = \frac{Wl^2}{2EI} = \frac{20 \times 10^3 \times 2000^2}{2 \times 12 \times 10^{12}} = \mathbf{0.0033\ rad.\ Ans}$$

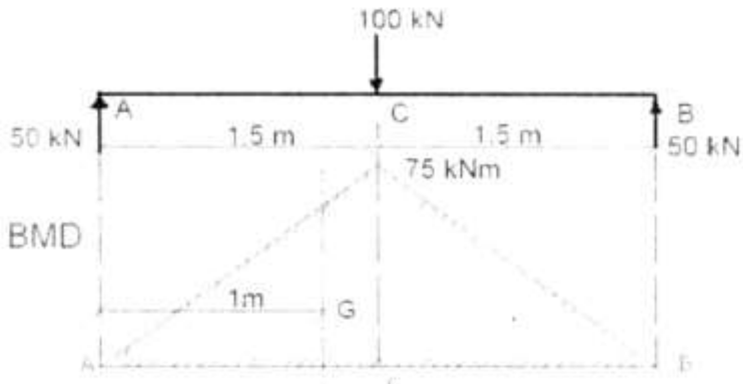
24. A rectangular simply supported beam of span 3 m and cross section 200 mm x 300 mm carries a point load of 100 kN at its mid span. Find the maximum slope and deflection of the beam if E = 0.2 x 10s N/mm². (May 2005)

Area moment method:

$$E = 0.2 \times 10^5 \ N/mm^2 = 0.2 \times 10^8 \ kN/m^2$$

$$I = \frac{bd^3}{12} = \frac{0.2 \times 0.3^3}{12} = 4.5 \times 10^{-4} m^4$$

$$EI = 0.2 \times 10^8 \times 4.5 \times 10^{-4} = 9 \times 10^3 \ kNm^2$$



$$y_{max} = \frac{\text{Moment of the area of BMD between A and C about A}}{EI}$$

Area of the BMD between A and C,

$$a = \frac{1}{2} \times b \times d = \frac{1}{2} \times 1.5 \times 75 = \mathbf{56.25}$$

Distance of centroid of the BMD between Ā and C from A

$$\bar{x} = \frac{2}{3} \times 1.5 = \mathbf{1m}$$

Maximum slope occurs at support

Slope at support A

$$i_A = \frac{\text{Area of BMD between A and C}}{EI} = \frac{a}{EI} = \frac{56.25}{9 \times 10^3}$$

$$\boxed{\mathbf{i_A = -0.00625 \ rad. \quad Ans}}$$

Maximum det1ection occurs at mid-point.

$$y_{max} = \frac{1}{EI} \times a\bar{x} = \frac{56.25 \times 1}{9 \times 10^3} = 0.00625 \ m$$

$$\boxed{\mathbf{y_{max} = 6.25 \ mm \ (downward). \quad Ans}}$$

OR

Alternate Method:

Double integration method using formula:

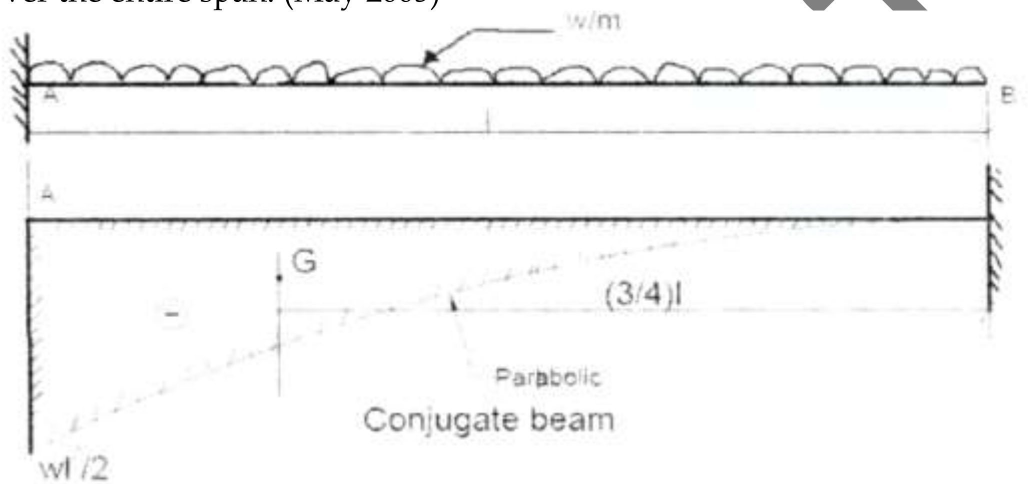
$$y_{max} = \frac{Wl^3}{48EI} = \frac{100 \times 10^3 \times 3000^3}{48 \times 9 \times 10^{12}}$$

$$\boxed{y_{max} = 6.25\ \text{mm (downward). Ans}}$$

$$i_A = \frac{Wl^2}{16EI} = \frac{100 \times 10^3 \times 3000^2}{16 \times 9 \times 10^{12}}$$

$$\boxed{i_A = 0.00625\ \text{rad. Ans}}$$

25. Draw conjugate beam for a cantilever carrying uniformly distributed load over the entire span. (May 2005)



Conjugate beam

26. **State Castigliano's theorem**. (April 2001) (Oct 2002) (May 2003)
In any beam or truss subjected to any load system, the deflection at any point r is given by the partial differential coefficient of the total strain energy stored with respect a force P_r acting at that point r in the direction in which the deflection is desired.

27. **What is Macaulay's method**? Where is it used? (Oct 2001)
Method of Singularity functions:
In Macaulay 's method a single equation is formed for all loading on a beam the equation is constructed in such a way that the constant of Integration apply to all portions of the beam. This method is also called method of singularity functions.

28. **What is the deflection at the free end of a cantilever beam of span 'l' and carrying a point load 'W' at the end**?
Deflection at the free end of a cantilever beam,

$$y_B = \frac{Wl^3}{3EI}$$

29. Define proof resilience and modulus of resilience. (Dec 2008)(May 2011) (Dec 2011) (May 2013)

- The maximum strain energy which can be stored in a body is called proof resilience.
- The proof resilience per unit volume of a material is called Modulus of resilience.

30. Define strain energy and write its unit. (May 2006)(Dec2012)

The energy which is absorbed in a body, when strained within the elastic limit, is known as strain energy.This strain energy is always capable of doing some work.Its unit is N-m or J

31. What is the strain energy stored when a bar of 6 mm diameter tm length is subjected to axial load of 4 kN, E = 200 *kN/mm2.*(Dec 2006)

$$\sigma = \frac{P}{A} = \frac{4 \times 10^3}{\frac{\pi}{4} \times 6^2} = 141.47 \text{ N/mm}^2$$

$$\text{The strain energy stored, } U = \frac{\sigma^2}{2E} \times V = \frac{(141.47)^2}{2 \times 200 \times 10^3} \times \left(\frac{\pi}{4} \times 6^2 \times 1000\right)$$

$$= 1414.7 \text{ N} - \text{mm}$$

$$\boxed{U = \mathbf{1.414\ N - m.\ \ Ans}}$$

32. Define strain energy density. (May 2004) (May 2005)

Strain energy density is defined as the maximum strain energy that can be stored in a material within the elastic limit per unit volume. It is also called **modulus of resilience.**

33. Calculate the strain energy stored per unit volume of a body due to an axial stress of200 *N/mm2.* Assume the modulus of elasticity of the material as 200 *kN/mm2.*(Oct 2002)

$$\text{The strain energy stored, } U = \frac{\sigma^2}{2E} \times V = \frac{(200)^2}{2 \times 200 \times 10^3} \times 1$$

$$= \mathbf{0.1\ Nmm}$$

Unit –V
THIN CYLINDERS, SPHERES AND THICK CYLINDERS

1. **Differentiate thick and thin shells**.(April 1998)(April 2000)(Dec 2010)(May 2013)

Sl No	Thin cylinder	Thick cylinder
1	The ratio of wall thickness to the diameter of the cylinder is less than 1/20	The ratio of wall thickness to the diameter of the cylinder is more than 1/20
2.	Circumferential stress is assumed to be constant throughout wall thickness.	Circumferential stress varies from inner to outer wall thickness

2. **Define circumferential and Hoop stress**. (May 2011)(May 2013)
   The stress acting along the circumference of the cylinder is called circumferential stress (or hoop stress) whereas the stress acting along the length of the cylinder is known as longitudinal stress.

3. **Define thin shell**. (May 2010) (Dec 2010)(Dec2012)
   If the thickness of the wall of the cylinder vessel is less than 1/20 of its internal diameter, the cylinder vessel is known as thin cylinder.

4. **Name the stresses induced in a thin walled cylinder subjected to internal fluid pressure**. (May 2003) (Dec2010)(Dec 2011)(May 2012)
   Circumferential stress (or hoop stress) andLongitudinal stress.

5. **A cylinder air receiver for a compressor is 3 m in internal diameter and made of plates of 20 mm thick. If the hoop stress is not to exceed 90 N/mm2 and the axial stress is not to exceed 60 N/mm², find the maximum safe air pressure**.(May2011)
   Pressure for hoop stress:

$$\sigma_C = \frac{pd}{4t}$$

$$90 = \frac{p \times 3000}{2 \times 20}$$

$$p = 1.2\,\mathrm{N/mm^2} = \mathbf{1.2\ MPa}$$

Pressure for longitudinal stress:

$$\sigma_l = \frac{pd}{4t}$$

$$60 = \frac{p \times 3000}{4 \times 20}$$

$$p = 1.6\,\text{N/mm}^2 = \mathbf{1.6\ MPa}$$

The safe pressure is 1.2 MPa (The least of the two values)

$$\boxed{P = \mathbf{1.2\ MPa} \quad \mathbf{Ans}}$$

6. **A thin spherical shell of 3 m inner diameter and 10 mm thickness is subjected to an internal pressure of 2 MPa. What is the maximum principal stress?**
(Dec 2010)

$$\sigma_C = \frac{pd}{4t}$$

$$\sigma_C = \frac{2 \times 3000}{4 \times 10} = 150\,\text{N/mm}^2$$

$$\boxed{\sigma_C = \mathbf{150\,N/mm^2} \quad \mathbf{Ans}}$$

7. **A thin cylindrical shell of length 1.5 m and internal diameter 400 mm is subjected to an internal pressure of 5 MPa. Determine the thickness of the cylinder if the maximum tensile stress in the material of the cylinder is limited to 200 MPa**. (Dec2010)

$$\sigma_C = \frac{pd}{2t}$$

$$t = \frac{5 \times 400}{2 \times 200}$$

$$\boxed{\mathbf{t = 5\ mm} \quad \mathbf{Ans}}$$

8. A storage tank of internal diameter 280 mm is subjected to an internal pressure of 2.5 MPa. Find the thickness of the tank, if the hoop and the longitudinal stresses are 75 MPa and 45 MPa respectively. (Dec 2008)
Thickness for hoop stress:

$$\sigma_C = \frac{pd}{2t}$$

$$t = \frac{2.5 \times 280}{2 \times 75} = 4.67\text{ mm say } \mathbf{5\ mm}$$

Thickness for longitudinal stress

$$\sigma_l = \frac{pd}{4t}$$

$$t = \frac{2.5 \times 280}{4 \times 45} = 3.89\text{ mm say } \mathbf{4\ mm}$$

The required minimum diameter is 5 mm

$$\boxed{t = 5 \text{ mm.} \quad \text{Ans}}$$

9. **A boiler of 800 mm diameter is made up of 10 mm thick plates. If the boiler is subjected to an internal pressure of 2.5 MPa, determine the circumferential and longitudinal stresses**. (Dec 2007)

$$\sigma_C = \frac{pd}{2t} = \frac{2.5 \times 800}{2 \times 10} = 100 \ \text{N/mm}^2$$

$$\boxed{\sigma_C = 100 \text{ MPa.} \quad \text{Ans}}$$

$$\sigma_l = \frac{\sigma_C}{2} = \frac{100}{2} = 50 \ \text{N/mm}^2$$

$$\boxed{\sigma_l = 50 \text{ MPa.} \quad \text{Ans}}$$

10. **A cylindrical pipe of diameter 1.5 m and thickness 15 mm is subjected to an internal fluid pressure of 1.2 N/mm2. Determine the longitudinal stress developed in the pipe**. (May 2007)

$$\sigma_l = \frac{pd}{4t} = \frac{1.2 \times 800}{4 \times 15} = 16 \ \text{N/mm}^2$$

$$\boxed{\sigma_l = 16 \text{ MPa} \quad \text{Ans}}$$

11. **Find the thickness of the pipe due to an internal pressure 10 N/mm2 if the permissible stress is 120 N/mm2. The diameter of the pipe is 750 mm**.(Dec 2006)

$$\sigma_C = \frac{pd}{2t}$$

$$120 = \frac{10 \times 750}{2 \times t}$$

$$t = 31.25 \text{ mm} \quad \text{say } 32\text{mm}$$

$$\boxed{t = 32 \text{ mm.} \quad \text{Ans}}$$

12. **A spherical shell of 1 m diameter is subjected to an internal pressure of *0.5N/mm2.*Find the thickness if the allowable stress in the material of the shell is 75 *N/mm2***. (May 2006)

$$\sigma_C = \frac{pd}{4t}$$

$$75 = \frac{0.5 \times 1000}{4 \times t}$$

$$t = 1.67 \text{ mm} \quad \text{say } 2 \text{ mm}$$

$$\boxed{t = 2 \text{ mm.} \quad \text{Ans}}$$

13. **A cylindrical shell of 500 mm diameter is required to withstand an internal pressure of 4 MPa. Find the minimum thickness of the shell, if maximum**

tensile strength in the palte material is 400 N/mm2 and the efficiency of the joint is 65 %. Take factor of safety as 5.(May 2005)

Safe working stress

$$\sigma_{safe} = \frac{\text{Maximum tensile strength}}{\text{Factor of safety}}$$

$$\sigma_C = \frac{400}{5} = 80 \ \text{N/mm}^2$$

$$\sigma_C = 80 = \frac{pd}{2t\eta} = \frac{4 \times 500}{2 \times t \times 0.65}$$

$$t = \mathbf{1}9.23 \text{ mm say } 20 \text{ mm}$$

$$\boxed{\mathbf{t = 20\ mm.\ Ans}}$$

14. **Explain the failure of a thin cylinder due to internal pressure**. (May 2005)
    If the stresses induced in the cylinders exceed the permissible limit. The cylinder is likely to fail in anyone of the following two ways.
    It may split into two troughs and
    1. It may split into two troughs and
    2. It may split up into two cylinders.

15. **List the assumptions made in the analysis of thin cylinders.** (May 2004)
    The stresses are uniformly distributed throughout the wall thickness.

16. **A spherical vessel 3 m in internal diameter is subjected to an internal pressure of 2 N/mm2. Find the thickness of the shell required if the allowable stress in the material is 80 N/mm2**. (Oct 2002)

$$\sigma_C = \frac{pd}{4t}$$

$$t = \frac{pd}{4\sigma_C} = \frac{2 \times 3000}{4 \times 80} = 18.75 \text{ mm say } 19 \text{ mm}$$

$$\boxed{\mathbf{t = 19\ mm\ Ans}}$$

17. **What do you understand by the term wire winding of thin cylinder**? (Oct1999)
    The thin cylinders are sometimes pre-stressed by winding with steel wire under tension in order to increase tensile strength of the thin cylinders to withstand high internal pressure without excessive increase in wall thickness.

18. **In a thin cylindrical shell, if hoop strain is 0.2 X 10-3 and longitudinal strain is 0.05 x 10-3, find out volumetric strain**. (Oct 1999)
    Volumetric strain,

$$e_v = \frac{\delta V}{V} = 2e_c + e_l$$

$$= 2 \times 0.2 \times 10^{-3} + 0.05 \times 10^{-3} = \mathbf{4.5 \times 10^{-4}}$$

19. Write down the expression for the change in diameter and change in length of a thin cylindrical shell when subjected to an internal pressure 'p'. (April 1999)

$$\delta d = \frac{pd^2}{2tE}\left(1 - \frac{\mu}{2}\right)$$

$$\delta l = \frac{pdl}{2tE}\left(\frac{1}{2} - \mu\right)$$

20. **Distinguish between cylindrical shell and spherical shell**.(April 1999)

Sl No	Cylindrical shell	Spherical shell
1.	Circumferential stress is twice the longitudinal stress.	Only hoop stress is present
2.	It withstands low pressure than spherical shell for the same diameter	It withstands more pressure than cylindrical shell for the same diameter

21. What is the circumferential stress in a thin spherical shell subjected to an internal pressure 'p'? (Oct 1996)(April 1998)

$$\sigma_C = \frac{pd}{4t}$$

22. Write down the volumetric strain in a thin spherical shell subjected to internal pressure 'p'. (April 1996)(April 1997)

$$e_V = 3e_C = \frac{3pd}{4tE}(1 - \mu)$$

23. Write down the expression for hoop stress in thin cylinder due to internal pressure 'p'. (April 1996)(April 1997)

$$\sigma_C = \frac{pd}{2t}$$

24. Write down the equation for strain along the longitudinal direction for the thin cylinder. (April 1995)

$$e_l = \frac{\delta l}{l} = \frac{pd}{2tE}\left(\frac{1}{2} - \mu\right)$$

25. Write down the equation for strain along the circumferential direction for the thin cylinder. (April 1995)

$$e_c = \frac{\delta d}{d} = \frac{pd}{2tE}\left(1 - \frac{\mu}{2}\right)$$

26. Write the relation for strain energy stored due to torsion of solid and hollow circular shafts.

For solid circular shaft,

$$U = \frac{q^2}{4G} \times V$$

For hollow circular shaft,

$$U = \frac{q^2}{4G}\left(\frac{D^2 + d^2}{D^2}\right) \times V$$

27. A solid shaft 120 mm diameter and 1.5 m long is used to transmit power from one pulley to another. Determine the maximum strain energy that can be stored in the shaft, if maximum allowable shear stress is 50 MPa. Take shear modulus as 80 GPa.

Volume of the shaft,

$$V = \frac{\pi}{4} \times 120^2 \times 1500 = 16.96 \times 10^6 \text{ mm}^3$$

Strain energy stored in that shaft,

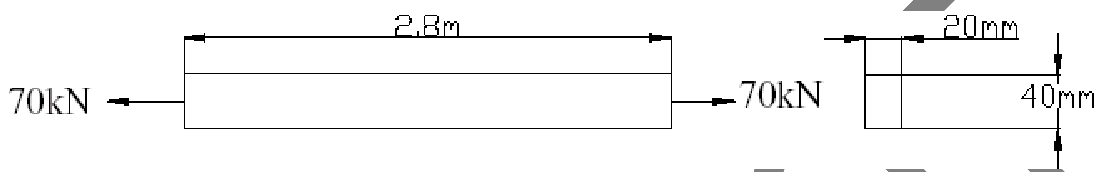
$$U = \frac{q^2}{4G} \times V = \frac{50^2}{4 \times 80 \times 10^3} \times 16.96 \times 10^6$$

$$\boxed{\mathbf{U = 132.5 \times 10^3} \text{ Nmm.} \ \mathbf{Ans}}$$

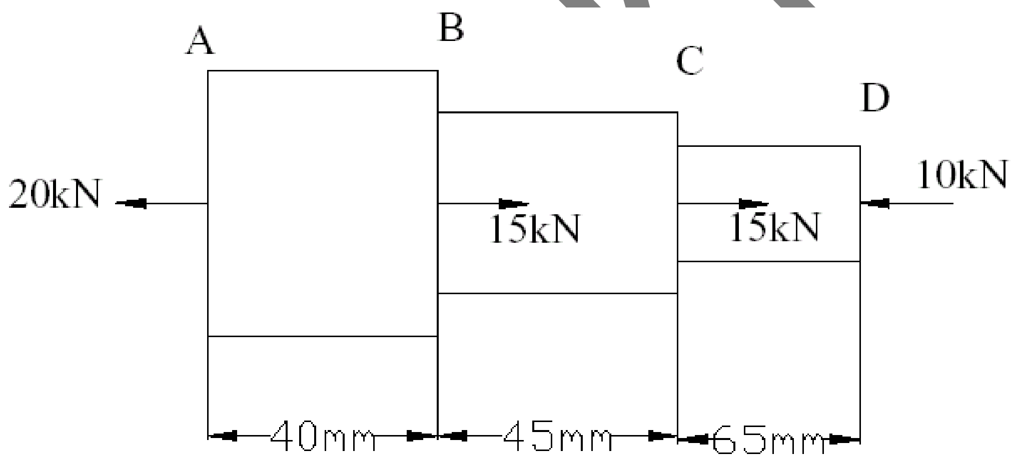
CE6306 - IMPORTANT QUESTIONS/ ASSIGNMENTS

UNIT-I (STRESS, STRAIN AND DEFORMATION OF SOLIDS)

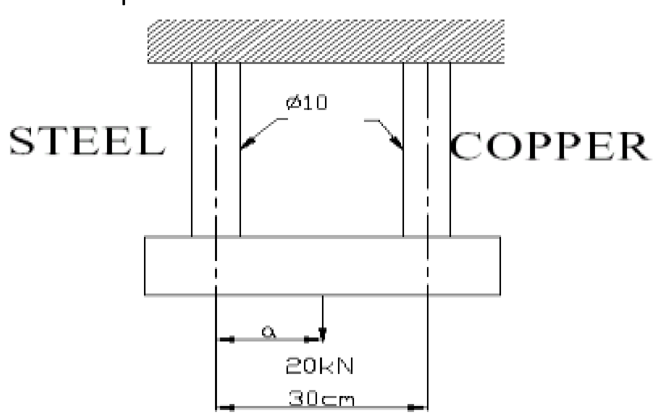
1. The prismatic bar with rectangular cross section (20x40) mm and the length 2.8 m is subjected to an axial tensile force of 70 KN .The measured elongation of bar is 1.2 mm. Calculate the tensile stress and strain in the bar



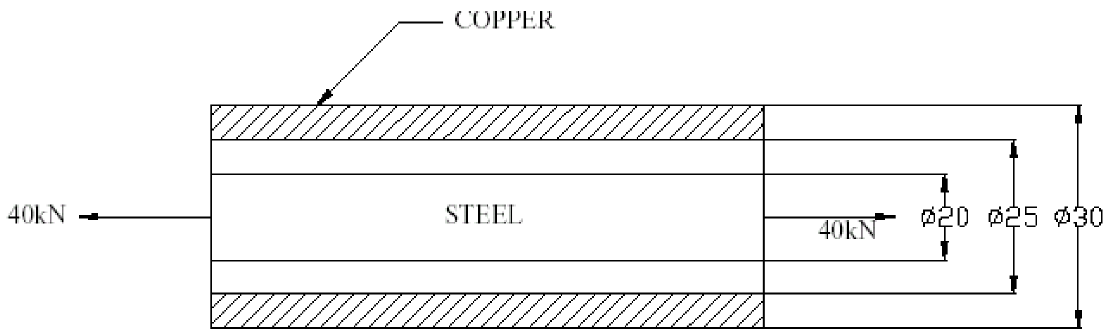
2. Consider the stepped bar loaded as shown below. Find the change in length of whole bar and stresses in all portions. If $E=2.1x10^5$ N/mm^2



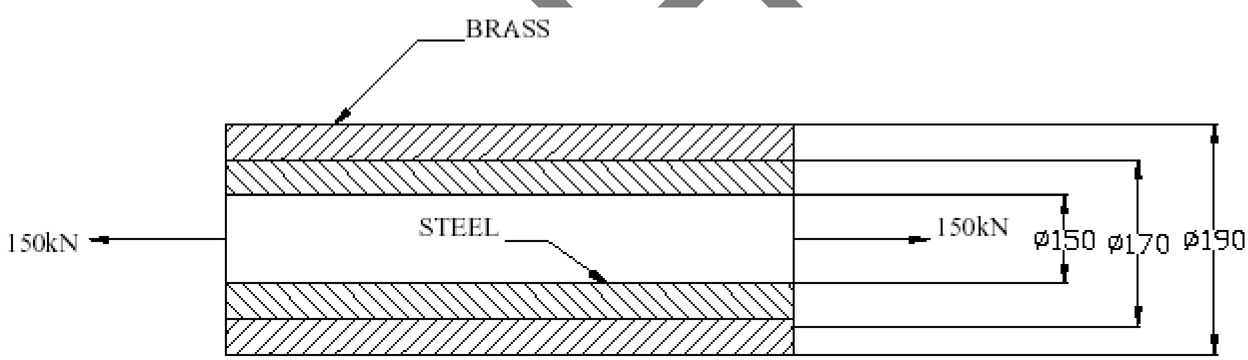
3. Two rods one of steel and other of copper are of same length and each rod have diameter of 10mm. A horizontal bar of negligible weight is attached to the lower end as shown. Find where a 20KN load is to be placed On the bar so that it remains horizontal ES/EC=13/7.



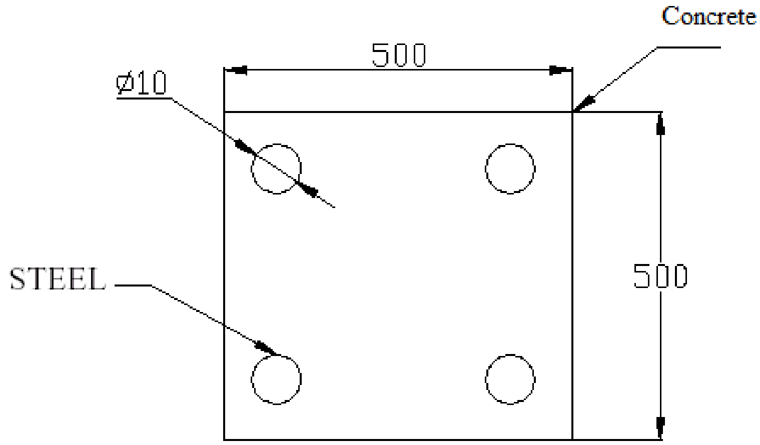
4. Concrete is weak in tension. When concrete is reinforced with steel rods, the system expands or contracts as a single unit. The load is shared by steel & concrete. An MS rod of 20 mm diameter and 300 mm long is enclosed centrally in a hollow copper tube of external diameter 30 mm and internal diameter 25 mm. The ends of the rods and tubes are brazed together and the bar is subjected to an axial pull of 40kN. E for steel is 200GN/mm2. E for copper is 100 GN/mm2. Find the extension and stresses induced in both rods and tubes.



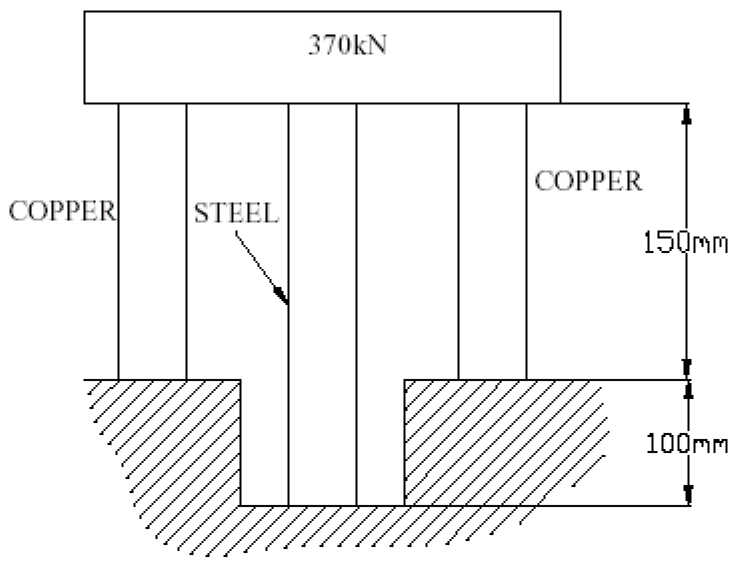
5. A 2 cm long steel tube 15 mm inner diameter and 1 mm thick is surrounded closely by a brass tube of same length and thickness. The tubes carry an axial load of 150kN. Estimate the load carried by each tube .Es = 2.1 x 105 MPa. Eb = 1 x 105 MPa.



6. A load of 2 MN is applied on a short concrete column (500 x 500) mm. The column is reinforced with 4 steel bars of 100 mm diameter. Find the stresses in concrete and steel bar. Es = 2.1 x 105 MPa. Ec = 1.4 x 105 MPa.

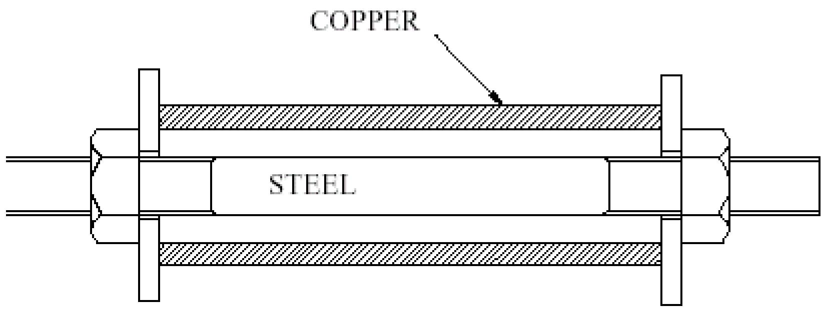


7. Steel and two copper rods support together a load of 370 KN as shown. The cross sectional area of steel is 2500 mm2 and that of each copper rod is 1600 mm2. Find the stresses in the rods and change in length if Es = 2 x 105MPa. Ec = 1 x 105 MPa.



8. A steel rod of 3 cm diameter and 5 cm long is connected to two grips and the rod is maintained at a temperature of 90 c. Determine the stress and pull existed When the temperature falls to 30 c if 1.the ends do not yield, 2.the ends yield by 0.12 cm. Take E= 2x105 MPa, α= 12x10-6 mm/mm/oC, θ=60^{o}.

9. A steel rod of 200 mm diameter passes externally through a copper tube of 50 mm external diameter and 40 mm internal diameter. The tube is closed at each end by rigid plates of negligible thickness. The nuts are tightened lightly on the projecting parts of the rod. If the temperature of the assembly is raised by 50 c calculates the stresses developed in copper and steel. Es= 200 GN/mm2 Ec= 100 GN/mm2. αs= 12x10-6 mm/mm/oC, αc= 18x10-6 mm/mm/oC.



10. A tensile load of 5 kN is gradually applied to a circular bar of 5 cm diameter and 4 m long. It the value of E = 2.0 x 105 N/mm2. Determine : (i) Stretch in the rod, (ii) stress in the rod, and (iii) strain energy absorbed by the rod.

11. A uniform metal bar has a cross-sectional area of 6 cm2 and a length of 1.4 m. If the stress at the elastic limit is 1500 N/cm2, find the proof resilience of the bar. Determine also the maximum value of an applied load, which may be suddenly applied without exceeding the elastic limit. Calculate the value of the gradually applied load which will produced the same extension as that reduced by the suddenly applied load above. Take E = 200KN/cm2.

12. A vertical compound tie member fixed rigidly at its upper end, consists of a steel rod 3 m long and 20 mm diameter, placed within an equally long brass tube 20 mm internal diameter and 20 mm external diameter. The rod and the tube are fixed together at the ends. The compound member is then suddenly loaded in tension by a weight of 1200 kgf falling through a height of 5 mm on to a flange fixed to its lower end. Calculate the maximum stresses in steel and brass. Assume Es = 2 x 106 kfg/cm2 and Eb = 1.0 x 106 kgf/cm2.

UNIT-II (TRANSVERSE LOADING ON BEAMS AND STRESSES IN BEAM)

1. A cantilever of 2m length carries a point load of 20 KN at 0.8 m from the fixed end and another point of 5 KN at the free end. In addition, a UDL of 15 KN/m is spread over the entire length of the cantilever. Draw the S.F.D, and B.M.D.

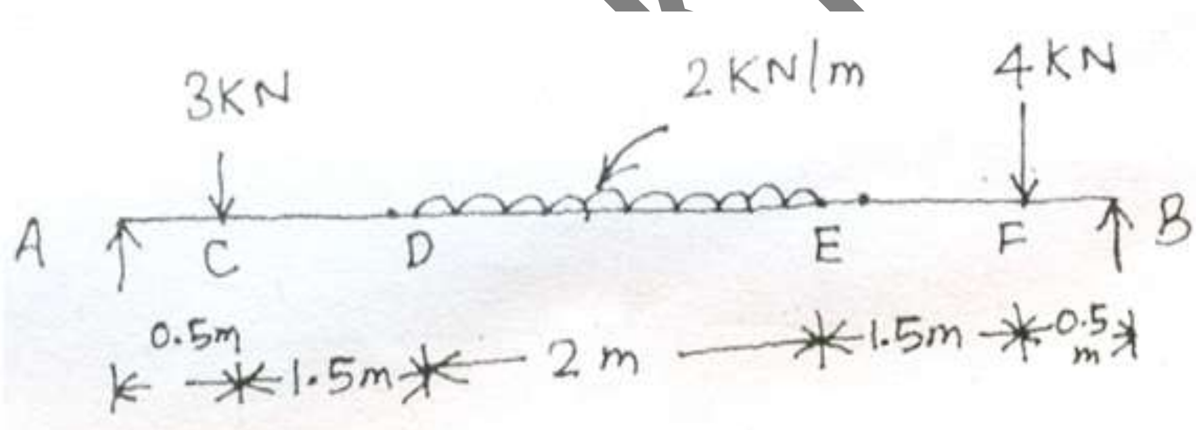
2. A Simply supported beam of effective span 6 m carries three point loads of 30 KN, 25 KN and 40KN at 1m, 3m and 4.5m respectively from the left support. Draw the SFD and BMD. Indicating values at salient points.

3. A Simply supported beam of length 6 metres carries a UDL of 20KN/m throughout its length and a point of 30 KN at 2 metres from the right support. Draw the shear force and bending moment diagram. Also find the position and magnitude of maximum Bending moment.

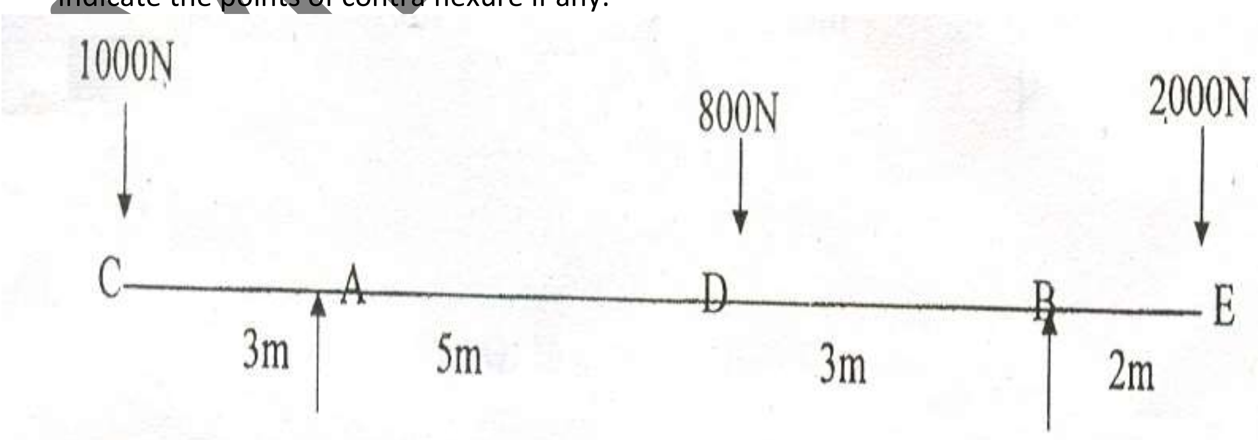
4. A Simply supported beam 6 metre span carries udl of 20 KN/m for left half of span and two point loads of 25 KN end 35 KN at 4 m and 5 m from left support. Find maximum SF and BM and their location drawing SF and BM diagrams.

5. A beam of length 10 m is simply supported at its ends carries two concentrated loads of 5 kN each at a distance of 3 m 7 m from the left support and also a uniformly distributed load of 1 kN/m between the point loads. Draw shear force and bending moment diagrams. Calculate the maximum bending moment.

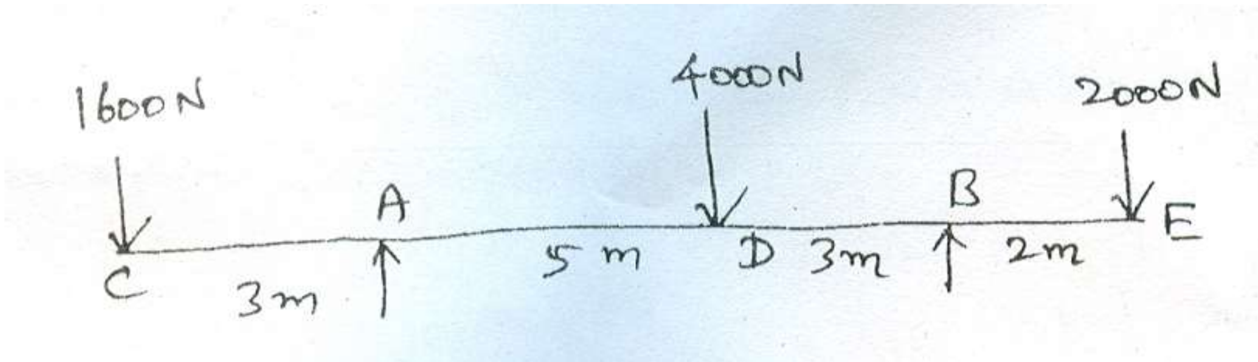
6. A simply supported beam is loaded as shown in fig . Draw the shear force and bending moment diagrams.



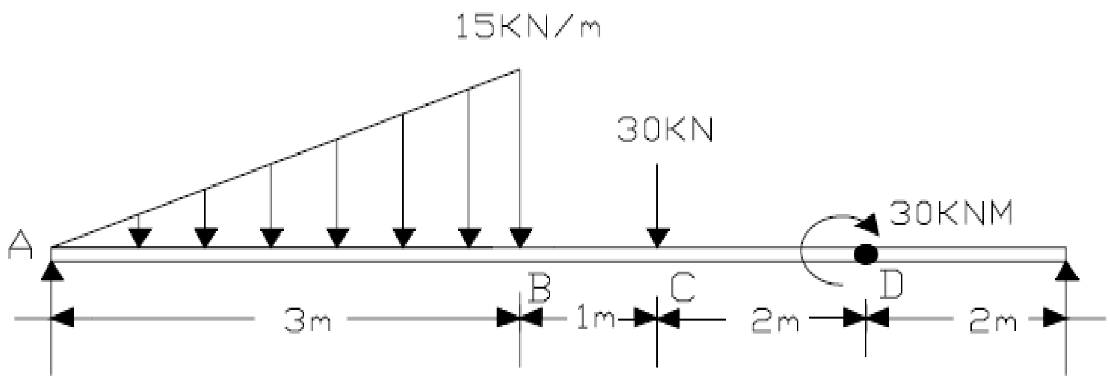
7. Draw the shear force and bending moment diagram for the beam shown in Fig. and also indicate the points of contra flexure if any.



8. Draw the S.F and B.M diagram for the beam shown in Fig. Determine the points of contra flexure.



9. Draws shear force and bending diagram for the beam shown in figure. Locate point of Contra flexure if any.

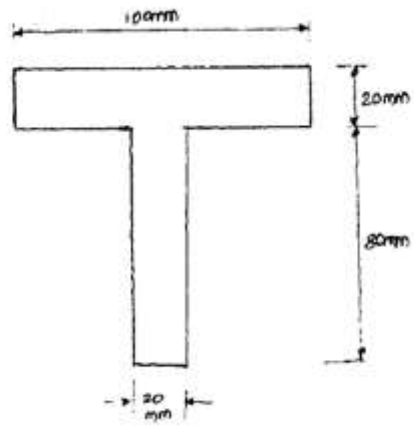


10. A timber beam of rectangular section is to support a load of 20 kN uniformly distributed over a span of 3.6 m, when the beam is simply supported. If the depth is twice the width of the section and the stress in timber is not to exceed 3.5 N/mm2, find the dimensions of the cross section?

11. a) State any four assumptions made in the theory of simple bending.

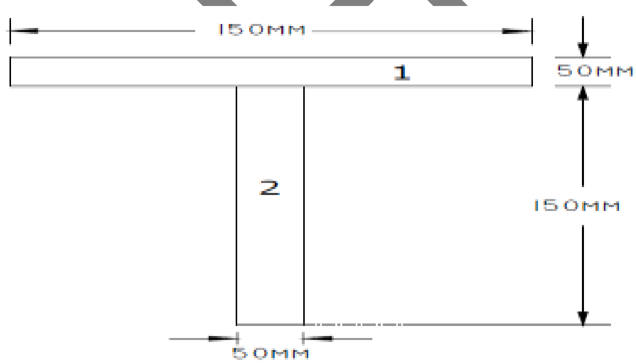
b) Derive the bending formula M/I = f/y = E/R

12. A cast iron beam is of T-section as shown in Fig. The beam is simply supported on a span of 6 m. The beam carries a uniformly distributed load of 2 kN/m on the entire length (span). Determine the maximum tensile and maximum compressive stress.

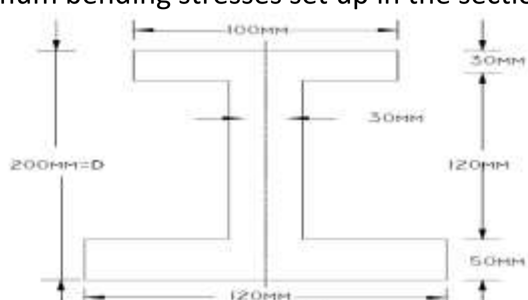


13. A hollow circular bar having outside diameter twice the inside diameter is used as a beam. From the bending moment diagram of of the beam, it is found that the bar is subjected to a bending moment of 40KN/m. if the allowable bending stress in the beam is to be limited to 100MN/m2, find the inside diameter of the bar.

14. Two wooden planks 150mm x 50mm each are connected to form a T-section of a beam. If a moment of 3.4 kNm is applied around the horizontal neutral axis, inducing tension below the neutral axis, find the stresses at the extreme fibres of the cross section. Also calculate the total tensile force on the cross-section.

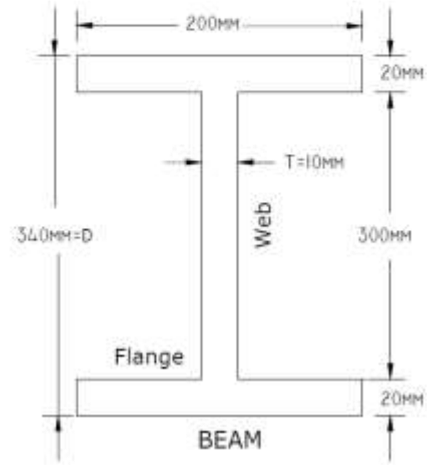


15. A beam simply supported at ends and having cross-section as shown in figure is loaded with a U.D.L., over whole of its span. If the beam is 8m long, find the U.D,L, if maximum permissible bending stress in tension is limited to 30N/m and in compression to 45MN/m2. What are the actual maximum bending stresses set up in the section.

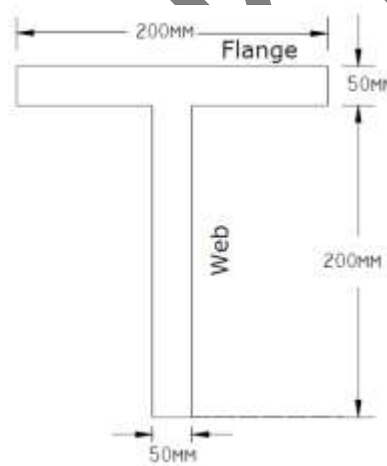


BEAM

16. An I-Section as shown in figure, beam 340 mm x 200 mm has a web thickness of 10mm and flange thickness of 20 mm. It carries a shearing force of 100 KN. Sketch the shear stress distribution across the section.



17. A T-shaped cross-section of a beam shown in figure is subjected to a vertical shear force of 100KN. Calculate the shear stress at the neutral axis and at the junction of the web and the flange. Moment of inertia about the horizontal neutral axis is 0.0001134 m4.



UNIT-III (TORSION AND SPRINGS)

1. Determine the diameter of a solid shaft which will transmit 300 KN at 250 rpm. The maximum shear stress should not exceed 30 N/mm$_2$ and twist should not be more than 10 in a shaft length 2m. Take modulus of rigidity = 1x 105N/mm^2.

2. A steel shaft ABCD having a total length of 2400 mm is contributed by three different sections as follows. The portion AB is hollow having outside and inside diameters 80 mm and 50 mm respectively, BC is solid and 80 mm diameter. CD is also solid and 70 mm diameter. If the angle of twist is same for each section, determine the length of each portion and the total angle of twist. Maximum permissible shear stress is 50 Mpa and shear modulus 0.82 x 105 MPa

3. Calculate the power that can be transmitted at a 300 rpm by a hollow steel shaft of 75 mm external diameter and 50 mm internal diameter when the permissible shear stress for the steel is 70N/mm2 and the maximum torque is 1.3 times the mean. Compare the strength

of this hollow shaft with that of an solid shaft. The same material, weight and the length of both the shafts are the same.

4. A solid shaft is subjected to a torque of 100 Nm. Find the necessary shaft diameter if the allowable shear stress id 100 N/mm^2 and the allowable twist is 3º per 10 diameter length of the shaft. Take C = 1×10^5 N/mm^2.

5. A hollow shaft, having an internal diameter 50% of its external diameter, transmits 600 KW at 150 rpm. Determine the external diameter of the shaft if the shear stress is not to exceed 65 N/mm^2 and the twist in a length of 3 m should not exceed 1.4 degrees. Assume maximum torque = 1.2 times the mean torque and modulus of rigidity = 1×10^5 N/mm^2

6. A hollow shaft with diameter ratio 3/8 is required to transmit 500 kW at 100 rpm, the maximum torque being 20% greater than the mean. The maximum shear stress is not to exceed 60 N/mm^2 and the twist in a length of 3 m is not to exceed 1.4º. Calculate the minimum diameters required for the shaft. C = 84 KN/mm^2.

7. A hollow steel shaft of outside diameter 75 mm is transmitting a power of 300 KW at 2000 rpm. Find the thickness of the shaft if the maximum shear stress is not to exceed 40 N/mm^2.

8. A solid cylindrical shaft is to transmit 300 KN power at 100 rpm. If the shear stress is not to exceed 60 N/mm^2, find its diameter. What percent saving in weight would be obtained if this shaft is replaced by a hollow one whose internal diameter equals to 0.6 of the external diameter, the length, the material and maximum shear stress being the same.

9. A solid shaft is subjected diameter of the shaft,The allowable twist is 1^0. Take C = 80GPa.To a torque of 1.6 KN-m. Find the necessary if the allowable shear stress is 50 MPa. for every 20 diameters length of the shaft.

10. A closely coiled helical spring of round steel wire 5 mm in diameter having 12 complete coils of 50 mm mean diameter is subjected to an axial load of 150 N. Find the deflection of the spring and the maximum shearing stress in the material. Modulus of rigidity (C) = 80GPa. Also, find stiffness of the spring.

11. A closely coiled helical spring of round steel wire 10 mm in diameter having 10 complete turns with a mean diameter of 12 cm is subjected to an axial load of 250 N. Determine
    (i) the deflection of the spring
    (ii) maximum shear stress in the wire and
    (iii) stiffness of the spring and
    (iv) frequency of vibration.
    Take C = 0.8 x 105 N/mm^2.

12. A close coiled helical spring is to have a stiffness of 1.5 N/mm of compression under a maximum load of 60 N. The maximum shearing stress produced in the wire of the spring 125 N/mm^2. The solid length of the spring is 50 mm. Find the diameter of coil, diameter of wire and number of coils
    C = 4.5 × 104 N/mm^2.

13. A helical spring of circular cross-section wire 18 mm in diameter is loaded by a force of 500 N. The mean coil diameter of the spring is 125 mm. The modulus of rigidity is 80 KN/mm^2. Determine the maximum shear stress in the material of the spring. What number of coils must the spring have for its deflection to be 6mm?

14. The stiffness of close coiled helical spring is 1.5 N/mm of compression under a maximum load of
60N.The maximum shear stress in the wire of the spring is 125 N/mm^2. The solid length of the spring (when the coils are touching) is 50 mm. Find the diameter of coil, diameter of wire and number of coils. C = 4.5 N/mm^2.

15. An open coiled helical spring of 12 effective coils of mean diameter 150 mm, made from 12 mm steel rod sustains an axial load 150N. Determine
    i . the axial deflection,
    i i. the axial twist , and
    iii. the twist about a horizontal axis, if the helix makes an angle of 60° with the axis.
  E =2.1 x 10^6 kg /cm^{2}andG. 8.4 x10^{5}kg/cm^2.

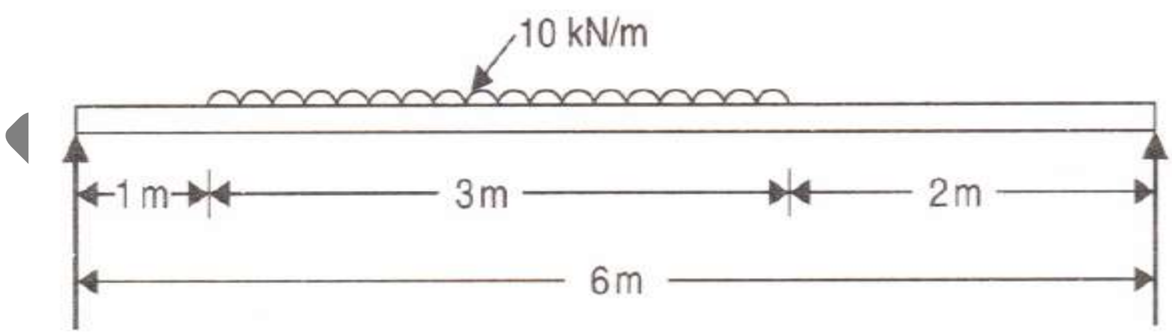
UNIT-IV (DEFLECTION OF BEAMS)

1. A beam of length of 10 m is simply supported at its ends and carries two point loads of 100 KN and 60 KN at a distance of 2 m and 5 m respectively from the left support. Calculate the deflections under each load. Find also the maximum deflection. Take I = 18 X 10^8 mm^4 and E = 2 X 10^{5}N/mm^2.

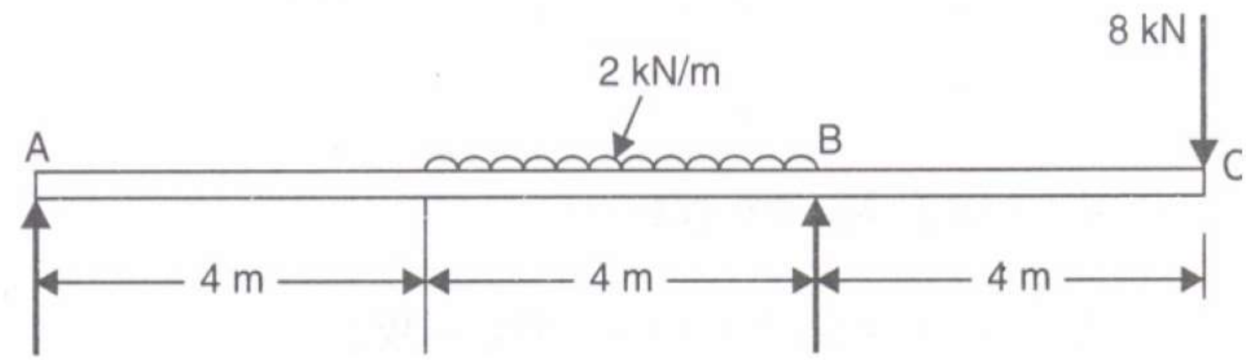
2. A cantilever of length 2 m carries a uniformly distributed load of 2.5 KN/m run for a length of 1.25 m from the fixed end and a point load of 1 KN at the free end. Find the deflection at the free end if the section is rectangular 12 cm wide and 24 cm deep and E=1 X 10^4 N/mm^2

3. A cantilever of length 2m carries a uniformly distributed load 2 KN/m over a length of 1m from the free end, and a point load of 1 KN at the free end. Find the slope and deflection at the free end if E = 2.1 X 10^5 N/mm^2 and I = 6.667 X 10^7 mm^4.

4. A beam of length of 6 m is simply supported at its ends. It carries a uniformly distributed load of 10 KN/m as shown in figure. Determine the deflection of the beam at its mid-point and also the position and the maximum deflection. Take EI=4.5 X 10^8 N/mm^2.

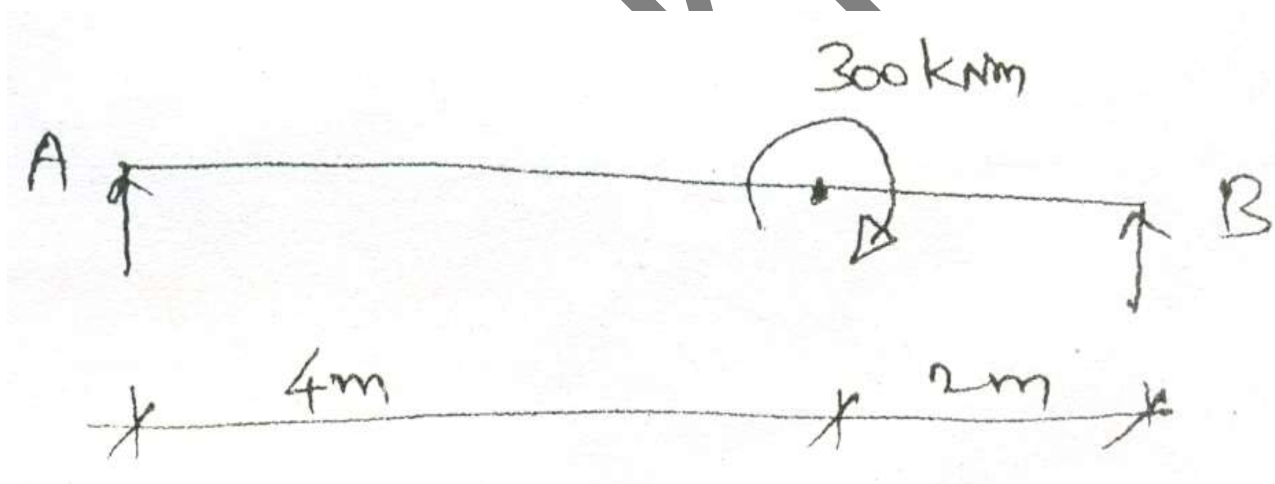


5. An overhanging beam ABC is loaded as shown is figure. Determine the deflection of the beam at point C. Take I = 5 X 10^8 mm and E = 2 X 10^5 N/mm^2.

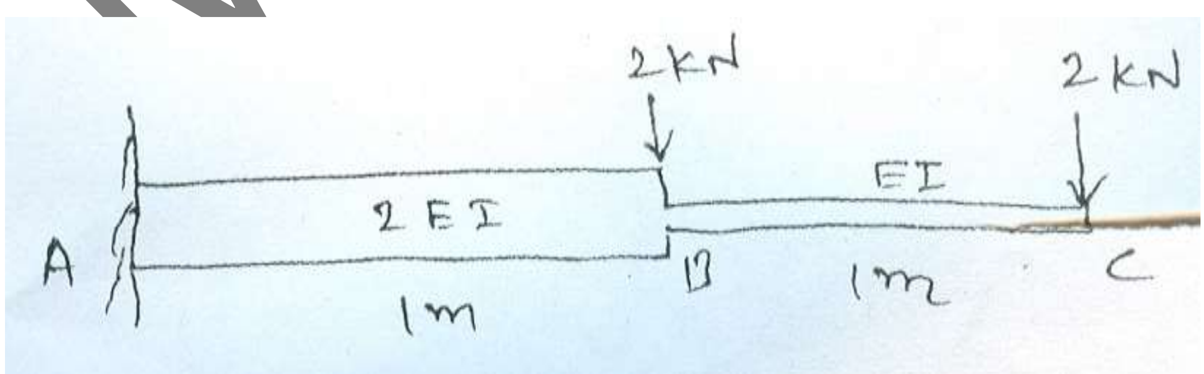


6. Beam is simply supported at its ends over a span of 10 m and carries two concentrated loads of 100 kN and 60 kN at a distance of 2 m and 5 m respectively from the left support. Calculate (i) slope at the left support (ii) slope and deflection under the 100 kN load. Assume EI = 36×10^4 kN-m^2.

7. Find the maximum deflection of the beam shown in Fig. EI = 1 × 1011 KN/mm^2. Use Macaulay's method.

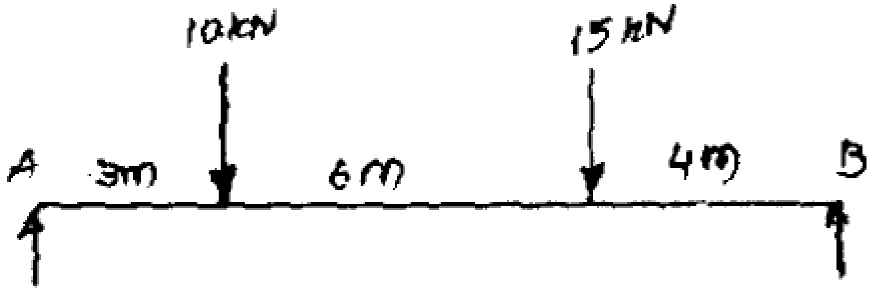


8. For the cantilever beam shown in Fig. Find the deflection and slope at the free end. EI = 10000 kN/m^2



9. A beam AB of length 8 m is simply supported at its ends and carries two point loads of 50 KN and 40 KN at a distance of 2 m and 5 m respectively from left support A. Determine, deflection under each load, maximum deflection and the position at which maximum deflection occurs. Take $E=2x10^5$ N/mm^2 and $I=85\ x10^6$ mm^4.

10. A beam is loaded as shown in Fig. Determine the deflection under the load points.Take E = 200 GPa and I = 160 x 10^6 mm^4.



11. An I section joist 400 mm x 200 mm x 20 mm and 6 m long is used as a strut with both ends fixed. What is Euler's crippling load for the column? Take .E = 200 GPa.

12. Derive Eulers equation for a column.

13. A I.2 m long column has a circular cross section of 45 mm diameter one of the ends of the column is fixed in direction and position and other ends is free. Taking factor of safety as 3, calculate the safe load using

(i) Rankine,s formula, take yield stress = 560 N/mm^2 and a = 1/1600 for pinned ends.

(ii) Euler's formula, Young's modulus for cast iron = 1.2 x 10^5 N/mm^2.

14. Find the Euler critical load for a hollow cylindrical cast iron column 150mm external diameter, 20 mm wall thickness if it is 6 m long with hinged at both ends. Assume Young's modulus of cast iron as 80 kN/mm^2. Compare this load with that given by Rankine formula. Using Rankine constants a = 1/1600 and 567 N/mm^2.

15. Determine the section of a hollow C.I. cylindrical column 5 m long with ends firmly built in. The column has to carry an axial compressive load of 588.6 KN. The internal diameter of the column is 0.75 times the external diameter. Use Rankine's constants. a = 1 / 1600, σc=58 KN/cm^2 and F.O.S = 6.

UNIT-V (THIN CYLINDERS, SPHERES AND THICK CYLINDERS)

1. A thick steel cylinder with internal diameter of 10 cm and external diameter 20 cm is fixed on the over circumference. Determine the stresses at inside and outside, if it is subjected to an internal fluid pressure of 100 kg/cm2. Assume μ = 0.3

2. Derive the equation of radial stresses and strains in thick spherical shell subjected to internal fluid pressure.

3. Derive the equation of hoop stress in thin walled cylindrical vessel with internal pressure P applied.

4. The maximum stress permitted in a thick cylinder of internal and external radius 200 mm and 300 mm respectively is 15.5 N/mm2. If the external pressure is 4 N/mm2, and the internal pressure that can be applied. Plot the curves showing the variation of hoop and radial stresses through the material. What will be the change in thickness of the cylinder? Take E = 2.1 X 105 N/mm2 and Poision's ratio is 0.3.

5. A Thin cylindrical shell 3 m long has 1m internal diameter and 15 mm metal thickness. Calculate the circumferential and longitudinal stresses induced and also the change in the dimensions of the shell, if it is subjected to an internal pressure of1.5 N/mm2 Take E = 2x105 N/mm2 and poison's ratio =0.3. Also calculate change in volume.

6. A closed cylindrical vessel made of steel plates 4 mm thick with plane ends, carries fluid under pressure of 3 N/mm2 The diameter of the cylinder is 25cm and length is 75 cm. Calculate the longitudinal and hoop stresses in the cylinder wall and determine the change in diameter, length and Volume of the cylinder. Take E =2.1x105 N/mm2 and 1/m = 0.286.

7. A cylindrical shell 3 m long which is closed at the ends, has an internal diameter of 1 m and a wall thickness of 20 mm. Calculate the circumferential and longitudinal stresses induced and also changes in the dimensions of the shell, if it is subjected to an internal pressure of 2.0 N/mm2. Take E = 2x 105 N/mm2 and 1/m = 0.3.

8. A cylindrical vessel 2 m long and 500 mm in diameter with 10 mm thick plates is subjected to an internal pressure of 2 MPa. Calculate the change in volume of the vessel. Take E = 200 GPa and Poisson's ratio = 0.3 for the vessel material.

9. A cylinder of outer diameter 280 mm and inner diameter 240 mm shrunk over. Another cylinder of outer diameter slightly more than 240 mm and inner diameter 200 mm to form a compound cylinder. The shrink fit pressure is 10 N/ mm2. If an internal pressure of 50 N/ mm2 is applied to the compound Cylinder, find the final stresses across the thickness. Draw sketches showing their variations.

10. A point is subjected to perpendicular stresses of 50 KN/m2 and both tensile, Calculate the normal tangential stresses and resultant stress and its obliquity on a plane making an angle of 30º with the axis of second stress.

11. At a point in a stressed body the principal stresses are 100 MN/m2 (tensile)and 60 MN/m2 (compressive). Determine the normal stress and the shear stress on a plane inclined at 50º to the axis of major principal stress. Also calculate the maximum shear stress at the point

12. The principal stresses at point across two perpendicular planes are 75 MN/m2 (tensile) and 35 MN /m2 (tensile) Find the normal , tangential stresses and the resultant stress and its obliquity on a plane 20º with the major principal plane.

13. A short metallic column of 500 mm2 cross-sectional area carries an axial compressive load of 100KN. For a plane inclined at 60º with the direction of load calculate:
    - i) Normal stress
    - ii) Tangential stress
    - iii) Resultant stress
    - iv) Maximum shear stress and
    - v) Obliquity of the resultant stress.

14. At a point in a strained material, the principal stresses are 100 N/mm2 (tensile) and 40 N/mm2 (compressive). Determine analytically the resultant stress in magnitude and direction on a plane inclined at 600 to the axis of major principal stress. What is the maximum intensity of shear stress in the material at that point?

15. A plane element in a boiler is subjected to tensile stresses of 400 MPa on one plane and 200 MPa on the other at right angles to the former. Each of the above stresses is accompanied by a shear stress of 100 MPa. Determine the principal stresses and their directions. Also, find maximum shear stress