UNIT : I

ENERGY METHODS

1. Define: Strain Energy

When an elastic body is under the action of external forces the body deforms and work is done by these forces. If a strained, perfectly elastic body is allowed to recover slowly to its unstrained state. It is capable of giving back all the work done by these external forces. This work done in straining such a body may be regarded as energy stored in a body and is called strain energy or resilience.

2. Define: Proof Resilience.

The maximum energy stored in the body within the elastic limit is called Proof Resilience.

3. Write the formula to calculate the strain energy due to axial loads (tension).

$$U = \int \frac{P^2}{2AE}\,dx \qquad \text{limit } 0 \text{ to } L$$

Where,

P = Applied tensile load.
L = Length of the member
A = Area of the member
E = Young's modulus.

4. Write the formula to calculate the strain energy due to bending.

$$U = \int \frac{M^2\,dx}{2EI} \qquad \text{limit } 0 \text{ to } L$$

Where,

M = Bending moment due to applied loads.
E = Young's modulus
I = Moment of inertia

5. Write the formula to calculate the strain energy due to torsion

$$U = \int \frac{T^2}{2GJ}\,dx \qquad \text{limit } 0 \text{ to } L$$

Where, T = Applied Torsion
G = Shear modulus or Modulus of rigidity
J = Polar moment of inertia

6.Write the formula to calculate the strain energy due to pure shear

$$U = K \int \frac{V^2}{2GA}\,dx \qquad \text{limit } 0 \text{ to } L$$

Where, V= Shear load
G = Shear modulus or Modulus of rigidity
A = Area of cross section.
K = Constant depends upon shape of cross section.

7. Write down the formula to calculate the strain energy due to pure shear, if shear stress is given.

2G

G = Shear modulus or Modulus of rigidity
V = Volume of the material.

8. Write down the formula to calculate the strain energy , if the moment value is given

$$U = \frac{M^2 L}{2EI}$$

Where, M = Bending moment L = Length of the beam E = Young's modulus
I = Moment of inertia

9. Write down the formula to calculate the strain energy , if the torsion moment value is given.

$$U = \frac{T^2 L}{2GJ}$$

Where, T = Applied Torsion
L = Length of the beam
G = Shear modulus or Modulus of rigidity
J = Polar moment of inertia

10. Write down the formula to calculate the strain energy, if the applied tension load is given.

$$U = \frac{P^2 L}{2AE}$$

Where,

P = Applied tensile load. L = Length of the member A = Area of the member
E = Young's modulus.

11. Write the Castigliano's first theorem.

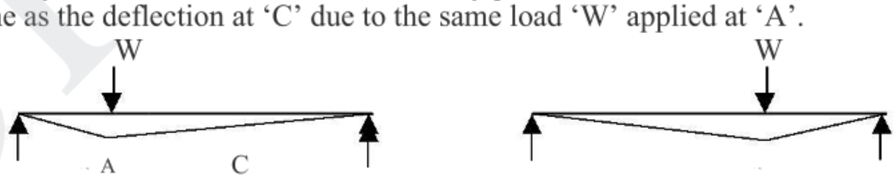
In any beam or truss subjected to any load system, the deflection at any point is given by the partial differential coefficient of the total strain energy stored with respect to force acting at a point.

12. What are uses of Castigliano's first theorem?

1. To determine the deflection of complicated structure.
2. To determine the deflection of curved beams, springs.

13. Define : Maxwell Reciprocal Theorem.

In any beam or truss the deflection at any point 'A' due to a load 'W' at any other point 'C' is the same as the deflection at 'C' due to the same load 'W' applied at 'A'.



14. Define: Unit load method.

The external load is removed and the unit load is applied at the point, where the deflection or rotation is to found.

15. Give the procedure for unit load method.

2. Remove the external loads and apply the unit vertical point load at the joint if the vertical deflection is required and find the stress.

3. Apply the equation for vertical and horizontal deflection.

16. Compare the unit load method and Castigliano's first theorem

In the unit load method, one has to analyze the frame twice to find the load and deflection. While in the latter method, only one analysis is needed.

17. Find the strain energy per unit volume, the shear stress for a material is given as 50 N/mm ². Take G= 80000 N/mm ².

$$8 = \frac{ð}{2G}$$

$= 50^2 / (2 \times 80000)$

$= 0.015625$ N/mm ². per unit volume.

18. Find the strain energy per unit volume, the tensile stress for a material is given as 150 N/mm ². Take E = 2 x10 N/mm ².

$$U = \frac{f^2}{2E} \quad \text{per unit volume}$$

$= (150)^2 / (2 \times (2\times10^2)$

$= 0.05625$ N/mm ². per unit volume.

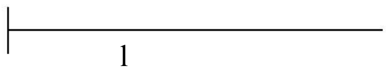
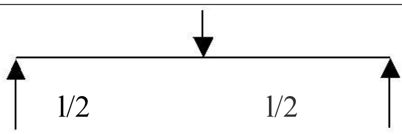
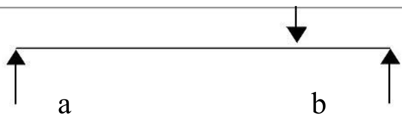
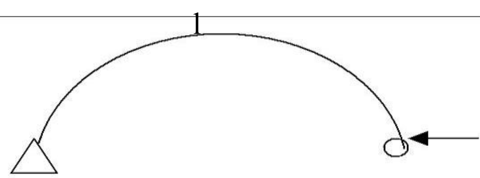
19.Define : Modulus of resilience.

The proof resilience of a body per unit volume. (ie) The maximum energy stored in the body within the elastic limit per unit volume.

20. Define : Trussed Beam.

A beam strengthened by providing ties and struts is known as Trussed Beams.

21. Deflection of beams

Type of beam	Deflection
	$\delta = wl^3 / 3EI$
	$\delta = wl^3 / 48EI$
	$\delta = wa^2b^2 / 3EIl$
	$\delta = 5wl^4 / 384EI$
	$\delta = wl^4 / 8EI$
	$\delta = \Pi wr^3$

UNIT : II

STATICALLY INDETERMINATE STRUCTURES

1. Explain with examples the statically indeterminate structures.

If the forces on the members of a structure cannot be determined by using conditions of equilibrium Example: Fixed beam, continuous beam.

2. Differentiate the statically determinate structures and statically indeterminate structures?

Sl.No	statically determinate structures	statically indeterminate structures
1.	Conditions of equilibrium are sufficient to analyze the structure	Conditions of equilibrium are insufficient to analyze the structure
2.	Bending moment and shear force is independent of material and cross sectional area.	Bending moment and shear force is dependent of material and independent of cross sectional area.
3.	No stresses are caused due to temperature change and lack of fit.	Stresses are caused due to temperature change and lack of fit.

3. Define: Continuous beam.

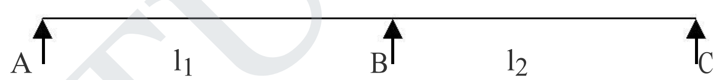
A Continuous beam is one, which is supported on more than two supports. For usual loading on the beam hogging (- ive) moments causing convexity upwards at the supports and sagging (+ ve) moments causing concavity upwards occur at mid span.

4. What are the advantages of Continuous beam over simply supported beam?

1. The maximum bending moment in case of continuous beam is much less than in case of simply supported beam of same span carrying same loads.

2. In case of continuous beam, the average bending moment is lesser and hence lighter materials of construction can be used to resist the bending moment.

5. Write down the general form of Clapeyron's three moment equations for the continuous beam.

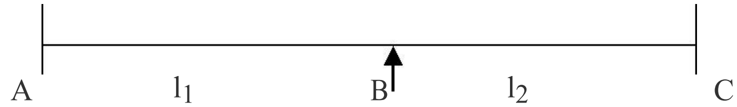


$$M_a l_1 + 2 M_b (l_1 + l_2) + M_c l_2 = -\left(\frac{6A_1 \bar{x}_1}{l_1} + \frac{6 A_2 \bar{x}_2}{l_2} \right)$$

where,

M_a = Hogging bending moment at A
M_b = Hogging bending moment at B
M_c = Hogging bending moment at C
l_1 = length of span between supports A,B
l_2 = length of span between supports B, C
$\bar{x}_1$ = CG of bending moment diagram from support A
$\bar{x}_2$ = CG of bending moment diagram from support C
A_1 = Area of bending moment diagram between supports A,B
A_2 = Area of bending moment diagram between supports B, C

6. Write down the Clapeyron's three moment equations for the continuous beam with sinking at the supports.



$$M_a l_1 + 2M_b(l_1 + l_2) + M_c l_2 = -\left(\frac{6A_1\bar{x}_1}{l_1} + \frac{6A_2\bar{x}_2}{l_2}\right), \quad \left(\frac{l_2}{l_1}\right) \quad \frac{}{l_2}$$

where,

M_a = Hogging bending moment at A
M_b = Hogging bending moment at B
M_c = Hogging bending moment at C
l_1 = length of span between supports A,B
l_2 = length of span between supports B, C
$\bar{x}_1$ = CG of bending moment diagram from support A
$\bar{x}_2$ = CG of bending moment diagram from support C
A_1 = Area of bending moment diagram between supports A,B
A_2 = Area of bending moment diagram between supports B, C
I = Sinking at support A with compare to sinking at support B
2 = Sinking at support C with compare to sinking at support B

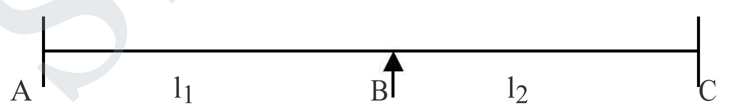
7. Write down the Clapeyron's three moment equations for the fixed beam

$$M_a + 2M_b = \left(\frac{6A\bar{x}}{l^2}\right)$$

where,

M_a = Hogging bending moment at A M_b
= Hogging bending moment at B
l = length of span between supports A,B
$\bar{x}$ = CG of bending moment diagram from support A
A = Area of bending moment diagram between supports A,B

8. Write down the Clapeyron's three moment equations for the continuous beam carrying UDL on both the spans.



$$M_a l_1 + 2M_b l_2 + M_c l_2 = \left(\frac{6A_1\bar{x}_1}{l_1} + \frac{6A_2\bar{x}_2}{l_2}\right) = \frac{w_1 l_1^3}{4} + \frac{w_2 l_2^3}{4}$$

where,

M_a = Hogging bending moment at A
M_b = Hogging bending moment at B
M_c = Hogging bending moment at C
l_1 = length of span between supports A,B
l_2 = length of span between supports B, C

9. Give the values of ($6A_1 \bar{x}_1 / l_1$), ($6A_2 \bar{x}_2 / l_2$) values for different type of loading.

Type of loading	$6A_1 x_1 / l_1$	$6A_2 x_2 / l_2$
UDL for entire span	$wl^3 / 4$	$wl^3 / 4$
Central point loading	$(3/8)\ Wl^2$	$(3/8)\ Wl^2$
Uneven point loading	$(wa / l) / (l^2 – a^2)$	$(wb / l) / (l^2 – b^2)$

10. Give the procedure for analyzing the continuous beams with fixed ends using three moment equations?

The three moment equations, for the fixed end of the beam, can be modified by imagining a span of length l_0 and moment of inertia, beyond the support the and applying the theorem of three moments as usual.

11. Define Flexural Rigidity of Beams.

The product of young's modulus (E) and moment of inertia (I) is called Flexural Rigidity (EI) of Beams. The unit is N mm^2.

12. What is a fixed beam?

A beam whose both ends are fixed is known as a fixed beam. Fixed beam is also called as built-in or encaster beam. Incase of fixed beam both its ends are rigidly fixed and the slope and deflection at the fixed ends are zero.

13. What are the advantages of fixed beams?

(i) For the same loading, the maximum deflection of a fixed beam is less than that of a simply supported beam.
(ii) For the same loading, the fixed beam is subjected to lesser maximum bending moment.
(iii) The slope at both ends of a fixed beam is zero.
(iv) The beam is more stable and stronger.

14. What are the disadvantages of a fixed beam?

(i) Large stresses are set up by temperature changes.
(ii) Special care has to be taken in aligning supports accurately at the same lavel.
(iii) Large stresses are set if a little sinking of one support takes place.
(iv) Frequent fluctuations in loadingrender the degree of fixity at the ends very uncertain.

15. Write the formula for deflection of a fixed beam with point load at centre.

$$\delta = \frac{-\ wl^3}{192\ EI}$$

This defection is ¼ times the deflection of a simply supported beam.

16. Write the formula for deflection of a fixed beam with uniformly distributed load..

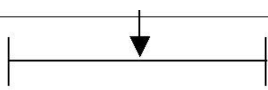
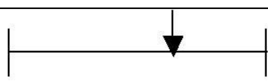
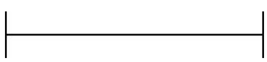
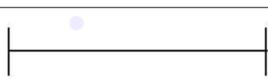
$$\delta = \frac{-\ wl^4}{384\ EI}$$

This defection is 5 times the deflection of a simply supported beam.

17. Write the formula for deflection of a fixed beam with eccentric point load..

$$\delta = \frac{-\ wa^3 b^3}{3EI\ l^3}$$

17. What are the **fixed end moments** for a **fixed beam** with the given loading conditions.

Type of loading	**MAB**	**MBA**
	-wl / 8	wl / 8
	$-wab^2 / l^2$	wab^2 / l^2
	$-wl^2 / 12$	$wl^2 / 12$
	$\frac{-wa^2}{12\ l^2}(6l^2 - 8la + 3a^2)$	$\frac{-wa^2}{12\ l^2}(4l-3a)$
	$-wl^2 / 30$	$-wl^2 / 30$
	$\frac{-5\ wl^2}{96}$	$\frac{-5\ wl^2}{96}$
	M / 4	M / 4
	$\frac{M_b\ (3a - l)}{l^2}$	$\frac{M_a\ (3b - l)}{l^2}$

UNIT : III

COLUMN

1.Define: Column and strut.

A column is a long vertical slender bar or vertical member, subjected to an axial compressive load and fixed rigidly at both ends.

A strut is a slender bar or a member in any position other than vertical, subjected to a compressive load and fixed rigidly or hinged or pin jointed at one or both the ends.

2. What are the types of column failure?

1. Crushing failure:

The column will reach a stage, when it will be subjected to the ultimate crushing stress, beyond this the column will fail by crushing The load corresponding to the crushing stress is called crushing load. This type of failure occurs in short column.

2. Buckling failure:

This kind of failure is due to lateral deflection of the column. The load at which the column just buckles is called buckling load or crippling load or critical load. This type of failure occurs in long column.

3. What is slenderness ratio (buckling factor)? What is its relevance in column?

It is the ratio of effective length of column to the least radius of gyration of the cross sectional ends of the column.

Slenderness ratio = l eff / r

l eff = effective length of column r
= least radius of gyration

Slenderness ratio is used to differentiate the type of column. Strength of the column depends upon the slenderness ratio, it is increased the compressive strength of the column decrease as the tendency to buckle is increased.

4. What are the factors affect the strength column?

1.Slenderness ratio

Strength of the column depends upon the slenderness ratio, it is increased the compressive strength of the column decrease as the tendency to buckle is increased.

2. End conditions: Strength of the column depends upon the end conditions also.

5. Differentiate short and long column

Short column	Long column
1. It is subjected to direct compressive stresses only.	It is subjected to buckling stress only.
2. Failure occurs purely due to crushing only.	Failure occurs purely due to bucking only.
3. Slenderness ratio is less than 80	Slenderness ratio is more than 120.
4.It's length to least lateral dimension is less than 8. (L / D ‹ 8)	It's length to least lateral dimension is more than 30. (L / D › 30)

6. What are the assumptions followed in Euler's equation?

1. The material of the column is homogeneous, isotropic and elastic.
2. The section of the column is uniform throughout.
3. The column is initially straight and load axially.
4. The effect of the direct axial stress is neglected.
5. The column fails by buckling only.

7. What are the limitations of the Euler's formula?

1. It is not valid for mild steel column. The slenderness ratio of mild steel column is less than 80.
2. It does not take the direct stress. But in excess of load it can withstand under direct compression only.

8. Write the Euler's formula for different end conditions.

1. Both ends fixed. $P_E = \frac{\pi^2 EI}{(0.5L)^2}$

2. Both ends hinged

$$P_E = \frac{\pi^2 EI}{(L)^2}$$

3. One end fixed ,other end hinged.

$$P_E = \frac{\pi^2 EI}{(0.7L)^2}$$

4. One end fixed, other end free.

$$P_E = \frac{\pi^2 EI}{(2L)^2}$$

L = Length of the column

9. Define: Equivalent length of the column.

The distance between adjacent points of inflection is called equivalent length of the column. A point of inflection is found at every column end, that is free to rotate and every point where there is a change of the axis. ie, there is no moment in the inflection points. (Or)

The equivalent length of the given column with given end conditions, is the length of an equivalent column of the same material and cross section with hinged ends , and having the value of the crippling load equal to that of the given column.

10. What are the uses of south well plot? (column curve).

The relation between the buckling load and slenderness ratio of various column is known as south well plot.

The south well plot is clearly shows the decreases in buckling load increases in slenderness ratio.

It gives the exact value of slenderness ratio of column subjected to a particular amount of buckling load.

11. Give Rakine's formula and its advantages.

$$P_R = \frac{f_C A}{(1 + a (l_{eff} / r)^2)}$$

where, P_R = Rakine's critical load f_C = yield stress A = cross sectional area a = Rakine's constant L = effective length r = radius of gyration

In case of short column or strut, Euler's load will be very large. Therefore, Euler's formula is not valid for short column. To avoid this limitation, Rankine's formula is l_{eff} designed. The Rankine's formula is applicable for both long and short column.

12. Write Euler's formula for maximum stress for a initially bent column?

$$= P/A + \frac{P\ a}{(1 - (P / P_E))Z}$$

Where, P = axial load A = cross section area P_E = Euler's load a = constant Z = section modulus

13. Write Euler's formula for maximum stress for a eccentrically loaded column?

$$= P/A + \frac{P\ e\ Sec\ (l\ eff / 2)\ ¥\ 3}{(P / P_E))\ Z}$$

Where, P = axial load A = cross section area P_E = Euler's load e = eccentricity Z = section modulus EI = flexural rigidity

14. What is beam column? Give examples.

Column having transverse load in addition to the axial compressive load are termed as beam column. Eg : Engine shaft, Wing of an aircraft.

15. Define buckling factor and buckling load.

Buckling factor : It is the ratio between the equivalent length of the column to the minimum radius of gyration.

Buckling load : The maximum limiting load at which the column tends to have lateral displacement or tends to buckle is called buckling or crippling load. The buckling takes place about the axis having minimum radius of gyration, or least moment of inertia.

16. Define safe load.

It is the load to which a column is actually subjected to and is well below the buckling load. It is obtained by dividing the buckling load by a suitable factor of safety (F.O.S).

$$\text{Safe load} = \frac{\text{Buckling load}}{\text{Factor of safety}}$$

17. Write the general expressions for the maximum bending moment, if the deflection curve equation is given.

$$BM = -EI\ (d^2y / dx^2)$$

18. Define thick cylinders.

Thick cylinders are the cylindrical vessels, containing fluid under pressure and whose wall thickness is not small. (t ≥ d/20)

19. State the assumptions made in Lame's theory.

i) The material is homogeneous and isotropic.
ii) Plane sections perpendicular to the longitudinal axis of the cylinder remain plane after the application of internal pressure.
iii) The material is stressed within the elastic limit.
iv) All the fibres of the material are to expand or contract independently without being constrained by the adjacent fibres.

20. Write Lame's equation to find out stesses in a thick cylinder.

Radial stress = $\sigma_r = (b - a) / r^2$

Circumferential or hoop stress = $\sigma_c = (b + a) / r^2$

21. State the variation of hoop stress in a thick cylinder.

The hoop stress is maximum at the inner circumference and minimum at the outer circumference of a thick cylinder.

22. How can you reduce hoop stress in a thick cylinder.

The hoop stress in thick cylinders are reduced by shrinking one cylinder over another cylinder.

UNIT : IV

THEORIES OF FAILURE

1. What are the types of failures?

   1. Brittle failure:

      Failure of a material represents direct separation of particles from each other, accompanied by considerable deformation.

   2. Ductile failure:

      Slipping of particles accompanied, by considerable plastic deformations.

2. List out different theories of failure
   1. Maximum Principal Stress Theory. (Rakine's theory)
   2. Maximum Principal Strain Theory. (St. Venant's theory)
   3. Maximum Shear Stress Theory. (Tresca's theory or Guest's theory)
   4. Maximum Shear Strain Theory. (Von –Mises- Hencky theory or Distortion energy theory)
   5. Maximum Strain Energy Theory. (Beltrami Theory or Haigh's theory)

3. Define: Maximum Principal Stress Theory. (Rakine's theory)

According to this theory, the failure of the material is assumed to take place when the value of the maximum Principal Stress $_1$) reaches a value to that of the elastic limit stress(f_y)

4. Define: Maximum Principal Strain Theory. (St. Venant's theory)

According to this theory, the failure of the material is assumed to take place when the value of the maximum Principal Stain (e_1) reaches a value to that of the elastic limit strain(f_y / E) of the material.

5. Define: Maximum Shear Stress Theory. (Tresca's theory)

According to this theory, the failure of the material is assumed to take place when the maximum shear stress equal determined from the simple tensile test.

6. Define: Maximum Shear Strain Theory (Von –Mises- Hencky theory or Distortion energy theory)

According to this theory, the failure of the material is assumed to take place when the maximum shear strain exceeds the shear strain determined from the simple tensile test.

Shear strain energy due to simple tension, $U = f_y^2 / 6G$

7. Define: Maximum Strain Energy Theory (Beltrami Theory)

According to this theory, the failure of the material is assumed to take place when the maximum strain energy exceeds the strain energy determined from the simple tensile test.

8. What are the theories used for ductile failures?
   1. Maximum Principal Strain Theory. (St. Venant's theory)
   2. Maximum Shear Stress Theory. (Tresca's theory)
   3. Maximum Shear Strain Theory. (Von –Mises- Hencky theory or Distortion energy theory)

9. Write the limitations of Maximum Principal Stress Theory. (Rakine's theory)

1. This theory disregards the effect of other principal stresses and effect of shearing stresses on other planes through the element.

2. Material in tension test piece slips along 45^0 to the axis of the test piece, where normal stress is neither maximum nor minimum, but the shear stress is maximum.

3. Failure is not a brittle, but it is a cleavage failure.

10. Write the limitations of Maximum Shear Stress Theory. (Tresca's theory).

This theory does not give the accurate results for the state of stress of pure shear in which the maximum amount of shear is developed (in torsion test).

11.Write the limitations of Maximum Shear Strain Theory.(Von –Mises- Hencky theory or Distortion energy theory).

It cannot be applied for the materials under hydrostatic pressure.

12. Write the limitations of Maximum Strain Energy Theory. (Beltrami Theory).

This theory does not apply to brittle materials for which elastic limit in tension and in compression are quite different.

13. Write the failure theories and its relationship between tension and shear.

5. Maximum principal stress theory 2. Maximum principal strain theory 3. Strain Energy theory 4.Maximum Shear Strain Theory (Von– Mises - Hencky theory or Distortion energy theory) Maximum Strain Energy Theory

14. Write the volumetric strain per unit volume.

$f_y^2 / 2E$

20. Define : Octahedral Stresses

A plane, which is equally inclined to the three axes of reference, is called octahedral plane. The normal and shearing stress acting on this plane are called octahedral stresses.

21. Define: Plasticity ellipse.

The graphical surface of a Maximum Shear Strain Theory (Von –Mises- Hencky theory or Distortion energy theory) is a straight circular cylinder.

UNIT : V

ADVANCED TOPICS IN BENDING

1. What are the assumptions made in the analysis of curved bars?
   1. Plane sections remain plane during bending.
   2. The material obeys Hooke's law.
   3. Radial strain is negligible.
   4. The fibres are free to expand or contract without any constraining effect from the adjacent fibres.

2. Write the formula for stress using Winkler-Bach theory?

$$\sigma = \frac{M}{R \times A}\left\{1 + \frac{R^2}{h^2}\left[\frac{y}{R+y}\right]\right\}$$

where σ = Bendind stress (i.e., σ_b)
M = Bending moment with which the bar is subjected
R = Radius of curvature of curved bar or it is the distance of axis of curvature from centroidal axis.
A = Area of cross-section
h^2 = is a constant for a cross-section

$$= \frac{1}{A}\int \frac{y^2\,dA}{1+\left[\frac{y}{R}\right]}$$

3. Define unsymmetrical bending.

If the plane of loading or that of bending, does not lie in (or parallel to) a plane that contains the principal centroidal axisof the cross-section, the bending is called unsymmetrical bending.

4. What are the reasons for unsymmetrical bending?
   1. The section is symmetrical but the load line is inclined to both the principal axes.
   2. The section itself is unsymmetrical and the load line is along the centroidal axis.

5. How will you calculate the stress due to unsymmetrical bending?

$$\sigma = \frac{M_U\,U}{I_{VV}} + \frac{M_V\,V}{I_{UU}}$$

where $u = x\cos\theta + y\sin\theta$
$v = y\cos\theta - x\sin\theta$

6. How will you calculate the distance of neutral axis from centroidal axis.

$$y_0 = \frac{-R \times h^2}{R + h^2}$$

-ve sign shows that neutral axis is below the centroidal axis.

7. How will you calculate the angle of inclination of neutral axis with respect to principal axis? $\alpha = \tan^{-1}\left(\frac{I_{UU}}{I_{VV}} \tan\theta\right)$

8. Write the formula for deflection of a beam causing unsymmetrical bending.

$$\delta = \frac{KWl^3}{E}\sqrt{\frac{\sin^2\theta}{I^2_{vv}} + \frac{\cos^2\theta}{I^2_{uu}}}$$

Where K = a constant depending upon the end conditions of the beam and the position of the load along the beam

l = length of the beam

θ = angle of inclination of load W with respect to VV principal axis

9. How will you calculate the resultant stress in a curved bar subjected to direct stress and bending stress.

$\sigma_r = \sigma_o + \sigma_b$

where σ_o = Direct stress = P/A σ_b = Bending stress

10. How eill you calculate the resultant stress in a chain link.

$\sigma_r = \sigma_o + \sigma_b$

where σ_o = Direct stress = $\frac{P \times \sin\theta}{2A}$

σ_b = Bending stress

11. What is shear centre or angle of twist?

The shear centre for any transverse section of the beam is the point of intersection of the bending axis and the plane of the transverse section.

12. Who postulated the theory of curved beam?

Winkler-Bach postulated the theory of curved beam.

13. What is the shape of distribution of bending stress in a curved beam?

The distribution of bending stress is hyperbolic in a curved beam.

14. Where does the neutral axis lie in a curved beam?

The neutral axis does not coincide with the geometric axis.

15. What is the nature of stress in the inside section of a crane hook? Tensile stress

16. Where does the maximum stress in a ring under tension occur?

The maximum stress in a ring under tension occurs along the line of action of load.

17. What is the most suitable section for a crane? Trapezoidal section.

18. What is pure bending of a beam?

When the loads pass through the bending axis of a beam, then there shall be pure bending of the beam.

19. How will you determine the product of inertia.

The product of inertia is determined with respect to a set of axes which are perpendicular to each other.

The product of inertia is obtained by multiplying each elementary area dA by its co-ordinates x and y and integrated over the area A.

$$I_{XY} = \int xy\, dA$$

20. Define principal moment of inertia.

The perpendicular axis about which the product of inertia is zero are called "principal axes" and the moments of inertia with respect to these axes are called as principal moments of inertia.

The maximum moment of inertia is known as Major principal moment of inertia and the minimum moment of inertia is known as Minor principal moment of inertia.

PART B

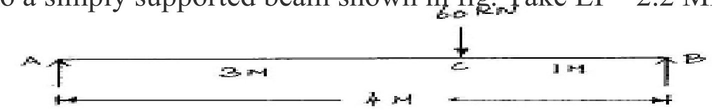
UNIT – 1 ENERGY PRINCIPLES

1. A beam of 4 m length is simply supported at the ends and carries a uniformly distributed load of 6 kN/m length. Determine the strain energy stored in the beam. Take E = 200 GPa and I = 1440 cm4.
2. A beam simply supported over a span of 3 m carries an UDLof 20 kN/m over the entire span. The flexural rigidity EI = 2.25 MNm2 Using Castigliano's theorem, determine the deflection at the centre of the beam.
3. A cantilever beam of span 3 m carries a UDL of 5 kN/m for the entire span in addition to a concentrated load of 20 kN at the free end. Using energy principle, calculate the deflection under the concentrated load. Assume EI = 2 x 104 kNmm2.
4. A simply supported beam of span 8 m carries two concentrated loads of 32 kN and 48 kN at 3 m and 6 m from left support. Calculate the deflection at the centre by strain energy principle.
5. A cantilever beam of span 3 m is carrying a point load of 50 kN at its free end. Compute the strain energy in the beam due to bending and hence deflection under the load. Assume EI = 2 x 105 kNm2.
6. A simply supported beam AB of span 5 m carries a UDL of 25 kN/m throughout its entire span. Calculate the strain energy due to bending and deflection at its mid span. Assume EI = 2 x 104 kNm2.
7. A simply supported beam of 10 m span carries a uniformly distributed load of 2 kN/m over the half of the span. Find the deflection at Mid-span using principle of virtual work. Take EI = 30000 kNm2.
8. A beam of span 8 m carries UDL of 20 kN/m for a length of 4 m from left end. Find the deflection and slope at the centre of the beam by strain energy method. EI is constant.
9. Calculate the strain energy stored in a cantilever beam of 4 m span, carrying a point load of 10 kN at free end. Take EI = 25000 kNm2.
10. Find the deflection at mid span of a simply supported beam carrying a uniformly distributed load of 2 kN/m over the entire span using principle of virtual work. Take span = 5 m; EI = 20000 kNm2.
11. A mild steel specimen of gauge length 50 mm has a cross sectional area of 145 mm2. When it is subjected to a axial pull of 32 kN, it stretches by 0.054 mm. Calculate the strain energy stored in the specimen. If the load at the elastic limit of the specimen is 58 kN, calculate the elongation at elastic limit and proof resilience.
12. A rectangular beam of cross section 100 x 200 mm and length 2 m is simply supported at its ends and carries a central load. If the maximum bending stress is 120 N/mm2. Find the strain energy stored in the beam due to bending. Take E = 2 x

105 N/mm2.

13. Using castigliano's theorem, obtain the deflection at the free end of a cantilever of length 2.5 m carrying a udl of 16.4 kN/m over the whole span. Assume uniform flexural rigidity.

14. Using castigliano's theorem, obtain the deflection under a single concentrated load applied to a simply supported beam shown in fig. Take EI = 2.2 MNm2.



15. A simply supported beam of span 6 m is subjected to a concentrated load of 45 kN at 2 m from the left support. Calculate the deflection under the load point. Take E = 200 x 106 kN/m2and I = 14 x10-6 m4.

UNIT – 2 INDETERMINATE BEAMS

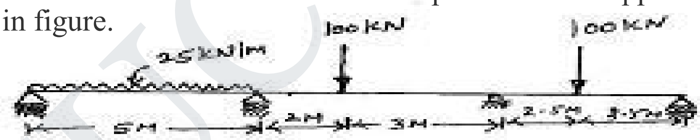
1. A fixed beam of 6 m span is loaded with point loads of 150 kN at a distance of 2 m from each support. Draw the shear force and bending moment diagram. Also find the maximum deflection. Take E = 200 GPa and I = 8 x 108 mm4.
2. A continuous beam consists of three successive spans of 6 m, 12 m and 4 m carries loads of 2 kN/m, 1kN/m and 3 kN/m respectively on the spans. Draw the bending moment diagram and shear force diagram for the continuous beam.
3. A fixed beam of 8 m span carries a uniformly distributed load of 40 kN/m run over 4 m length starting from left end and a concentrated load of 80 kN at a distance of 6 m from the left end. Find

(i) Moments at the supports (ii)Deflection at centre of the beam. Take EI = 15000 kNm2.

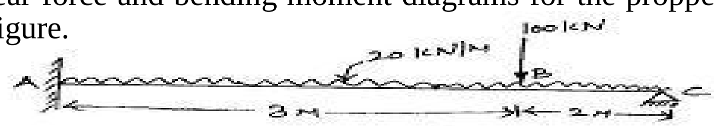
4. A cantilever AB of span 6 m is fixed at the end 'A' and propped at the end B. It carries a point load of 50 kN at the mid span. Level of the prop is the same as that of the fixed end.

(i) Determine reaction at the prop.(ii) Draw the S.F and B.M diagrams.

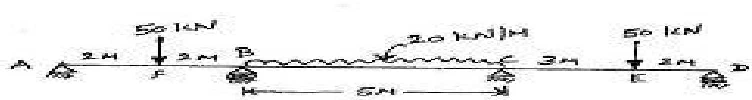
5. Compute the moment and reaction developed at each support of the continuous beam shown in figure.



6. A propped cantilever of span 6 m having the prop at the end is subjected to two concentrated loads of 24 kN and 48 kN at one third points respectively from left fixed end support. Draw shear force and bending moment diagram with salient points.
7. A continuous beam ABC has fixed end at A and is simply supported at B and C. AB = 4 m BC =5 m. Span AB carries a load of 20 kN at 3 m from A. Span BC carries two concentrated loads of 10 kN and 20 kN at 2 m and 3 m from right support C. Draw shear force and bending moment diagrams.
8. Draw the shear force and bending moment diagrams for the propped cantilever beam shown in figure.



9. Compute the moment at each support of the continuous beam shown in figure.



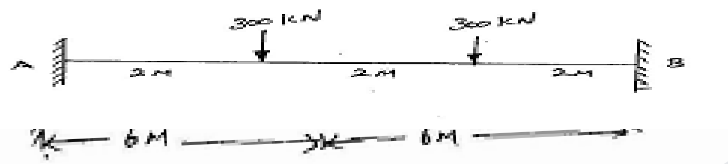
10. A continuous beam of 12 m long, supported over spans AB = BC = CD =4 m, carries a UDL of 3 kN/m over the span AB, a concentrated load of 4 kN at a

distance of 1 m from support B on the span BC, and a concentrated load of 3 kN at the centre of the span CD. Determine moments and reactions developed at each support.

11. A fixed beam of ACB of span 6 m is carrying a uniformly distributed load of 4 kN/m over the left half of the span AC. Find the fixing moments and support reactions.

12. Analyse the beam shown in fig.

13. Analyse the beam shown in fig. EI = constant. Draw the bending moment diagram.



14. A continuous beam ABC consists of two consecutive spans AB and BC 4 m each and carrying an UDL of 60 kN/m. The end A is fixed and C is simply supported. Find the support moments by using three moment equation.

UNIT – 3 COLUMNS

1. A 1.5 m long cast iron has a circular cross section of 50 mm diameter. One end of the column is fixed in direction and position and the other is free. Taking factor of safety as 3, calculate the safe load using Rankine-Gordan formula. Take yield stress as 560 MPa and constant $\alpha = 1/1600$.
2. A pipe of 200 mm internal diameter and 50 mm thickness carries a fluid at a pressure of 10 MPa. Calculate the maximum and minimum intensities of circumferential stress across the section. Also sketch the radial stress distribution and circumferential stress distribution across the section.
3. Find the greatest length of a mild steel rod of 30 mm x 30 mm which can be used as a compressive member with one end fixed and the other end hinged. It carries a working load of 40 kN. Factor of safety = 4, $\alpha = 1/7500$ and $\sigma c = 300$ N/mm2. Compare the result with Euler. Take E = 2 x 105 N/mm2.
4. A column with one end hinged and the other end fixed has a length of 5 m and a hollow circular cross section of outer dia 100 mm and wall thickness 10 mm. If E = 1.60 x 105 N/mm2 and crushing stress $\sigma c = 350$ N/mm2, find the load that the column may carry with a factor of safety of 2.5 according to Euler theory and Rankine-Gordon theory.
5. A solid round bar 4 m long and 60 mm in diameter is used as a strut. Determine the Euler's crippling load under the following end conditions:
   (i) Both ends hinged. (ii) One end fixed and the other end free. (iii)Both ends are fixed and (iv) One end is fixed and the other end is hinged.
   Assume the modulus of elasticity of the material of the bar as 200 kN/mm2.
6. Find the Rankine's critical load for a column of 150 mm internal diameter, 15 mm thick and of length 5.2 m hinged at both ends. E= 200 kN/mm2. Assume fc = 500 MN/m2 and $\alpha = 1/1600$.
7. A hollow cast iron column whose outside diameter is 150 mm and has a wall thickness of 25 mm respectively. It is 3 m long and is fixed at both ends. Using Rankine-Gordan formula, find the critical load. Take Rankine constants as $\alpha = 1/1600$ and $\sigma c = 567$ N/mm2.
8. A T-section 150 mm x 120 mm x 20 mm is used as a strut of 4 m long with hinged at its both ends. Calculate the crippling load, if young's modulus for the material will be 200 GPa.
9. A hollow cast iron strut 150 mm outer and 100 mm inner diameter and 8 m in joi nted and other end rigidly fixed, is subjected to the axial

compressive load. Taking a factor of safety of 5 and Rankine's constants, α = 1/1600 and σc = 550 N/mm2respectively. Using Rankine's formula, calculate the safe load.

10. Find the Euler's critical load for a cast iron hollow column of external diameter 200 mm diameter, 25 mm thick and of length 6 m hinged at both ends. E = 0.8 x 104 N/mm2. Compare Euler's load with Rankine's critical load. Assume fc = 550 N/mm2 and α = 1/1600. Find the length of column at which both critical loads are equal.

11. A pipe of 400 mm internal diameter and 100 mm thick contains a fluid at a pressure of 10 N/mm2. Find the maximum and minimum hoop stress across the section. Also sketch the stress distribution.

12. Find the thickness of steel cylindrical shell of internal diameter 200 mm to withstand an internal pressure of 35 N/mm2.Maximum hoop stress in the section not to exceed 120 N/mm2.

13. Find the greatest length of mild steel bar 25 mm x 25 mm in cross-section which can be used as compression member with one end fixed and the other end free to carry a working load of 35 kN. Allow a factor of safety of 4. Take α = 1/1600 and fc = 320 N/mm2.

14. A hollow cylindrical cast iron column is 4 m long and fixed at the ends. Design the column to carry an axial load of 250 kN. Use Rankine's formula and adopt a factor of safety of 5. The internal diameter may be taken as 0.8 times the external diameter. Take fc = 550 N/mm2and Rankine's constant is 1/1600.

UNIT – 4 STATE OF STRESS IN THREE DIMENSIONS

1. The rectangular stress components of a point in three dimensional stress system are defined as σx = 20 MPa, σy = -40 MPa, σz = 80 MPa, τxy = 40 MPa, τyz = -60 MPa and τzx = 20 MPa. Determine the principal stresses at the given point.

2. A steel shaft is subjected to an end thrust produces a stress of 90 MPa and the maximum shearing stress on the surface arising from torsion is 60 MPa. The yield point of the material in simple tension was found to be 300 MPa. Calculate the factor of safety of the shaft according to (i) Maximum shear stress theory and (ii) Maximum distortion energy theory.

3. Two mutually perpendicular planes of an element of a material are subjected to direct stresses of 10.5 MN/m2 (tensile); and 3.5 MN/m2 (compressive) and shear stress of 7 MN/m2. Find (i) The magnitude and direction of principal stresses.
(ii) The magnitude of the normal and shear stresses on a plane on which the shear Stress is maximum.

4. At a point in a strained material there is a tensile stress of 80 N/mm2 upon a horizontal plane and a compressive stress of 40 N/mm2 upon a vertical plane. There is also a shear stress of 48 N/mm2 upon each of these planes. Determine the planes of maximum shear stress at the point. Determine also the resultant stress on the planes of maximum shear stress.

5. A solid circular shaft is subjected to a bending moment of 40 kN.m and a torque of 10 kN.m. Design the diameter of shaft according to (i) Maximum principal stress theory (ii) Maximum shear stress theory (iii) Maximum strain energy theory. Take μ = 0.25, stress at elastic limit = 200 N/mm2 and factor of safety = 2.

6. A solid circular shaft is subjected to a bending moment of 40 kN.m and a torque of 10 kN.m. Design the diameter of the shaft according to
   (i) Maximum principal stress theory (ii) Maximum shear stress theory
   (iii) Maximum strain energy theory.

7. The normal stress in two mutually perpendicular directions are 600 N/mm2 and 300 N/mm2 both tensile. The complimentary shear stresses in these directions are of intensity 450 N/mm2. Find the normal and tangential stresses in the two planes which are equally inclined to the planes carrying the normal stresses mentioned

8. The state of stress (N/mm2), at a point is given by

$$\begin{pmatrix} 40 & 20 & 30 \\ 20 & 60 & 10 \\ 30 & 10 & 50 \end{pmatrix}$$

Determine the principal stresses and the orientation of any one of the principal plane.

9. At a point in a strained material, the major principal stress is 200 N/mm2 tensile and the minor principal stress. If the yield stress of the material is 250 N/mm2, find the value of the minor principal stress at which yielding commence, according to (i) Maximum principal stress theory (ii) Maximum shear stress theory and (iii) Total strain energy theory. Assume Poisson's ratio as 0.28.

10. At the central point in a strained material the principal stresses (MPa) are 60 (tensile), 40 (tensile) and 40 (compressive) respectively. Calculate

(i) The total strain energy per unit volume (ii) Volumetric strain energy per unit volume (iii) Shear strain energy per unit volume. Assume the modulus of elasticity and Poisson's ratio for the material as 120 kN/mm^2.

11. In a triaxial stress system, the six components of the stress at a point are given below: σx= 6 MN/m2, σy = 5 MN/m2, σz = 4 MN/m2, τxy = τyx 1 MN/m2, τyz = τzy 3 MN/m2 and τzx = τxz 2 MN/m2. Find the magnitude of the three principal stresses.

12. The stress tensor at a point is given by

$$\begin{pmatrix} 20 & 15 & 0 \\ 15 & 10 & 5 \\ 0 & 5 & 5 \end{pmatrix} \text{ N/mm2.}$$

Calculate the minimum principal stress.

13. A bolt is under an axial thrust of 9.6 kN together with a transverse force of 4.8 kN. Calculate its diameter according to maximum principal stress theory and maximum shear stress theory. Assume the following, yield strength of material of bolt = 270 N/mm2, factor of safety = 3.0.

14. The state of stress at a point is given by MPa.

$$\begin{pmatrix} 4 & 2 & 3 \\ 2 & 6 & 1 \\ 3 & 1 & 5 \end{pmatrix}$$ Determine the principal stresses.

15. Explain any two theories of failure.

16. In a material the principal stresses are 40 MN/m2, 48 MN/m2 and -30 MN/m2. Calculate

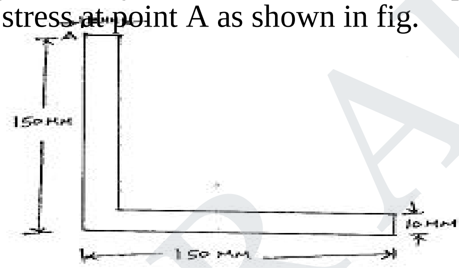
(i) Total strain energy per unit volume
(ii) Shear strain energy per unit volume.
(iii) Volumetric strain energy per unit volume and
(iv) Factor of safety on the total strain energy criterion if the material yields at 110 MN/m2. Poisson's ratio = 0.3, E = 200 x 109 N/m2.

17. The state of stress at a point is given by

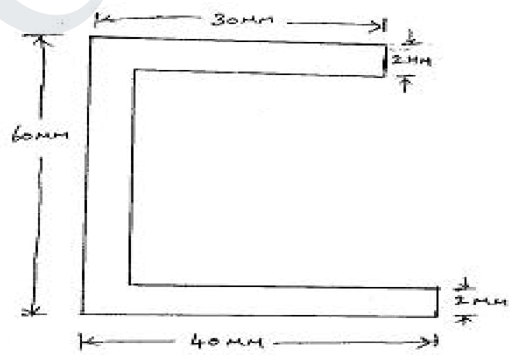
$$\begin{pmatrix} 9 & 6 & 3 \\ 6 & 5 & 2 \\ 3 & 2 & 4 \end{pmatrix}$$ MPa. Determine the principal stresses.

UNIT – 5 ADVANCED TOPICS IN BENDING OF BEAMS

1. Find the centroidal principal moments of inertia of an equal angle section 30 mm x 30 mm x 10 mm.
2. A compound tube is composed of 250 mm internal diameter and 25 mm thick shrunk on tube of 250 mm external diameter and 25 mm thick. The radial pressure at the junction is 8 N/mm2. Find the variation of hoop stress over the wall of the compound tube.
3. Calculate the thickness of metal necessary for a steel cylindrical shell of internal diameter 100 mm to withstand an internal pressure of 40 N/mm2, if the allowable tensile stress is 120 N/mm2.
4. Explain with figure the conduct of Fatigue test for a material in the laboratory.
5. Find the thickness of metal necessary for a steel cylinder of internal diameter 200 mm to withstand an internal pressure of 50 N/mm2. The maximum hoop stress in the section is not to exceed 150 N/mm2. Assume thick cylinder.
6. An equal angle section 150 mm x 150 mm x 10 mm is used as a simply supported beam of 4 m length is subjected to a vertical load passing through the centroid. Determine bending stress at point A as shown in fig.



7. Find the principal moment of inertia of angle section 60 mm x 40 mm x 6 mm.
8. Find the thickness of metal necessary for a cylindrical shell of internal diameter 150 mm to withstand an internal pressure of 50 N/mm2. The maximum hoop stress in the section is not to exceed 150 N/mm2.
9. Determine the principal moment of inertia for an unequal angle section 60 mm x40 mm x 6mm.
10. Find the principal moment of inertia of channel section shown in fig.



11. A beam of Tee section having flange of 100 mm x 20 mm and web of 150 mm x 10mm and 3 m long is simply supported at its ends. It carries 4 kN at 30 ° to vertical and passing through the centroid of the section. Calculate the maximum tensile stresses and maximum compressive stresses. E = 200 kN/mm2.
12. Determine the principal moment of inertia for an angle section 80 mm x80 mm x 10 mm
13. A 80 x 80 x 10 mm angle is used as a simply supported beam over a span of 2.4 m. It carries a load of 400 kN along the vertical axis passing through the centroid of the section. Determine the resulting bending stress on the outer corners of the section along the middle section of the beam.