1. Basic Concepts

1.1 Introduction:

Structural Engineering

- Analysis (SOM, SA)
  - Equilibrium
  - Compatibility
  - Energy
- Design (RCC, PSC, STEEL)
  - Safety
  - Serviceability
  - Durability
  - Economy
  - Aesthetic

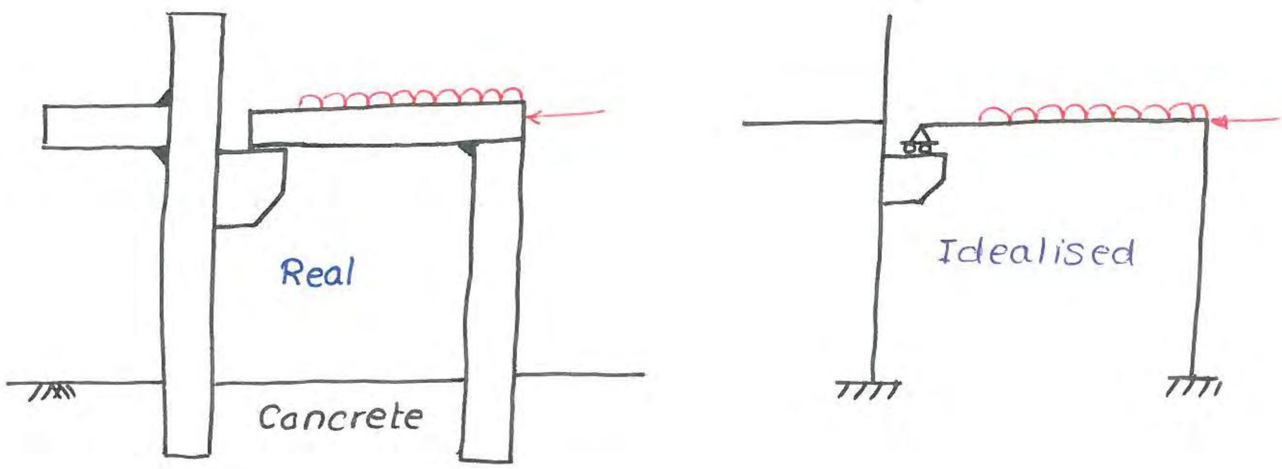
1.2 What is a Structure?

Any arrangement of members that can transfer load acting upon it to the supports safely can be termed as Structure.

1.3 Meaning of Structural Analysis:

Support Reactions → BMD & SFD (SA) → Deflection and Rotation, Stress, Strain (SOM)

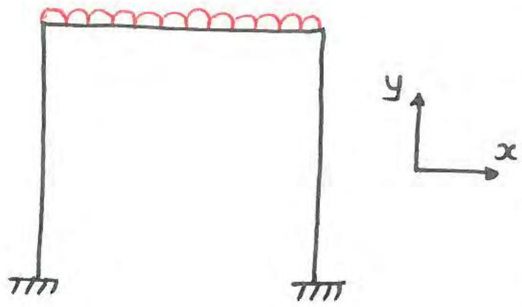
1.4 Idealisation of Structure:



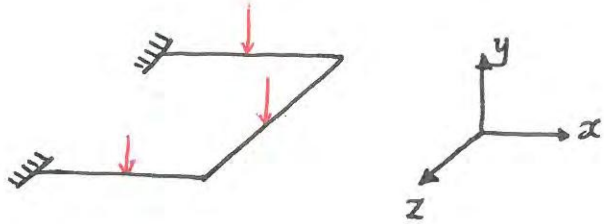
1.5 Planar and 3D Structure:

If 2-axes are sufficient to define geometry and loading of a structure then that structure is called 2D structure/ planar structure.

If 3-axes are required to define geometry and loading of a structure then that structure is called 3D structure.

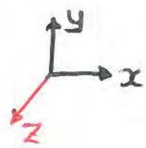
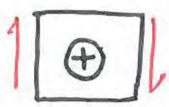


2D



3D

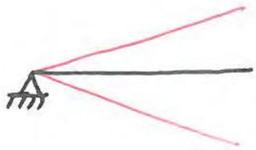
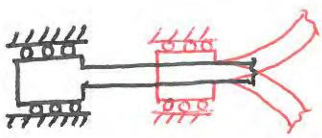
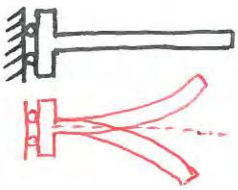
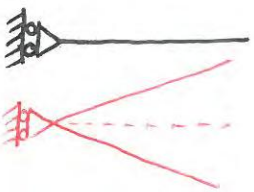
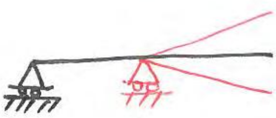
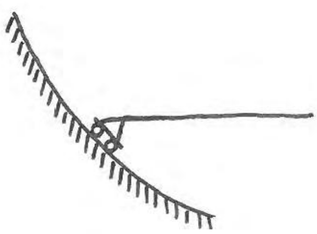
1.6 Sign Convention:

	Positive
x-axis	→
y-axis	↑
z axis	$\vec{x} \times \vec{y}$ 
Rotation	Clockwise
Forces	Along axis
Moment	Clockwise
SF	
BM	

1.7 Types of Support :

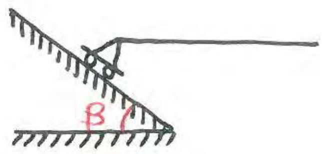
Any arrangement that can restrict movement of any point of a structure is called as support.

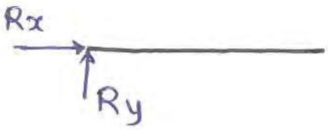
Reaction at support is always due to restriction of movement so direction of reaction is always in opposite direction to expected movement.

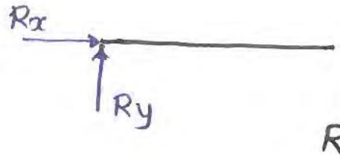
Movement Restricted	Representation	Reaction	Remarks.
x, y. rotation			Fixed
x, y			pin / Hinge
y. rotation			Guided Roller
x, rotation			Guided Roller
x			Roller
y			Roller
			Inclined Roller.

* Note:

Inclined roller support and hinge support both don't provide any movement in x and y direction but we get one reaction for inclined roller and two reactions for hinge support.

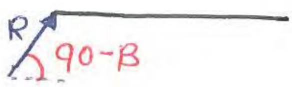






$R_x = R \sin\beta$

$R_y = R \cos\beta$

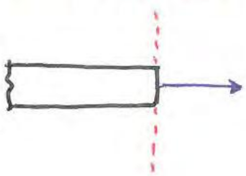


Two unknowns are either (R_x and R_y) or (R and θ)

Unknown is only R because β is known.

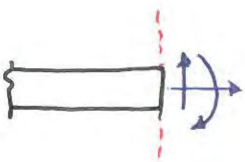
1.8 Types of Structural Member:

1) Axial Member.



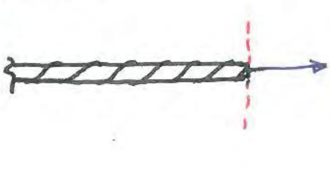
Unknown member forces = 1
(Axial Tension or compression)

2) Beam/Frame Member.



Unknown Member forces = 3
(Axial Tension or compression, Shear, Moment)

3) Cable:



Unknown Member Forces = 1
(Axial Tension)

1.9 Equilibrium and Static Equilibrium:

• **Equilibrium:**

If net force (force and moment) acting on a body is zero in all directions then body is in equilibrium.

For e.g. Bodies in space, vehicle moving with constant speed

For 3D :-

$\Sigma F_x = 0 \quad \Sigma M_x = 0$

$\Sigma F_y = 0 \quad \Sigma M_y = 0$

$\Sigma F_z = 0 \quad \Sigma M_z = 0$

For 2D (x-y plane)

$\Sigma F_x = 0$

$\Sigma F_y = 0$

$\Sigma M_z = 0$

• **Static Equilibrium:**

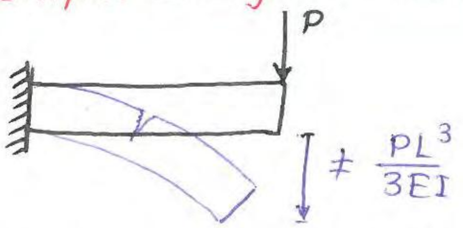
If net force acting on a body is zero and body is in rest/static state then only body can be classified under static equilibrium condition.

For e.g. Buildings, Bridges etc.

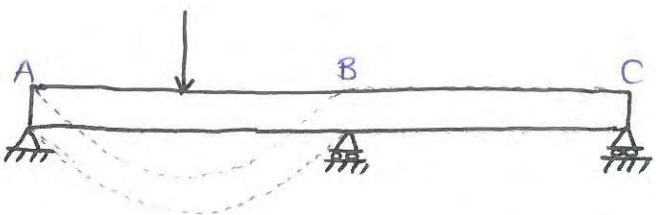
1.10 Compatibility:

The continuity or good-fit of material or member or components while being deformed under loading is called compatibility of structure.

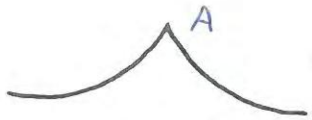
1.10.1 Compatibility of Member:



Compatibility is not maintained due to fracture in member



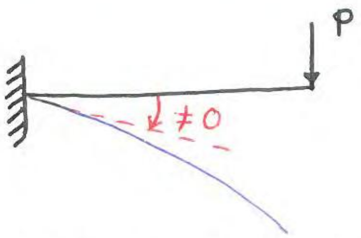
Compatibility is not maintained because of sudden change in slope at B.



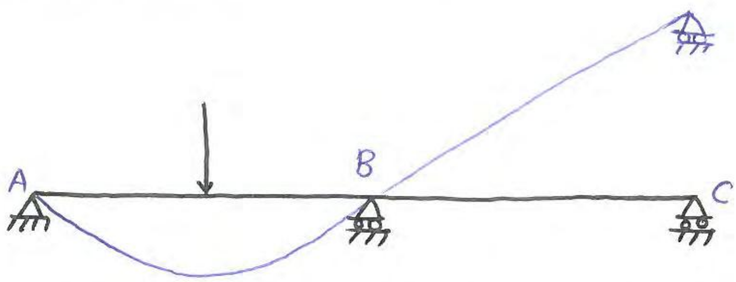
Sudden change in slope at A

Smooth Curve.

1.10.2 Compatibility of Support:

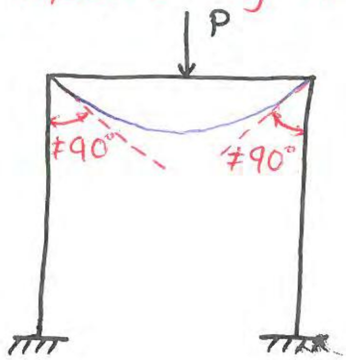


Compatibility is not maintained because of non-zero slope at fixed support.

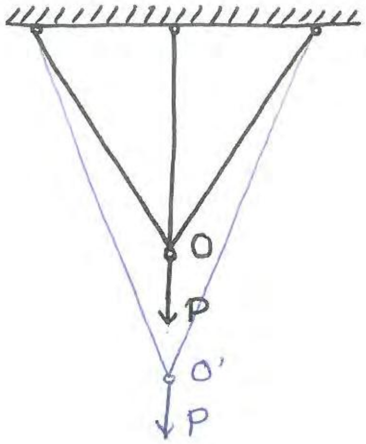


Compatibility is not maintained because of non-zero vertical deflection at C.

1.10.3 Compatibility of Joint:



Compatibility is not maintained because of change in angle between members at rigid joints B & C



Compatibility is not maintained because all 3 members are not intact at O!

1.11 Free Body Diagram:

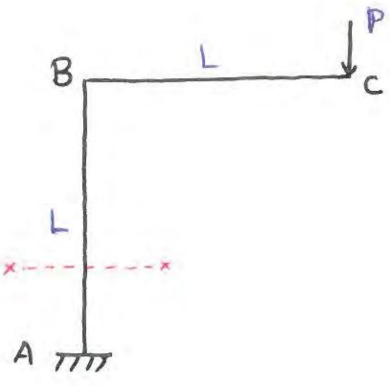
It is a graphical representation of body with all forces (internal and external) acting upon it.

1.11.1 Statically Determinate Structure:

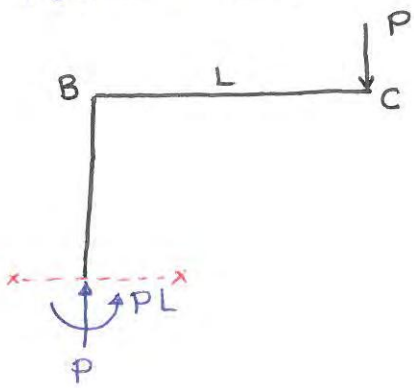
Step I: Make body free from all loads and reactions.

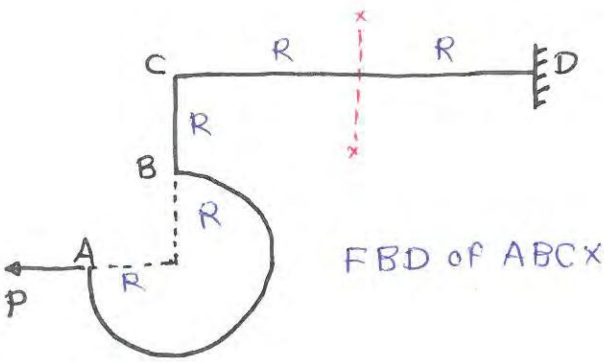
Step II: Apply all loads and support reactions.

Step III: Apply all internal forces at cut section to satisfy conditions of equilibrium.

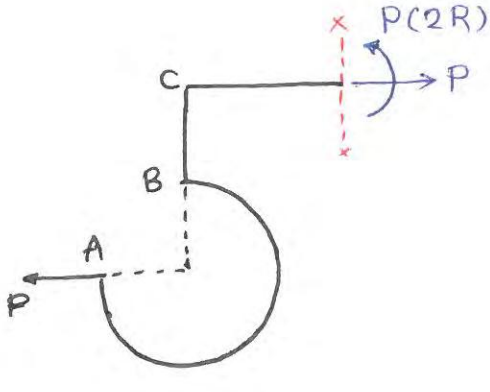


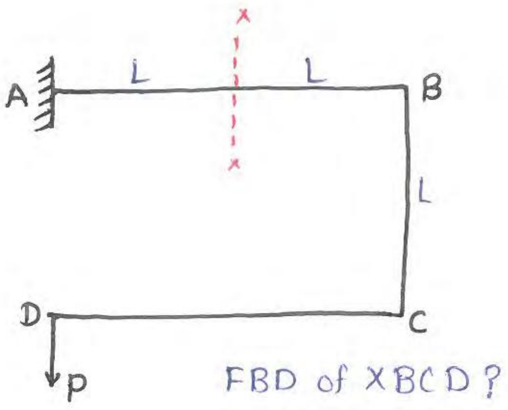
FBD of XBC?

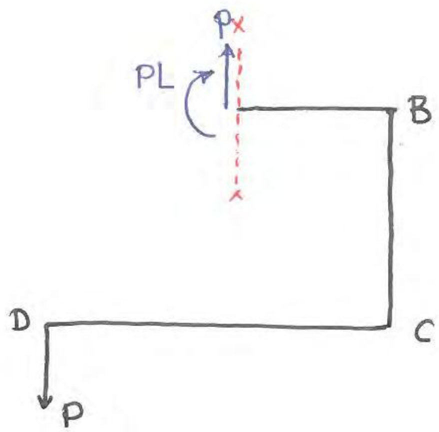




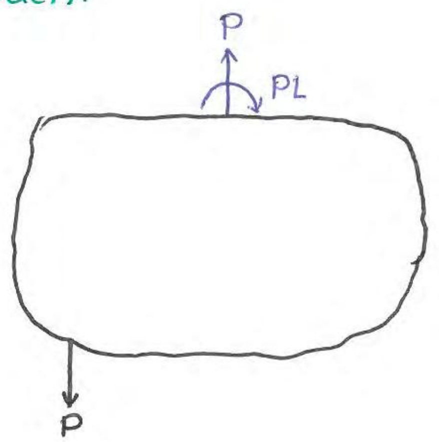
FBD of ABCX?





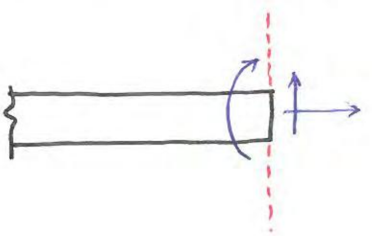


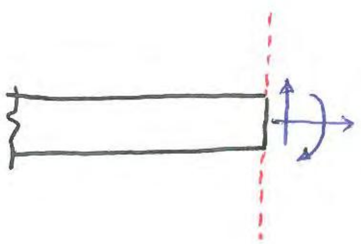
Approach:



*Note:

Preferable way of representation of force at cut section.



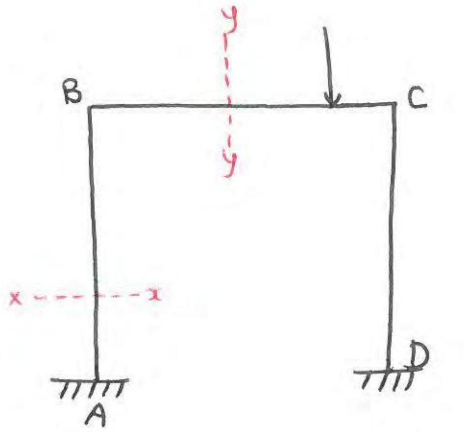


1.11.2 Statically Indeterminate Structure:

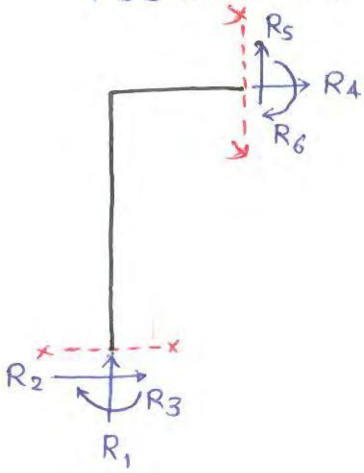
StepI: Make body free from all loads and reactions.

StepII: Apply all external loads and all possible support reactions. (because support reactions are not known).

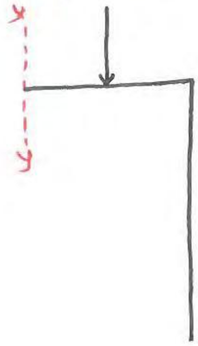
StepIII: Apply all possible internal forces at cut section (because member forces are not known)

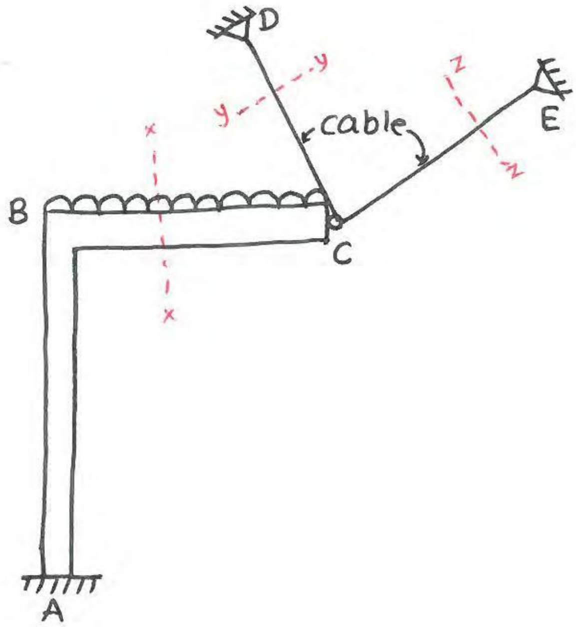


FBD of XBY?

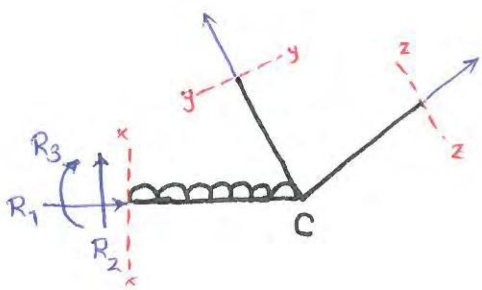


FBD of YCD?





FBD of XCYZ?



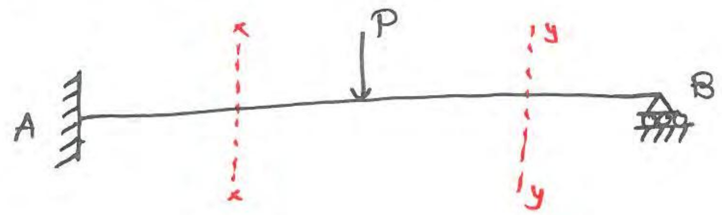
1.12 Static Indeterminacy:

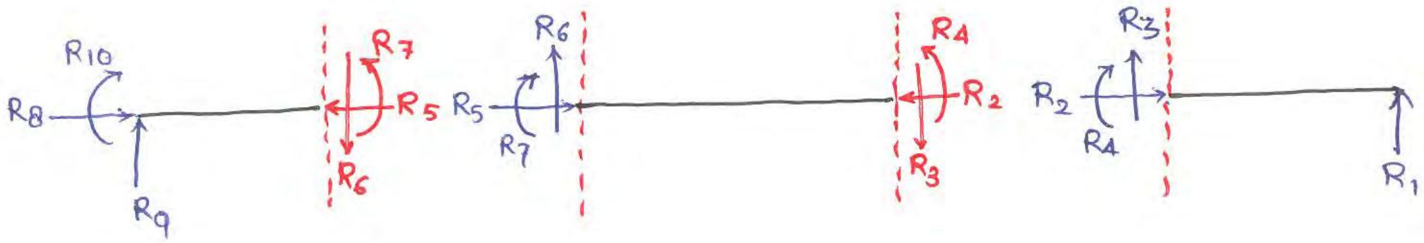
If available equations from conditions of equilibrium are not sufficient to analyse the structure completely then such type of structure is called statically indeterminate structure.

1.12.1 Degree of Static Indeterminacy:

Total number of unknowns (internal forces and support reactions) − Total number of available equations from conditions of equilibrium is called degree of static indeterminacy.

1.12.2 Meaning of DSI





- Observation:

  i) In above FBD, total number of unknown are 10 (R_1 to R_{10})

  ii) Total number of available equations from conditions of static equilibrium are 9 for 3 portions ($3 \times 3 = 9$)

- Conclusion:

  From above FBD, it is clear that only 1 unknown (R_1) is required to be known to calculate all other unknowns (R_2 to R_{10}) so degree of static indeterminacy is 1.

In general, minimum number of unknown forces (support reaction or member forces) are required to be known to calculate all other unknown forces (support reactions and member forces) of a structure is Dsi of that structure.

1.12.3 Procedure:

StepI: Identify start joint.

StepII: Calculate Total number of unknowns (member forces and support reactions) at that joint.

StepIII: Calculate total number of available equations (including extra equations due to release) at that joint.

StepIV: Calculate StepII - Step III. This is static indeterminacy at that joint. It may be positive or negative.

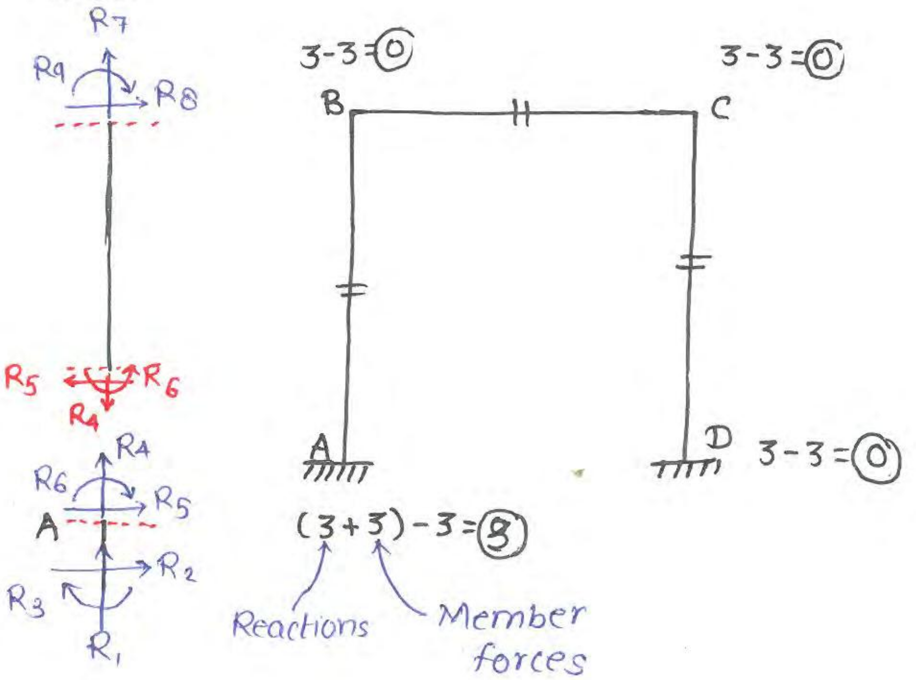
StepV: Make mark on each member meeting at that joint.

StepVI: Repeat stepII to StepV at all joints.

StepVII: Add up values obtained from stepIV for all joints. This is Dsi of entire structure.

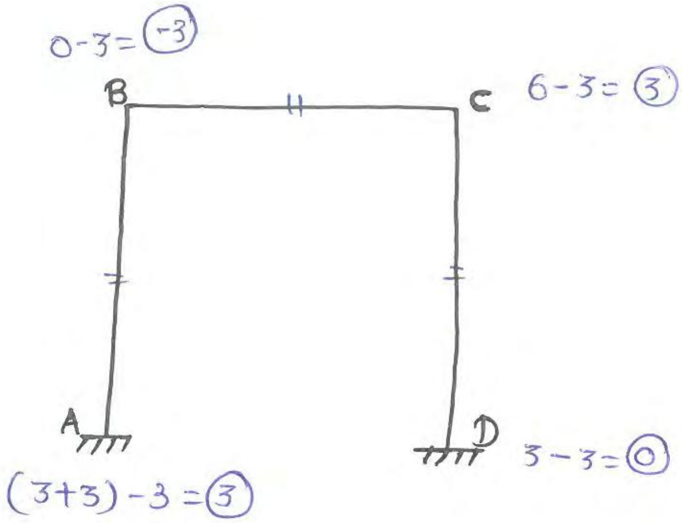
*** Note:**
Free end of overhang portion should also be considered as joint.

Ex.1.



Seq → ABCD

DSI = 3+0+0+0
= 3

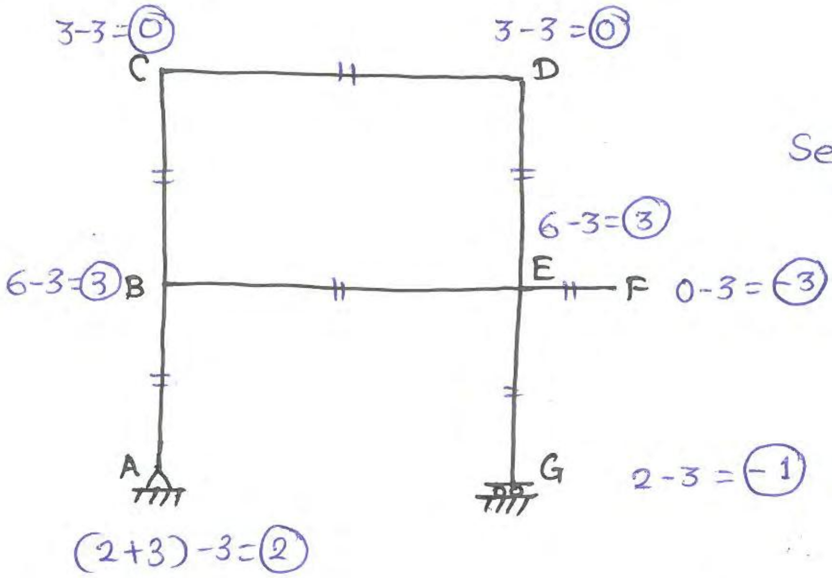


Seq - CABD

DSI = 3+3-3+0

= 3

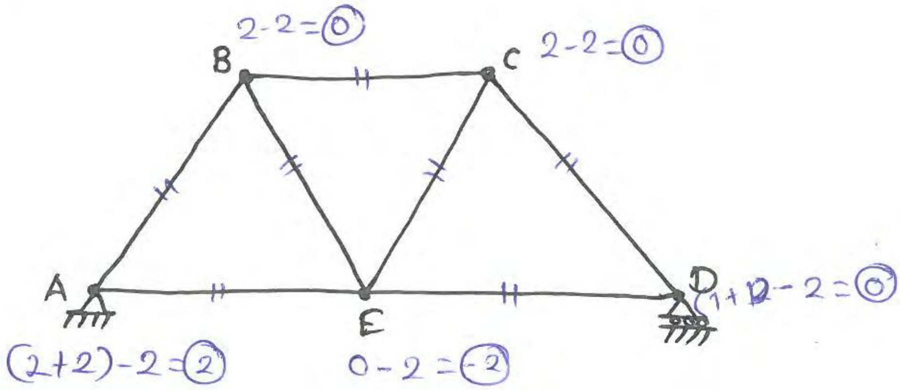
Ex.2



Seq. ABCDEFG

DSI = 2+3+3-3-1 = 4

Ex.3.

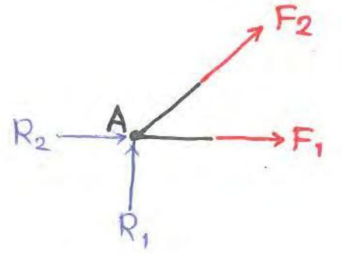


Seq. ABCDE

DSI = 2 - 2 = 0

*Note:

$\Sigma M_Z = 0$ does not provide any equilibrium equation at joint of truss because all forces are concurrent at joint of truss.

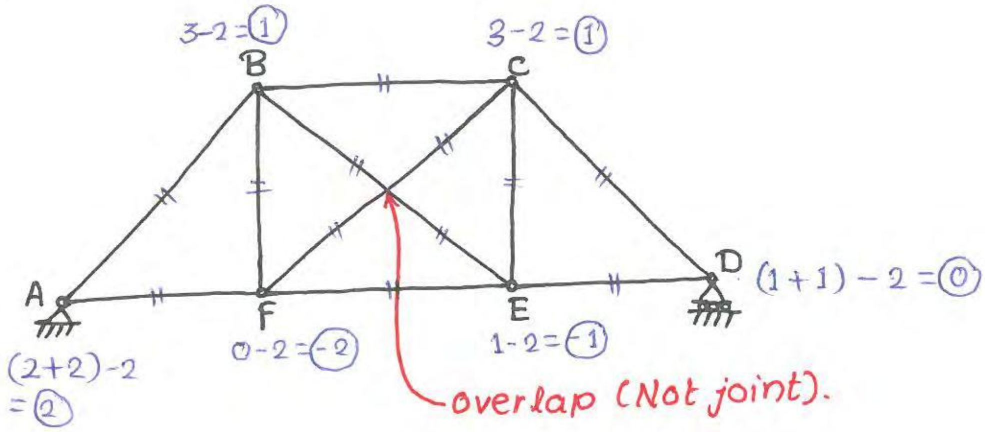


$\Sigma M_Z = 0$

$\Rightarrow \Sigma M_A = 0$

$\Rightarrow 0 = 0$ (useless)

Ex.4.



Seq. A to F

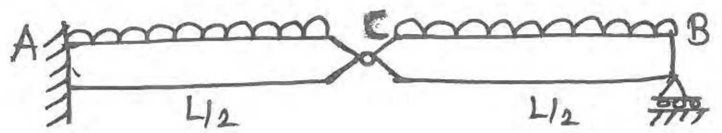
DSI = 2 + 1 + 1 + 0 - 1 - 2 = 1

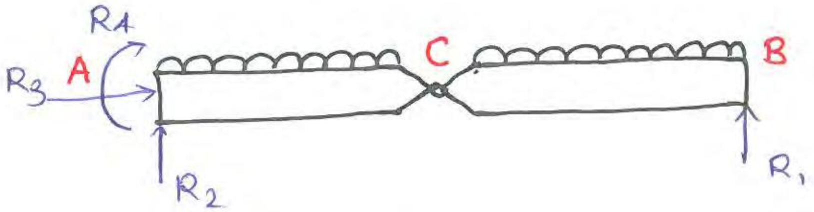
1.12.4 Effect of Internal Hinge:

- Internal Hinge:-

It is a joint in a structure about which part of a structure may rotate.

If structure is in equilibrium then no part of a structure is rotating about hinge. It means, moment about internal hinge from either side must be zero.





$\Sigma F_x = 0$

$\Rightarrow R_3 = 0$ ----- (i)

$\Sigma F_y = 0$

$\Rightarrow R_1 + R_2 - WL = 0$ ----- (ii)

$\Sigma M_z = 0$

$\Rightarrow \Sigma M_A = 0$

$\Rightarrow R_4 + WL \times \frac{L}{2} - R_1 \times L = 0$ ---- (iii)

$M_c = 0$ (Right)

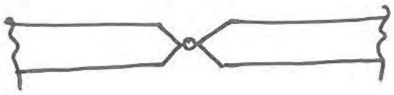
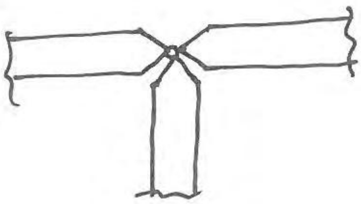
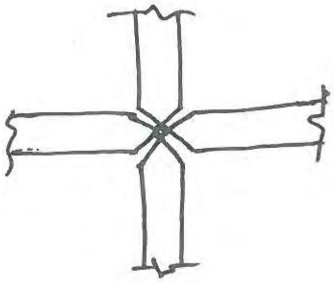
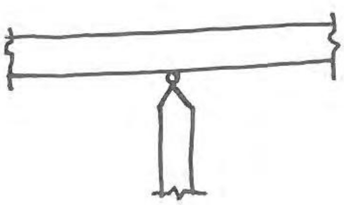
$\Rightarrow W \times \frac{L}{2} \times \frac{L}{4} - R_1 \times \frac{L}{2} = 0$ ---(iv)

$M_c = 0$ (Left)

$\Rightarrow R_2 \times \frac{L}{2} + R_4 - W \times \frac{L}{2} \times \frac{L}{4} = 0$ ---- (v)

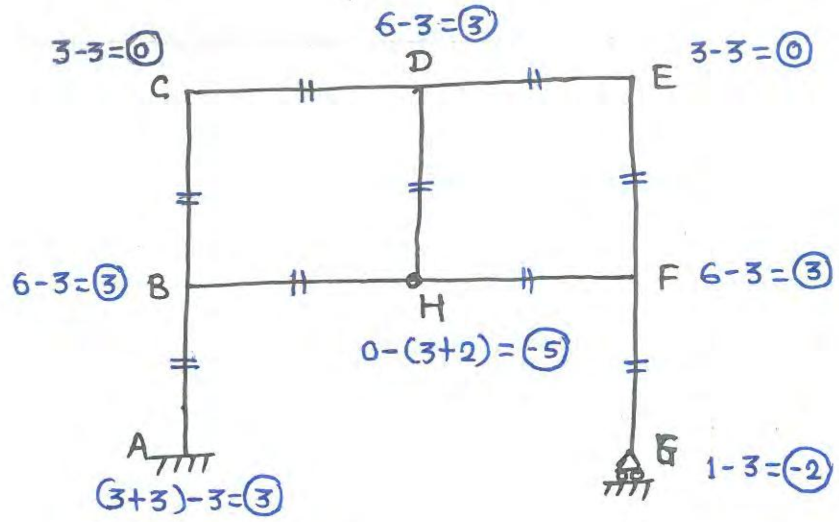
By adding equation (iv) and (v) and replacing R_2 in terms of R_1 from equation (ii), we get equation (iii). It means, moment about hinge equal to zero from both sides does not provide independent equations.

Moment about hinge equal to zero from all sides is equivalent to $\Sigma M_z = 0$.

Arrangement of Hinge	No of extra equation. 2D	No of extra equation. 3D
	1	3
	2	6
	3	9
	1	3

In general for 2D structure.

No. of extra equations at hinge = No. of members connected through hinge − 1

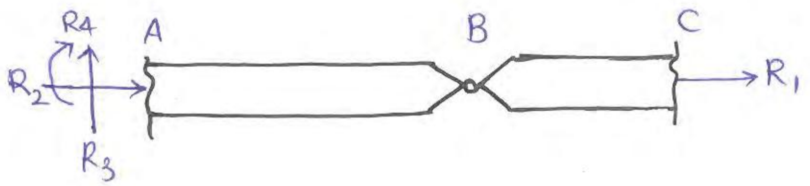


seq. A to H

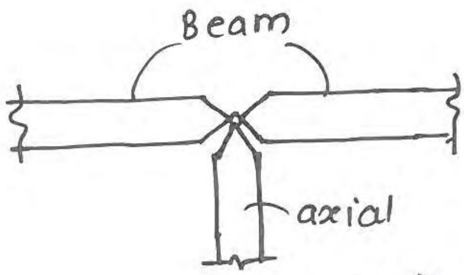
DSI = 12-7 = 5

***Note:**

If axially loaded member is connected through hinge then that does not provide any extra equation at hinge.

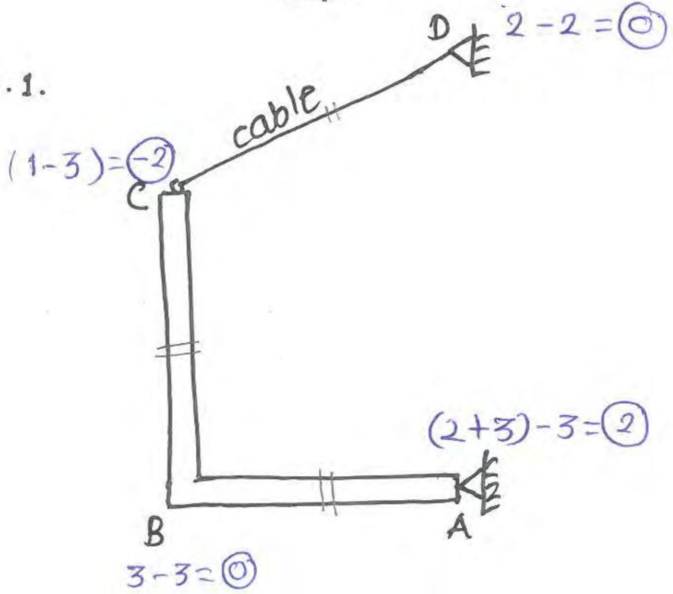


No extra equation



One extra equation.

Ex. 1.



seq. ABCD

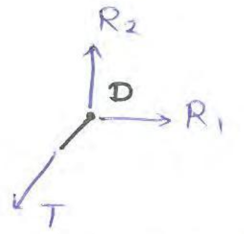
DSI = 0

At joint C:

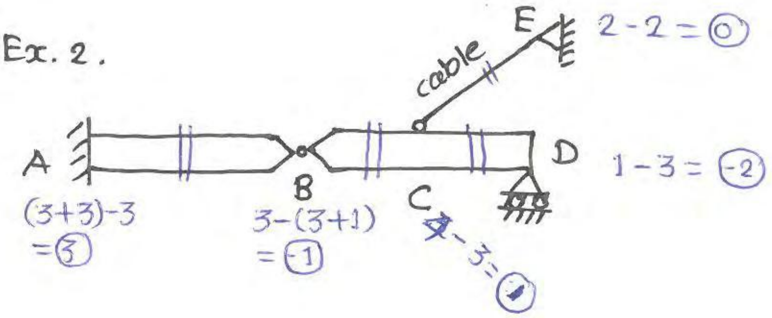
Hinge doesn't provide any extra equation because CD is axial (cable)

At joint D:-

$\Sigma M_z = 0$ doesn't provide any equation because all forces are concurrent at D.



Ex. 2.



seq. ABCDE

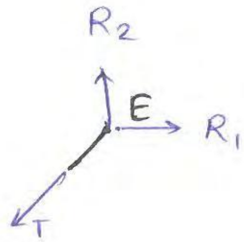
DSI = 1

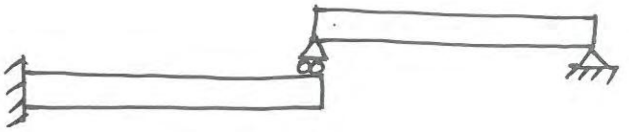
At joint C:

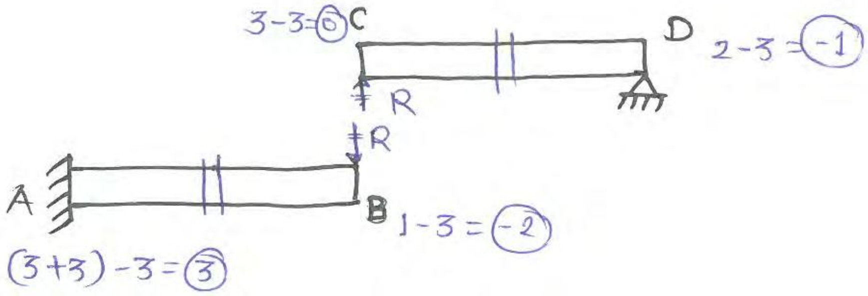
Hinge doesn't provide any extra equation because CE is axial (cable)

At joint E:-

$\Sigma M_z = 0$ doesn't provide any equation because all forces are concurrent at E.







Seq.- ABCD

DSI = 0

1.12.5 External and Internal Static Indeterminacy:

DSI

- External
- Internal

External

- For 2D Structure:

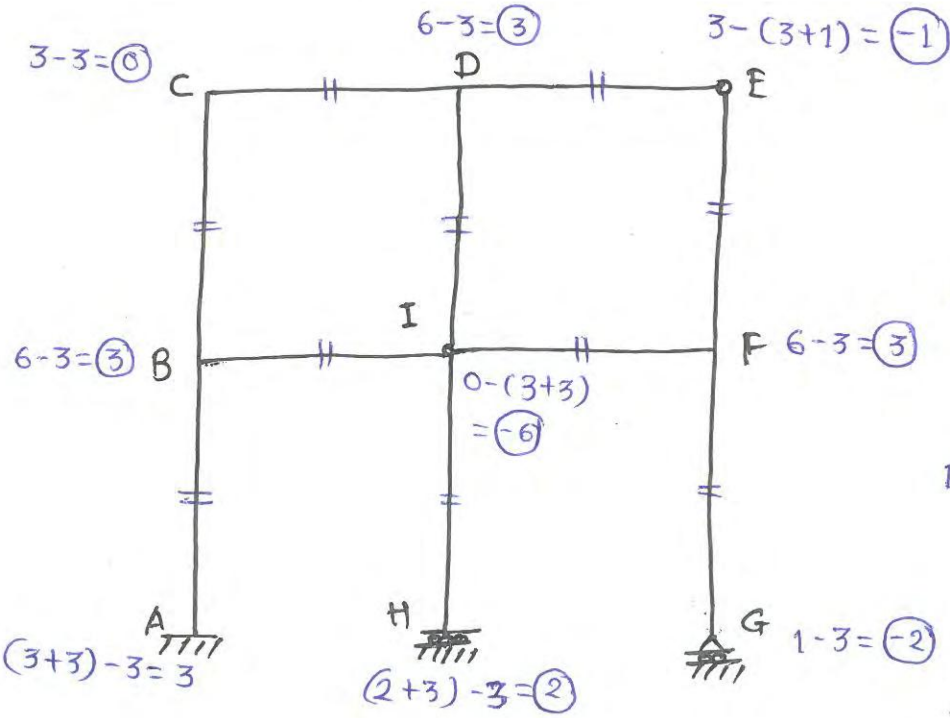
$$DSI_e = \text{Total No. of Reactions} - 3$$

- For 3D Structure

$$DSI_e = \text{Total No. of Reactions} - 6$$

Internal

$$DSI_i = DSI_{Total} - DSI_e$$



Seq. A to I

$DSI_{Total} = 5$

$$DSI_e = \text{Total No of reactions} - 3$$

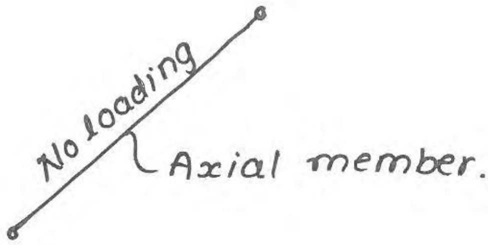
$$= 6 - 3 = 3$$

$$DSI_i = DSI_{Total} - DSI_e$$

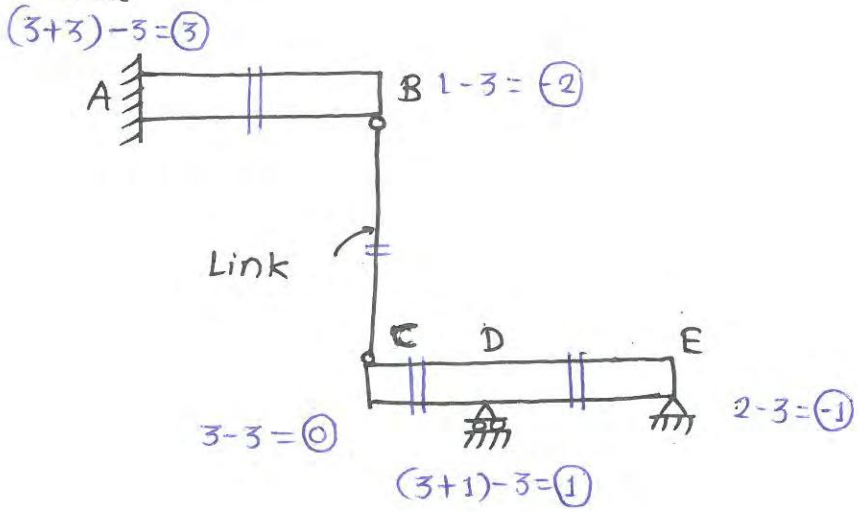
$$= 5 - 3 = 2$$

1.12.6 Concept of Link:

Link is a structural member connected through hinges at both ends and subjected to no loading in between then it has axial force only.



Ex.1

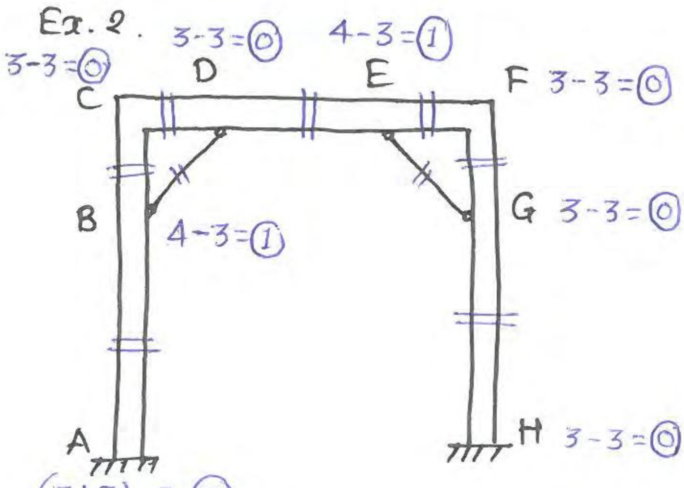


Seq A to E

$DSI_{Total} = 1$

Hinges of B and C don't provide any extra equation because BC is axial (Link).

Ex.2

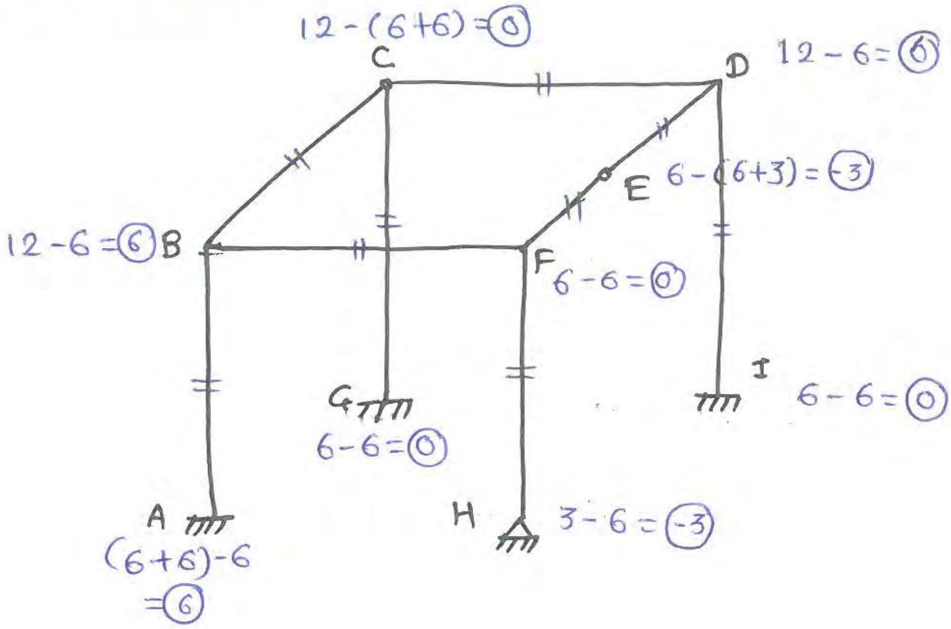


seq A to H

$DSI_{Total} = 5$

Hinges of B, D, E and G don't provide any extra equation because BD and EG are axial (Link)

1.12.7 3D Structure:



seq. A to I

DSI = 12

1.12.8. Formula for DSI

DSI = Total No. of Unknowns − Total No. of available equations

- For 2D:-
  - Beams & Frames:-

    DSI = (3m + r) − (3j + Extra eqns due to release)

  - Truss:-

    DSI = (m + r) − (2j)

- For 3D:-
  - Beams & Frames:-

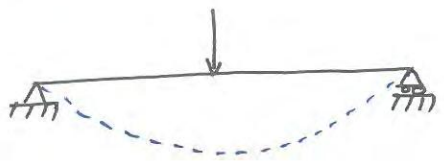
    DSI = (6m + r) − (6j + Extra eqns due to release)

  - Truss:-

    DSI = (m + r) − (3j)

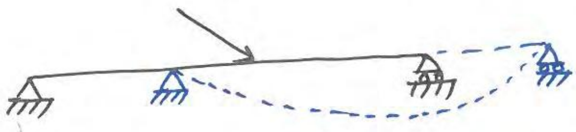
1.13 Stability of a Structure:

1.13.1 Difference between Movement and Deformation:



Deformation

Movement



Deformation + Movement.

*Note:

Structure is considered as stable if there is no movement due to application of load.

1.13.2 Stability Check:

Step I: Calculate DSI of a structure.

Step II: If DSI < 0 then structure is unstable.

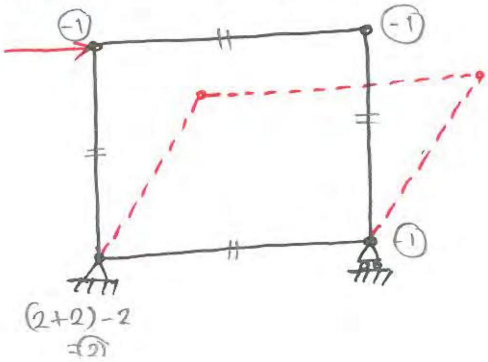
If DSI ≥ 0 then structure is unstable if

a) All reactions are parellel

b) All reactions are concurrent.

c) By visual inspection.

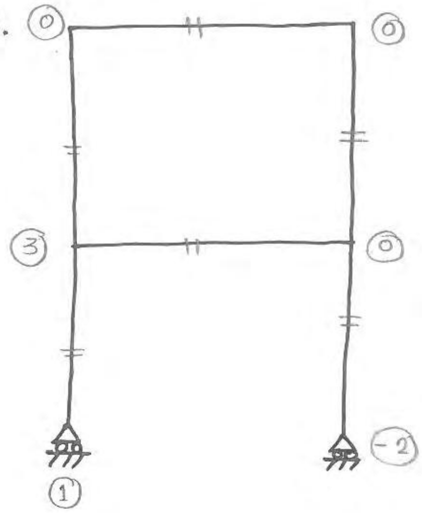
Ex.1. Check stability of given truss.



DSI = $-1 < 0$

So unstable.

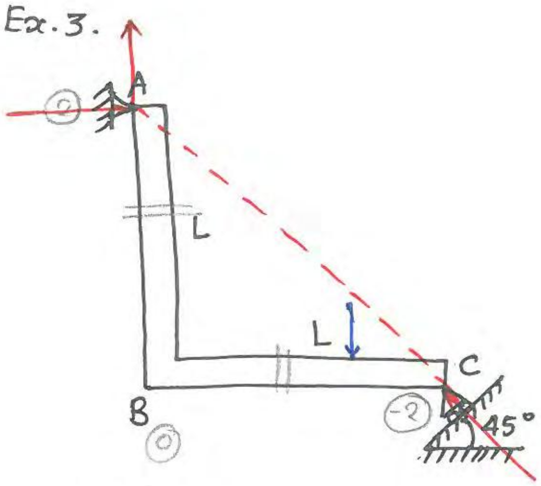
Ex.2.



DSI = 2 >0

Unstable because all reactions are parellel.

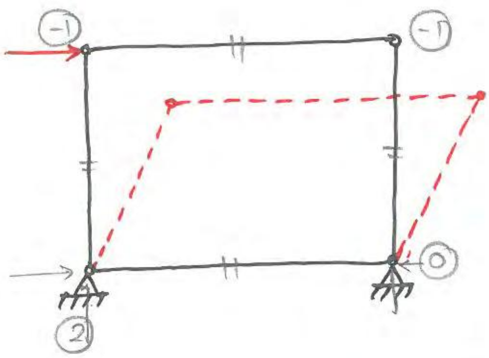
Ex.3.



DSI = 0

Unstable because all reactions are concurrent

Ex. 4. Check stability of given truss:

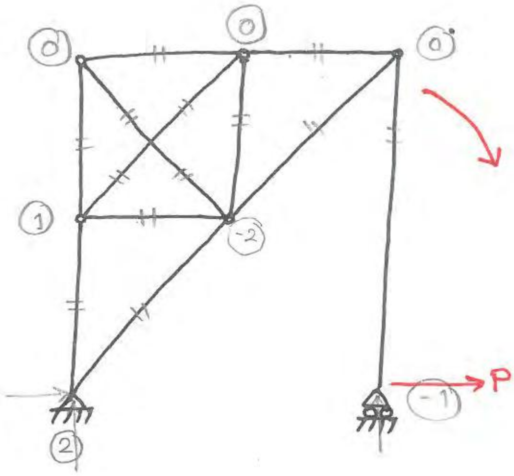


DSI = 0

Unstable by visual inspection.

Rectangular panel of truss makes truss unstable.

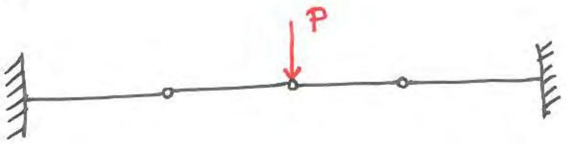
Ex. 5.



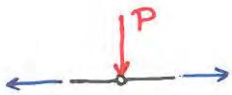
DSI = 0

Unstable by visual inspection.

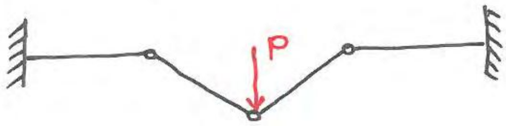
Ex. 6.

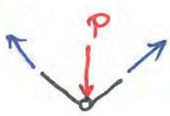


DSI = 0



$\Sigma F_y \neq 0$ ⇒ Unstable.

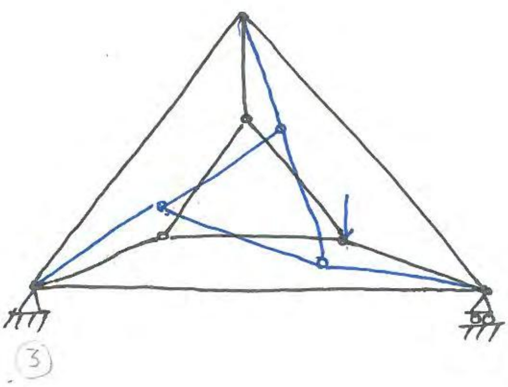




$\Sigma F_y = 0$ ⇒ Stable

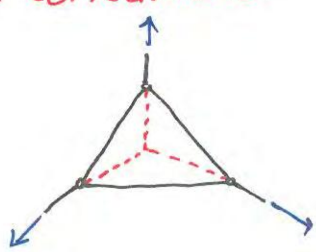
• Note: Three collinear hinges makes structure unstable.

Ex. 7.

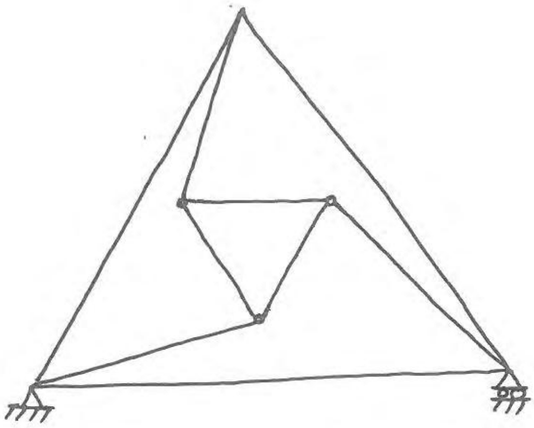


DSI = 0

Unstable because supporting forces of internal triangle are concurrent.



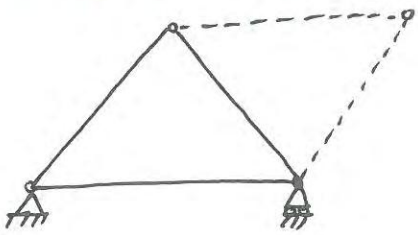
Ex. 8.



DSI = 0
Stable.

- Note:
  - Externally Unstable → Car without brake.
  - Internally Unstable → swing.

1.13.3 Deficient Truss:



$m = 2j - 3$ (Perfect Truss)

$m < 2j - 3$ (Deficient Truss) Unstable

$m > 2j - 3$ (Redundant)

1.14 Kinematic Indeterminacy / Degree of Freedom:

Sum of all independent displacements of all joints of a structure is called KI/DOF of structure.

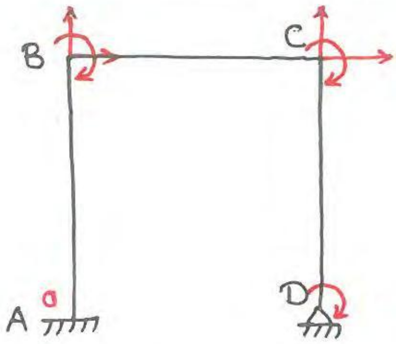
For visualisation only

Rigid ⟶ Stone

Inextensible ⟶ Reinforcing Bar

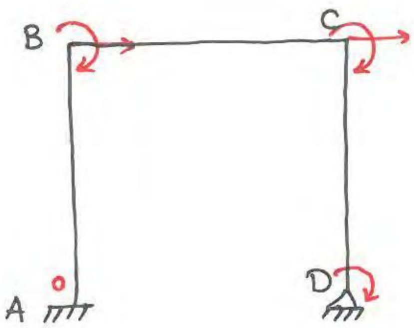
Extensible ⟶ A bar of rubber.

Ex. 1.a) If members are Extensible



$KI = 7$ (Δ_{xB}, Δ_{YB}, θ_B, Δ_{xC}, Δ_{YC}, θ_C, θ_D)

Ex. 1.b) If members are Inextensible.

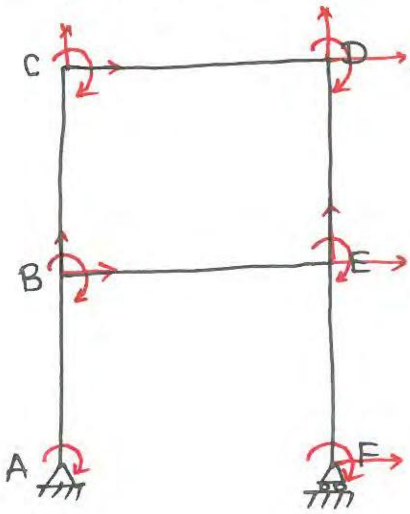


Dependent

$KI = 4$ (Δ_{xB}, θ_B, $\boxed{\Delta_{xC} = \Delta_{xB}}$ θ_C, θ_D)

Ex. 2.

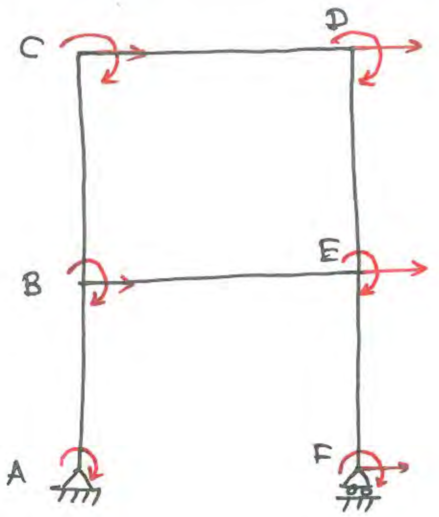
a) Extensible



$KI = 15$ (θ_A, Δ_{xB}, Δ_{YB}, θ_B, Δ_{xC}, Δ_{YC}, θ_C, Δ_{xD}, Δ_{YD}, θ_D, Δ_{xE}, Δ_{YE}, θ_E, Δ_{xF}, θ_F)

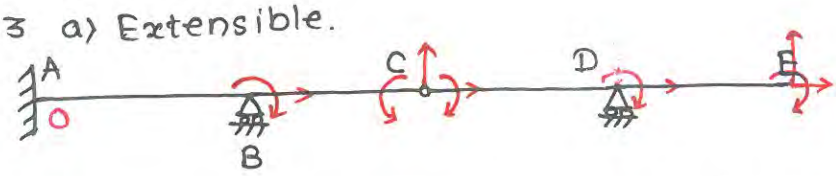
Ex. 2.

b) Inextensible.



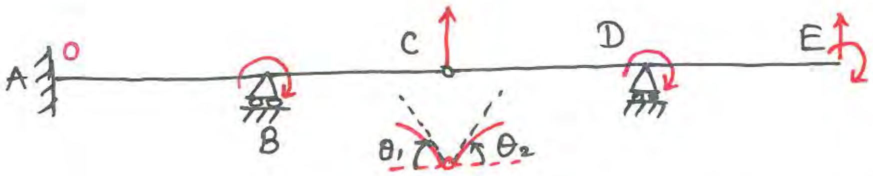
KI = 9 (θ_A, Δ_{xB}, θ_B, Δ_{xC}, θ_C,
$\cancel{\Delta_{xD} = \Delta_{xC}}$, θ_D,
$\cancel{\Delta_{xE} = \Delta_{xB}}$, θ_E,
Δ_{xF}, θ_F

Ex. 3 a) Extensible.



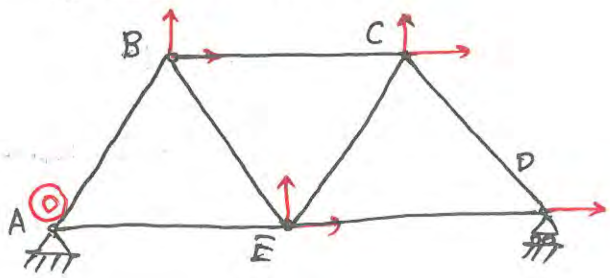
KI = 11 (θ_B, Δ_{xB}, Δ_{xC}, Δ_{YC}, θ_{CD}, θ_{CB}, Δ_{xD}, θ_D,
Δ_{xE}, Δ_{YE}, θ_E)

b) Inextensible.



KI = 7 (θ_B, Δ_{YC}, θ_{CB}, θ_{CD}, θ_D, Δ_{YE}, θ_E)

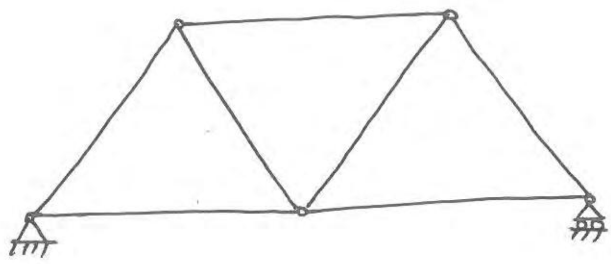
Ex. 4. a) Extensible



KI = 7 (Δ_{xB}, Δ_{YB},
Δ_{xC}, Δ_{YC},
Δ_{xD}, Δ_{xE}, Δ_{YE})

b) Inextensible

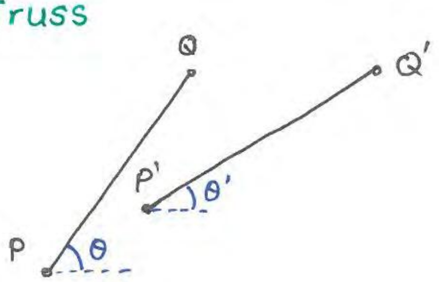
$KI = 0$



* Note:

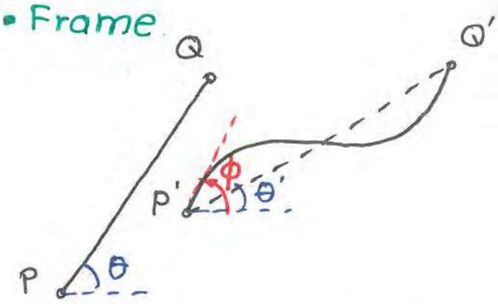
- Rotation of member at joint of truss is not considered as kinematic indeterminacy because member of truss remains straight.

- Truss



$\theta - \theta' = f(\Delta_{xP}, \Delta_{YP}, \Delta_{xQ}, \Delta_{YQ})$

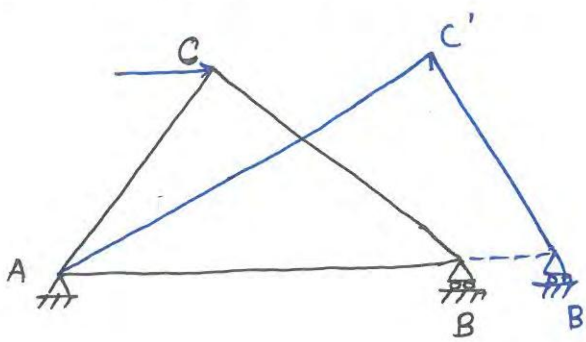
- Frame



$\theta - \theta' = f(\Delta_{xP}, \Delta_{YP}, \Delta_{xQ}, \Delta_{YQ})$

ϕ is considered as KI (not $\theta - \theta'$)

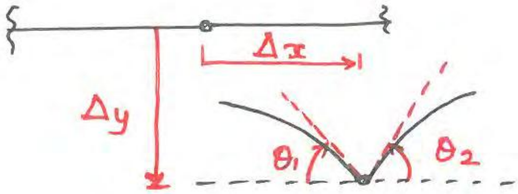
- KI of truss with inextensible member is always zero.



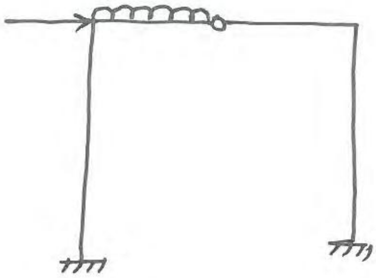
To move joint C to C', elongation and compression are required in member AC and BC respectively. For inextensible member, elongation and compression are not permitted so joint C will not move to C'. It means possible displacements at C is zero.

1.14.1 Types of Release:

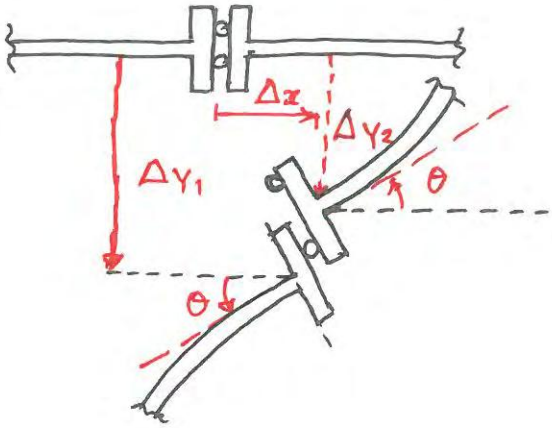
1) Bending Release.



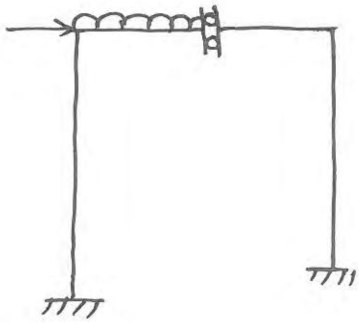
Real Structure



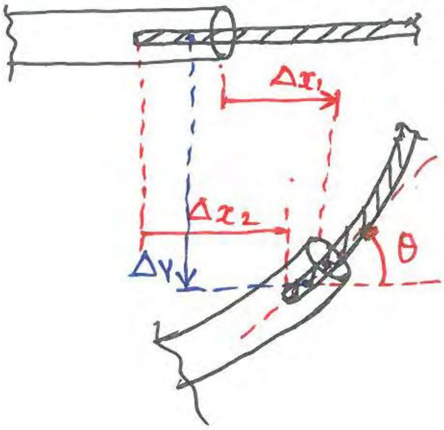
2) Shear Release



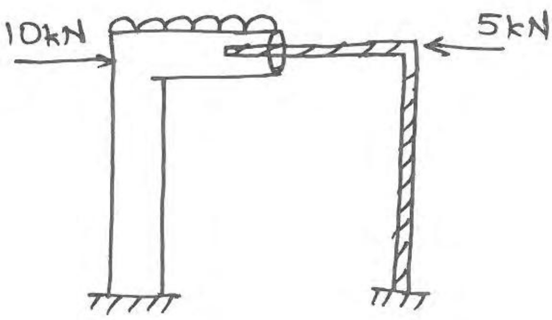
Real Structure



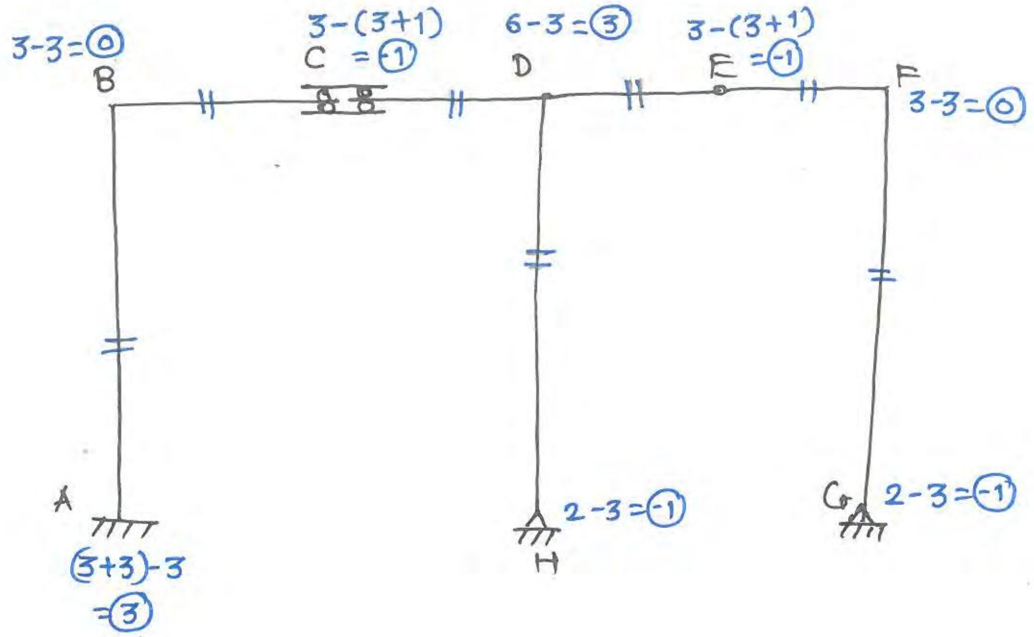
3) Axial Release.



Real Structure

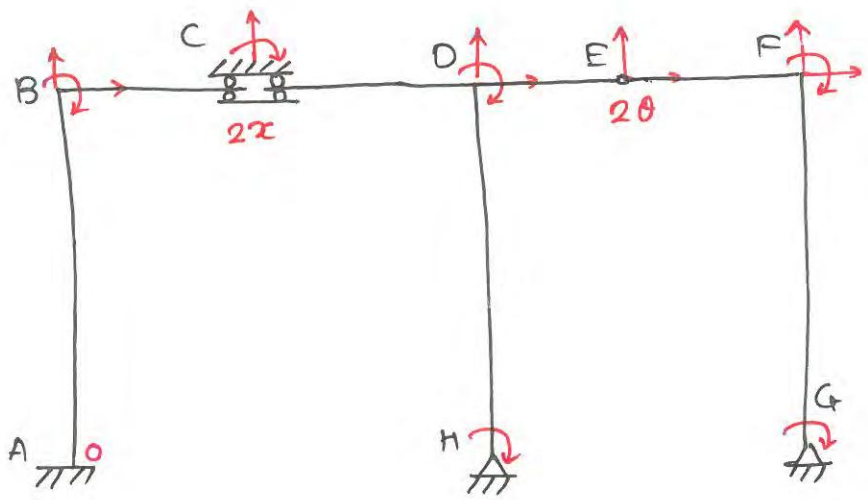


Representation.



Seq. A to H

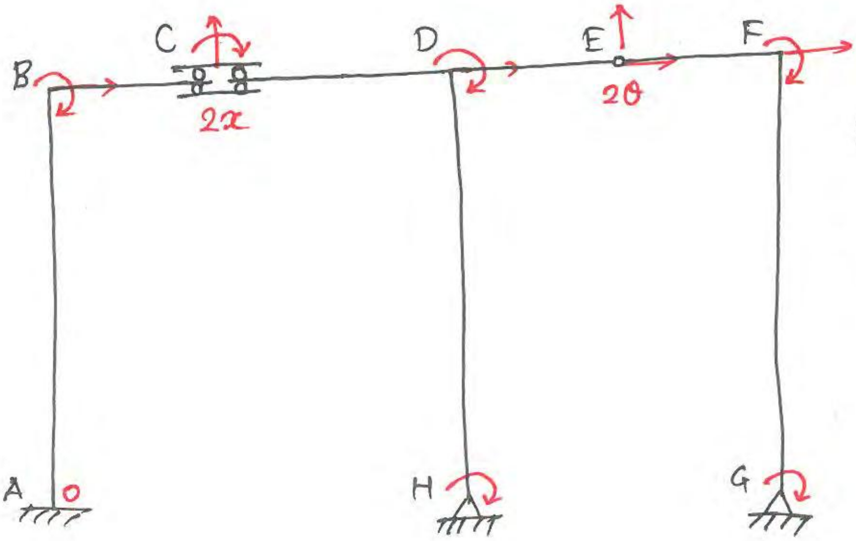
DSI = 2



Extensible

KI = 19

$(\Delta_{xB}, \Delta_{YB}, \theta_B,$
$\Delta_{xCB}, \Delta_{xCD}, \Delta_{YC}, \theta_C$
$\Delta_{xD}, \Delta_{YD}, \theta_D,$
$\Delta_{xE}, \Delta_{YE}, \theta_{ED}, \theta_{EF},$
$\Delta_{xF}, \Delta_{YF}, \theta_F, \theta_G, \theta_H)$



Inextensible

KI = 12

$(\Delta_{xB}, \theta_B, \cancel{\Delta_{xCB} = \Delta_{xB}},$
$\Delta_{xCD}, \Delta_{YC}, \theta_C,$
$\cancel{\Delta_{xD} = \Delta_{xCD}}, \theta_D,$
$\cancel{\Delta_{xE} = \Delta_{xCD}}, \Delta_{YE},$
$\theta_{ED}, \theta_{EF}, \cancel{\Delta_{xF} = \Delta_{xCD}}$
$\theta_F, \theta_G, \theta_H)$

- Formula for KI :-
  - For 2D :-
    - Beams and Frames :-

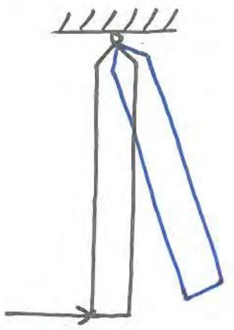
$$KI = \left(3j + \begin{matrix}\text{extra displacements} \\ \text{due to release}\end{matrix}\right) - \left(r + \begin{matrix}\text{No. of inextensible} \\ \text{members}\end{matrix}\right)$$

    - Truss :-

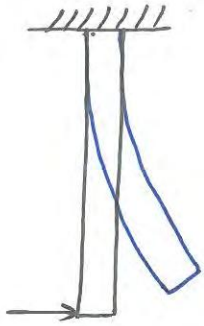
$$KI = (2j) - (r + \text{No. of inextensible members})$$

1.15 Elastic Curve

1.15.1. Difference between elastic curve and deflected shape:-



Deflected Shape



Elastic Curve

All elastic curves are deflected shape but all deflected shapes are not elastic curve.

1.15.2 How to Draw Elastic Curve?

StepI: By visual inspection.

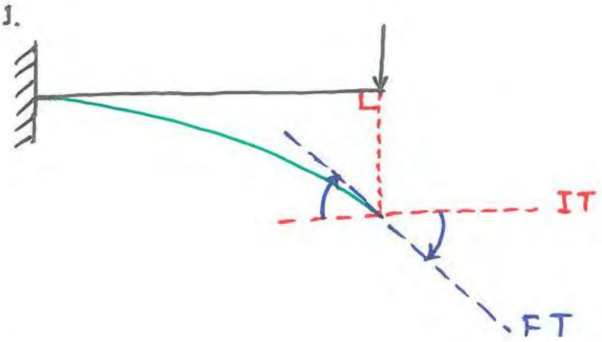
StepII: By satisfying compatibility conditions.

StepIII: By making BMD and elastic curve consistent.

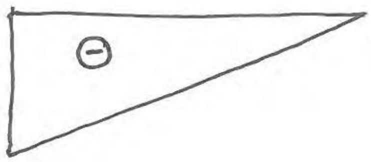
*Note:
In all coming examples, all members are assumed to be axially inextensible.

- Statically Determinate Beams:

Ex.1.

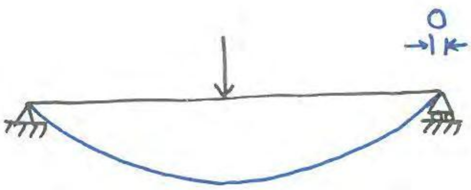


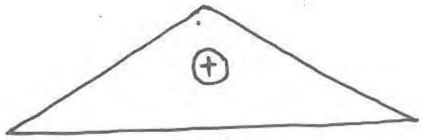
BMD



*Note:
Member always deflects in $\perp^{lar}$ direction to its longitudinal length provided member is inextensible & displacement is small.

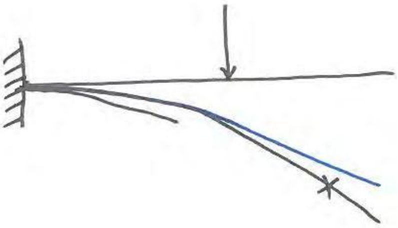
Ex. 2.

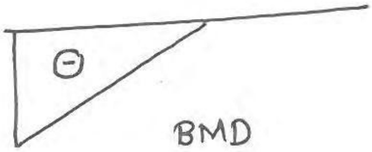




BMD.

Ex. 3.

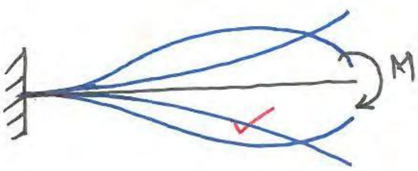


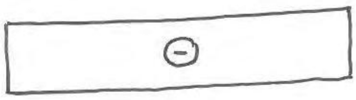


BMD

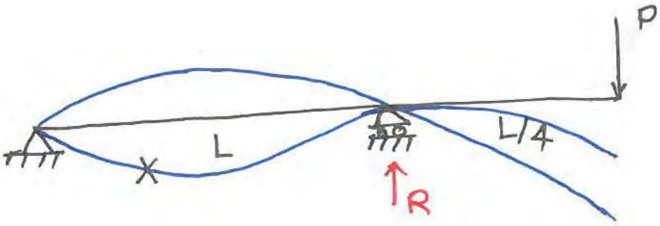
*Note : Member never bends without bending moment.

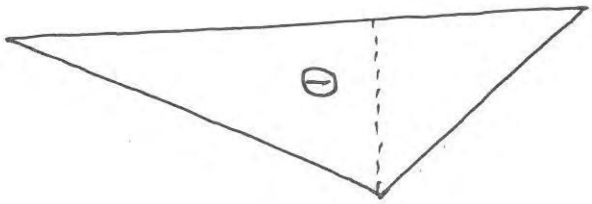
Ex. 4.



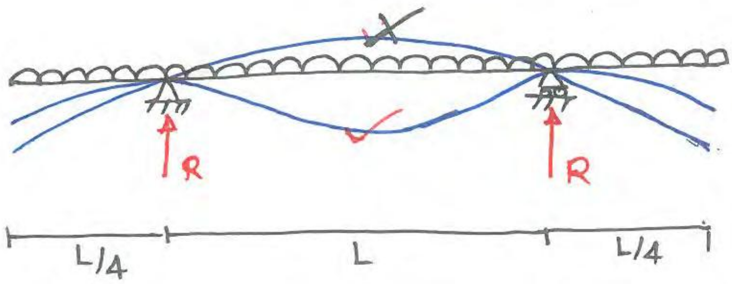


Ex. 5.





Ex. 6.

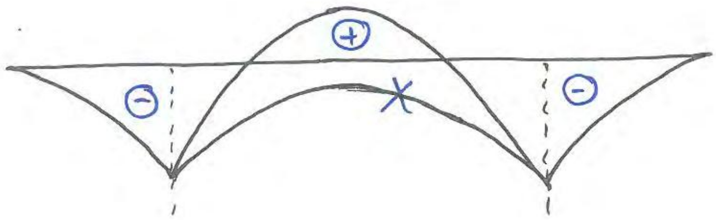


$$R = \frac{w\left(\frac{L}{4} + L + \frac{L}{4}\right)}{2}$$

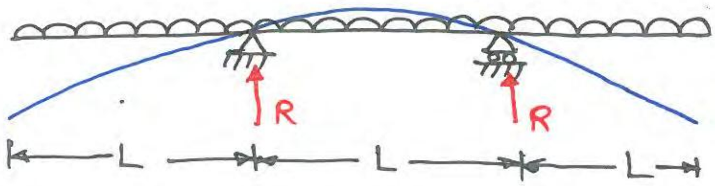
BM midspan

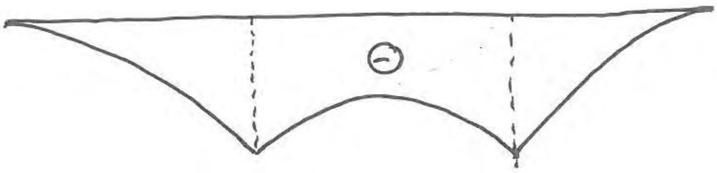
$$= R \times \frac{L}{2} - \frac{w\left(\frac{L}{4} + \frac{L}{2}\right)^2}{2}$$

$$= +ve.$$



Ex. 7.



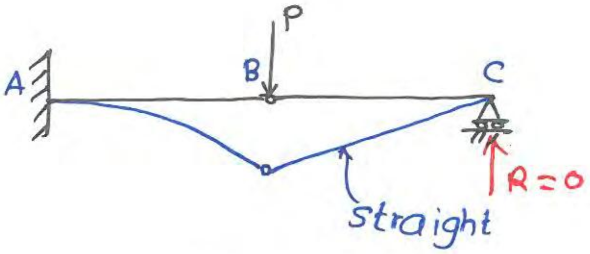


$$R = \frac{w\,(L + L + L)}{2}$$

$$BM_{midspan} = R \times \frac{L}{2} - \frac{w\left(L + \frac{L}{2}\right)^2}{2}$$

$$= -ve.$$

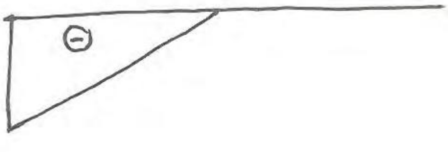
Ex. 8.



$M_B = 0$ (RHS)

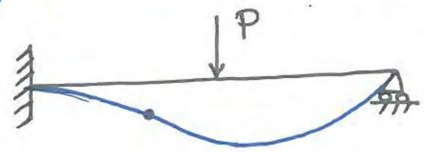
$\Rightarrow -R \times \frac{L}{2} = 0$

$\Rightarrow R = 0$

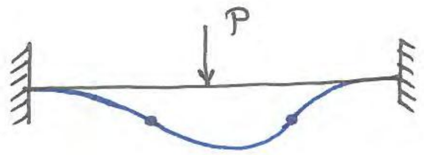


• Statically Indeterminate Beams:

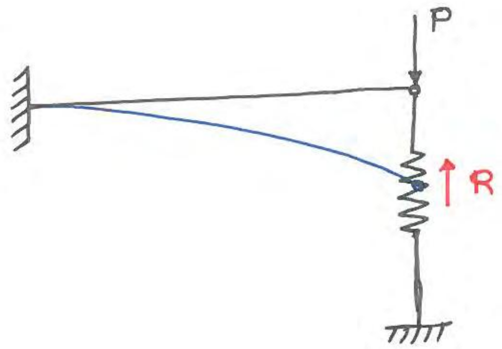
Ex.1.



Ex.2.



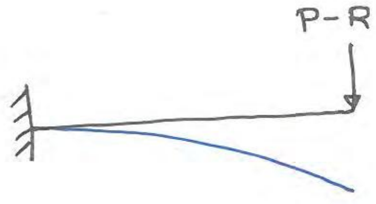
Ex.3.



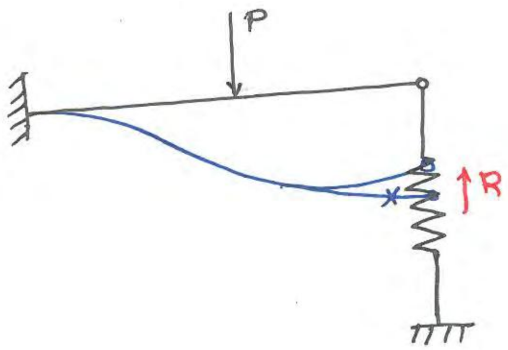
$P > R$ ✓

$P = R$

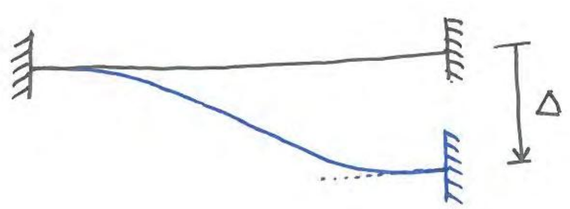
$P < R$



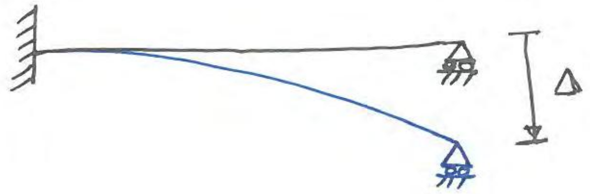
Ex.4.



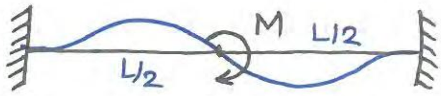
Ex.5

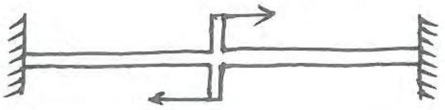


Ex.6.

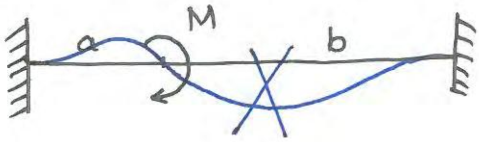


Ex. 7.





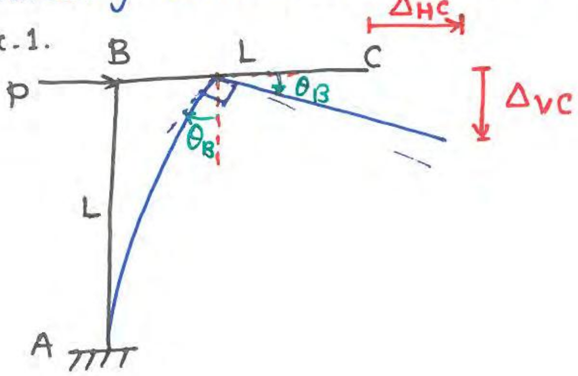
Ex. 8.

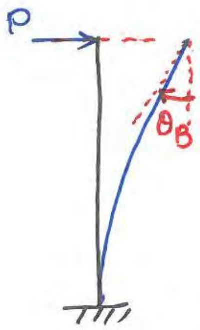


$a \neq b$

• Statically Determinate Frames :

Ex. 1.

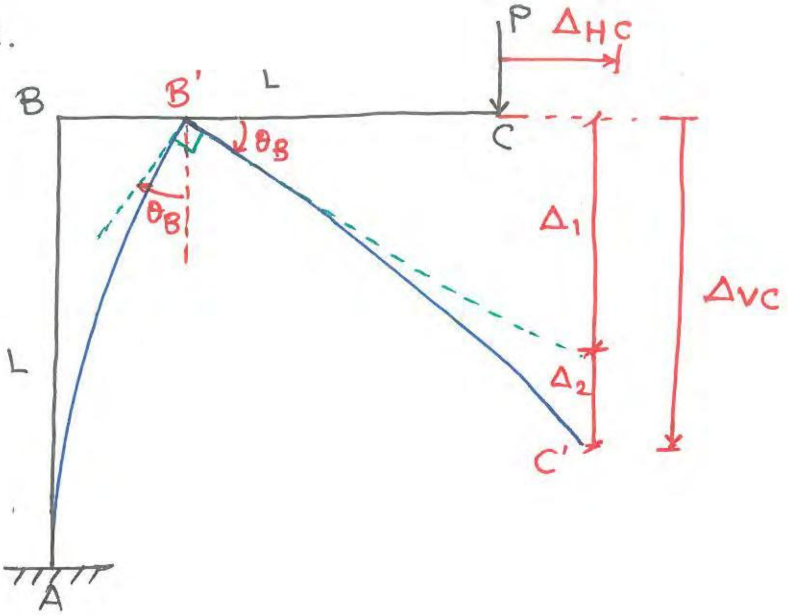


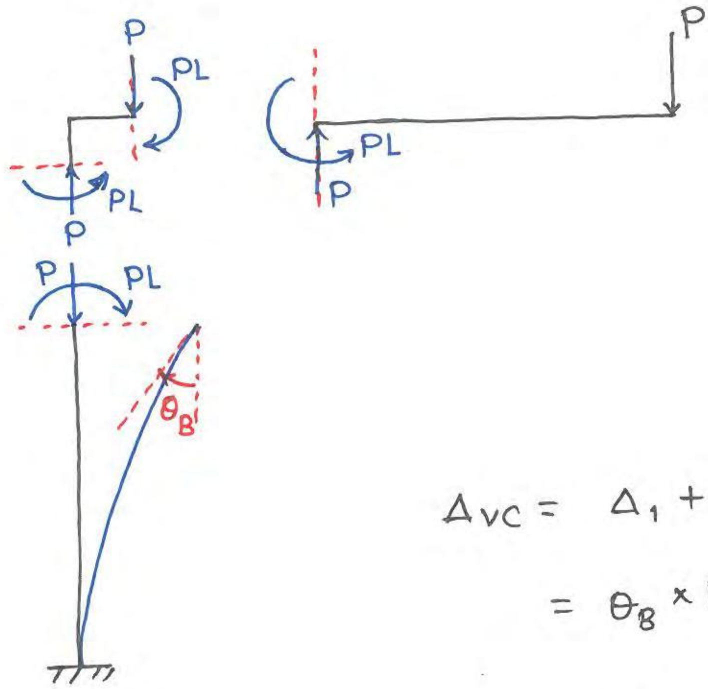


$$\Delta_{HC} = \Delta_{HB} = \frac{PL_{AB}^3}{3EI} = \frac{PL^3}{3EI}$$

$$\Delta_{VC} = \theta_B \cdot L_{BC} = \frac{PL_{AB}^2}{2EI} \cdot L = \frac{PL^3}{2EI}.$$

Ex. 2.





$$\Delta_{HC} = \Delta_{HB}$$

$$= \frac{ML_{AB}^2}{2EI}$$

$$= \frac{PL \times L^2}{2EI}$$

$$= \frac{PL^3}{2EI}$$

$$\Delta_{VC} = \Delta_1 + \Delta_2$$

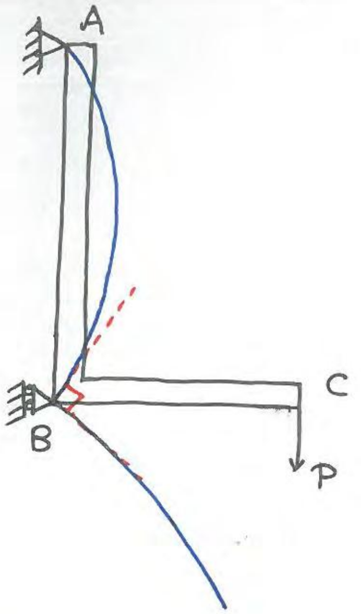
$$= \theta_B \times L_{BC} + \frac{PL_{BC}^3}{3EI}$$

$$= \frac{ML_{AB}}{EI} \times L + \frac{PL^3}{3EI}$$

$$= \frac{PL \times L}{EI} \times L + \frac{PL^3}{3EI}$$

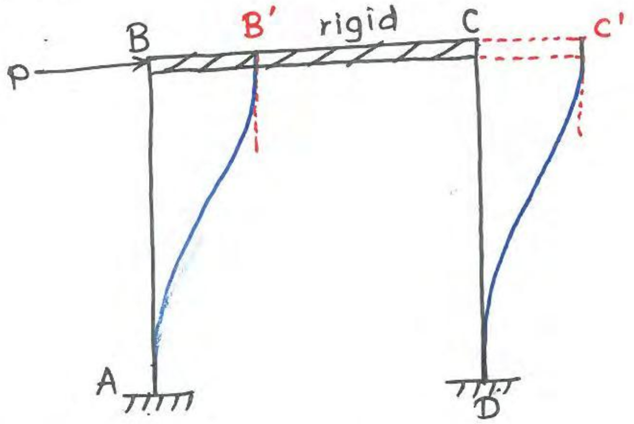
$$= \frac{4PL^3}{3EI}$$

Ex.3.

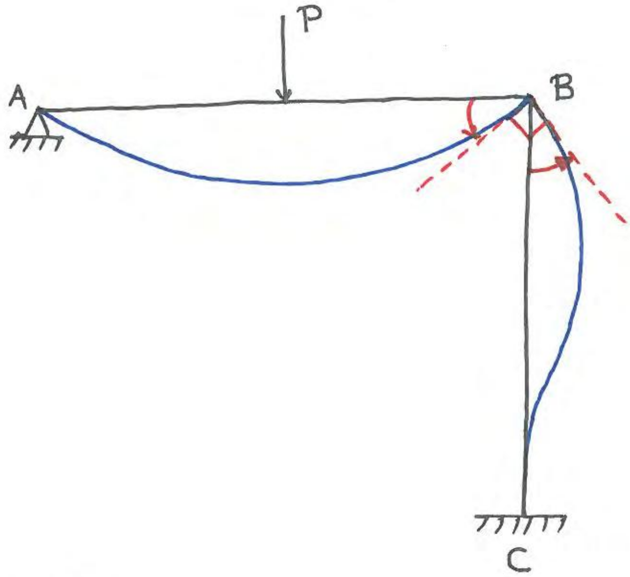


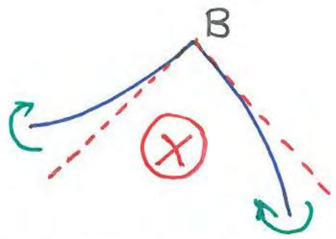
- Statically Indeterminate Frames:

Ex.1.



Ex.2.

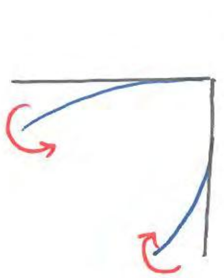




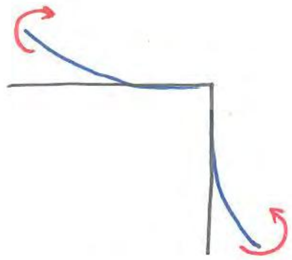
Joint B is NOT in equilibrium.

Concept:

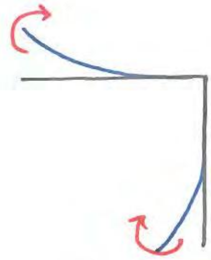
If two members are meeting at a rigid joint and subjected to no point moment at that joint then elastic curve of that joint will be like fig.1 or fig.2. Fig3 is not possible.



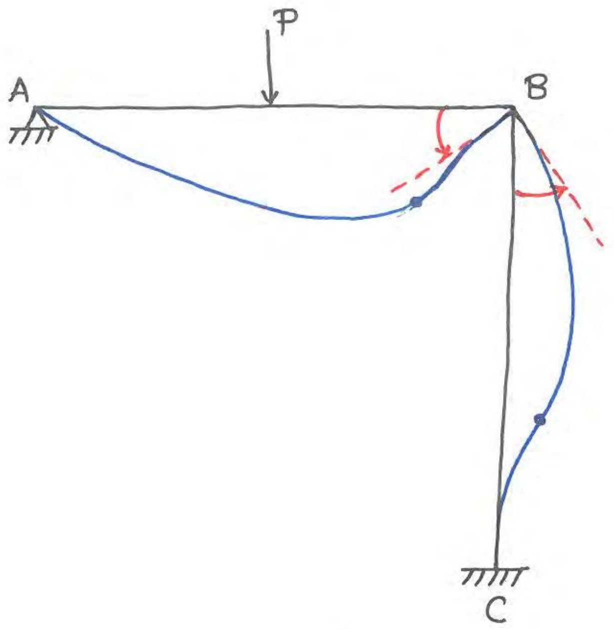
(I)

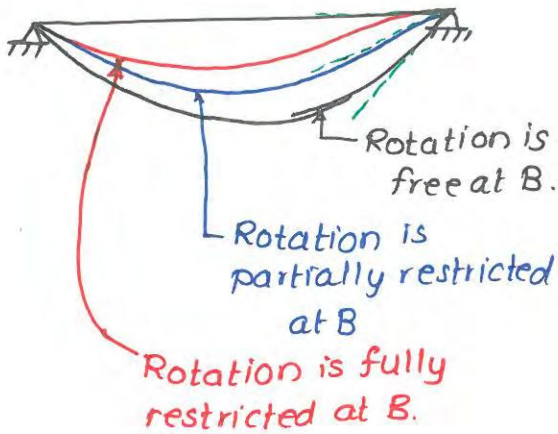


(II)

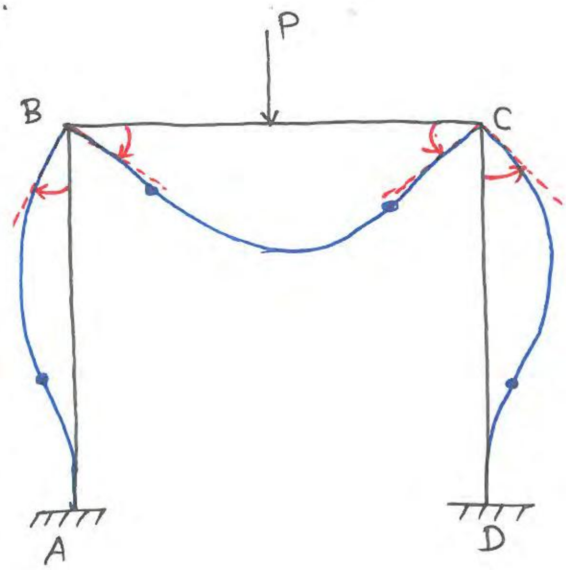


(III)

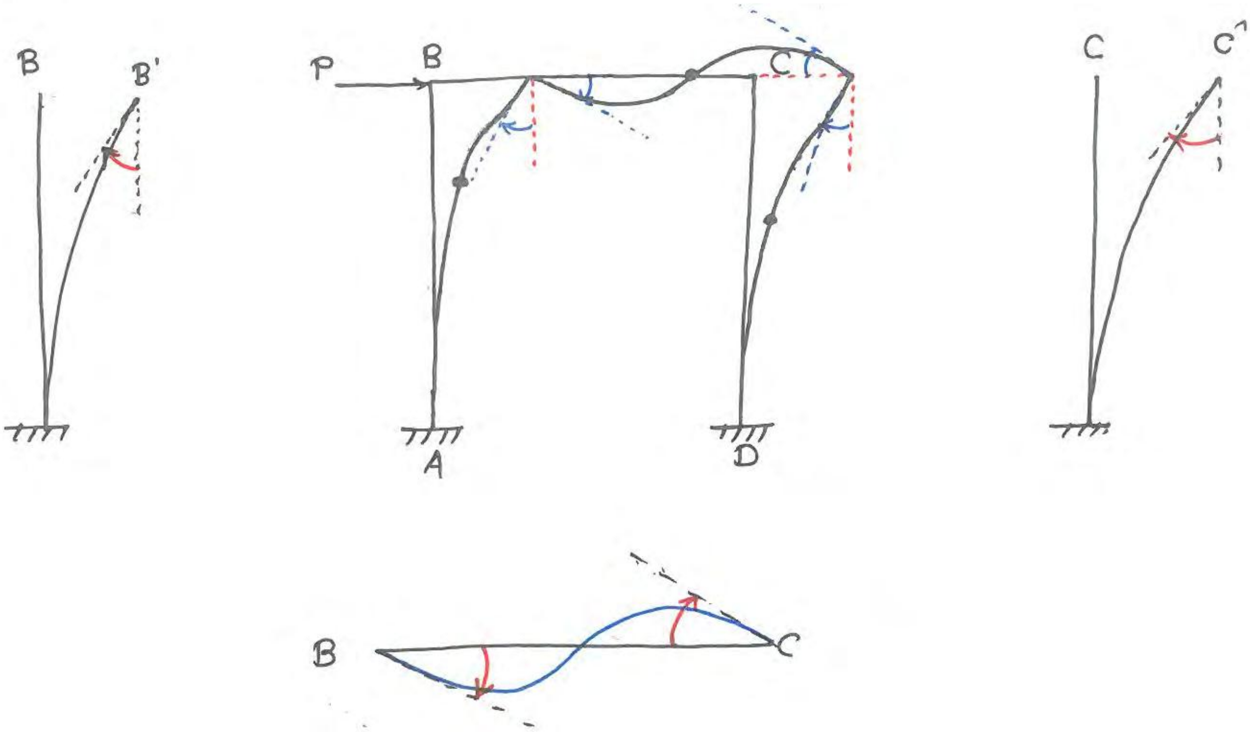

P
A
B
C


Rotation is free at B.
Rotation is partially restricted at B
Rotation is fully restricted at B.

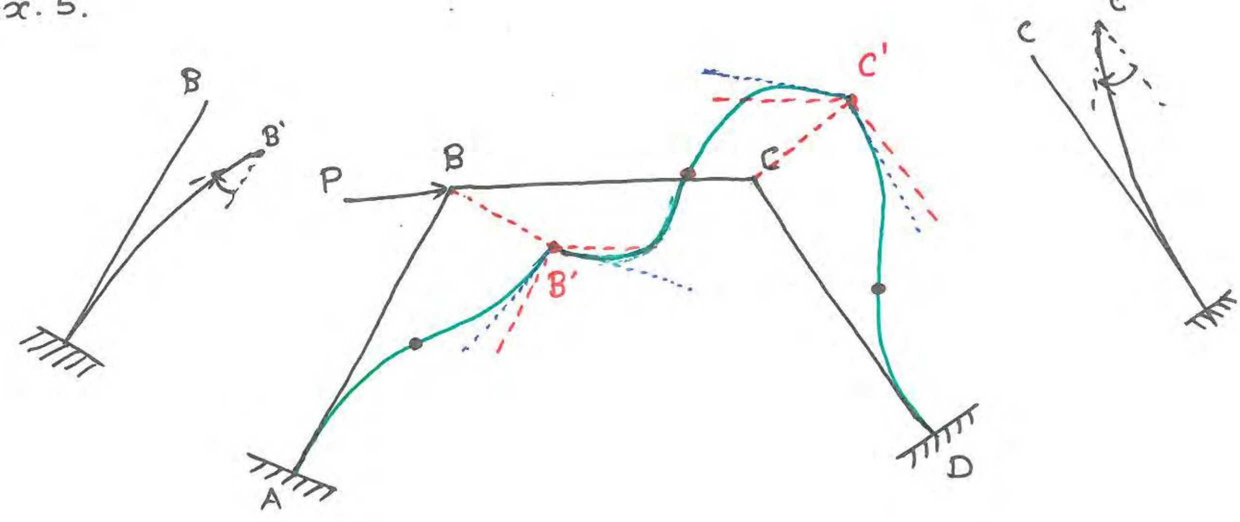
Ex. 2.


P
B
C
A
D

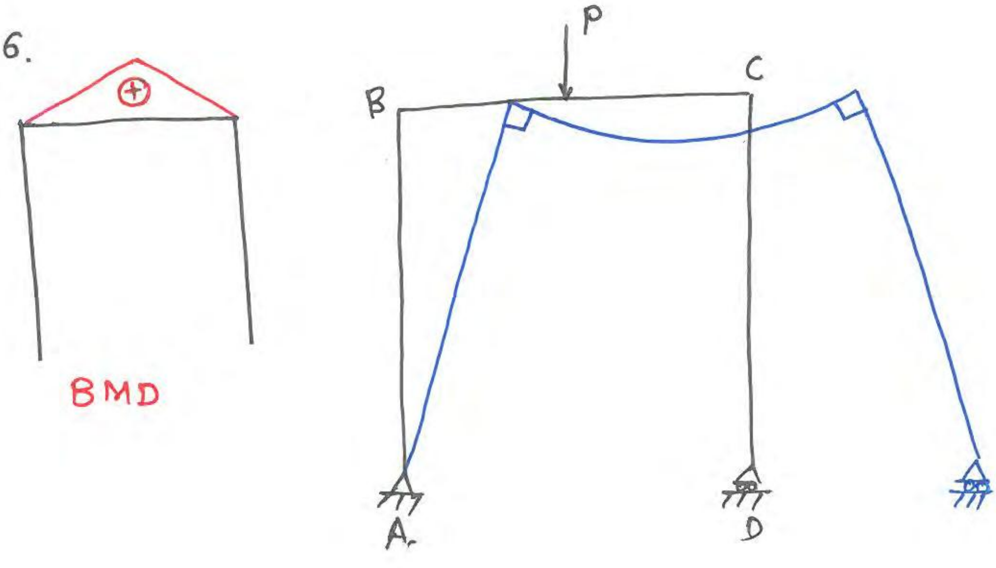
Ex.4.



Ex. 5.



Ex. 6.



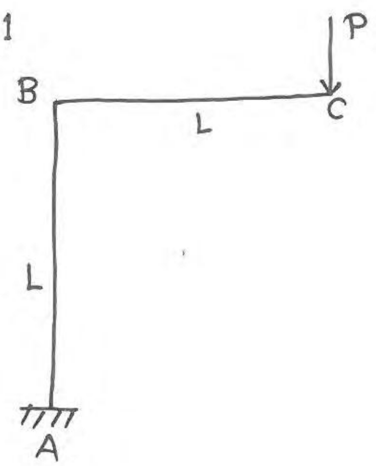
1.16 BMD for Frames:

Step I: Select reference face.

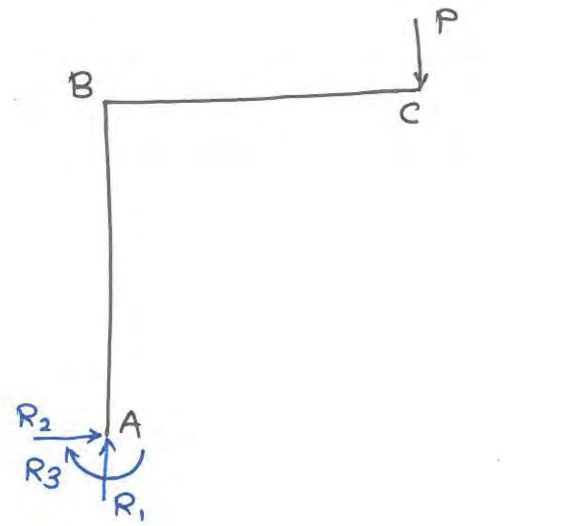
Step II Write Bending Moment at any section by considering moment producing compression on reference face as positive

Step III: Positive Bending Moment is plotted on reference face side and negative BM on opposite reference face.

Ex. 1



FBD:-



$\Sigma F_x = 0$

$\Rightarrow R_2 = 0$ ---- (i)

$\Sigma F_y = 0$

$\Rightarrow R_1 - P = 0$

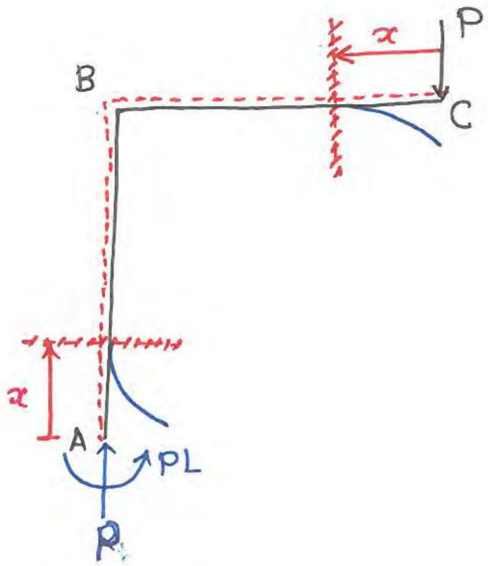
$\Rightarrow R_1 = P$ ---- (ii)

$\Sigma M_z = 0$

$\Rightarrow \Sigma M_A = 0$

$\Rightarrow R_3 + PL = 0$

$\Rightarrow R_3 = -PL$



Considering outer face as reference face.

For CB:-

$BM_x = -Px$ (-ve becoz tension on reference face)

At $x = 0$, $BM = 0$

at $x = L$, $BM = -PL$

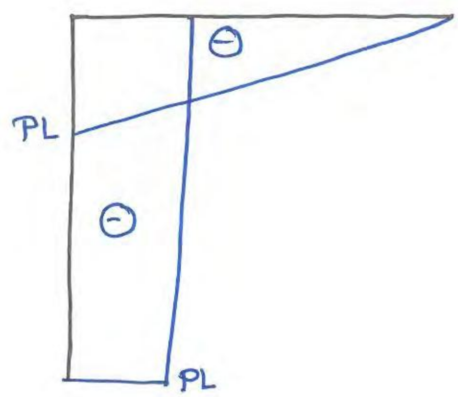
For AB :-

$BM_x = -PL$ (-ve becoz tension on reference face)

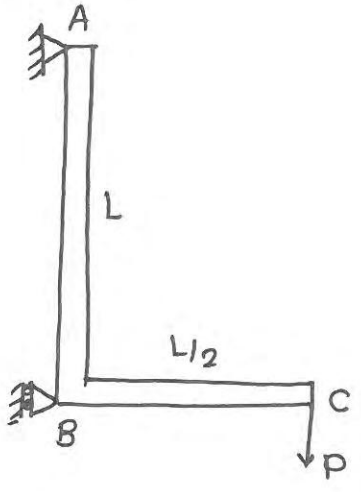
At $x=0$, $BM = -PL$

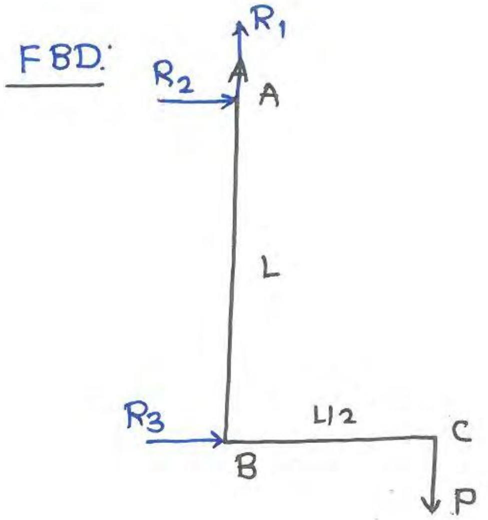
$x = L$, $BM = -PL$

BMD :-



Ex. 2.





$\Sigma F_x = 0$

$\Rightarrow R_2 + R_3 = 0$

$\Rightarrow R_3 = -R_2$

$\Sigma F_y = 0$

$\Rightarrow R_1 - P = 0$

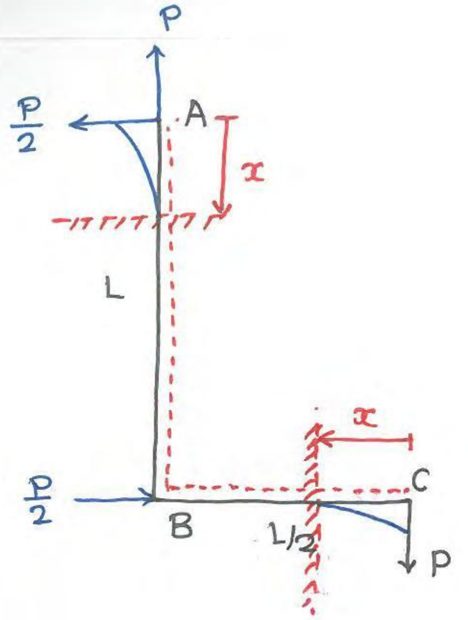
$\Rightarrow R_1 = P$

$\Sigma M_z = 0$

$\Rightarrow \Sigma M_A = 0$

$-R_3 L + P \times \frac{L}{2} = 0 \quad \Rightarrow R_3 = \frac{P}{2}$

$\Rightarrow R_2 = -P/2$



Considering outer face as reference face.

For CB:-

$BM_x = -Px$ (-ve becoz tension on ref face)

At $x=0$, $BM = 0$

$x = L/2$, $BM = -\frac{PL}{2}$

For AB:-

$BM_x = -\frac{P \cdot x}{2}$ (-ve becoz tension on ref. face).

At $x=0$, $BM=0$

$x = L$, $BM = \frac{-PL}{2}$

BMD:-