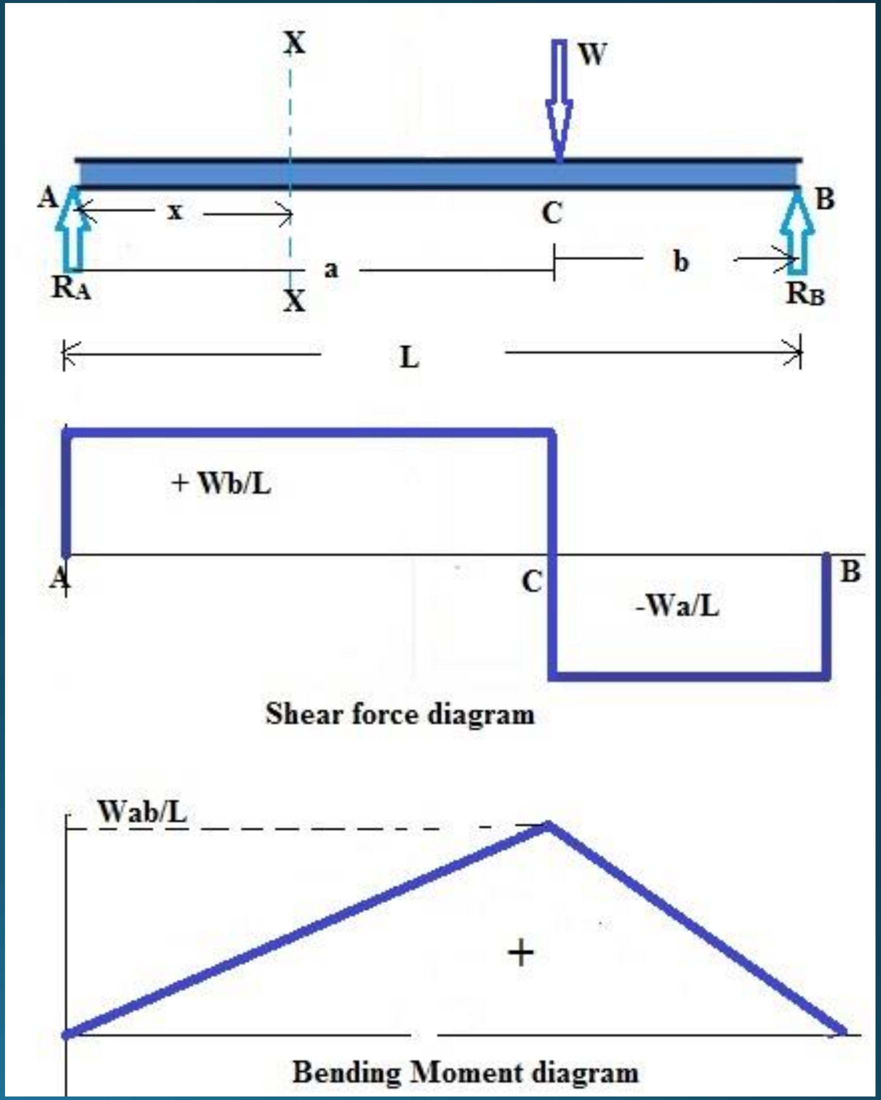
BEAM

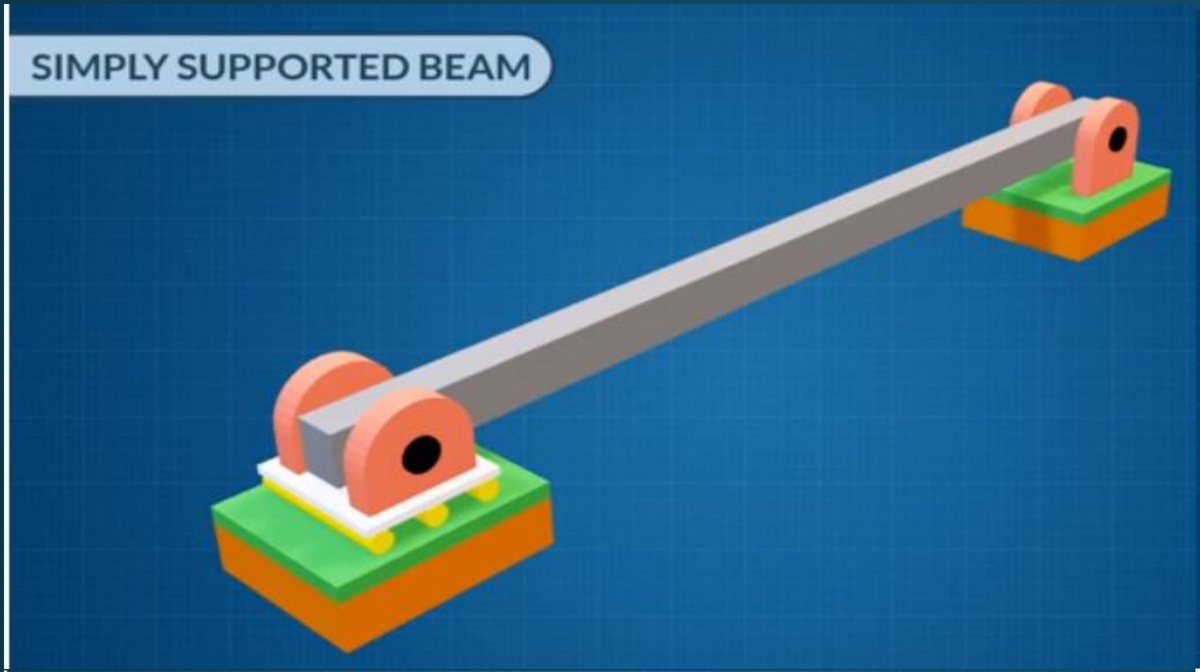
- A beam is **a structural element that primarily resists loads applied laterally to the beam's axis.**

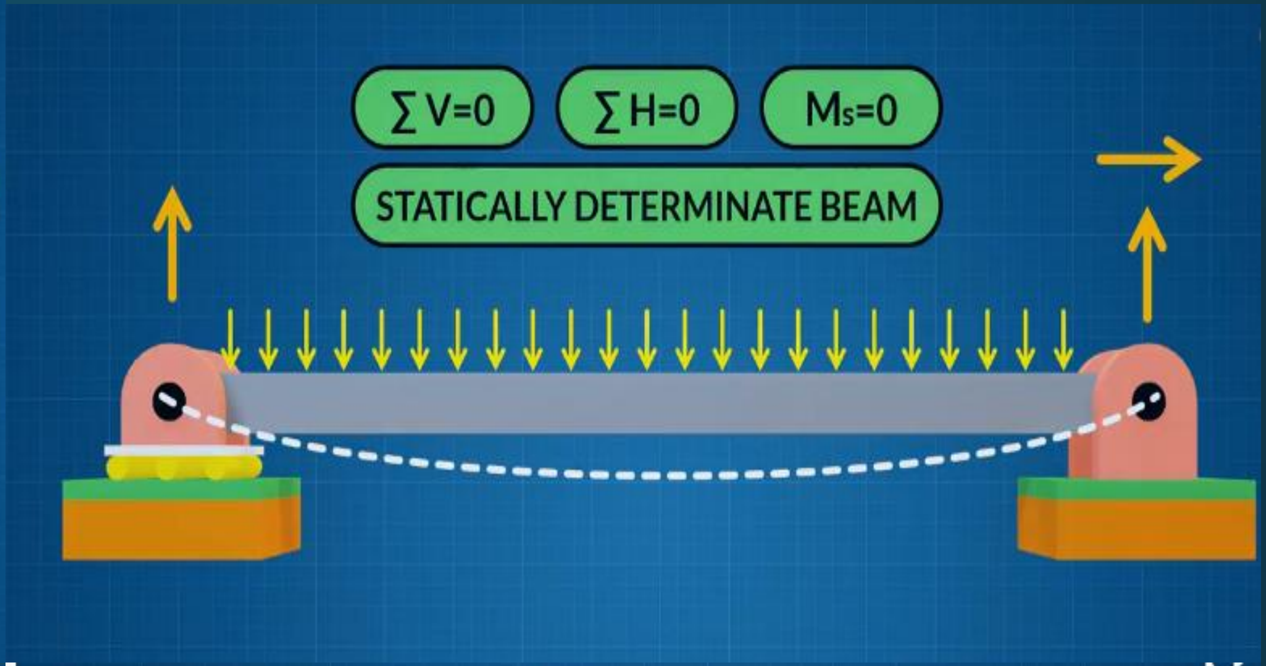
- Determinate beam is that the beam in which unknown support reactions can be calculated by using static equilibrium equations only.

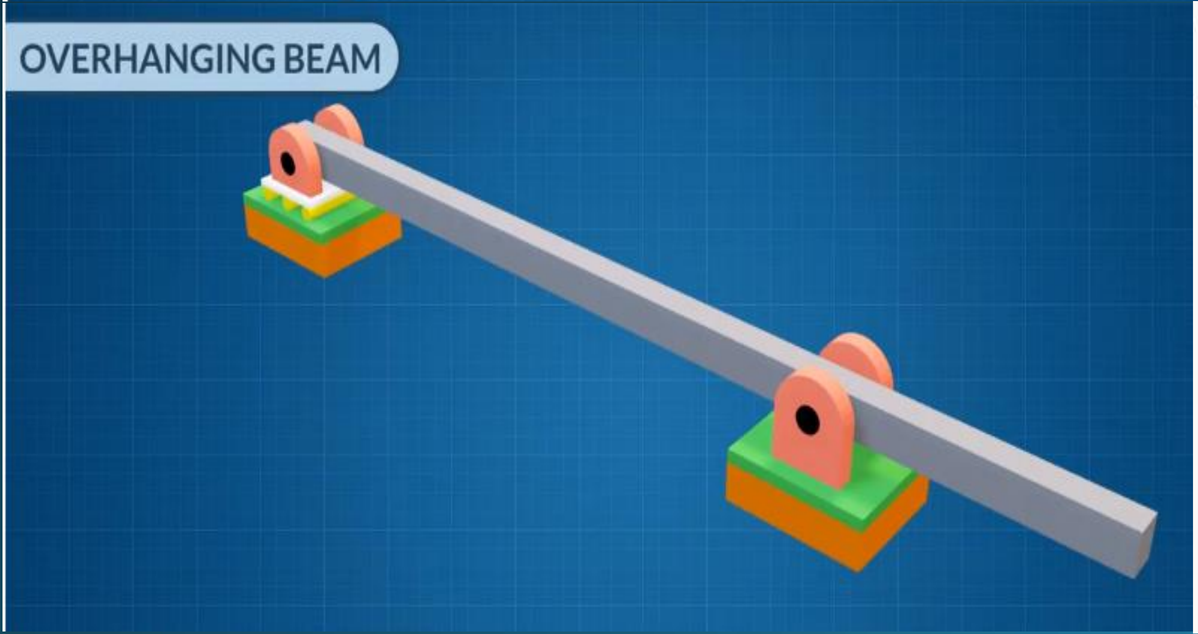
- Indeterminate beam is that the beam in which unknown support reactions can not be calculated by using static equilibrium equations.

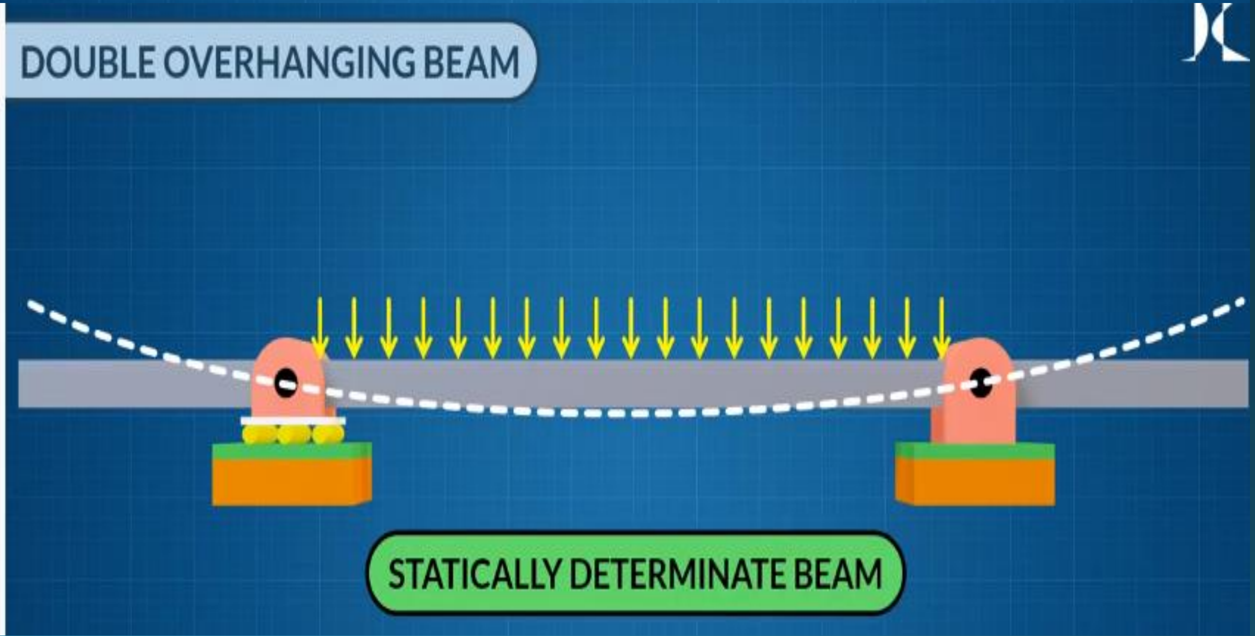
- Analysis of beam consist of finding the support reactions and determining the shear force and bending moment by the given load.

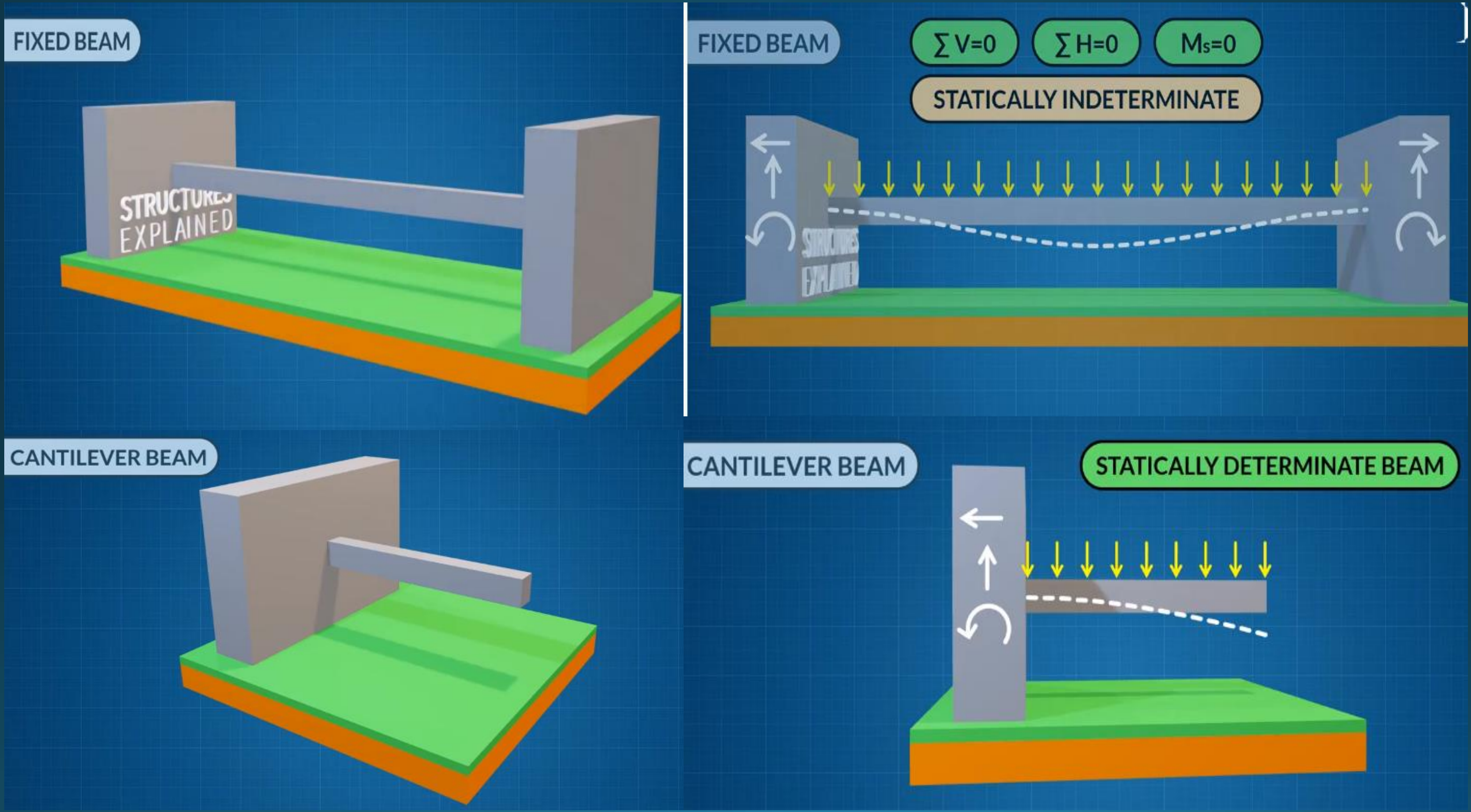


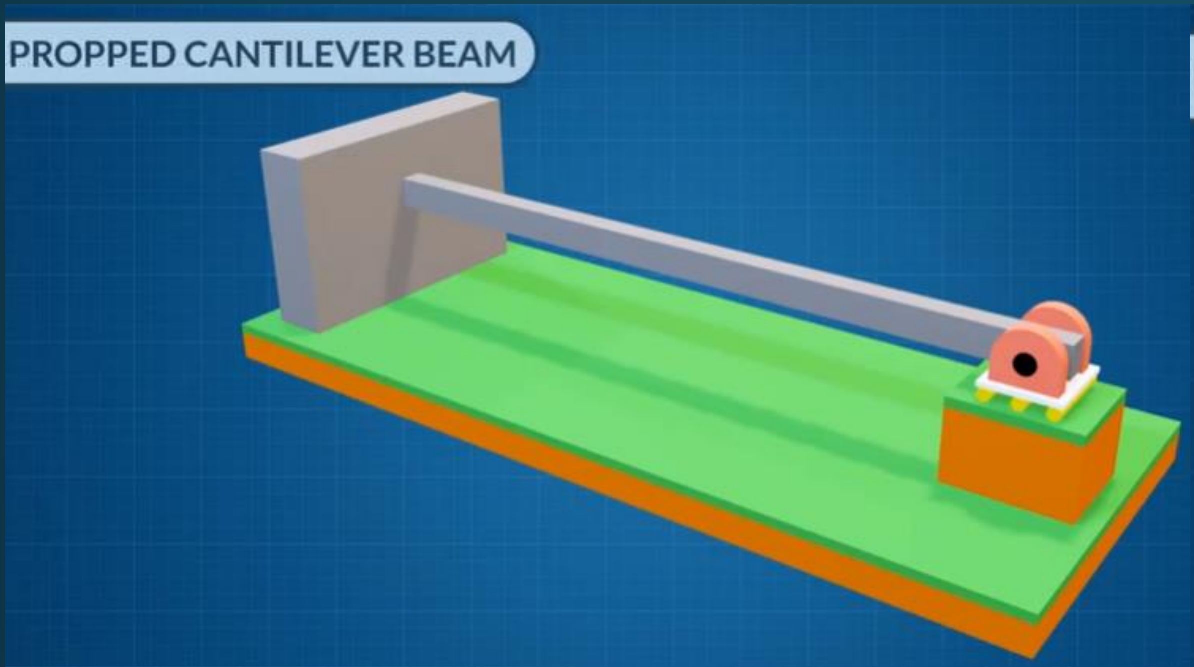
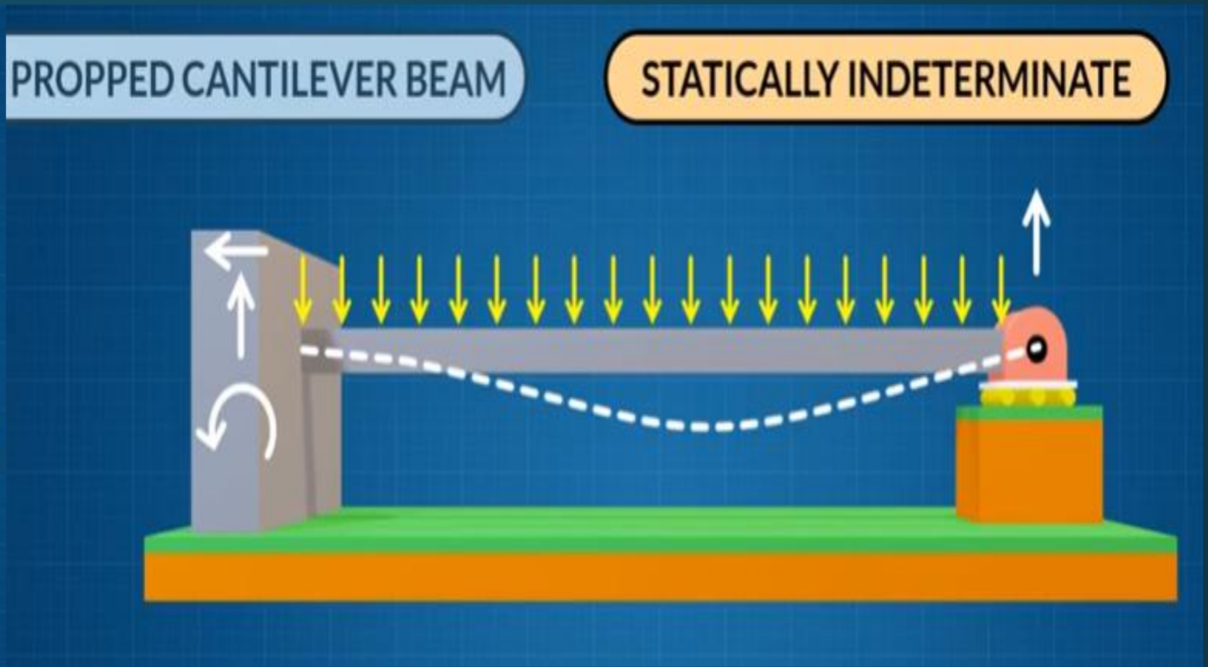
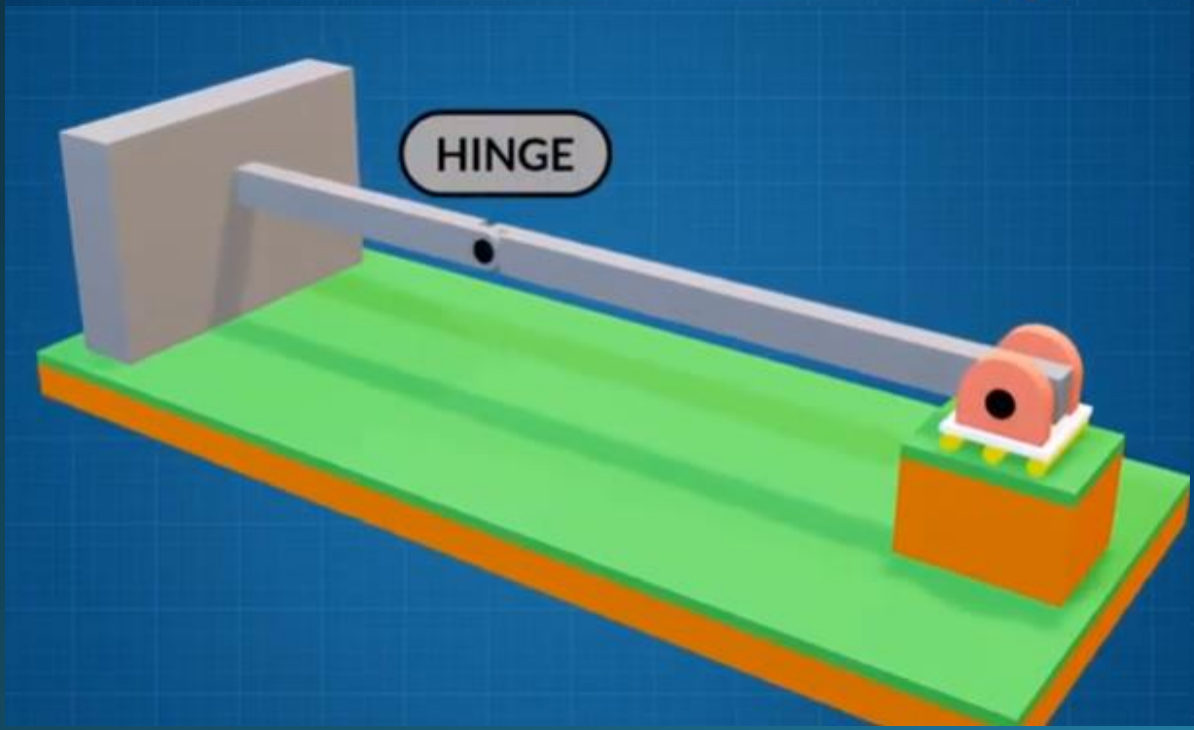
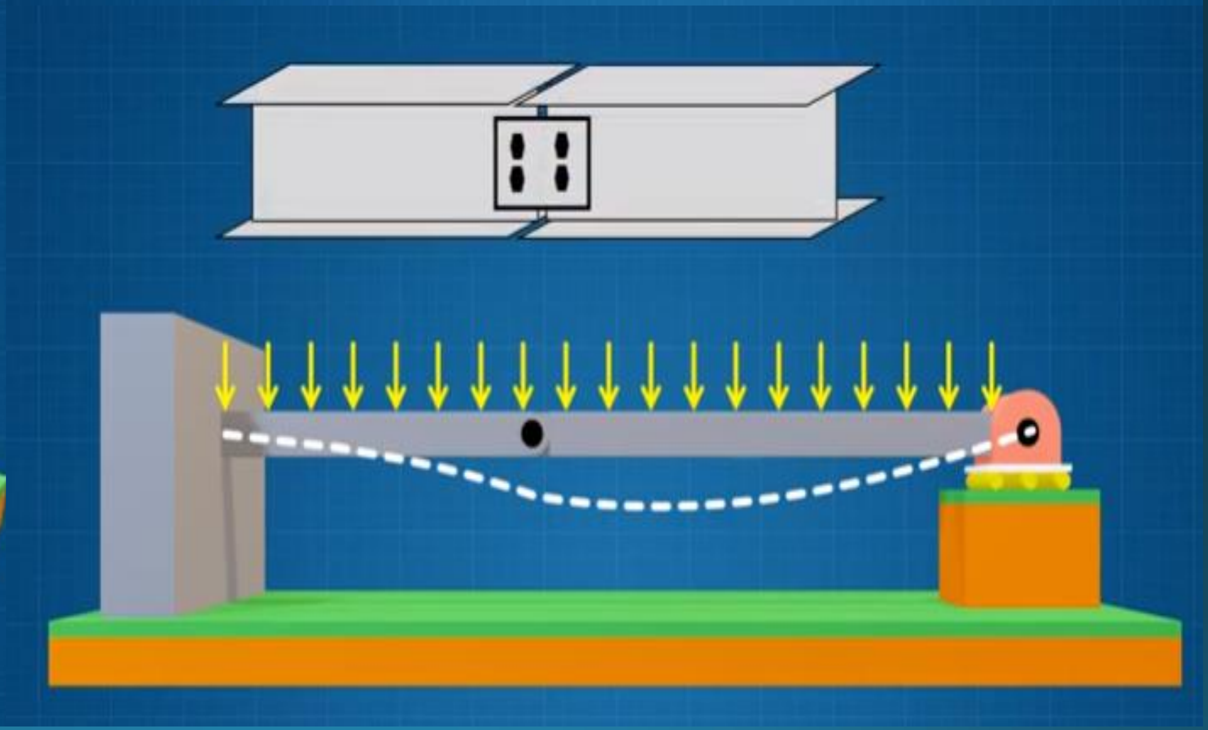

SIMPLY SUPPORTED BEAM

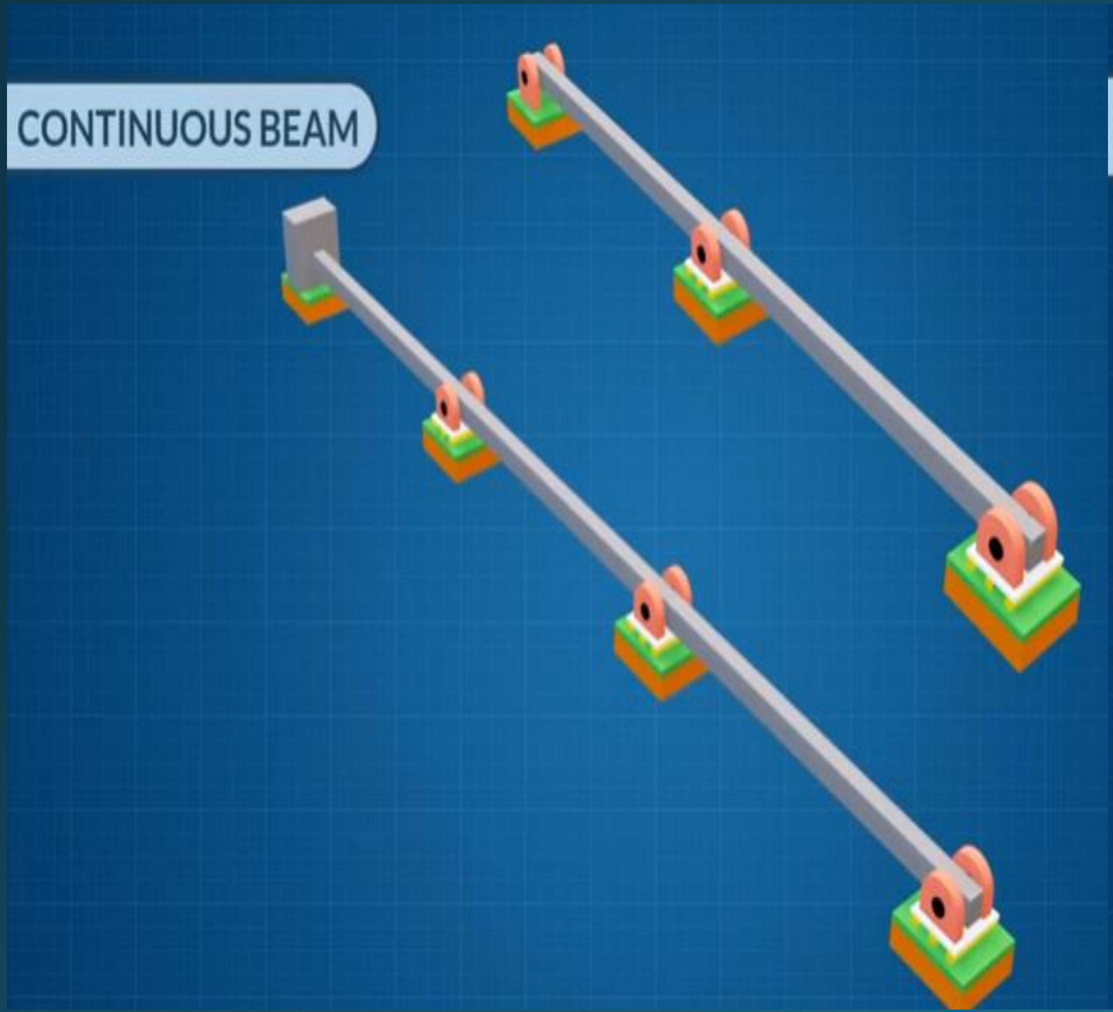

∑V=0
∑H=0
Ms=0
STATICALLY DETERMINATE BEAM

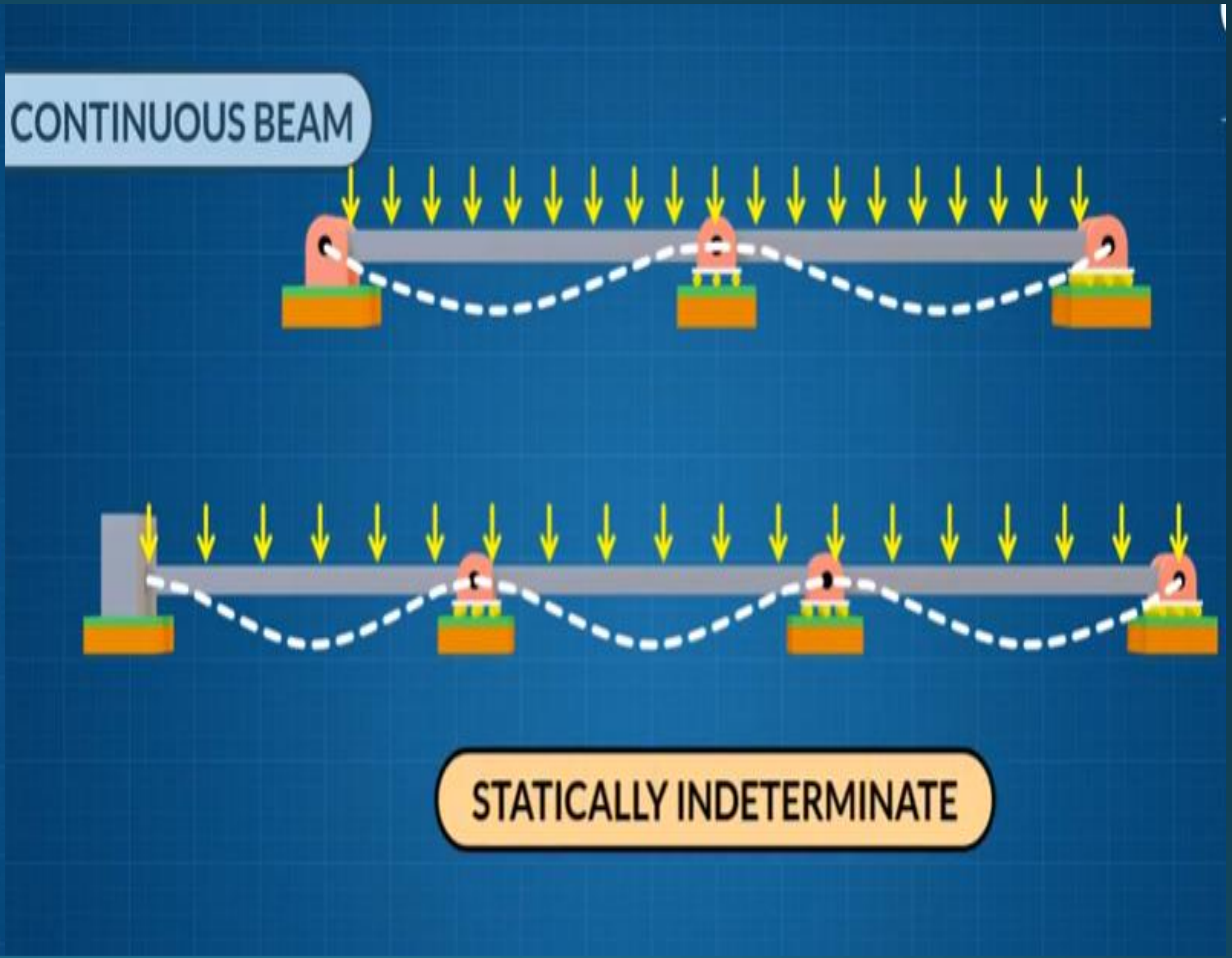

OVERHANGING BEAM


DOUBLE OVERHANGING BEAM
STATICALLY DETERMINATE BEAM


FIXED BEAM
STRUCTURES
EXPLAINED
FIXED BEAM
∑ V=0
∑ H=0
Ms=0
STATICALLY INDETERMINATE
CANTILEVER BEAM
CANTILEVER BEAM
STATICALLY DETERMINATE BEAM

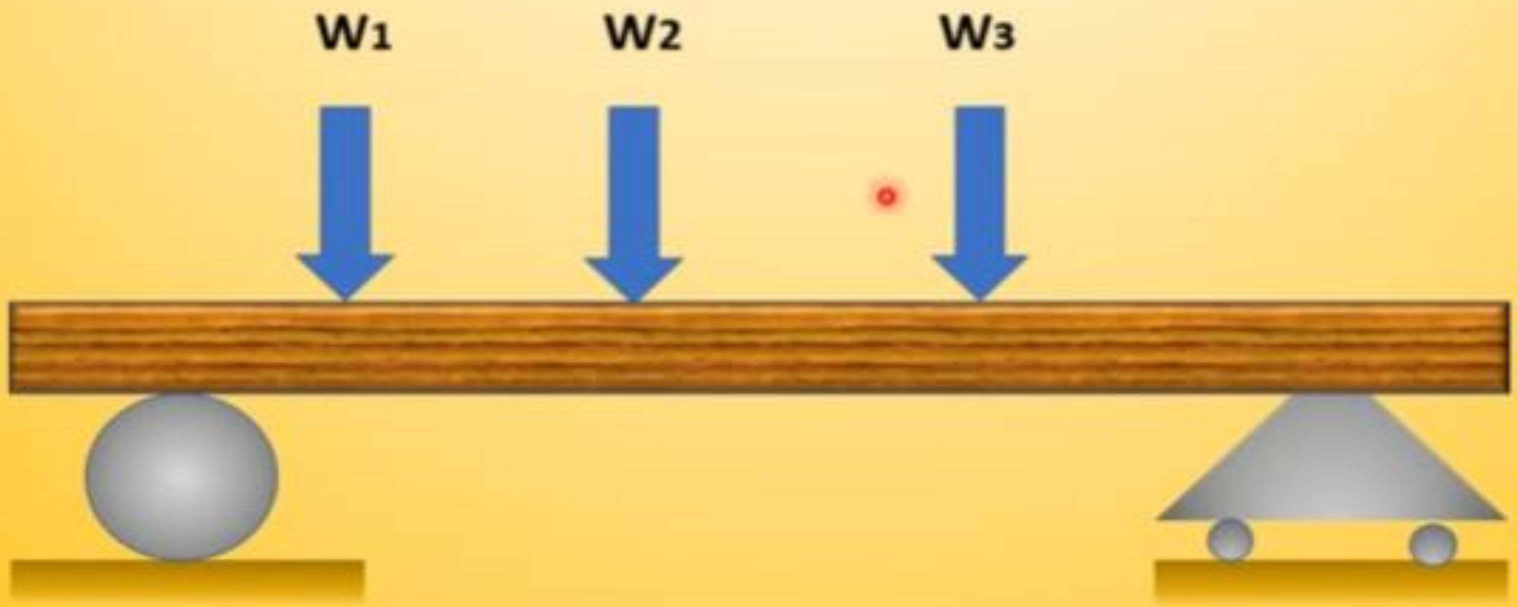

PROPPED CANTILEVER BEAM

PROPPED CANTILEVER BEAM
STATICALLY INDETERMINATE

HINGE



CONTINUOUS BEAM


CONTINUOUS BEAM
STATICALLY INDETERMINATE

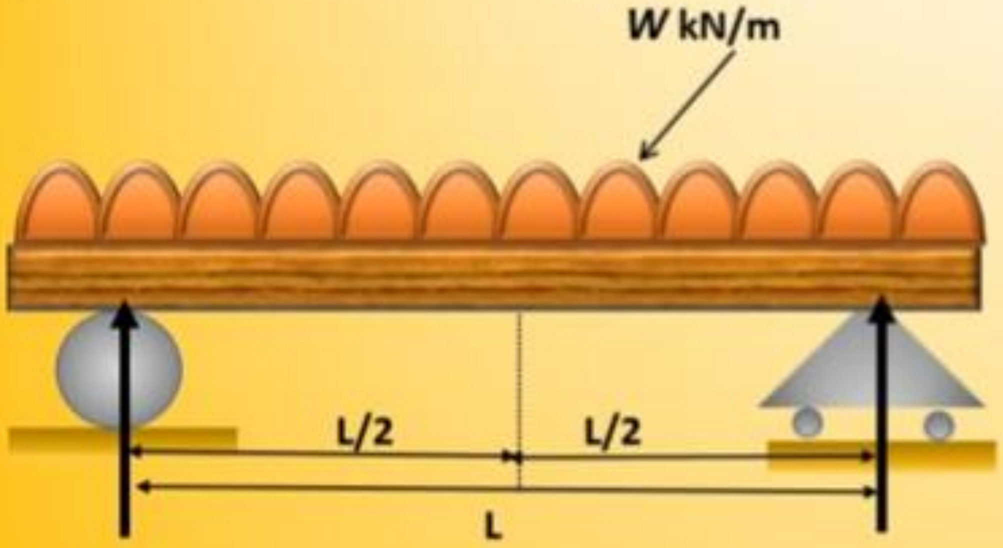
Point load or concentrated load

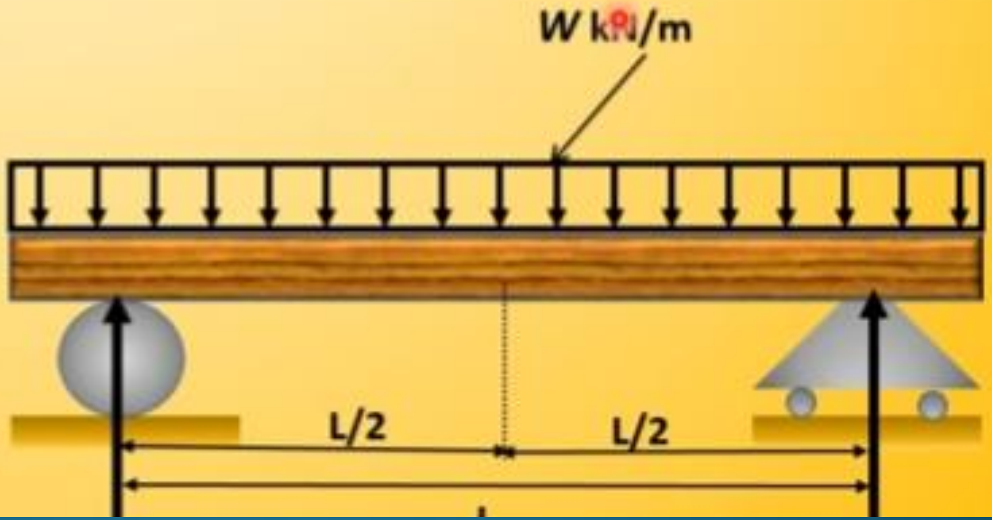
A load, which is assumed to be acting at single point on a beam, is called point load or concentrated load. Unit of point load is N, kN or tonne.



U.D.L. or Uniformly distributed load-

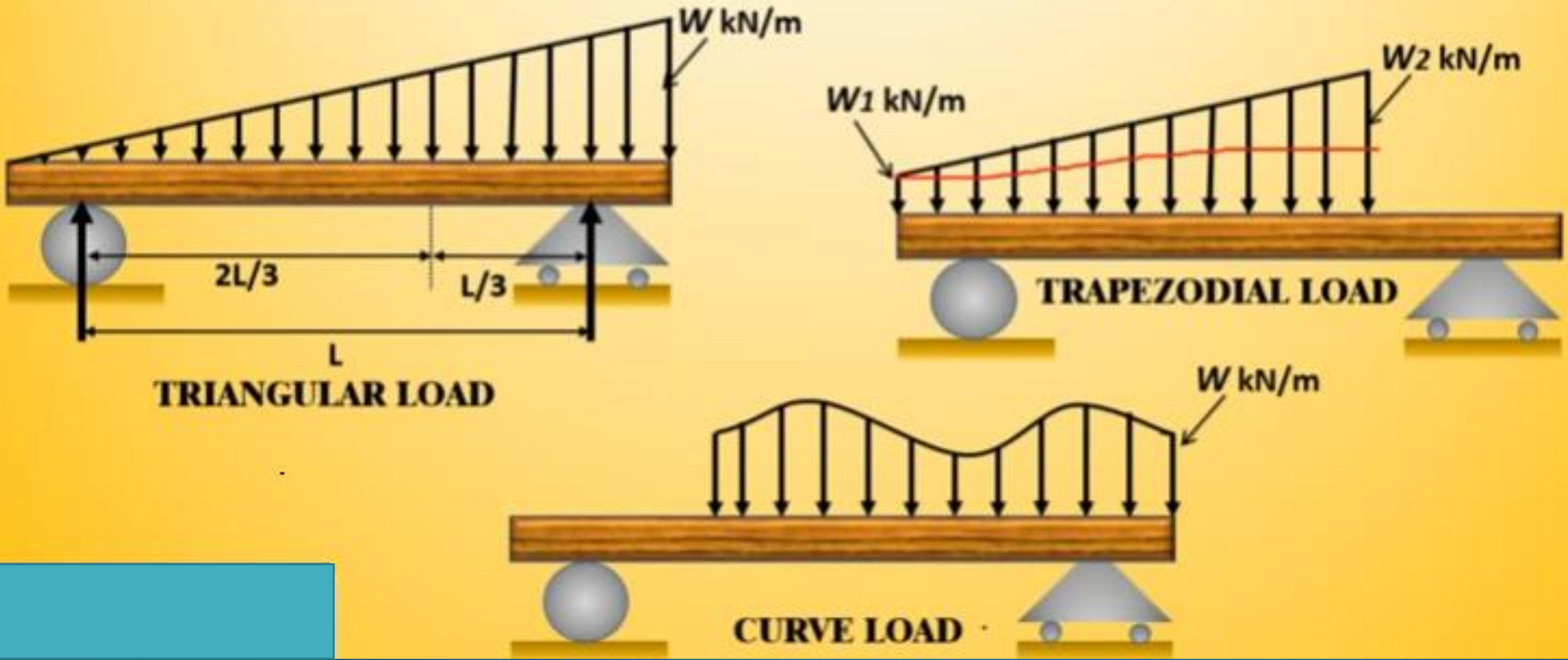
U.D.L. is distributed uniformly over the entire length or part of length of beam. Unit of U.D.L. is kN/m or tonne/m.



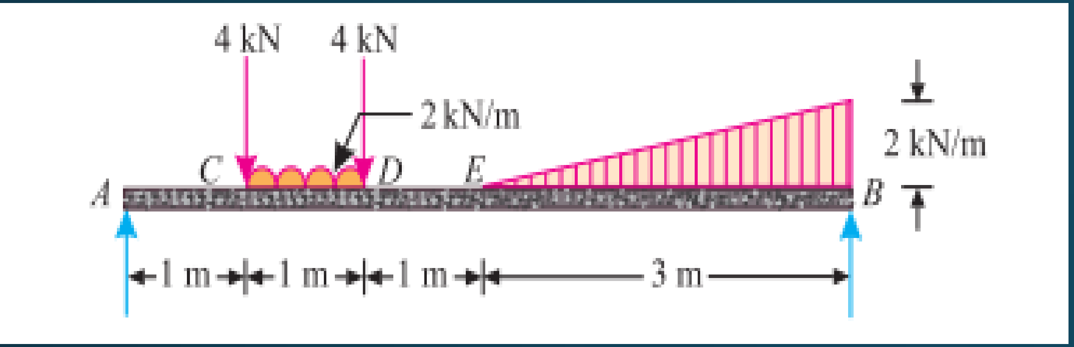


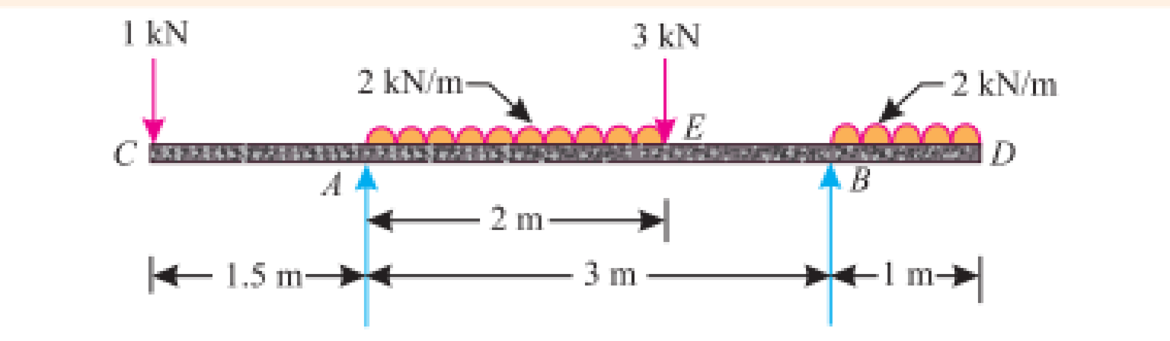
U.V.L. or uniformly varying load

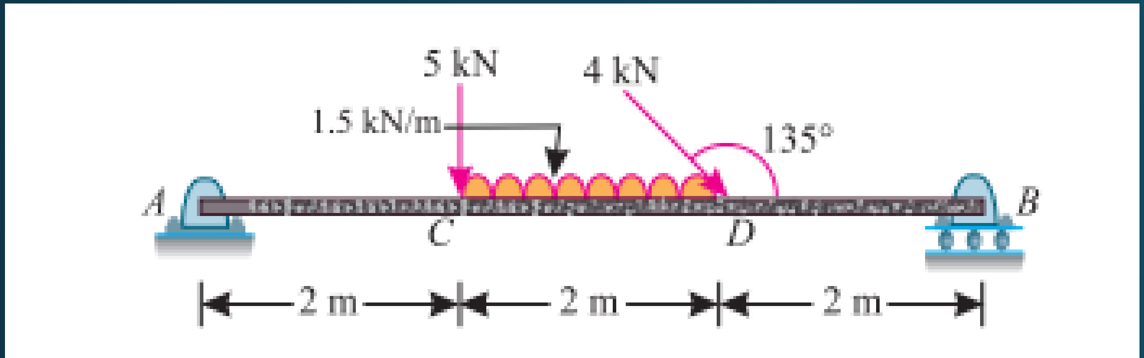
U.V.L. varies uniformly over the entire length or part of length of beam. Unit of U.D.L. is kN/m or tonne/m.

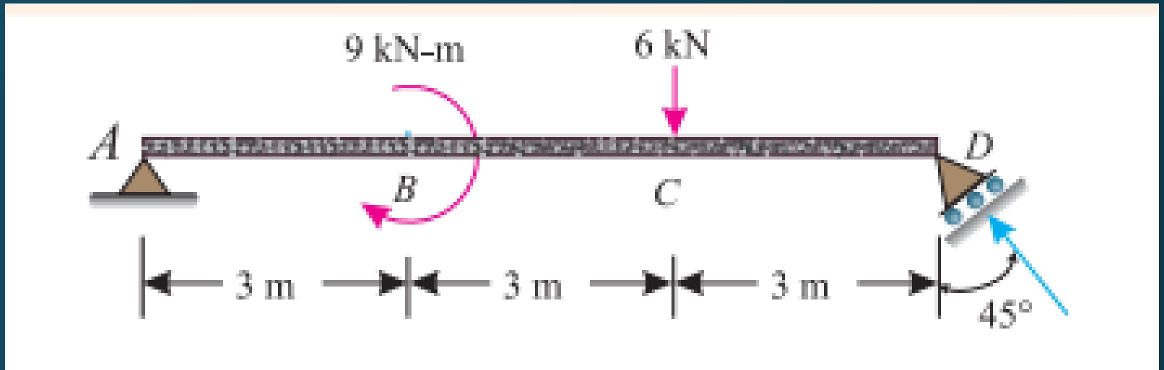


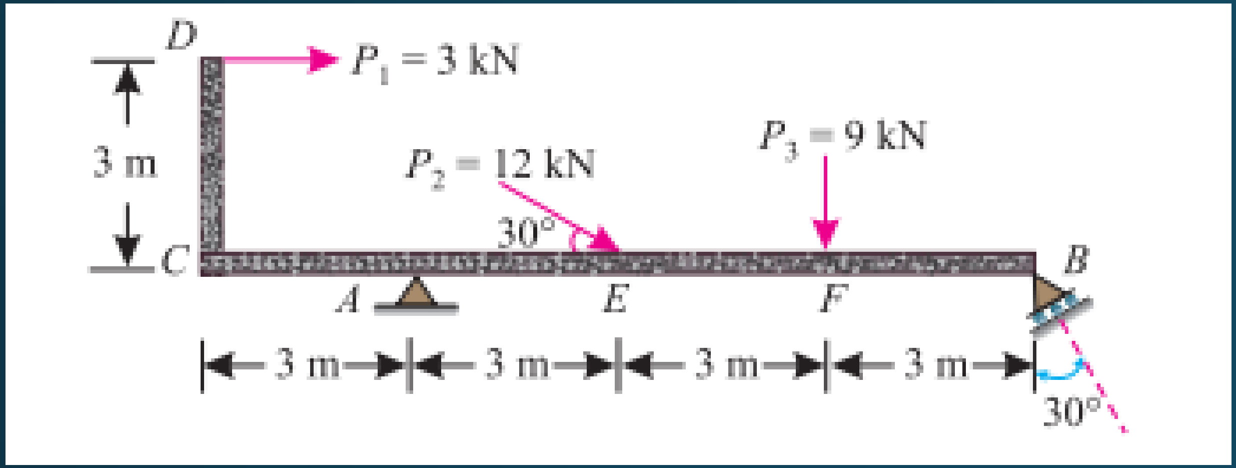
Beam Reactions






5 kN
4 kN
1.5 kN/m
135°
A
C
D
B
2 m
2 m
2 m


9 kN-m
6 kN
A
B
C
D
3 m
3 m
3 m
45°



D
$P_1 = 3$ kN
3 m
$P_2 = 12$ kN
$P_3 = 9$ kN
30°
C
A
E
F
B
3 m
3 m
3 m
3 m
30°

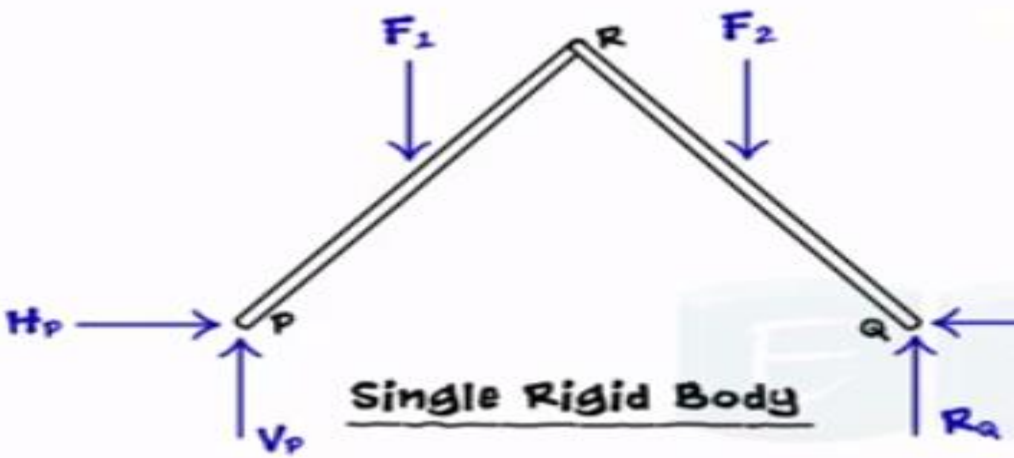
Truss

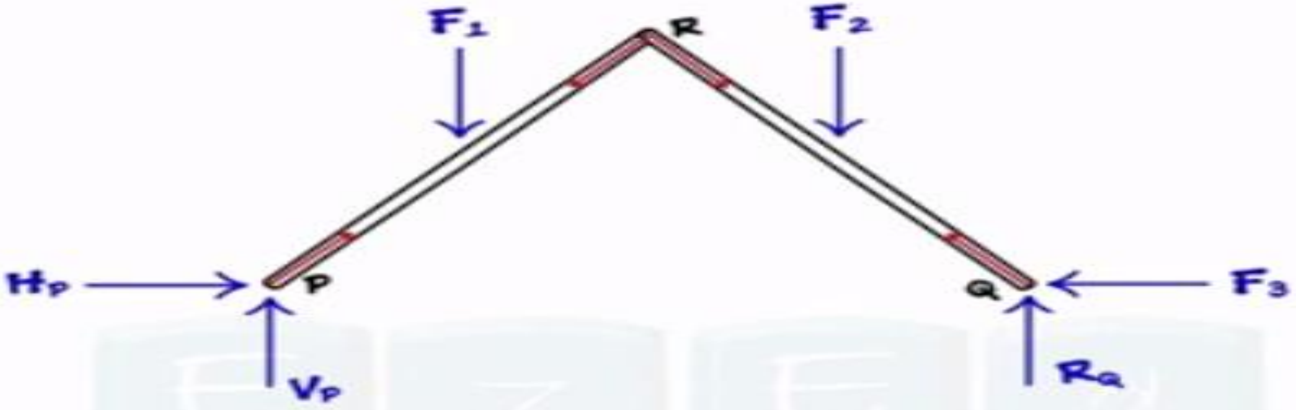
COE

$$\Sigma F_x = 0$$

$$\Sigma F_y = 0$$

$$\Sigma M = 0$$



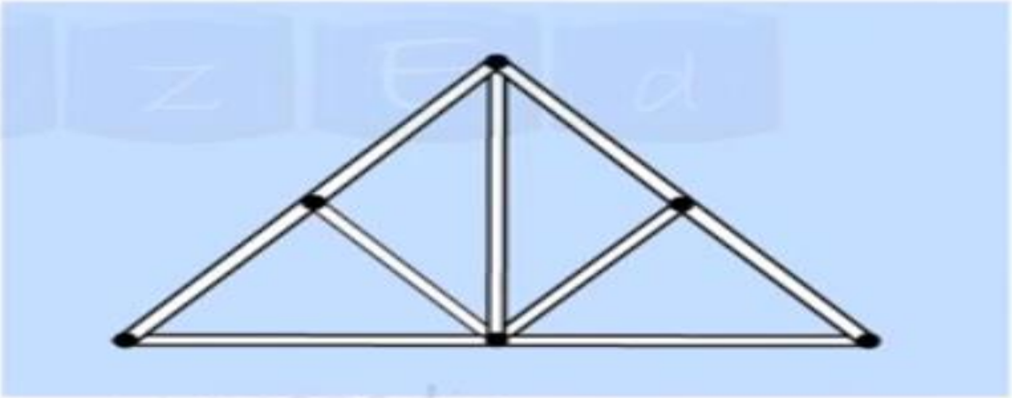


Engineering Structure

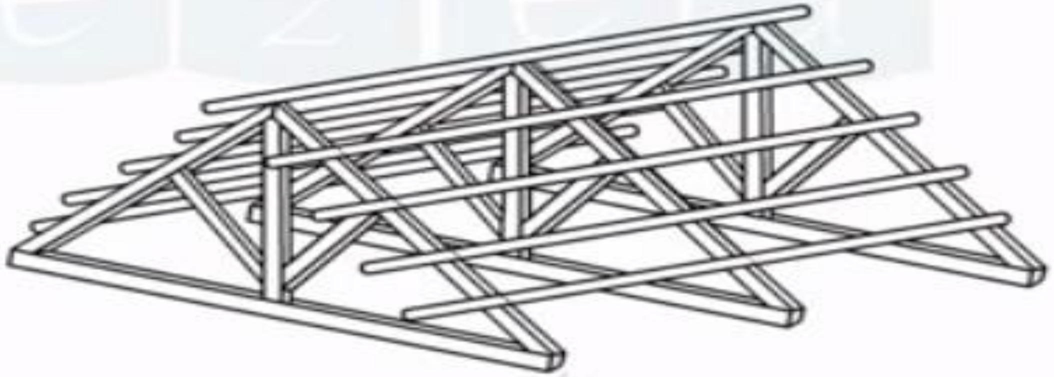
- Trusses
- Frames

Basic Types of Trusses

- Planar Truss

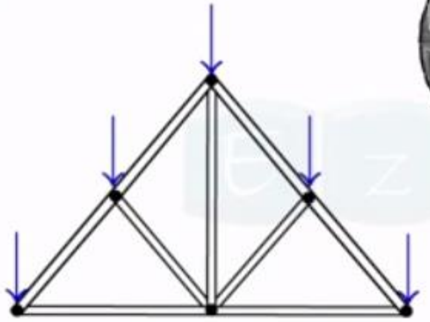


- Space Frame Truss



Applications Of Trusses

Roof Truss



Railway Platform

Stadium

Designed to carry the load of a roof at its top

Electrical Transmission Towers

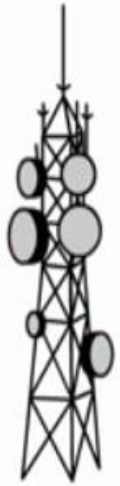
Vertical Steel Truss

Carries the load and tension of the heavy electrical cables

Microwave Transmission Towers

Vertical Steel Truss

Carries the load of the heavy parabolic antennas

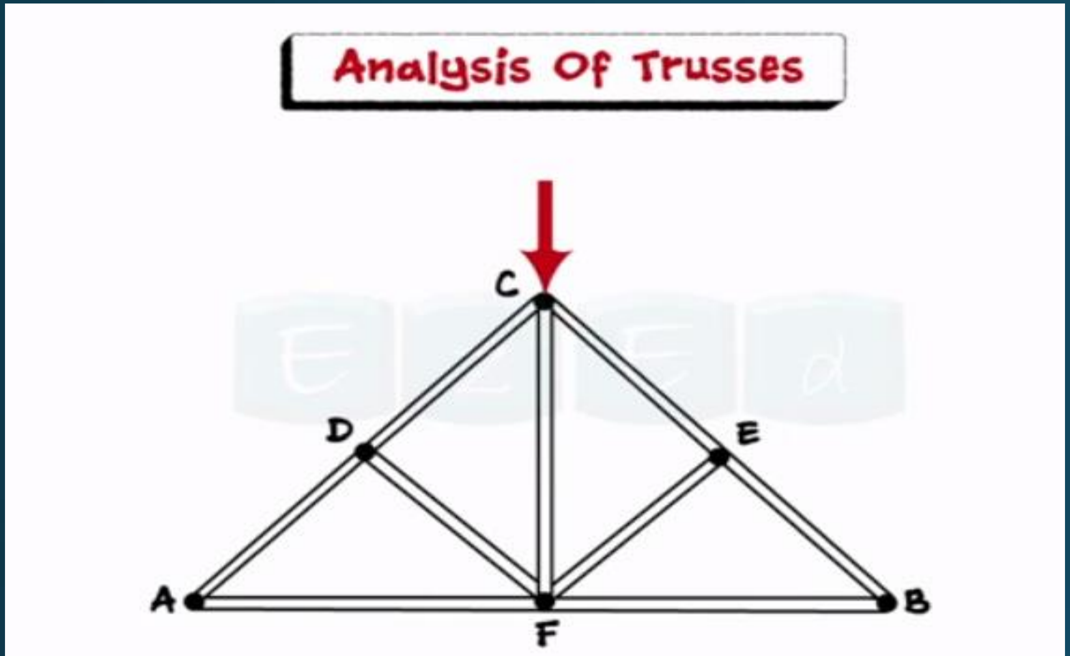


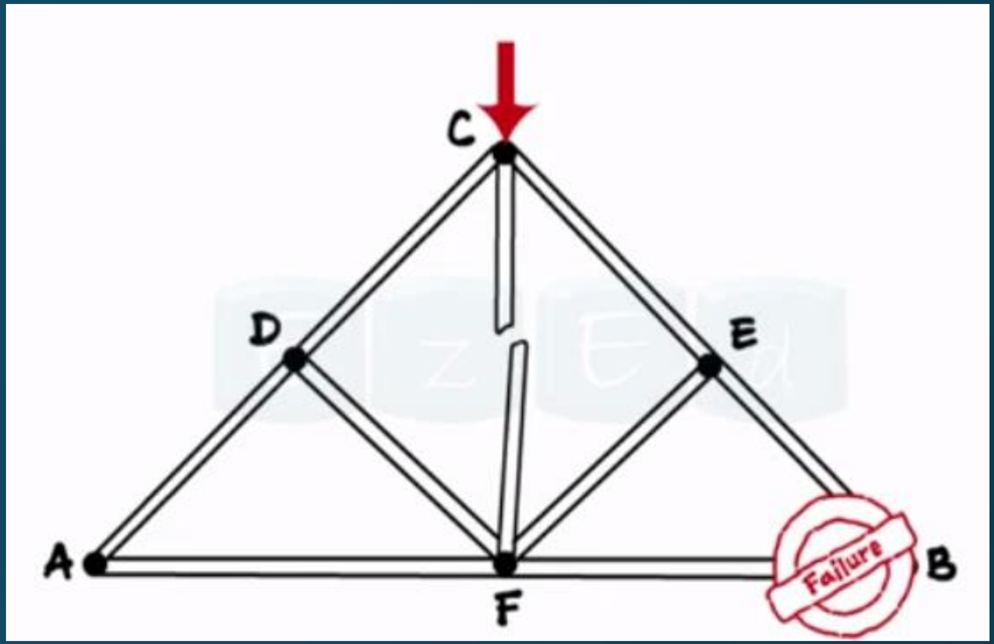
Bridge Truss

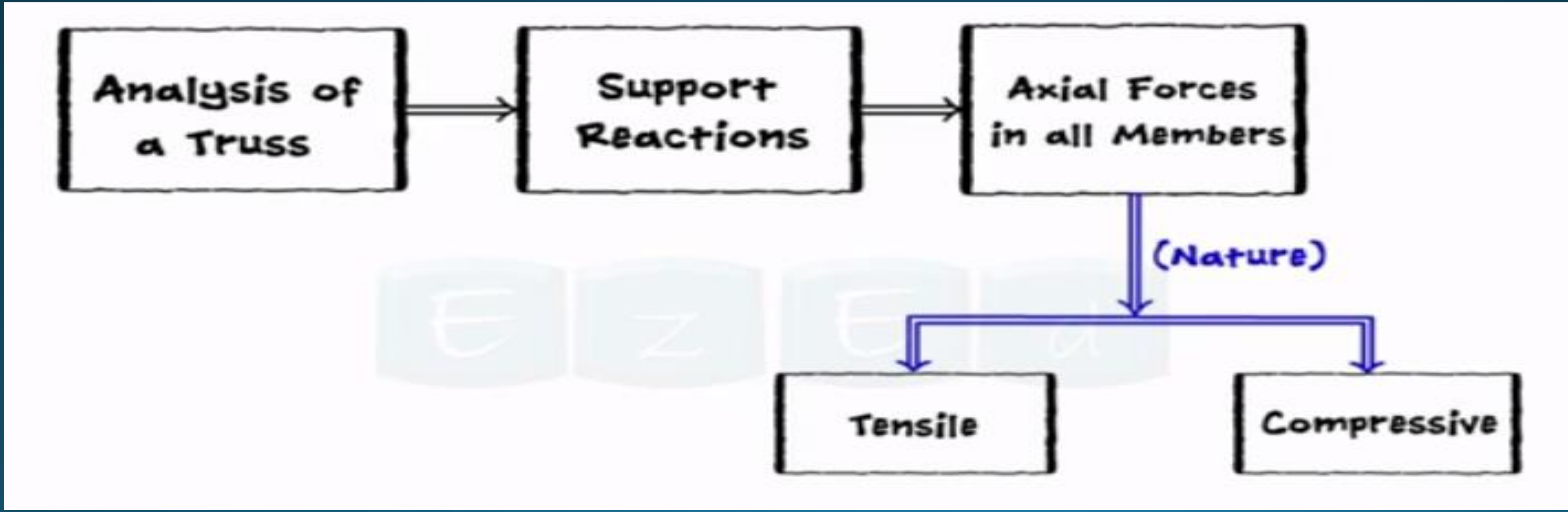
Railway

Road

Supports the floor of the bridge

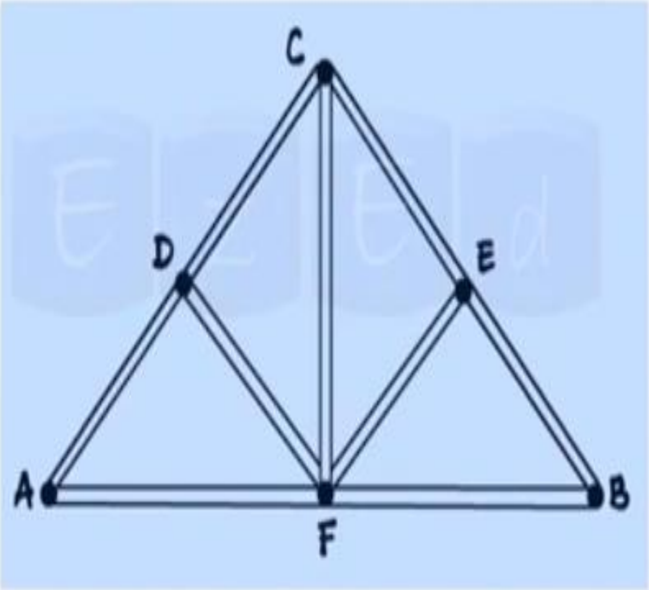

Analysis Of Trusses
C
D
E
A
F
B


C
D
E
A
F
B
Failure


Analysis of a Truss
Support Reactions
Axial Forces in all Members
(Nature)
Tensile
Compressive

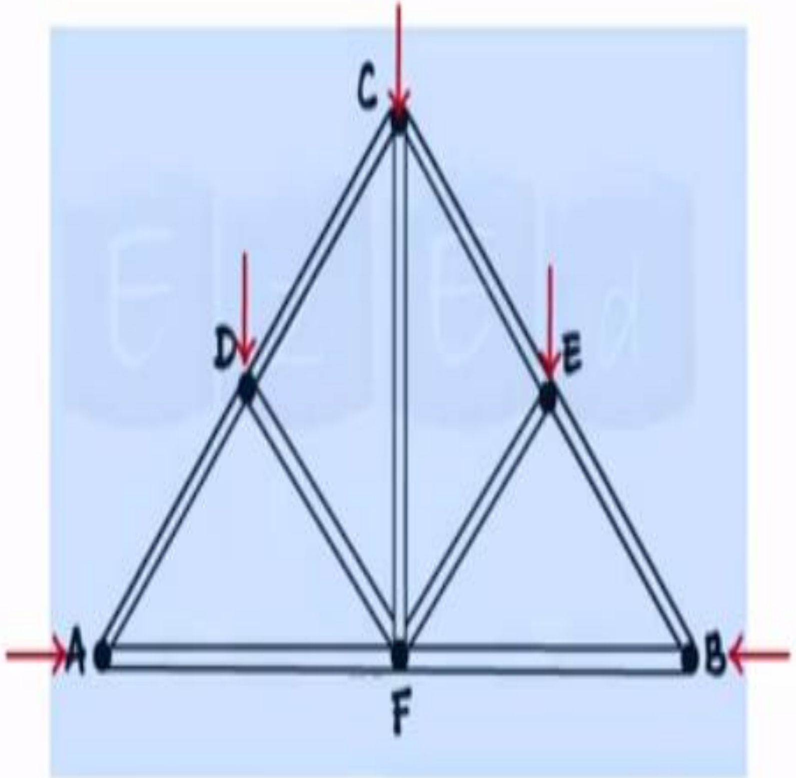
Analysis Of Trusses

Assumptions Made in Analysis of Plane Trusses



1. All the members of the truss lie in a single plane, thus together forming a planar truss

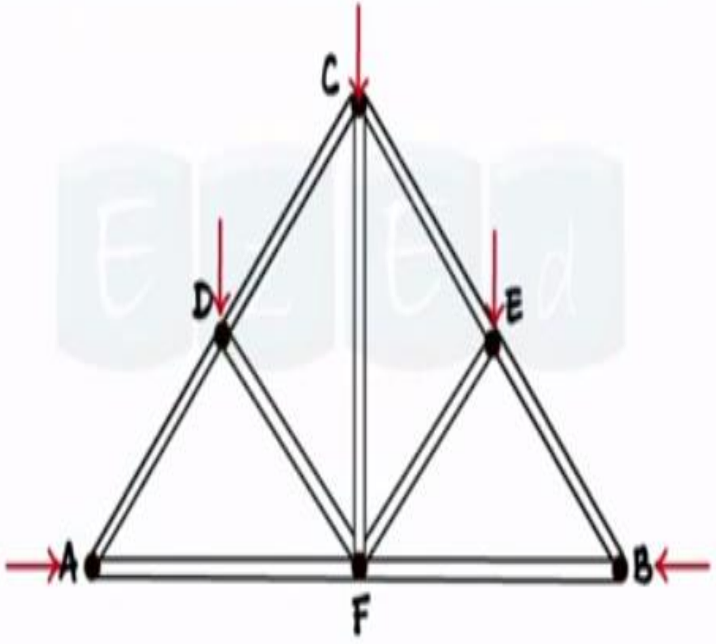
Assumptions Made in Analysis of Plane Trusses



2. All the loads acting on the truss lie in the plane of the truss

Analysis Of Trusses

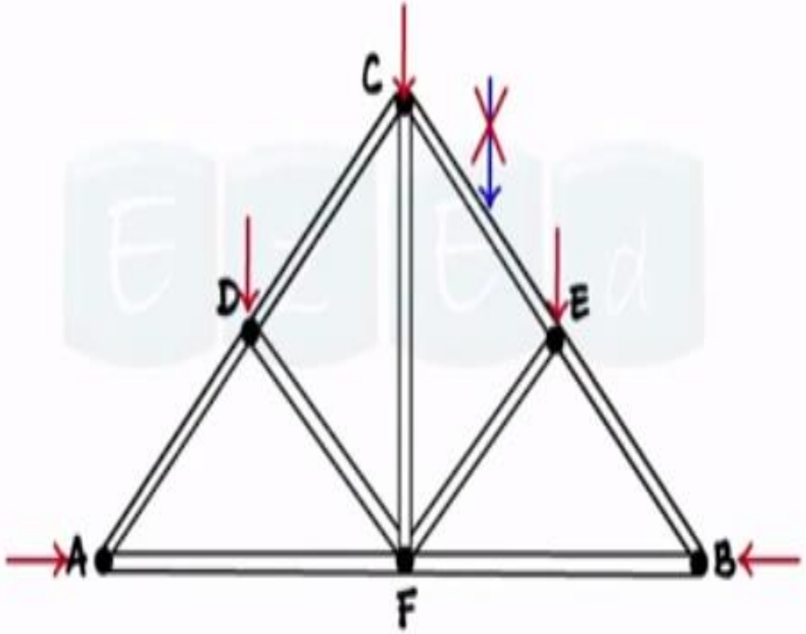
Assumptions Made in Analysis of Plane Trusses



3. The members of the truss are joined at the ends by internal hinges known as pins

Analysis Of Trusses

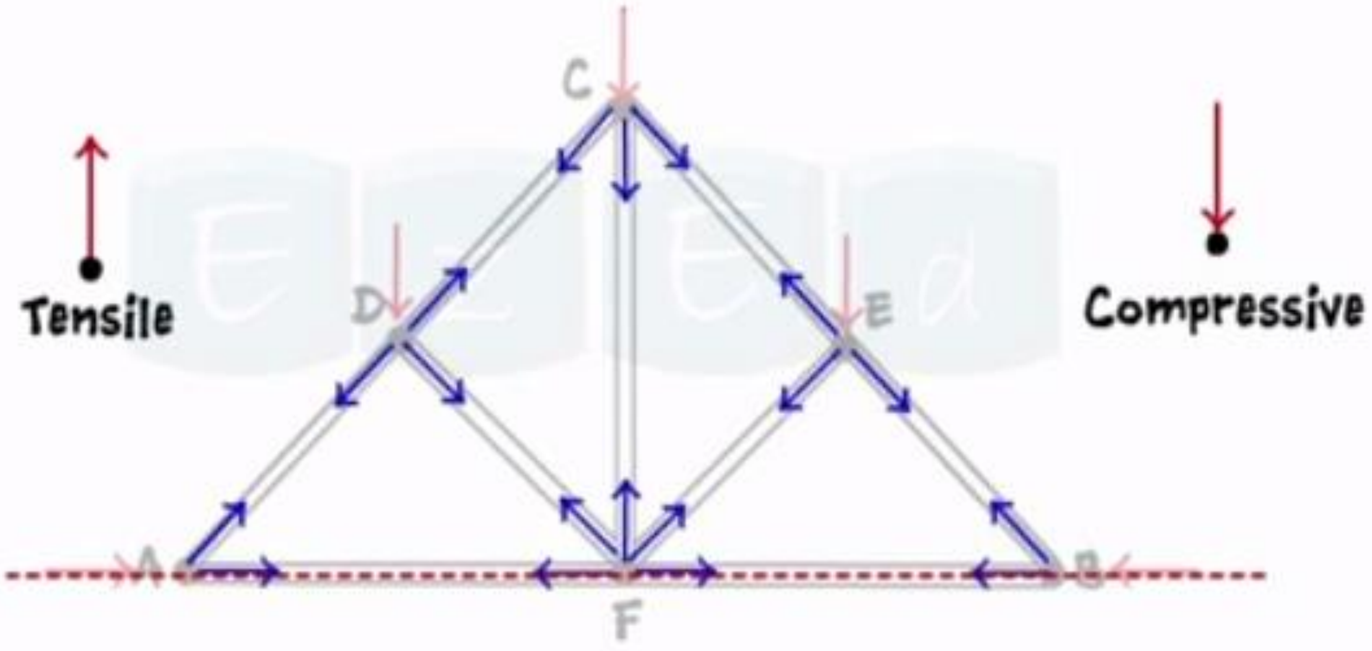
Assumptions Made in Analysis of Plane Trusses



4. Loads act only at the joints and not directly on the members

Analysis Of Trusses

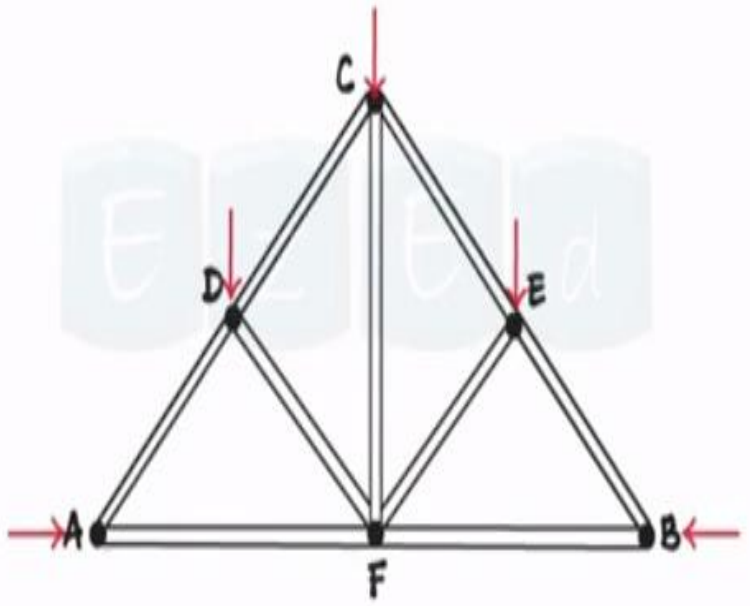
Assumptions Made in Analysis of Plane Trusses



5. All members of the truss are two force bodies and therefore resulting in axial forces which are tensile or compressive in nature

Analysis Of Trusses

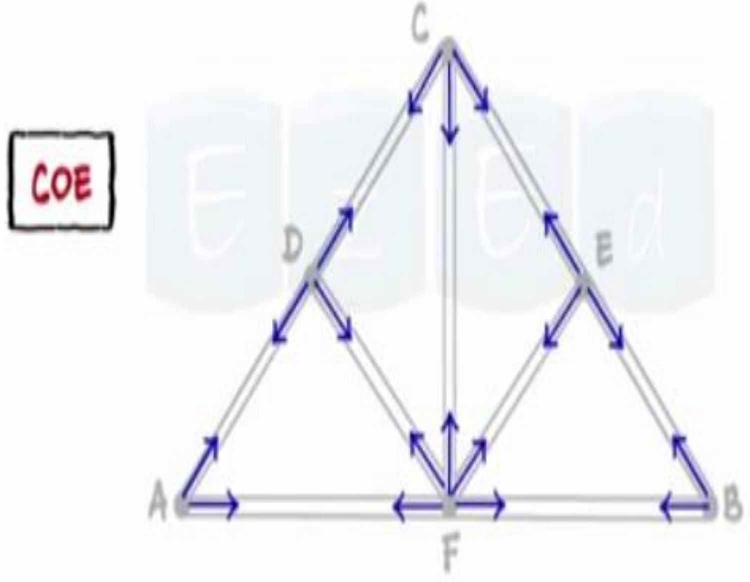
Assumptions Made in Analysis of Plane Trusses



6. As the self weight of the members is very small in comparison to the loads, the self weight of the members is neglected

Analysis Of Trusses

Assumptions Made in Analysis of Plane Trusses



7. The truss is statically determinate

Method Of Joints

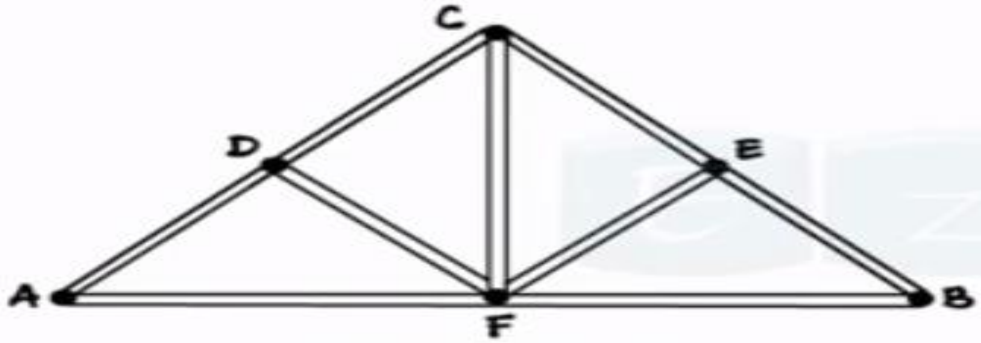
Analysis of a Truss ⟹ Method of Joints ⟹ COE ⟹ Forces in all the Members ✓

Method of Joints:

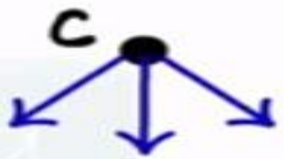
- Isolate the Joints
- Show the Forces of the Members

Principle

"If the truss is in equilibrium, an isolated joint of the truss will also be in equilibrium"

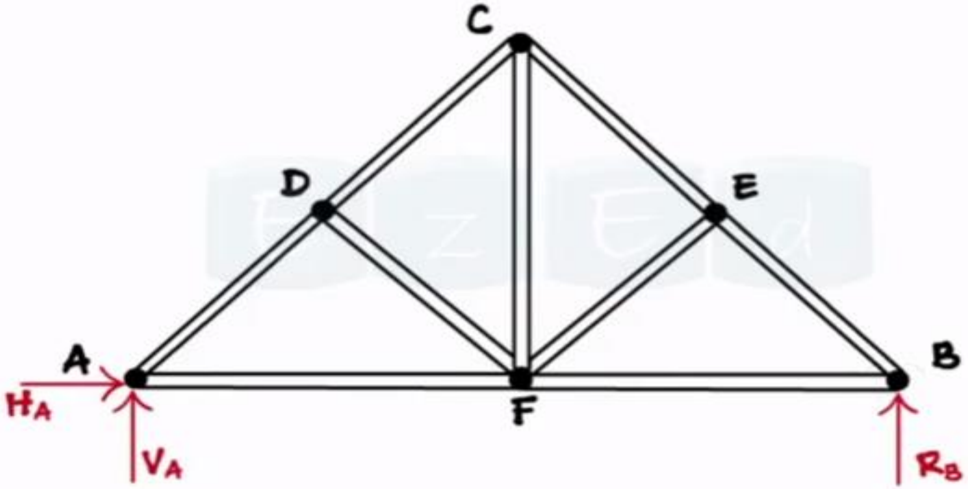


Equilibrium

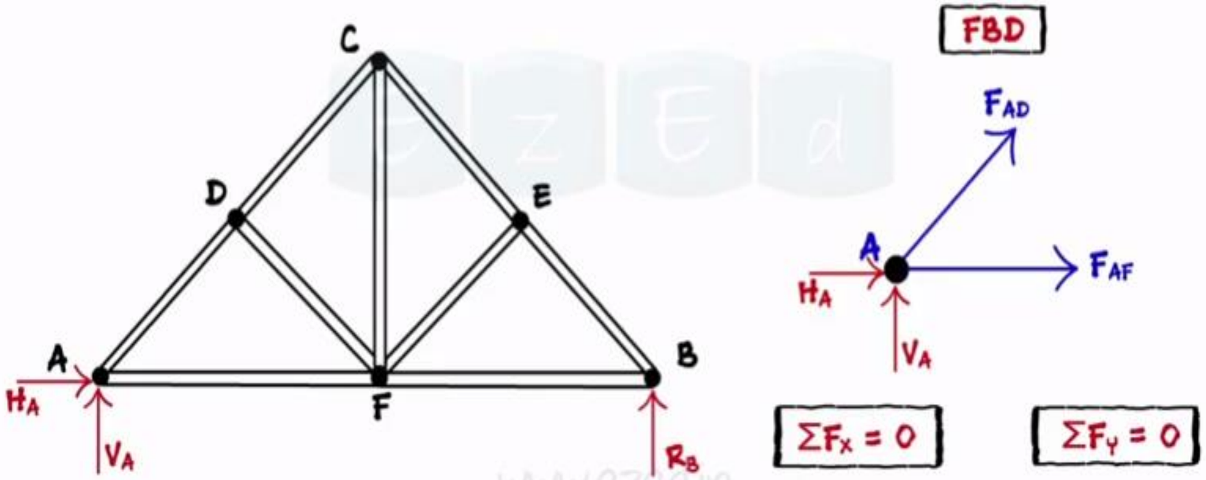


Equilibrium

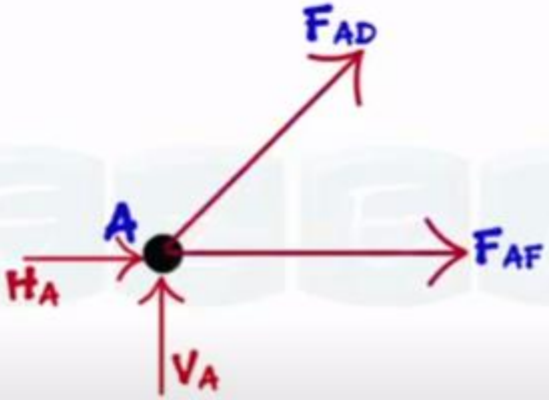
$\boxed{\text{Step 1}}$ COE → Entire Truss → Support Reactions.



$\boxed{\text{Step 2}}$ Select Joint → Isolate from truss → FBD

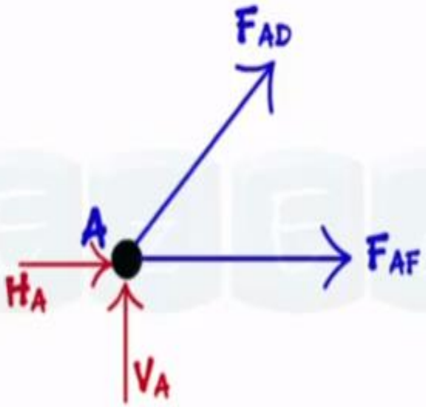


$\boxed{\text{Step 3}}$ Assume Tensile Forces



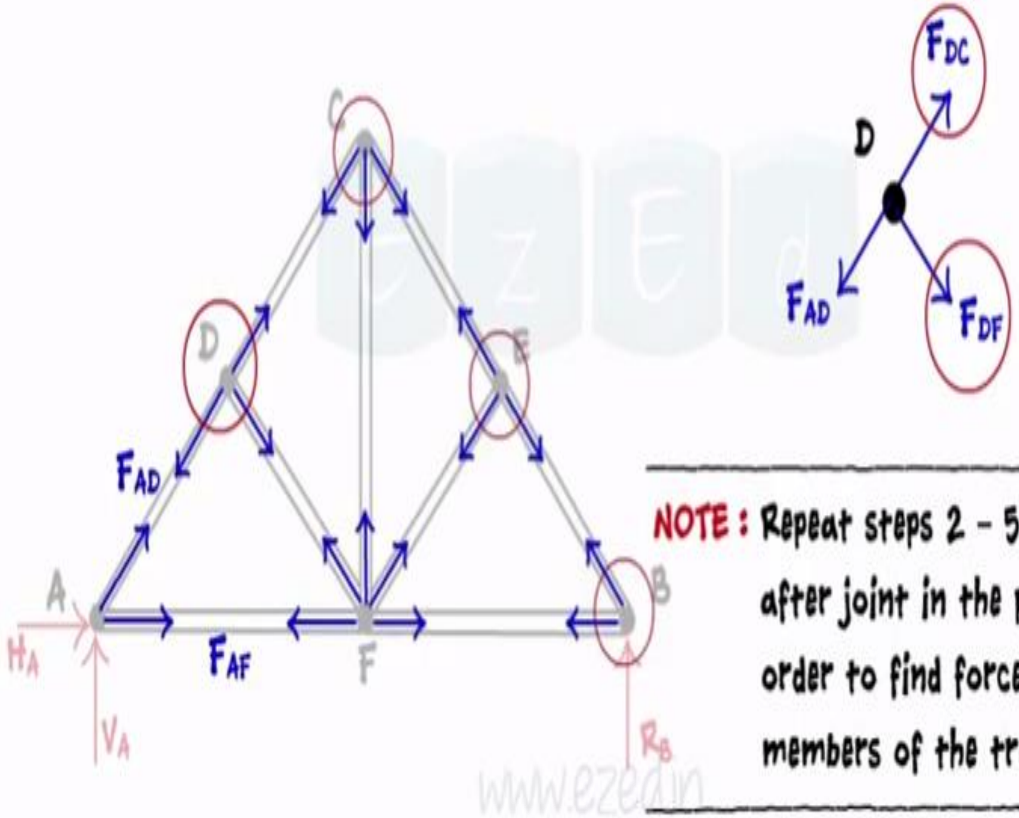
$\boxed{\text{Step 4}}$ Concurrent Force system → 2 COE

$\Sigma F_x = 0$ (→ +ve) $\Sigma F_y = 0$ (↑ +ve)



Method Of Joints

Step 5 Select and isolate another joint



NOTE : Repeat steps 2 – 5 solving joint after joint in the process in order to find forces in all members of the truss

Method Of Joints

Step 6 Results ⟶ Table

Member	Magnitude	Nature
AD	—	Tensile
AF	—	Compressive
—	—	—
—	—	—

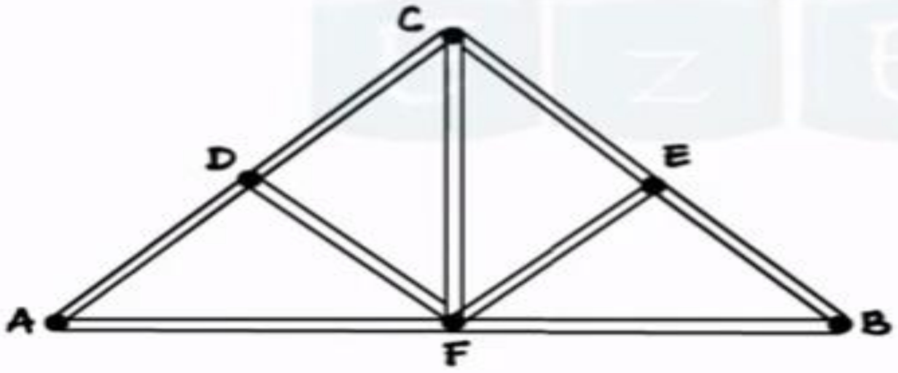
Method Of Sections

Analysis of a Truss ⇒ Method of Sections ⇒ COE ⇒ Forces in the Required Members ✓

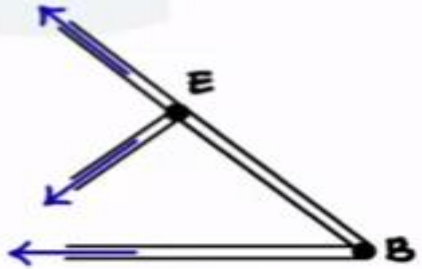
Method of Sections:
- Select the Cutting Section
- Show the Forces in the Members

Method of Sections

Principle : "If the truss is in equilibrium, an isolated part of the truss will also be in equilibrium."



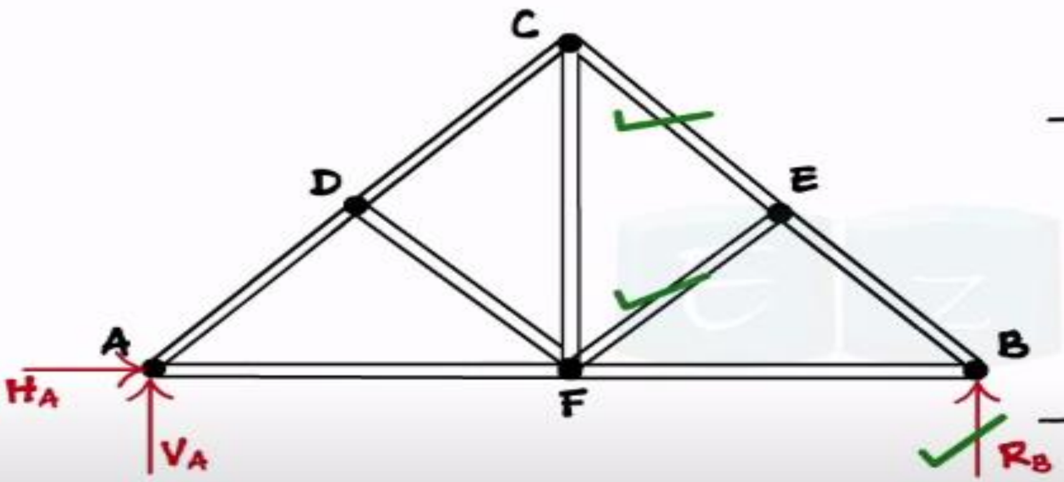
Equilibrium



Equilibrium

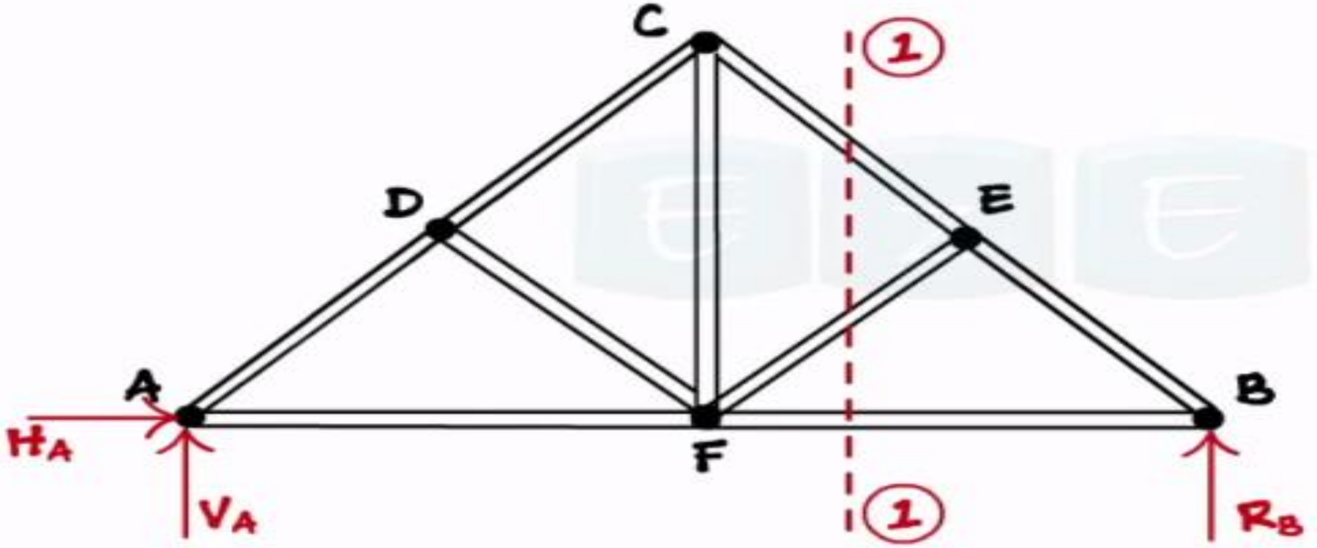
Method of Sections

Step 1 Mark members



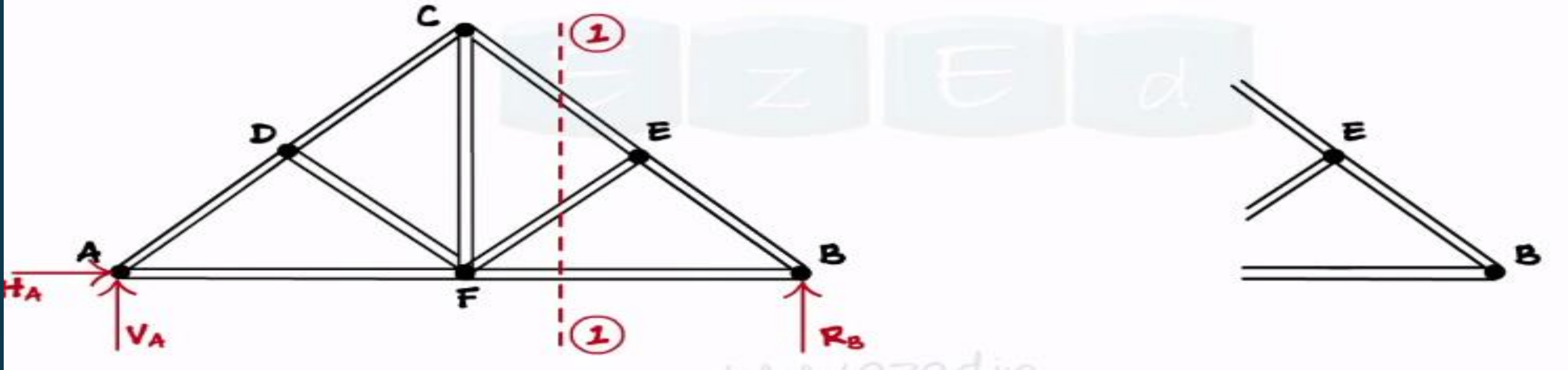
NOTE : In this method, it is not necessary to find all the support reactions offered by the supports. If any of the reactions are required, we calculate them at the start itself.

Step 2 Cutting section ⟶ 3 members

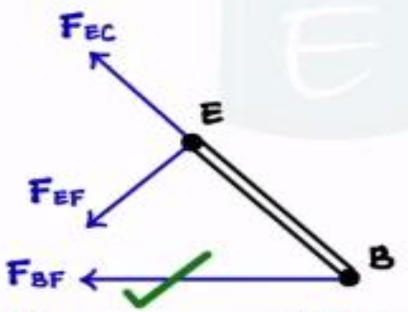


Step 3

Select → Isolate



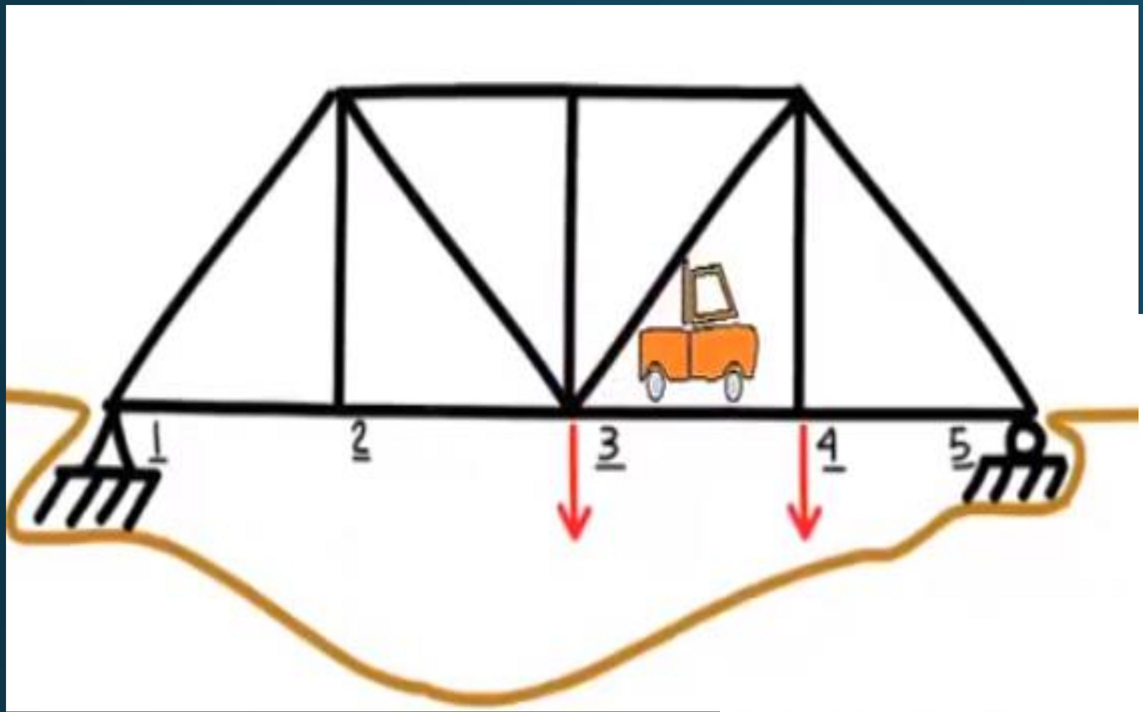
Step 4

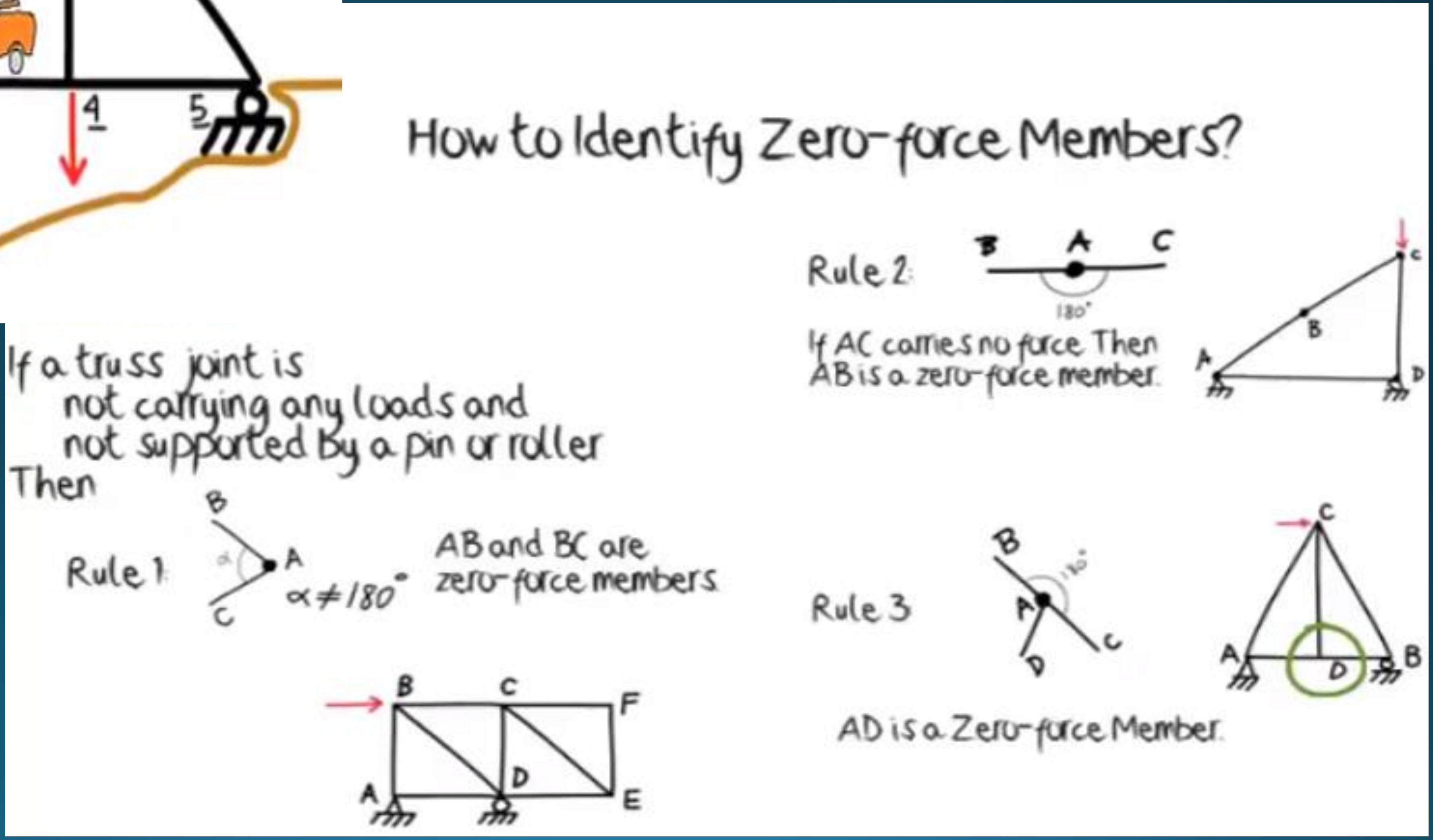


$\boxed{\Sigma F_x = 0 \;(\rightarrow +ve)}$ $\boxed{\Sigma F_y = 0 \;(\uparrow +ve)}$

$\boxed{\Sigma M = 0 \ldots \circlearrowright +ve}$

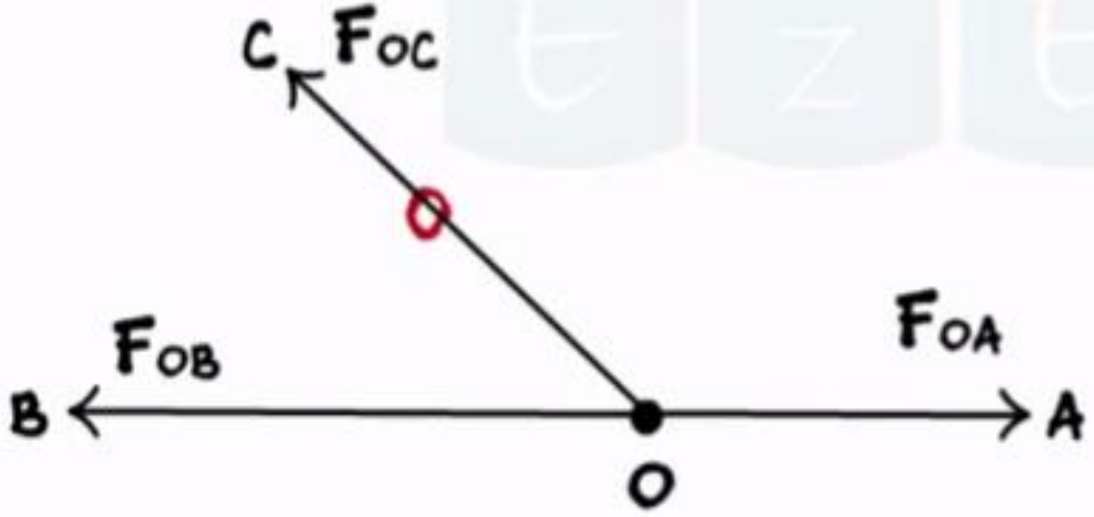
NOTE : Moments are usually calculated about a point where two forces meet in order to find the third force


1
2
3
4
5


How to Identify Zero-force Members?
If a truss joint is
not carrying any loads and
not supported by a pin or roller
Then
Rule 1:
B
A
C
α≠180°
AB and BC are zero-force members
B
C
F
A
D
E
Rule 2:
B
A
C
180°
If AC carries no force Then AB is a zero-force member.
C
B
A
D
Rule 3
B
A
C
D
180°
C
A
D
B
AD is a Zero-force Member.

Case 1 :

'If three members meet at a point among which two are collinear, and there is no load at the joint, then the third member is a zero force member and the two collinear forces have the same magnitude and nature'.

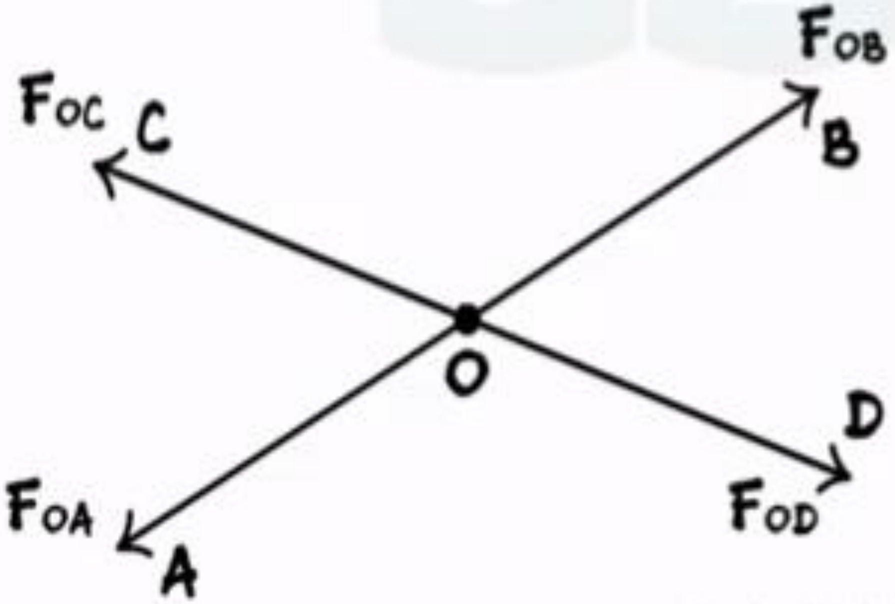


$\boxed{F_{OC} = 0}$

$\boxed{F_{OA} = F_{OB}}$

Case 2 :

'If four members meet at a point, forming two pairs of collinear members, and there is no load at the joint, then the forces in the collinear members have the same magnitude and nature'.

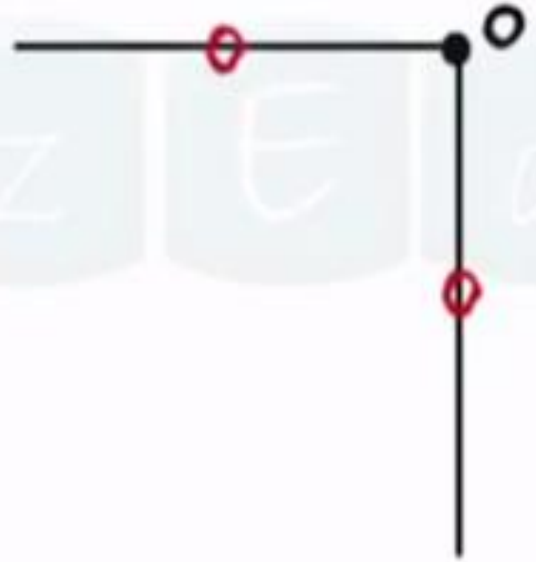


$$\boxed{F_{OA} = F_{OB}}$$

$$\boxed{F_{OC} = F_{OD}}$$

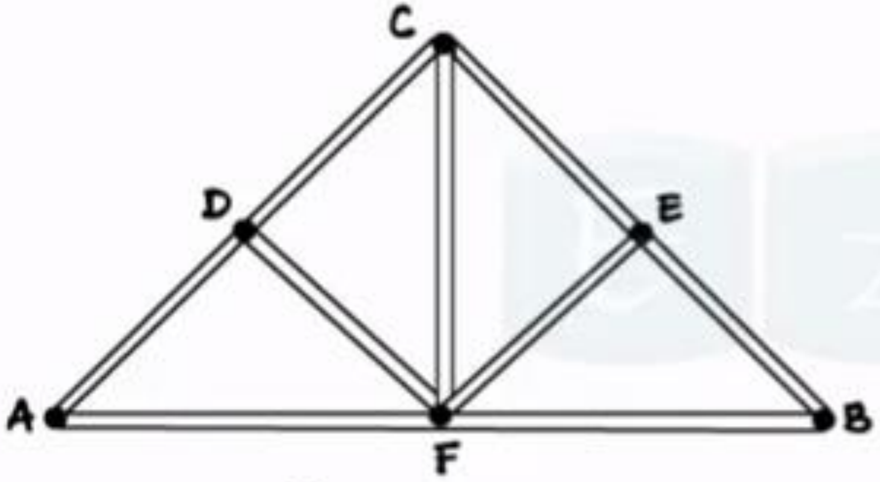
Case 3 :

'If two members meet at a joint and the joint is unsupported and unloaded, then both the members are zero force members'.



Determinacy Of Trusses

Statically Determinate Truss



$$\boxed{m = 2j - r}$$

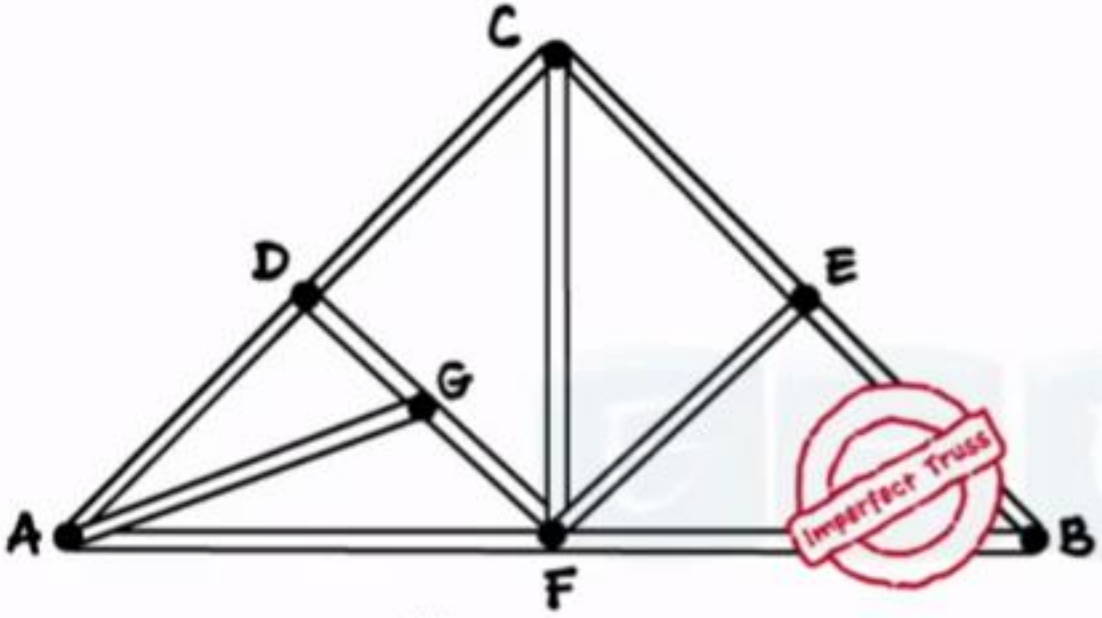
where, m = number of members

j = number of joints

r = number of support reactions

A truss which can be analyzed completely is called as a Statically Determinate Truss

Statically Indeterminate Truss

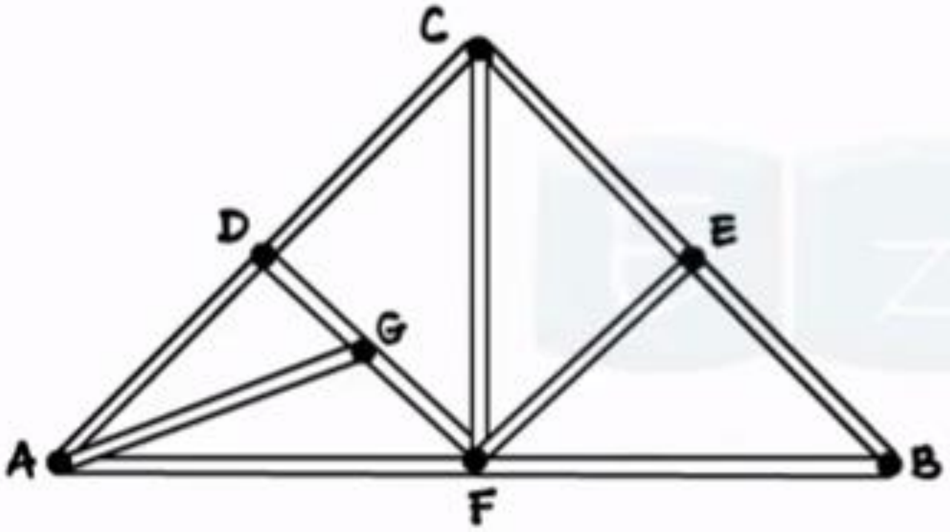


$$\boxed{m \neq 2j - r}$$

A truss which cannot be analyzed completely is called as a Statically Indeterminate Truss.

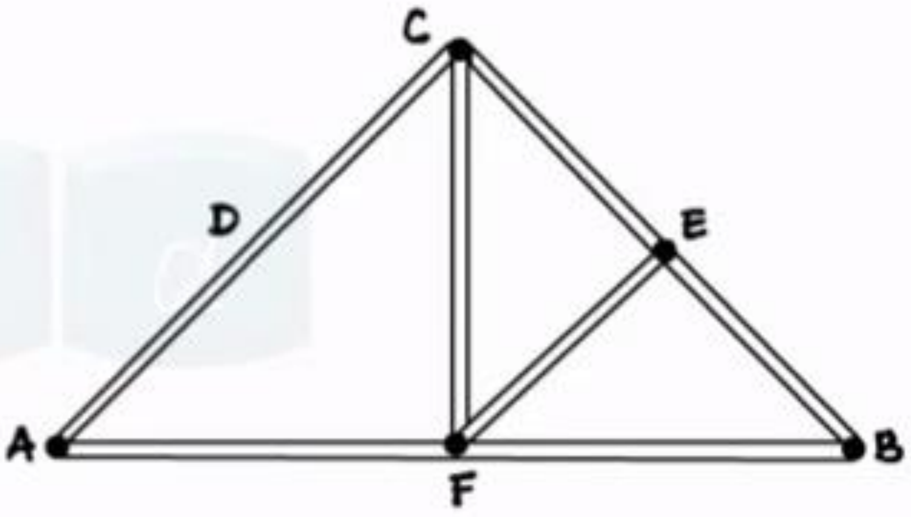
Determinacy Of Trusses

1. Redundant or Over Rigid Truss

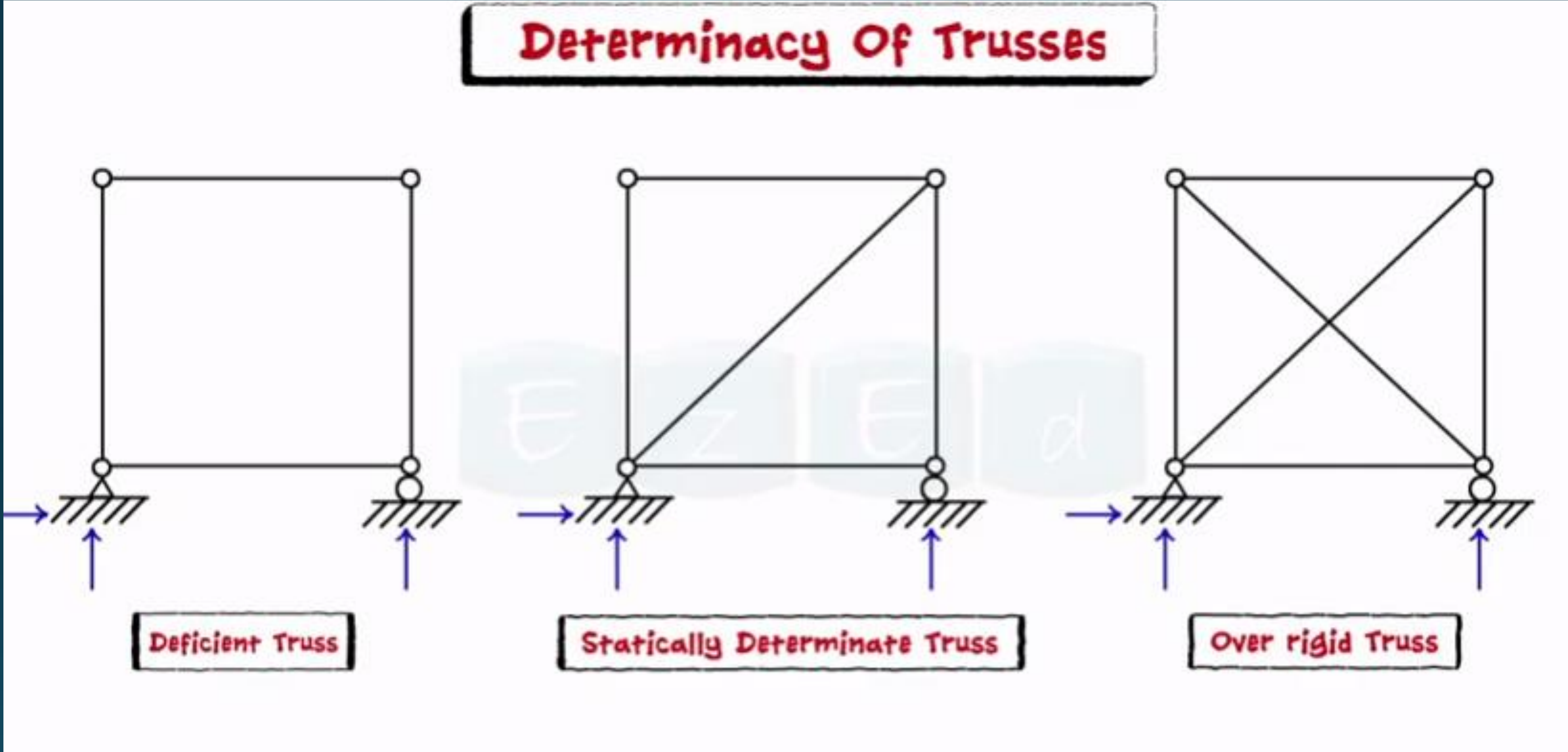


$\boxed{m > 2j - r}$

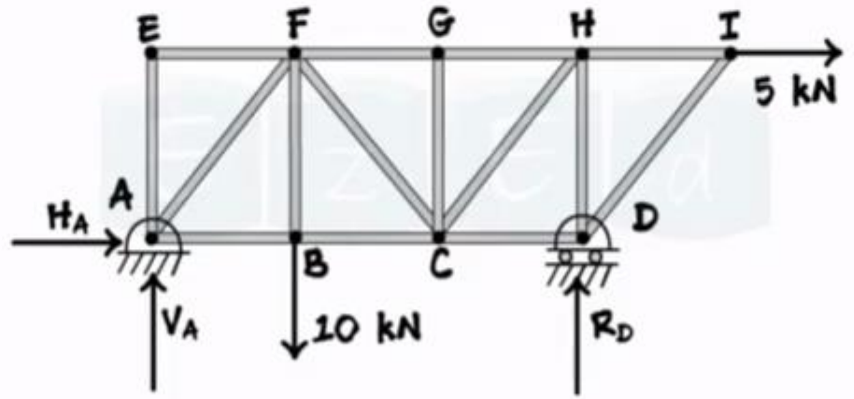
2. Deficient truss

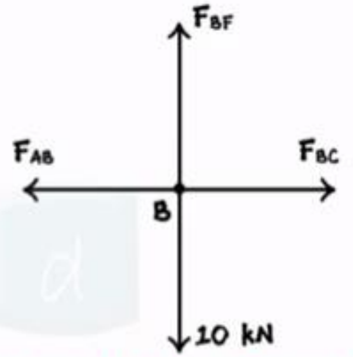


$\boxed{m < 2j - r}$


Determinacy Of Trusses
Deficient Truss
Statically Determinate Truss
Over rigid Truss

Q. Find forces in as many members as possible by inspection (without calculations).

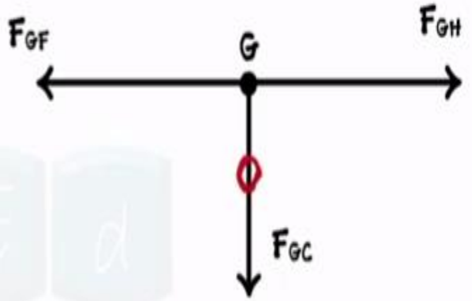




Applying special Case 2 to joint B

$\boxed{F_{BF} = 10 \text{ kN (Tension)}}$

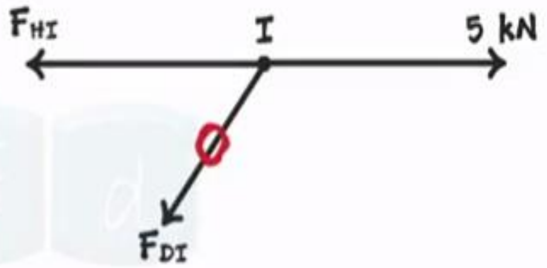
$\boxed{F_{AB} = F_{BC}}$



Applying special Case 1 to joint G

$\boxed{F_{GC} = 0}$

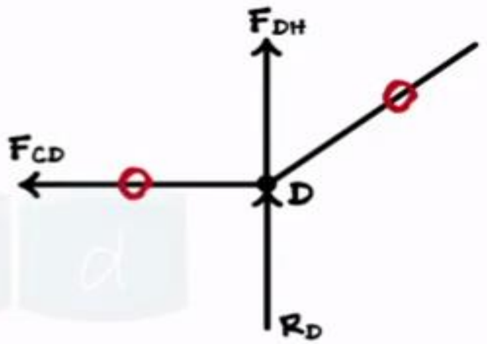
$\boxed{F_{GF} = F_{GH}}$



Applying Special Case 1 to Joint I

$\boxed{F_{HI} = 5 \text{ kN (Tension)}}$

$\boxed{F_{DI} = 0}$



Applying special Case 1 to joint D

$\boxed{F_{CD} = 0}$

$\boxed{F_{DH} = R_D}$

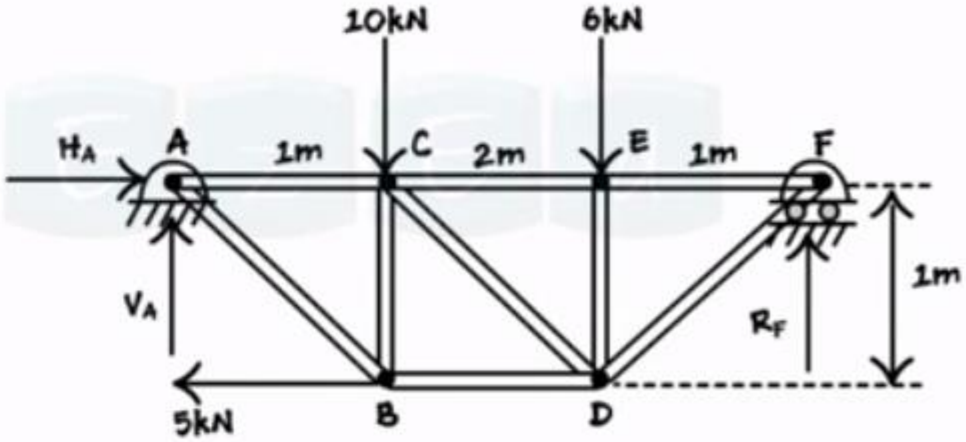
Applying special Case 3 to joint E

$\boxed{F_{AE} = 0}$

$\boxed{F_{EF} = 0}$

Problem

Q. Using method of joints, analyze the truss shown.



Applying COE to the Entire Truss

$\Sigma M_A = 0 \ldots. \circlearrowright +ve$

$$-5(1) - 10(1) - 6(3) + R_F(4) = 0$$

$$\boxed{R_F = 8.25 \text{ kN} (\uparrow)}$$

$\Sigma F_x = 0 \ldots. \rightarrow +ve$

$$H_A - 5 = 0$$

$$\boxed{H_A = 5 \text{ kN} (\rightarrow)}$$

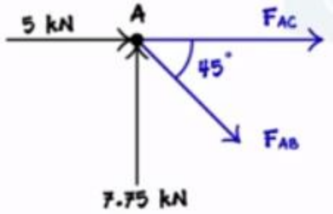
$$\boxed{R_F = 8.25 \text{ kN} (\uparrow)} \quad \boxed{H_A = 5 \text{ kN} (\rightarrow)}$$

$\Sigma F_y = 0 \ldots. \uparrow +ve$

$$V_A - 10 - 6 + R_F = 0$$

$$V_A - 16 + 8.25 = 0$$

$$\boxed{V_A = 7.75 \text{ kN} (\uparrow)}$$



Applying COE,

$\Sigma F_y = 0 \ldots. \uparrow +ve$

$$7.75 - F_{AB} \sin 45 = 0$$

$$\boxed{F_{AB} = 10.61 \text{ kN (Tension)}}$$

$\Sigma F_x = 0 \ldots. \rightarrow +ve$

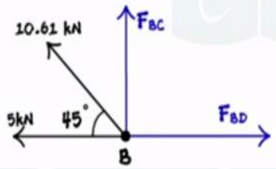
$$5 + F_{AC} + F_{AB} \cos 45 = 0$$

$$5 + F_{AC} + 10.61 (\cos 45) = 0$$

$$F_{AC} = -12.5 \text{ kN}$$

$$\boxed{F_{AC} = 12.5 \text{ kN (Compression)}}$$

Joint B



Applying COE,

$\Sigma F_x = 0 \ldots. \rightarrow +ve$

$$-5 - 10.61 \cos 45 + F_{BD} = 0$$

$$\boxed{F_{BD} = 12.5 \text{ kN (Tension)}}$$

$$\Sigma F_y = 0 \ldots \uparrow + ve$$

$$10.61 \sin 45 + F_{BC} = 0$$

$$F_{BC} = -7.5 \text{ kN}$$

$$\boxed{F_{BC} = 7.5 \text{ kN (Compression)}}$$

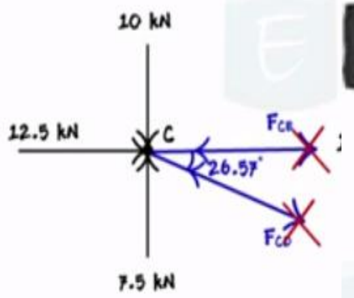
$$\Sigma F_y = 0 \ldots \uparrow + ve$$

$$7.5 - 10 - F_{CD} \sin 26.57 = 0$$

Joint C

$$F_{CD} = -5.6 \text{ kN}$$

$$\boxed{F_{CD} = 5.6 \text{ kN (Compression)}}$$



Applying COE,

$$\Sigma F_x = 0 \ldots \rightarrow + ve$$

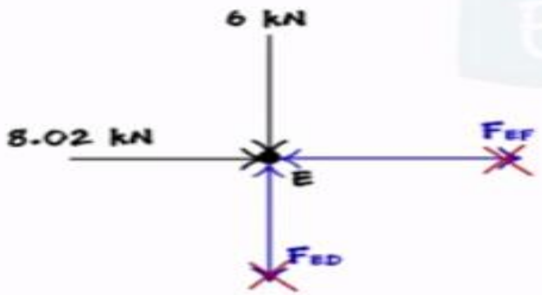
$$12.5 + F_{CD} \cos 26.57 + F_{CE} = 0$$

$$12.5 + (-5.6)(\cos 26.57) + F_{CE} = 0$$

$$F_{CE} = -8.02 \text{ kN}$$

$$\boxed{F_{CE} = 8.02 \text{ kN (Compression)}}$$

Joint E



Applying COE,

$$\Sigma F_x = 0 \ldots \rightarrow + ve$$

$$8.02 + F_{EF} = 0$$

$$F_{EF} = -8.02 \text{ kN}$$

$$\boxed{F_{EF} = 8.02 \text{ kN (Compression)}}$$

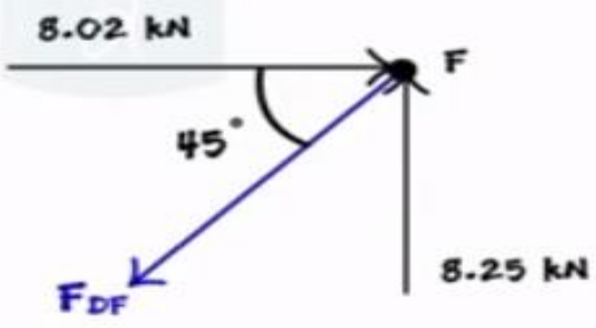
Applying COE,

$$\Sigma F_y = 0 \ldots \uparrow + ve$$

$$-6 - F_{ED} = 0$$

$$F_{ED} = -6 \text{ kN}$$

$$\boxed{F_{ED} = 6 \text{ kN(Compression)}}$$



Applying COE,

$$\Sigma F_x = 0 \ldots \rightarrow + ve$$

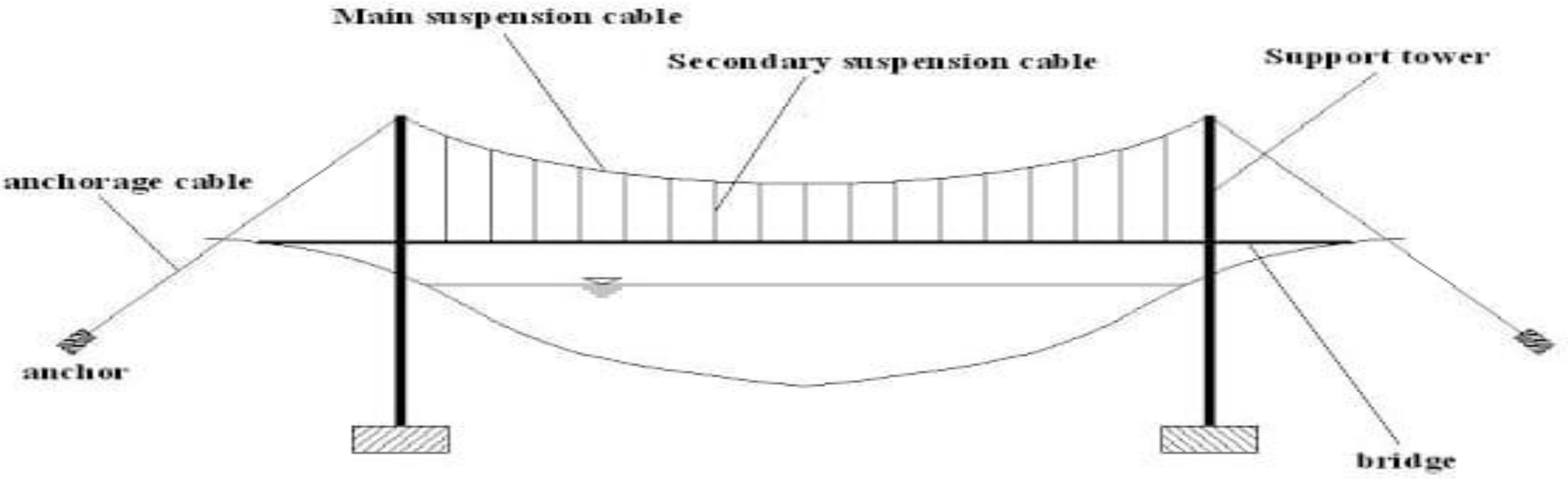
$$8.02 - F_{DF} \cos 45 = 0$$

$$\boxed{F_{DF} = 11.34 \text{ kN (Tension)}}$$

Member	Force (kN)	Nature
AB	10.61	Tension
AC	12.5	Compression
BD	12.5	Tension
BC	7.5	Compression
CD	5.6	Compression
CE	8.02	Compression
EF	8.02	Compression
ED	6	Compression
DF	11.34	Tension

Cable Structure

Cables are often used in engineering structures for support and to transmit loads from one member to another. When used to support suspension bridges, cables form the main load-carrying element in the structure.



Note: Cable can only carrying tensile force.

Cables: Assumptions

- Cable is perfectly flexible & inextensible
- No resistance to shear/bending: same as **truss bar**
- The force acting the cable is always tangent to the cable at points along its length

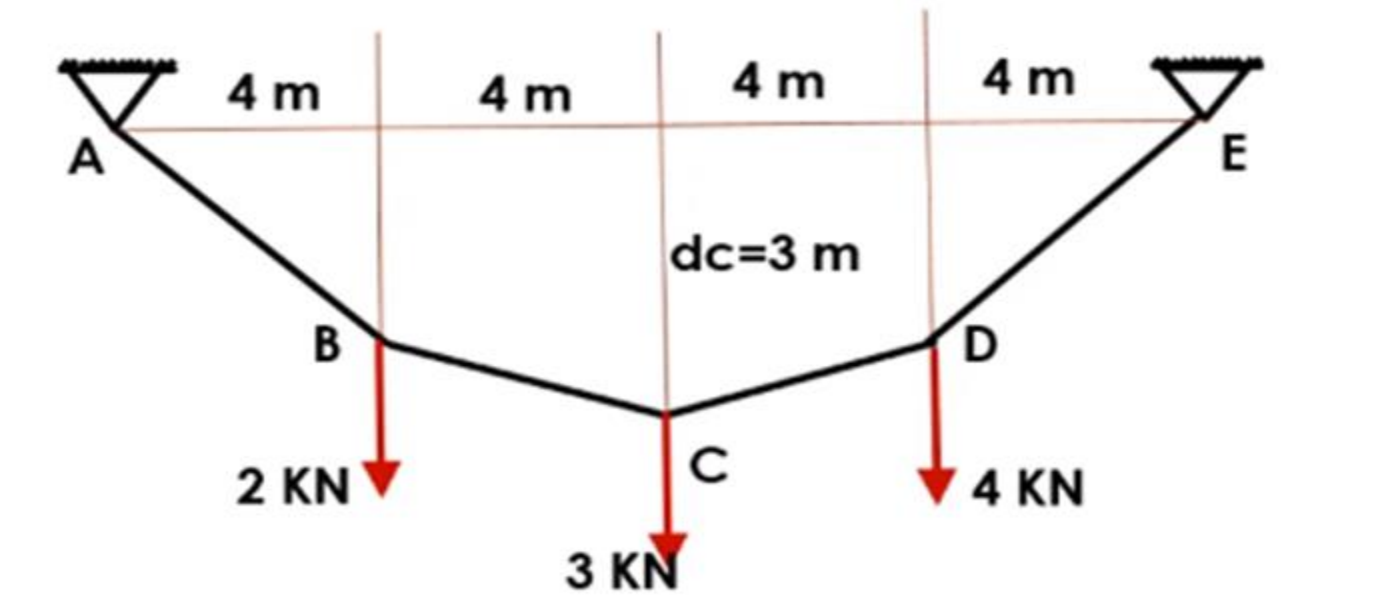
Only axial force!

Analysis of Cables-

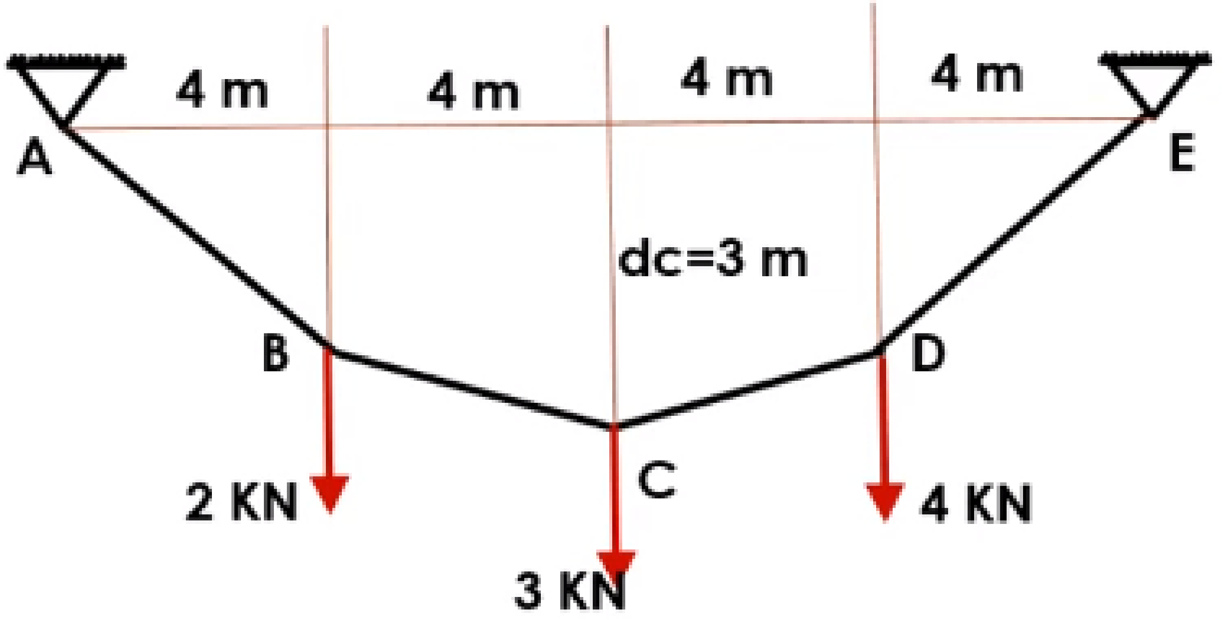
The procedure for the analysis of cables subjected to concentrated point load is as explained below,

1. Draw the free body diagram of the entire cable.
2. Now, there will be 4 unknown components and only 3 equations of equilibrium then identify the point of additional information as position or slope of the point.
3. Then, cut the cable at that point end draw free body diagram of any one side section left or right. And write the additional equation to determine the unknown as,
   - If the position is known, take $\sum M = 0$ about the point of cut for the new free body diagram.
   - If the slope is known, take $\sum H = 0$ and $\sum V = 0$ for the new free body diagram.

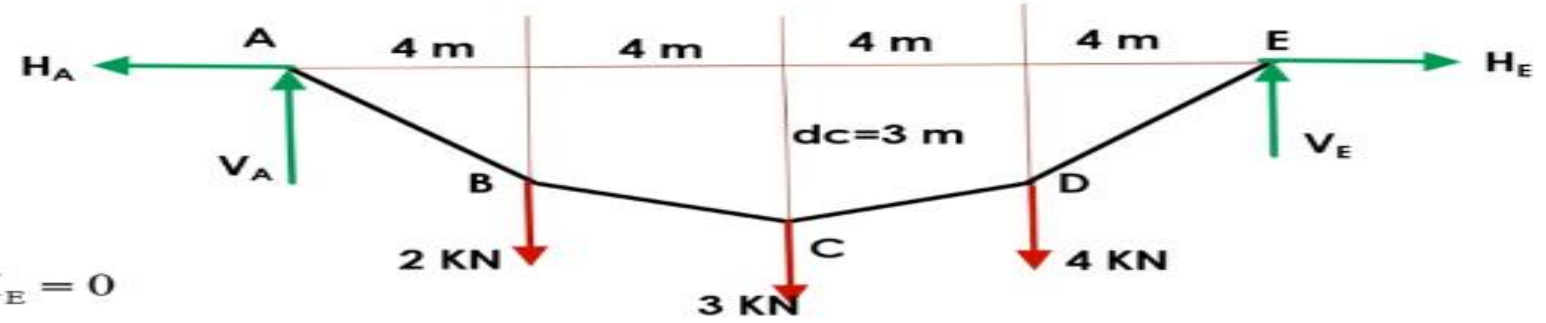
4. To find the elevation of a cable at a given point or slope and tension at that point- cut the cable at that point (where elevation is to be determined) and draw the free body diagram of any one side of the section and writing $\sum M = 0$ about the point gives elevation and writing $\sum H = 0$ and $\sum V = 0$ gives tension in the member.
5. For a cable supporting vertical load only the maximum tension occurs in the steepest portion of the cable.



1. Three loads are suspended as shown from the cable ABCDE. Knowing that dc= 3m, determine a) the components of the reaction at E, b) the maximum tension in the cable.



Step 1-
Considering the equilibrium of entire cable and applying the conditions of equilibrium to find the reactions at support



$$\sum H = 0, \quad -H_A + H_E = 0$$

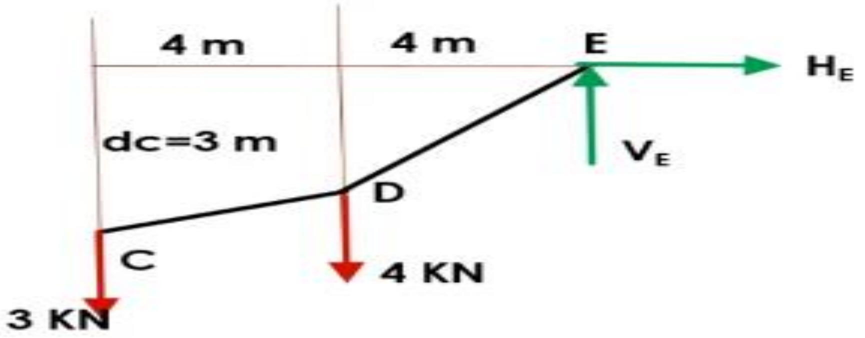
$$\sum V = 0, \quad V_A + V_E = 9$$

$$\sum M_A = 0, \quad 2x4 + 3x8 + 4x12 - V_E x16 = 0$$

$$V_E = 5KN$$

$$\therefore \quad V_A = 4KN$$

Step2-
Cut the cable at point C and consider the free body diagram of the right side,



$$\sum M_C = 0, \quad 4x4 - 5x8 + H_E x3 = 0$$

$$\therefore \quad H_E = 8KN \quad \text{and} \quad H_A = 8KN$$

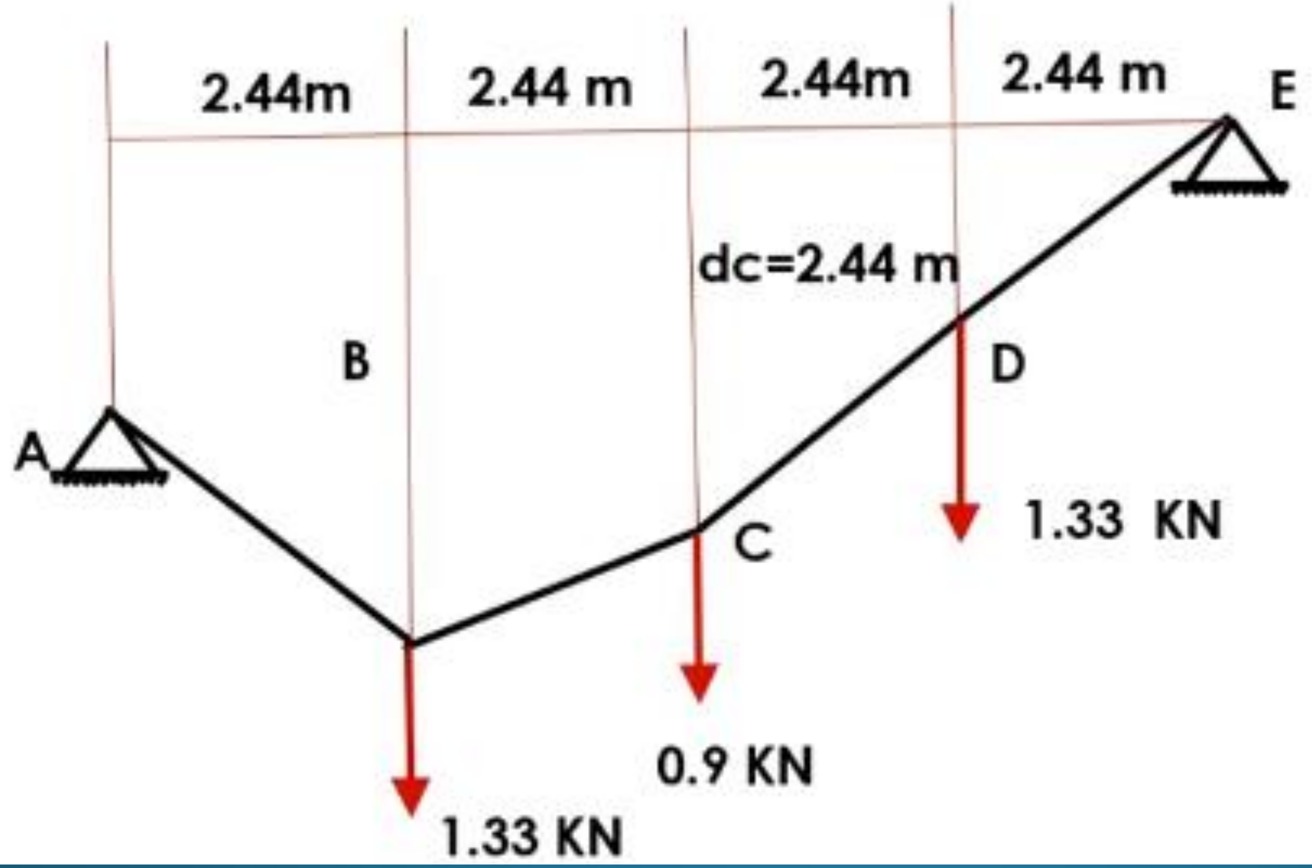
$$\therefore R_A = \sqrt{H_A^2 + V_A^2} = 8.944KN$$

$$R_E = \sqrt{H_E^2 + V_E^2} = 9.43KN$$

$$\text{Maximum tension in cable} = R_E = 9.43KN$$

Example-

- 2. Knowing that dc=2.44m, determine a)the reaction at A, b)the reaction at E.



0

Solution:

Step 1-

Considering the equilibrium of entire cable and applying the conditions of equilibrium to find the reactions at support

$$\sum H = 0,$$

$$-H_A + H_E = 0$$

$$\sum V = 0,$$

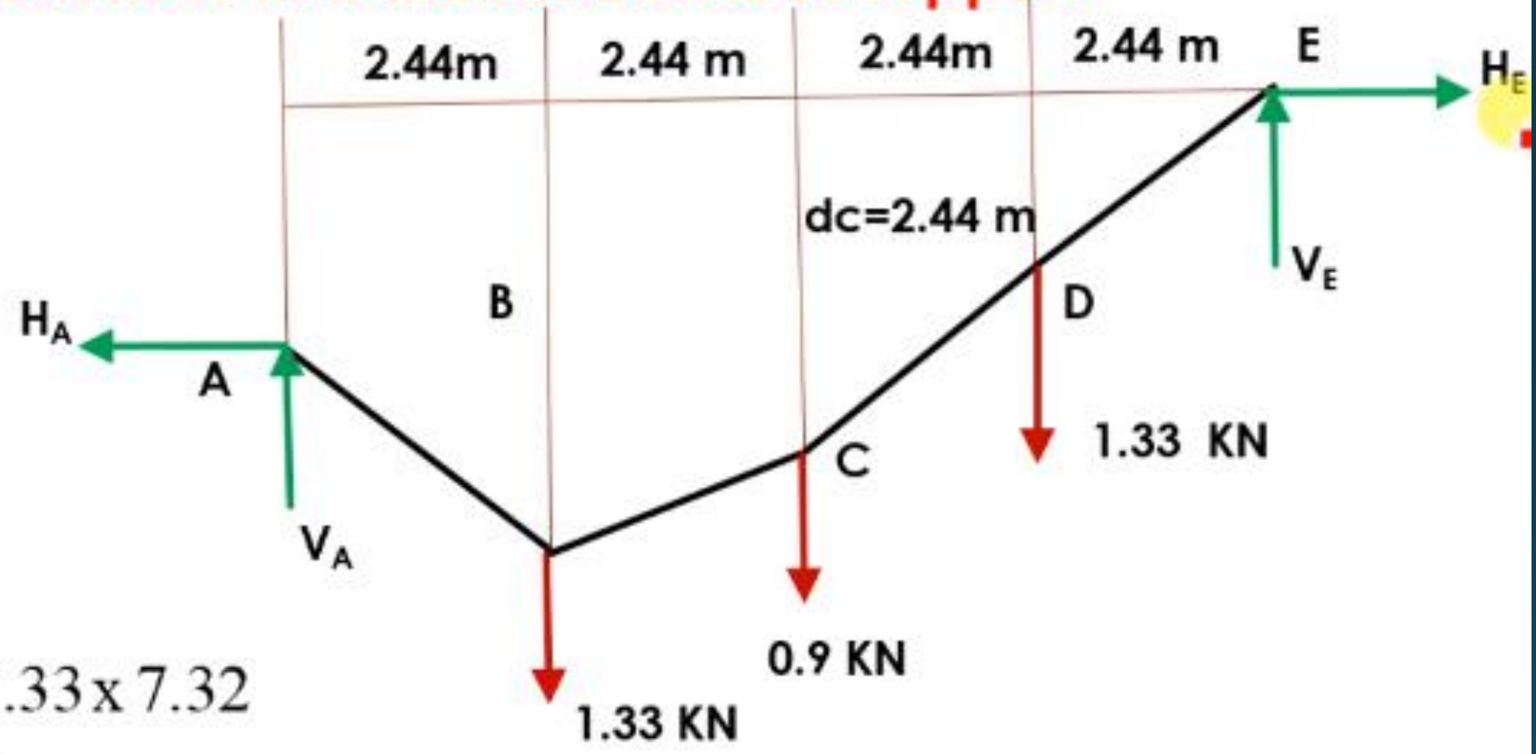
$$V_A + V_E = 3.56$$

$$\sum M_A = 0,$$

$$1.33 \times 2.44 + 0.9 \times 4.88 + 1.33 \times 7.32$$

$$-V_E \times 9.76 + H_E \times 1.83 = 0$$

$$1.83H_E + 9.76V_E = -17.37 \quad \ldots\ldots\ldots\ldots\ldots (1)$$



Step2-
Cut the cable at point C and consider the free body diagram of the right side,

$$\sum M_C = 0\,, \quad 1.33 \text{ x } 2.44 + H_E \text{ x } 2.44 + V_E \text{ x } 4.88 = 0$$

$$\therefore \quad H_E - 2V_E = -1.33$$

solving the simultaneous equations,

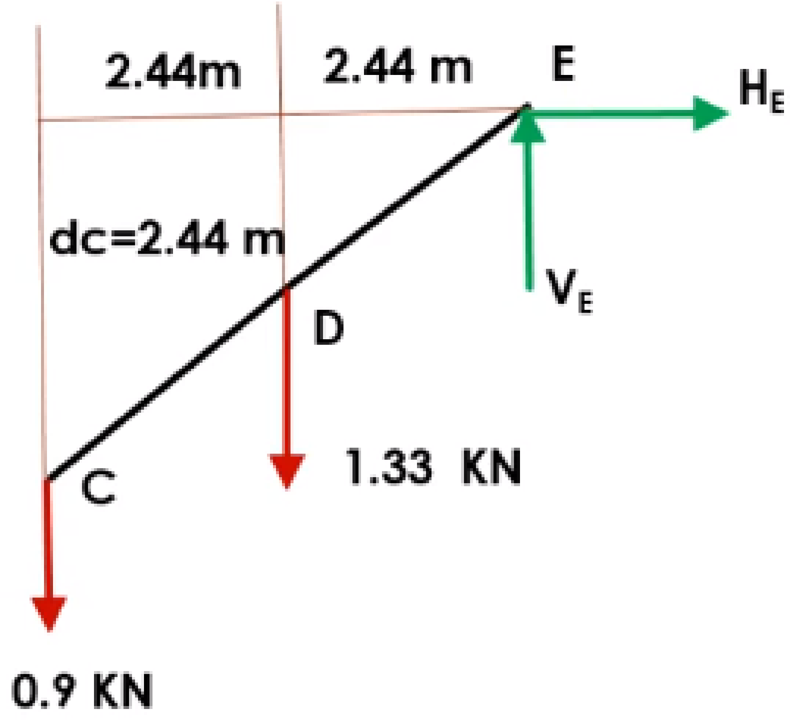
$$\therefore \quad H_E = 3.545\text{KN}, \quad V_E = 2.437\text{KN}$$

$$\text{and } H_A = 3.545\text{KN}, \quad V_A = 1.123\text{KN}$$

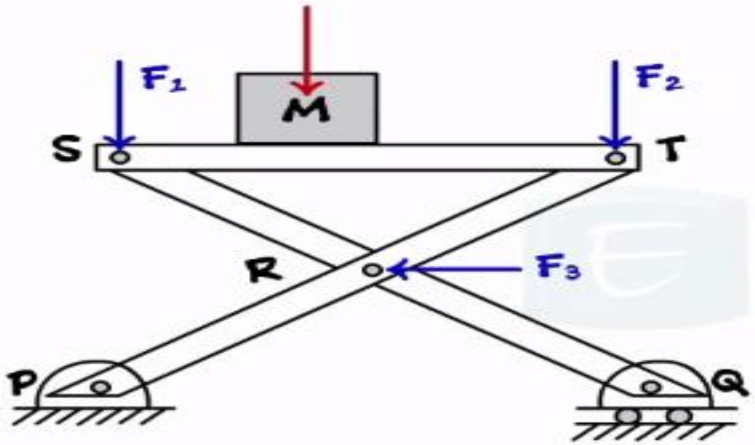
$$\therefore R_A = \sqrt{H_A^2 + V_A^2} = 3.71\text{KN}$$

$$R_E = \sqrt{H_E^2 + V_E^2} = 4.30\text{KN}$$

$$\text{Maximum tension in cable} = R_E = 9.43\text{KN}$$



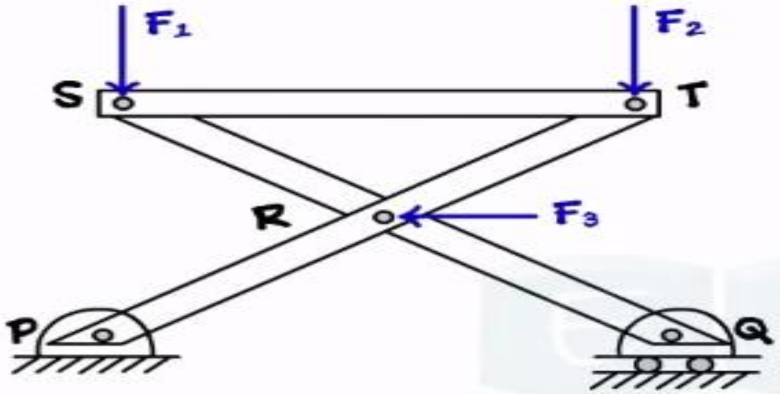
Introduction to Pin-jointed Frames



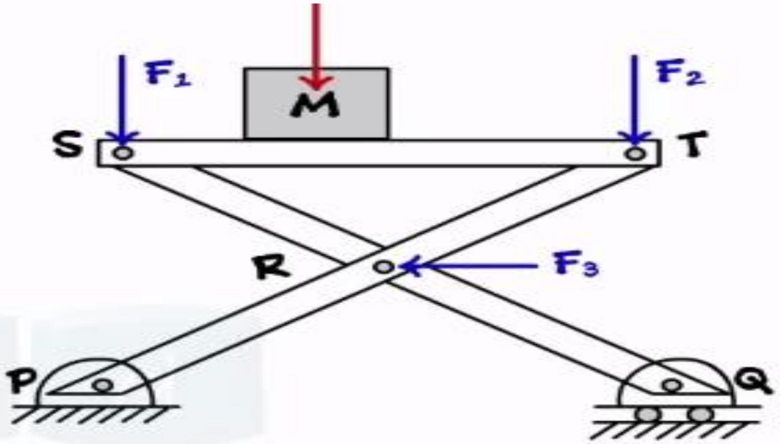
Pin - Jointed Frame

Members / Bars of Frames

- Bending
- Tension / Compression

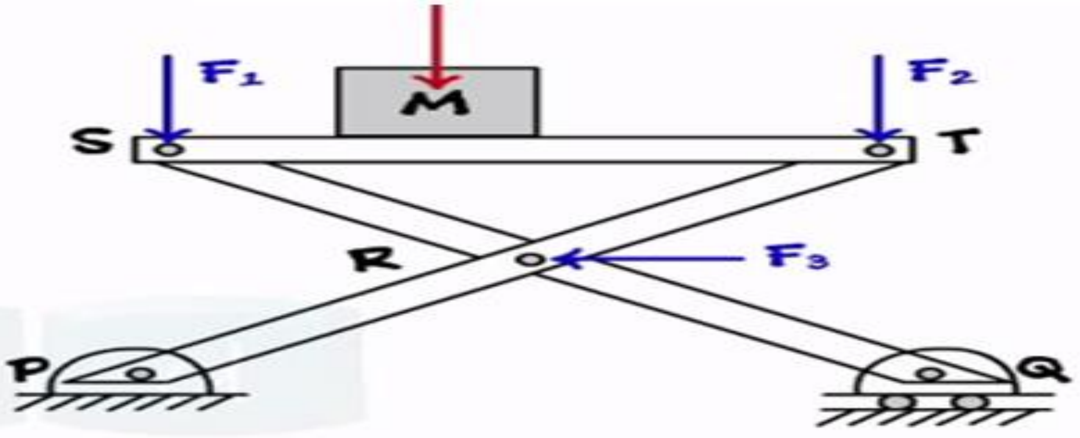


Truss



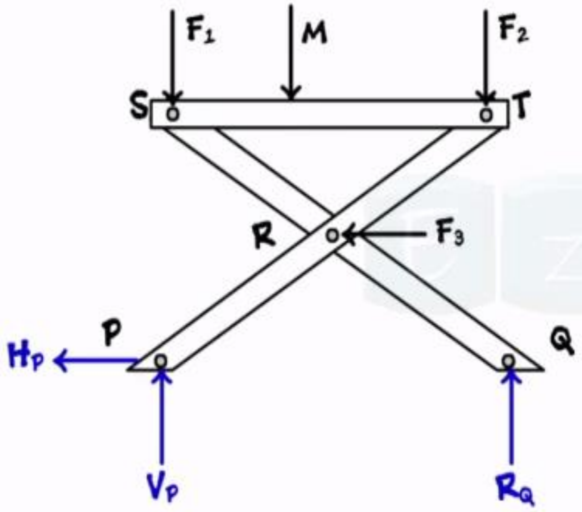
Pin - Jointed Frame

Analysis Of Pin-Jointed Frames



Pin – Jointed Frame

Step 1



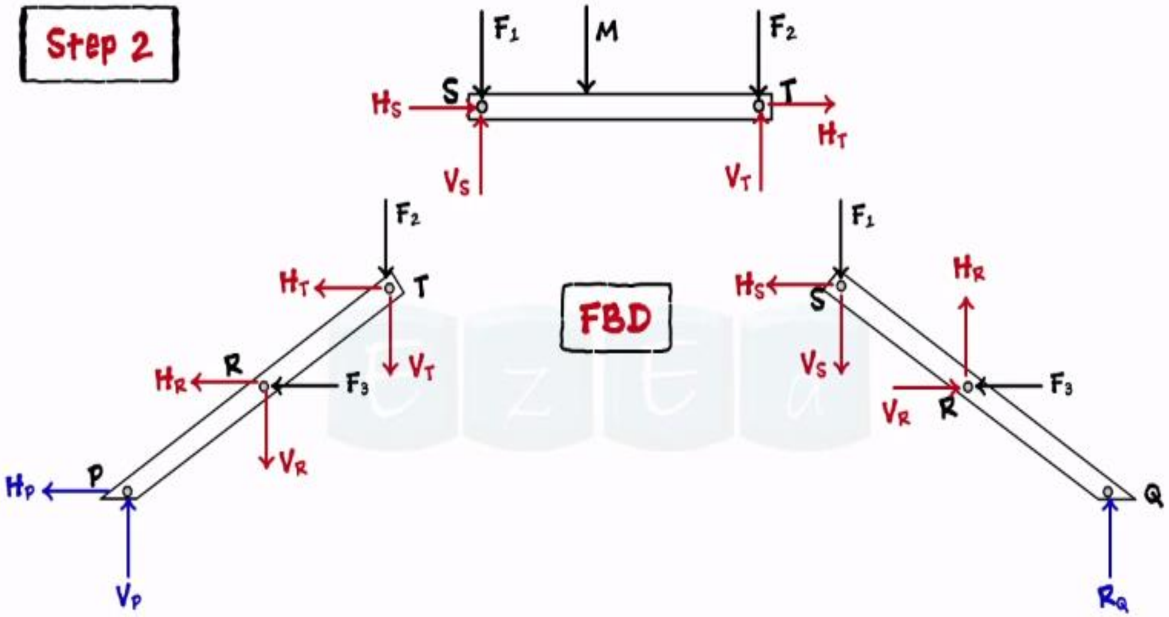
Apply COE

$\Sigma F_x = 0 \ldots . \rightarrow + ve$

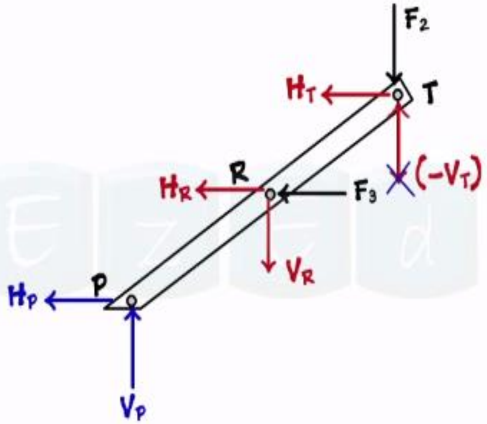
$\Sigma F_y = 0 \ldots . \uparrow + ve$

$\Sigma M = 0 \ldots . \circlearrowleft + ve$

Step 2



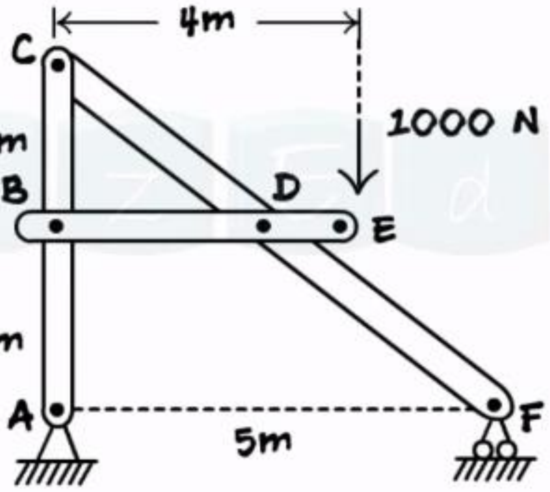
Step 3

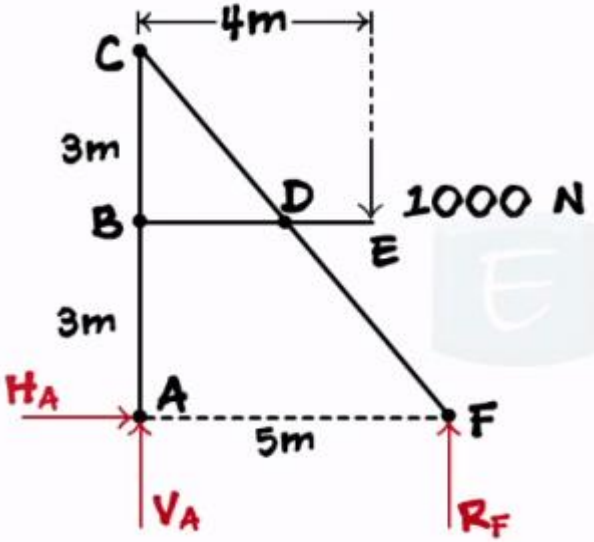


NOTE: If any value of a pin reaction is found to be negative, it implies that the assumption was incorrect and the assumed direction of that reaction must be reversed.

Problem

Q. Consider the frame shown alongside. Compute reactions at pin connected joints B, C and D.





Support reactions

Apply COE to the Entire Frame

$\Sigma F_x = 0 \ (\rightarrow +ve)$

$\boxed{H_A = 0}$

$\Sigma M_A = 0 \ldots \circlearrowleft +ve$

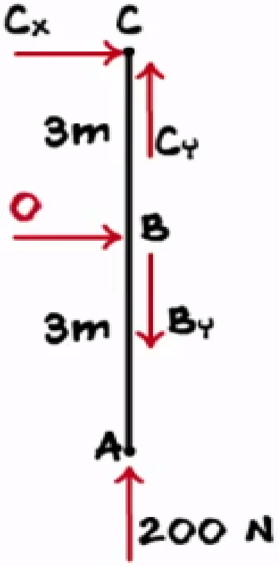
$R_F(5) - 1000(4) = 0$

$\boxed{R_F = 800 \text{ N } (\uparrow)}$

$\Sigma F_y = 0 \ (\uparrow +ve)$

$V_A + R_F - 1000 = 0$

$\boxed{V_A = 200 \text{ N } (\uparrow)}$



Consider FBD of member CBA

Applying COE

$\Sigma M_C = 0 \ldots \circlearrowleft +ve$

$B_x(3) = 0$

$\boxed{B_x = 0}$

$\Sigma F_x = 0 \ldots \rightarrow +ve$

$C_x + B_x = 0$

$\boxed{C_x = 0}$

$\Sigma F_y = 0 \ldots \uparrow +ve$

$C_y - B_y + 200 = 0$

$\boxed{C_y - B_y = -200 \ldots(1)}$

$$\boxed{C_y - B_y = -200 \quad \ldots(1)}$$

Consider FBD of member BDE

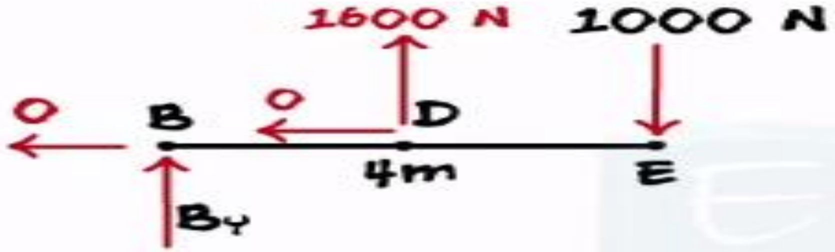
Applying COE

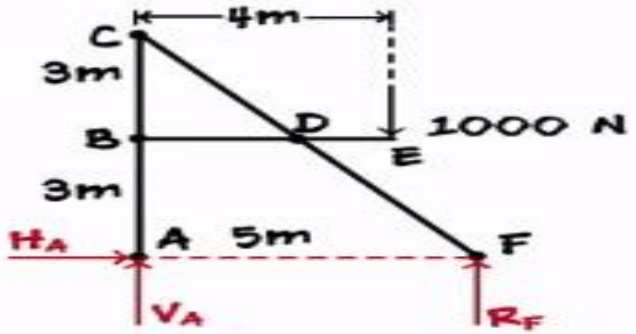
$$\Sigma M_B = 0 \ldots \circlearrowleft +ve$$

$$D_y(2.5) - 1000(4) = 0$$

$$\left\{ \frac{CA}{CB} = \frac{AF}{BD} \quad \therefore \frac{6}{3} = \frac{5}{BD} \quad \therefore BD = 2.5\ m \right\}$$

$$\boxed{D_y = 1600\ N\ (\uparrow)}$$





$$\boxed{C_y - B_y = -200 \quad \ldots(1)}$$

Consider FBD of member BDE

Applying COE

$$\Sigma F_y = 0 \quad (\uparrow +ve)$$

$$D_y + B_y - 1000 = 0$$

$$1600 + B_y = 1000$$

$$B_y = -600\ N$$

$$\boxed{B_y = 600\ N\ (\downarrow)}$$

$$\boxed{C_y - B_y = -200 \quad \ldots(1)}$$

$$C_y - (-600) = -200$$

$$C_y = -800\ N$$

$$\boxed{C_y = 800\ N\ (\downarrow)}$$