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STRUCTURE ANALYSIS

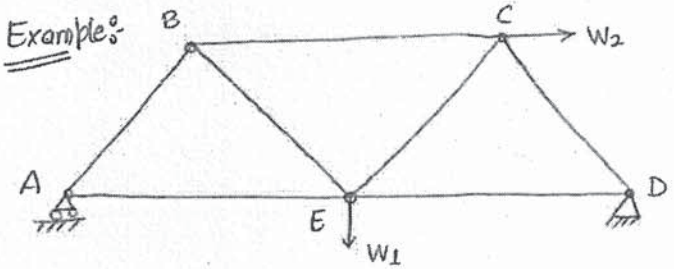
02/Aug/25

I Topic :- Analysis of statically determinate trusses → MOJ / MOS

Concept :- 1] TRUSS :- It is a structure in which all members are subjected to axial forces only. (Tension and comp.).

Bending moment is zero every where in the truss.

Example :-

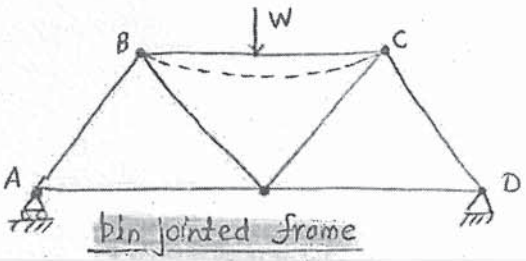


Truss [In a truss all members are called links).

* Link - means a straight member connected at ends by pins. (smooth pins). and not loaded at any intermideate location.

Concept :-

2] FRAME :- It is a structure in which members are subjected to BM also [In addition to T and C].

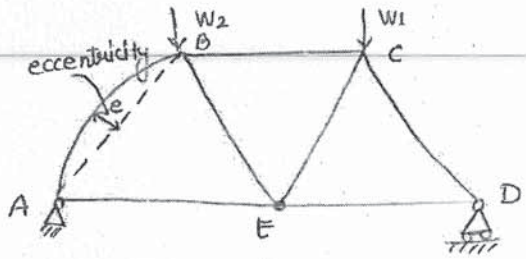


pin jointed frame

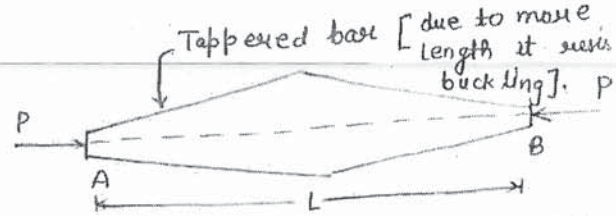
Frame { Bcz link BC is loaded at intermidiate location so it bends.].

Concept 3 :- Assumptions in the analysis of trusses :-

i] All members must be straight and connected by smooth pins at the ends. [If they are curved bending moments are developed]. and structure can't be called as a truss.]



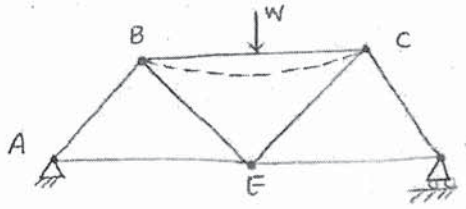
Not a truss {curved member AB bends}



- members must be straight. But, need not always be prismatic {Having same c/s throughout its length}.

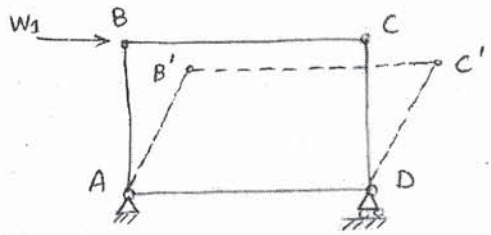
- Buckling means: It is a permanent deformation due to excessive Bending of member. After removal of load member not regain its orignal position.

ii] loads must be applied only at the joints [otherwise, if the loads are applied at intermidiate locations of the members then they will bend and structure can't be called as a truss.]

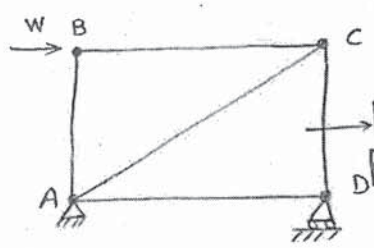


- Not a truss (members BC bends)
- for its analysis method of VW is used. not by MOJ and MOS.

Concept 4:- Mechanism (means Unstable structure).



4 link mechanism
(Unstable structure)



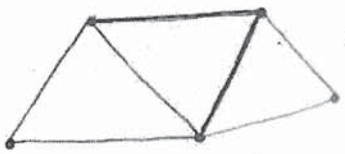
Stable structure

[Basic truss is triangle.]
[It's necessary the triangle are bound to be formed for stablity.]

Note:- Without developing any stress, if structure translates or rotates, then it is called mechanism or unstable structure.

Concept 05:- In a truss, the total no. of members (m) and the total no. of joints (j) are related by $\boxed{m = 2j - 3}$

Ex:-



- for the first 3 joints, 3 members are required. for each additional joint, 2 members are required combining these two statements, we get $\boxed{m = 2j - 3}$

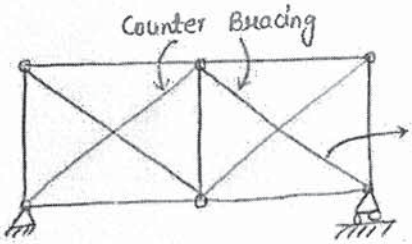
Note :- If the above condition is satisfied, then we get stable, triangulated simple determinate truss.

Concept6 :- If $m = 2j - 3$ ⇒ Perfect stable truss.

If $m =< 2j - 3$ ⇒ unstable or deficient truss.

If $m > 2j - 3$ ⇒ Redundant truss. (we provide more than $(2j-3)$ members to make the truss more stable. These additional members are called counter bracings (or counter diagonals).

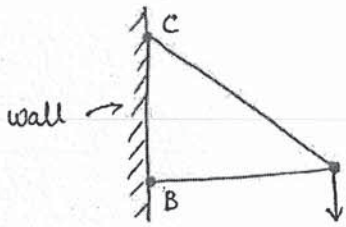
Ex :-



इस member की length अगर ज्यादा हो जायेगी और अगर ये comp. में आ गया तो ज्यादा length होने की वजह से Buckle कर जायेगा इस Buckling को avoid करने के लिये counter Bracings दे देंगे।

Problems :-

1] For the structure shown in fig. BM exist in the member.



A] AB only

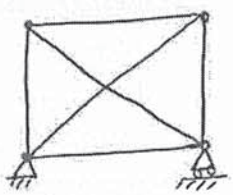
B] AC only

C] Both AB & AC

D] No member.

Note :- All members are straight, connected by pins at the ends and not loaded at intermediate locations, they behave like links. So, no member bends.

2] The truss shown in fig



$m = 6$

$J = 4$

$m \quad (2j - 3)$

$6 > 5$ Redundant.

(There is one counter bracing member)

• जो member $(2j-3)$ से ज्यादा होंगे वही counter bracings होंगे

Analysis of Trusses :-

- Method of joints. (take equilibrium of a joint) — ↑ special case of FBD.
- Method of section. (take equilibrium of a section).

A] Method of Joint :-

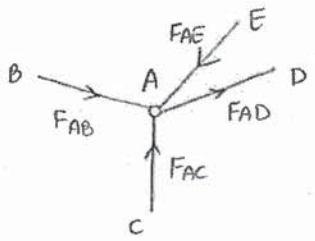
Concept I :- Equilibrium of a joint is considered in the MOJ.

Procedure :- Step a] ⇉ Find the support reactions by considering equilibrium of entire truss.

Step b] Consider equilibrium of a joint where only **two unknown forces are available** and use $\Sigma x = 0$ and $\Sigma y = 0$ to find them. similiarly proceed to the other joints also.

- Colinear – same line of action.
- Copalanar = lying in the same plane.
- Concurrent = Meeting at one point.

Ex :-



$\Sigma x = 0$ ✓

$\Sigma Y = 0$ ✓

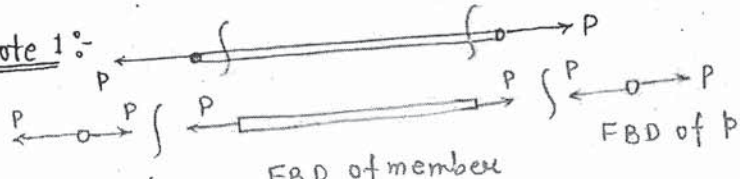
$\Sigma M_A = 0+0+0 = 0$ ✗ it is of No use ✗

Coplanar and concurrent force system

No. of equilibrium eqns only 2 → $\Sigma F_x = 0$, $\Sigma F_y = 0$

In a copalanar and concurrent force system, the no. of equations of equilibrium available are only two with two eqns of equilibrium, we can only find two unknown forces. so, we must select a joint where only two unknown forces are available.

Note 1 :-

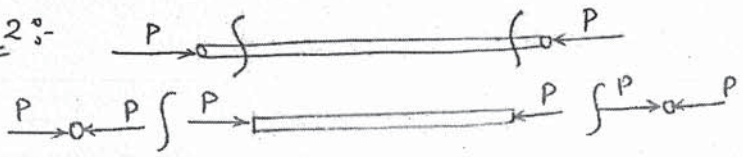


FBD of member

FBD of pin or bolt or joint.

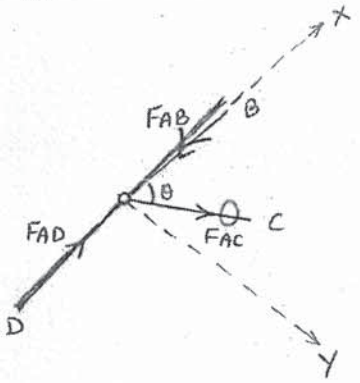
Conclusion :- If arrow marks is away from the pin, then, it means force in member is tensile.

Note 2:-



Conclusion:- It arrow mark is towards the pin, then, it means that force in the member is compressive.

Note 3:-



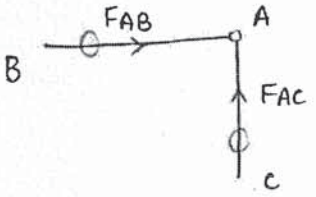
$\Sigma F_y = 0$, $F_{AC} \sin\theta = 0$

$\sin\theta \neq 0$

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

Conclusion:- At a joint, if 3 members or forces are meeting two members are collinear, then force in the third member is always zero.

Note 3:-

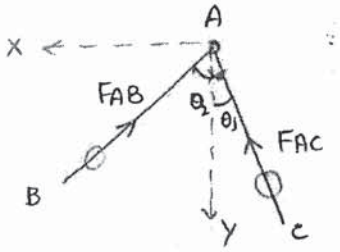


Two Non colinear members.

$\Sigma F_x = 0$, $\rightarrow + F_{AB} = 0$

$\Sigma F_y = 0$, $+\uparrow F_{AC} = 0$

$\boxed{F_{AB} = F_{AC} = 0}$



Two non colinear members.

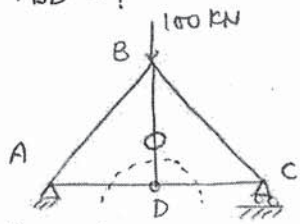
$\Sigma F_x = 0$, $+ F_{AB} \sin\theta_2 - F_{AC} \sin\theta_1 = 0$

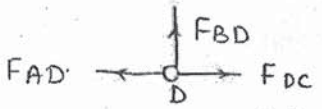
$\Sigma F_y = 0$, $+ F_{AB} \cos\theta_2 + F_{AC} \cos\theta_1 = 0$

$\boxed{F_{AB} = F_{AC} = 0}$

Conclusion:- At a joint, if two non collinear members are meeting with no external load at that joint, then, forces in both members will be zero.

Problem :- i] $F_{BD} = ?$





FBD of pin or bolt D.

- BD not take any force bcz No other force from D.

$\Sigma F_y = 0, \quad F_{BD} = 0$

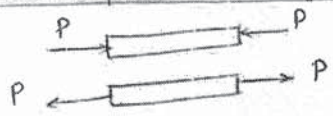
$\Sigma F_x = 0, \quad +F_{DC} - F_{AD} = 0$

$\boxed{F_{DC} = F_{AD}}$

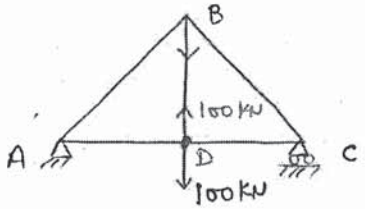
- For a member to bend – require 2 forces.

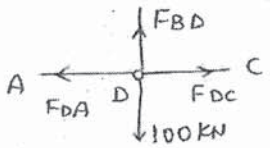
- For a member to twist – 2 forces are required.

- For a member to be in tension and comp. → 2 forces are required

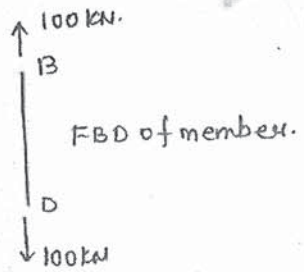


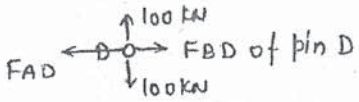
Problem :- 2] $F_{BD} = ?$

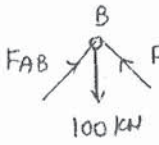




$\boxed{F_{BD} = 100 \text{ KN}}$



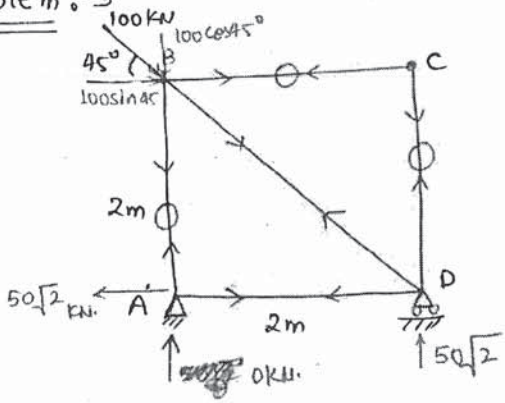




FBD of pin B.

$F_{BC} = 0$

Problem :- 3



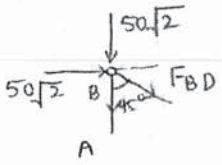
$\boxed{F_{BC} = 0}$ $\boxed{F_{CD} = 0}$

$R_A + R_D = 50\sqrt{2}$

$+\circlearrowleft \Sigma M_A = 0$

$R_D \times 2 - 50\sqrt{2} \times 2 = 0$

$R_D = 50\sqrt{2}$ KN.



$\Sigma F_x = 0, \quad 50\sqrt{2} + F_{BD} \cos 45° = 0$ $\boxed{F_{BD} = -100 \text{ KN}}$

$\Sigma F_y = 0, \quad -50\sqrt{2} - F_{BA} - F_{BD} \sin 45° = 0$

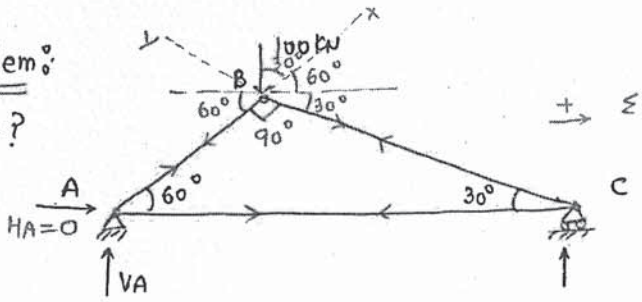
$\boxed{F_{BA} = 0}$

Short trick :-

$\Sigma M_D = 0, \ \Sigma F_x = 0$ $\quad 100 \times 0 + 50\sqrt{2} \times 0 + V_A \times 2 = 0$

Problem:-

$F_{AC} = ?$

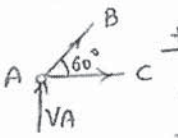


Solu:- at joint B :-

$\xrightarrow{+} \Sigma F_x = 0, \quad -F_{BA} - 100\cos 30^\circ = 0$

$\boxed{F_{AB} = -86.60 \text{ kN}}$

At joint A :-



$\xrightarrow{+} \Sigma F_x = 0,$

$+F_{AC} + F_{AB}\cos 60^\circ = 0$

$\boxed{F_{AC} = +43.3 \text{ kN}}$

Problem:-

(II) Method of Section :-

Concept 1 :- Equilibrium of a sections of truss is considered in method of section.

2] The advantage of method of sections is that, force in any Intermediate member can be found directly without finding forces in any other members.

Procedure :- Step I :- Find support reactions by considering equilibrium of entire truss.

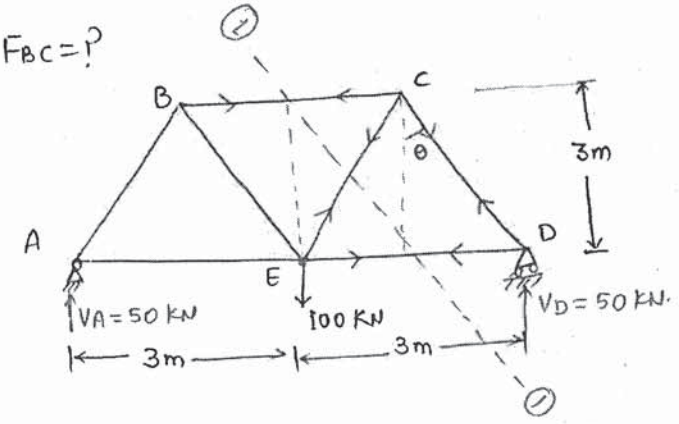
Step II - Cut the member under consideration by a section ①-① and consider equilbrium of either LHS of ①-①. or RHS of ①-① and use $\Sigma x = 0$, $\Sigma y = 0$, & $\Sigma M = 0$ to find the unknown member forces.

Note I]:- Cut the member such that entire truss is divided into two seperate parts.

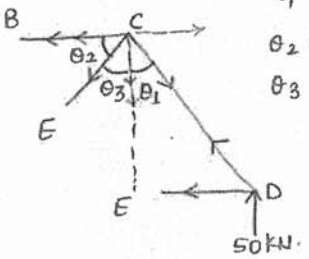
2] Preferably, don't cut more than three members. (bcz, in mos, we have only 3 eqns of equilibrium.) $\Sigma x = 0$, $\Sigma y = 0$, & $\Sigma M = 0$ with 3 eqns we can only find three forces.

3] cut the members such that all the cut members do not meet at one point. [Reason – bcz, if they meet at one point, then $\Sigma M = 0$, becomes useless eqn and it becomes a method of joints problem.

Problem $F_{BC} = ?$



$V_A = V_D = 50$ KN.



$\theta_1 = 26.56°$

$\theta_2 = 63.43°$

$\theta_3 = 26.56°$

$\pm \Sigma F_x = 0$,

$-F_{BC} - F_{CE}\cos\theta_2 - F_{DE} = 0$

$F_{BC} = -F_{CE} \times (63.43°)\cos - F_{DE}$

$F_{BC} = -50$ KN.

$+\uparrow \Sigma F_y = 0$,

$-F_{CE}\sin\theta_2 + 50 = 0$

$F_{CE} = +55.9$ KN

$+\circlearrowleft \Sigma M_C = 0$,

$+50 \times 1.5 - F_{DE} \times 3 = 0$

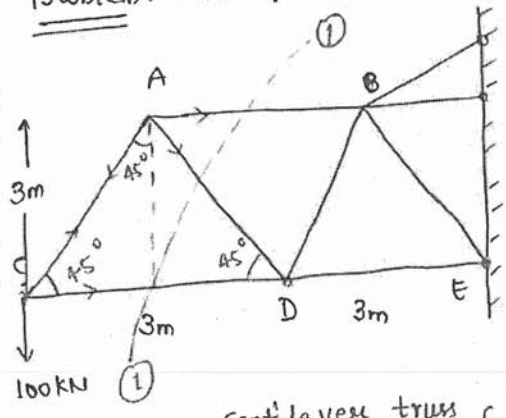
$F_{DE} = +25$ KN

Note :- $\Sigma M_C = 0$, It is a equilibrium eq not a BM equation.

It deals with external moments. (like acce. etc).

It deals with internal effects of moments. (like sagging, Hogging)

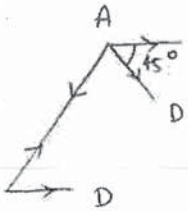
Problem: $F_{AB} = ?$



Cantilever truss

cut it by 1 – 1

LHS of 1 – 1 {so, keep arrow marks on LHS of 1 1 only.



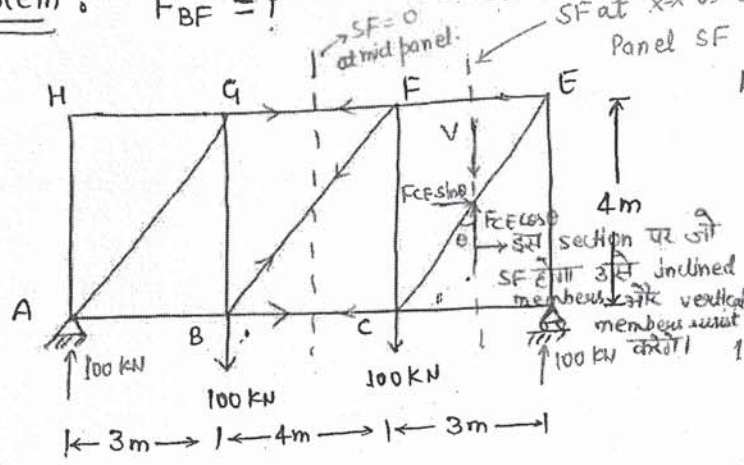
$+\circlearrowleft \Sigma M_D = 0$,

$-F_{AB} \times 3 + 100 \times 3 = 0$

$F_{AB} = 100$ KN

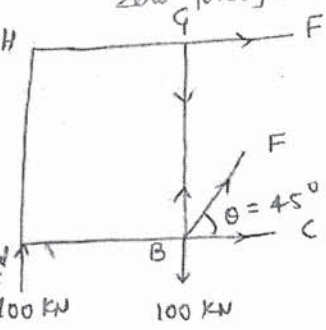
PANEL SHEAR CONCEPT FOR FINDING ZERO FORCE MEMBERS:-

Problem :- $F_{BF} = ?$



(If panel SF is zero that means inclined members have zero force.)

इस section पर जो SF होगा उसे inclined members और vertical members resist करेंगे।



$\pm \Sigma F_x = 0, \quad + F_{GF} + F_{BC} + F_{BF}\cos 45^\circ = 0$

$+\uparrow \Sigma F_y = 0, \quad +100 - 100 + F_{BF}\sin 45^\circ = 0$

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

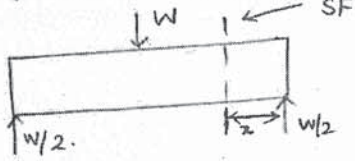
Short solution:

$+\uparrow \Sigma f_y = 0$

$+100 - 100 + F_{BF}\sin$

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

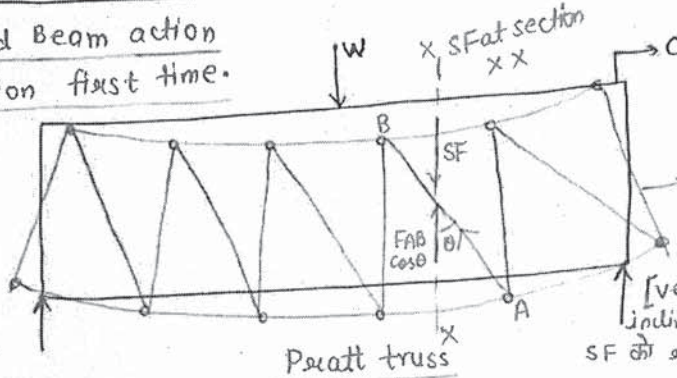
Note :- i] From SOM :-



Conclusion :- If panel SF is zero in any panel, then force in the inclined member in that panel is always zero.

Concept :- Beam action converted into truss action :-

Pratt converted Beam action into truss action first time.

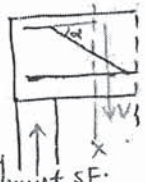


- Due to truss dead load is very less as compare to Beam (solid).

* all top members of Truss are in comp. due to BM but this Bending comp. converted to axial comp. bcz BM is zero bcz of pin
- same for tension side

- BM is resisted by top & bottom members as axial forces SF is resisted by vertical + diagonal members.
- Due to less dead load of truss we can increase the depth of truss इसकी वजह से z बढ़ जायेगा और Bending को easily resist करलेगा (with min^m deflection).

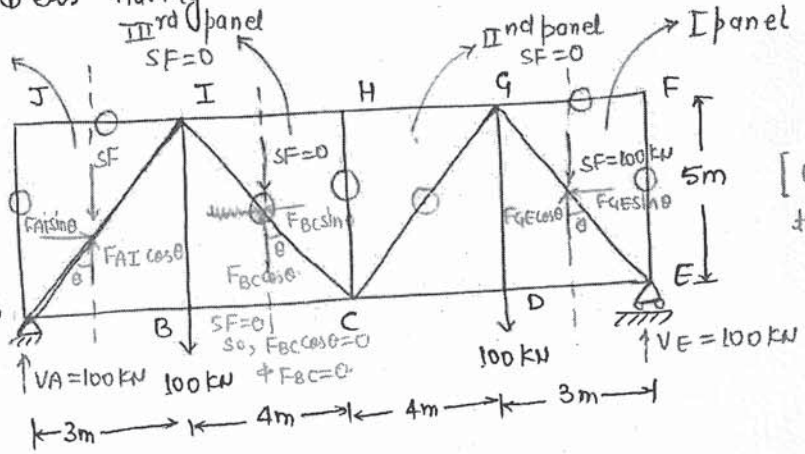
Concept:-



Bent up bars only resist maximum 50% SF of the section bcz its only vertical component resist SF.

- SF(V) resisted by vertical component of bent up bar tension force.
- Bent up bar is in tension so, $V_{us} = \sigma A_{sv} \sin\alpha$
- Bent up bar & vertical component of Tension force of Bent up bar resist SF at that section.

Problem (6) No. of members having zero force are?



[This SF is resisted by Vertical component of diagonal member] [$F_{AI}\cos\theta$ resist the panel SF]

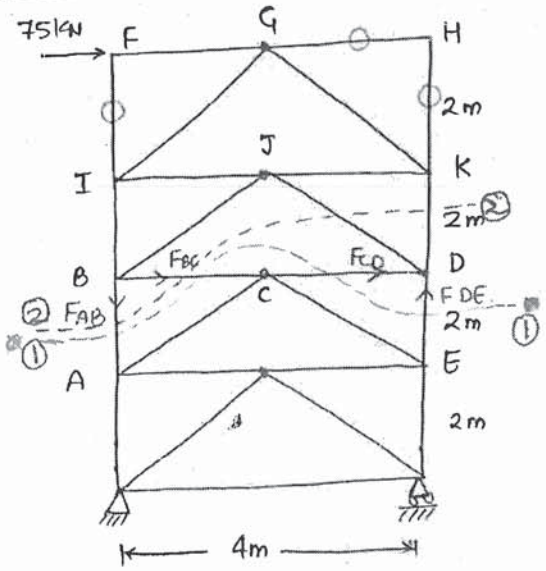
[$F_{GE}\cos\theta$ resist the panel S.F]

Total 7 members have zero forces.

[AJ, JI, CI, CH, CG, GF, EF]

$F_{CI} = 0$, $F_{CG} = 0$ } Because panel SF in the II panel & III panel are zero.

Problem 7:- F_{AB} = ? Type:- * when unwanted forces pass through common joint.



F_{AB} :- ?

cut it by (i) – (i)

Equilibrium of upper side of of (1) (1)

[so, Keep ~~dots~~ arrow marks on upper side of (1) (1) only].

$\Sigma M_D = 0$

$+75 \times 4 - F_{AB} \times 4 = 0$

$F_{AB} = 75$ kN Tension

Note:- we can also cut AB by (2)-(2) we get same result.

जब तीन से ज्यादा member cut रहे हो तो unwanted members का moment जिसके about zero हो रहा हो उसके about moment लेंगे। ex. at about D : F_{BC}, F_{CD} & F_{DE} तीनो का Moment zero है तो बचा F_{AB} को Find कर लेंगे।