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Structural Analysis

(1) Trusses : { Analysis of trusses, deflections in trusses, Force in redundant trusses, I.L.D's for Forces in truss members. }

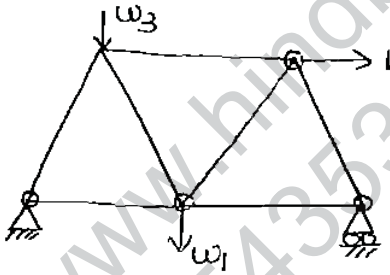
Analysis of trusses :-

Concept-1 :

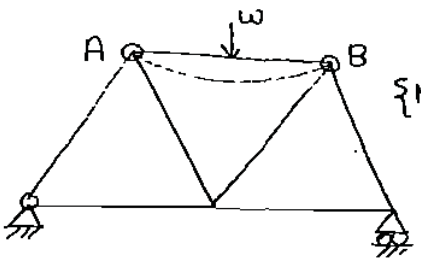
Assumptions in the analysis of trusses :-

(1) It is assumed that all the loads are applied only at the joints. (otherwise if the loads are applied at intermediate locations of the members. then they will bend and the str. can not be called as a truss. It is called a frame.)

(a)



(Truss)

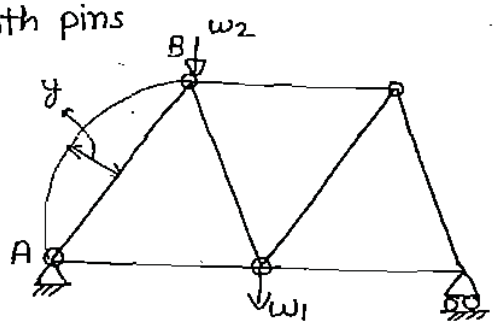


{Member AB bends}

Not a truss (frame)

(2) All the members assumed to be straight and connected by so smooth pins. (otherwise, if the members are curved, then B.M. developed in those members & the structure can not be called as truss.)

(b) Smooth pins



(Member AB Bend due to initial Radius of curvature)

(3) B.M due to self wt. of member is neglected.

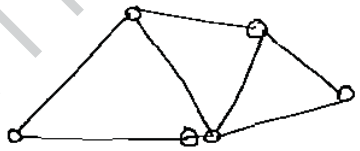
Concept-2

In a truss, total no. of members (m) & the total no. of joints (j) are related by

$$\boxed{m = 2j - 3}$$ {if this cond^n is satisfied, then we get stable triangulated truss}.

Ex. For Ist 3 joints

→ 3 members



For each additional joint ⇒ 2 members

So, $\boxed{m = 2j - 3}$

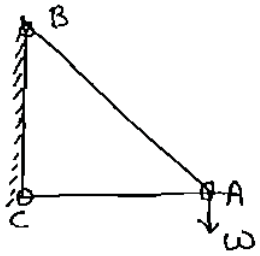
Note: (1) If $m = 2j - 3$ ⟶ Perfect, stable truss.

$m < (2j - 3)$ → Unstable (or) deficient truss.

$m > (2j - 3)$ → Redundant (or) over rigid truss.

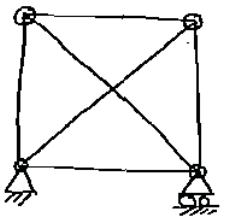
Ques: (1) For the truss shown in figure B.M. exists in the member —

(a) AB (b) AC (c) AB & AC both (d) No members.



Note : The assumptions in the analysis of trusses are made to ensure that the members are subjected to either tension or compression only. B.M is zero, everywhere in the truss.

Ques:(2) The truss shown in fig. is –



(A) Perfect

(B) Deficient

(C) Redundant

(D) None

$m = 2j - 3$

$m = 6$

$J = 4$

$6 > (2 \times 4 - 3)$ so, Redundant.

Concept-3

Analysis of trusses →
- (a) Method of Joints → It is a special case of method of Sect^n only.
- (b) Method of Sections

(a) Method of Joints :-

(i) Equilibrium of a joint is considered in method of joints

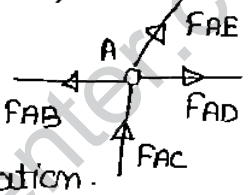
(ii) Procedure : Step-1 Find the support reactions, considering equilibrium of the entire truss.

Step-2

$\Sigma M = 0 \Rightarrow$ at joint $M = 0$

Consider equilibrium of a joint where only 2 unknown member forces are available & use $\Sigma x = 0$, $\Sigma y = 0$ to find them. Similarly, proceeded to the other joints (we have to select a joint where only two unknowns are available b/c we have only 2 equations of equilibrium at any joints)

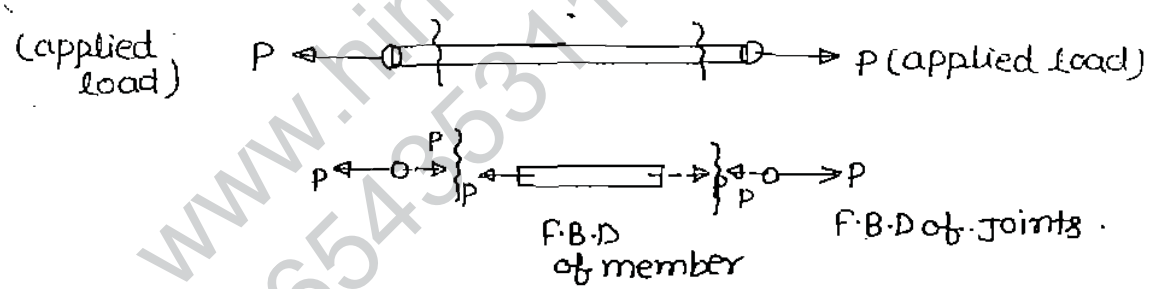
$\boxed{\Sigma A = 0 \Rightarrow 0 = 0}$



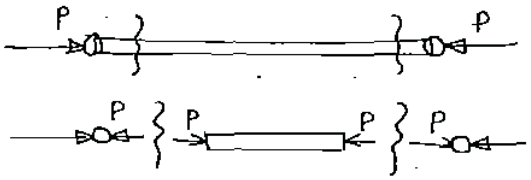
$\Sigma M = 0$ becomes useless equation.

Note:

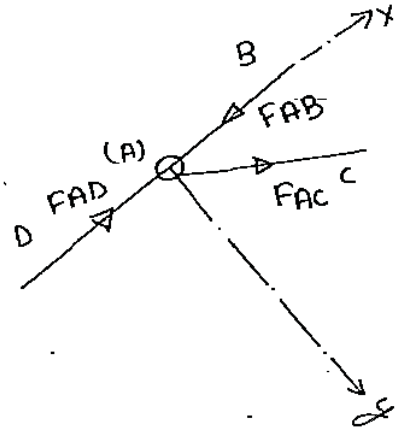
(1) If arrow mark is away from the joints, it means that force in the member is tensile.



(2) If arrow mark is towards the joints, it means that force in the member is compressive.



(3) At a joint if three members are meeting, two members are in line with each other (colinear), then force in the third member is always zero. (If there is no external load at that joint)



$\Sigma Y = 0 \Rightarrow F_{AC} \cdot \sin\theta = 0$ {Colinear}

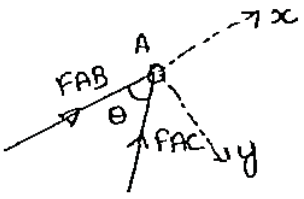
$\sin\theta \neq 0$

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

(4) If 2 non-colinear member forces on meeting at a joint & there is no external load at that joint, then forces in both members will be zero.

$\Sigma X = 0, \Rightarrow F_{AB} = 0$

$\Sigma Y = 0 \Rightarrow F_{AC} = 0$



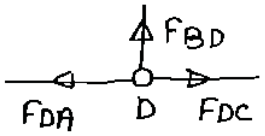
$\Sigma Y = 0 \Rightarrow F_{AC} \cdot \sin\theta = 0$

$\Rightarrow F_{AC} = 0$

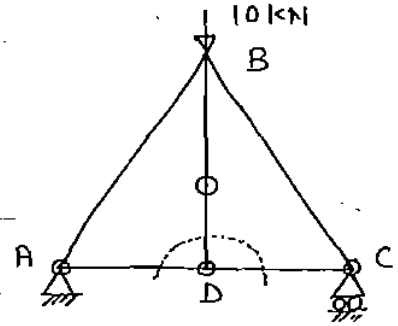
$\Sigma X = 0 \Rightarrow +F_{AB} = 0$

Ques: (1) For a truss shown in figure. Force in the memb. BD is

F·B·D of Joint D

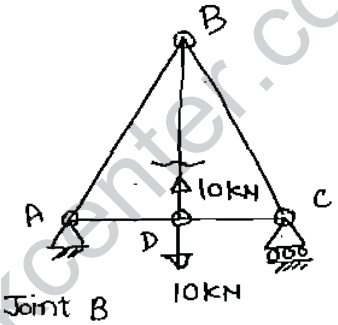


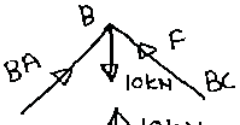
$\Sigma Y = 0 \Rightarrow F_{BD} = 0$



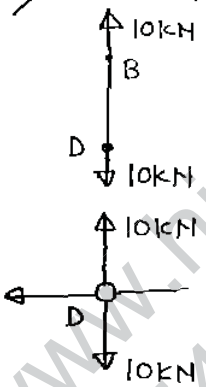
(2) Find $F_{BD} = ?$

$F_{BD} = 10KN(T)$





F·B·D of Joint B

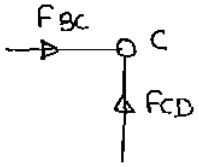


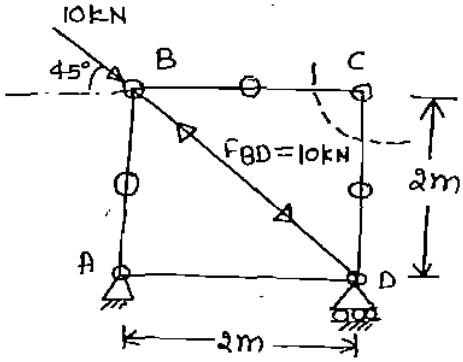
F·B·D of member BD

F·B·D of joint D

(3) $F_{BC} = ?$

F·B·D of Joint C





$\Sigma X = 0 \Rightarrow + F_{BC} = 0$

$\Sigma Y = 0 \Rightarrow F_{CD} = 0$

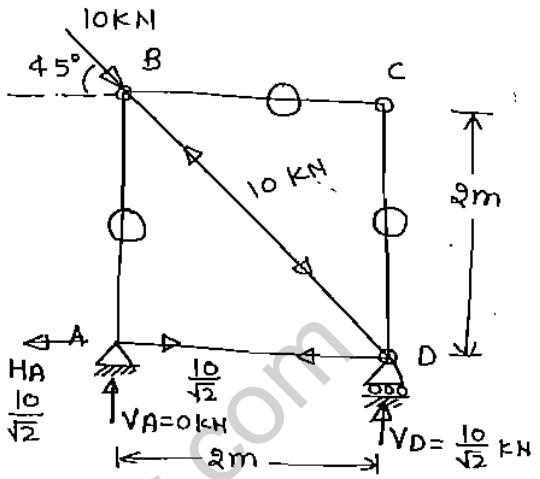
$F_{BC} = 0$

$F_{CD} = 0$

$F_{AB} = 0$

$F_{BB} = 10KN$ (comp.)

(4) The support reactions are



$\Sigma X = 0$

$[\overrightarrow{+ve}\ \overleftarrow{-ve}]$

$\Rightarrow -HA + 10\cos 45° = 0$

$\Rightarrow \boxed{HA = \frac{10}{\sqrt{2}}\ KN}$ —— ①

$\Sigma M_D = 0$

$[\underset{+ve}{\circlearrowright}\ \underset{-ve}{\circlearrowleft}]$

$\Rightarrow +VA \times 2 + 10 \times 0 = 0$

$\boxed{VA = 0\ KN}$

$\Sigma Y = 0$

$[\underset{+ve}{\uparrow}\ \underset{-ve}{\downarrow}]$

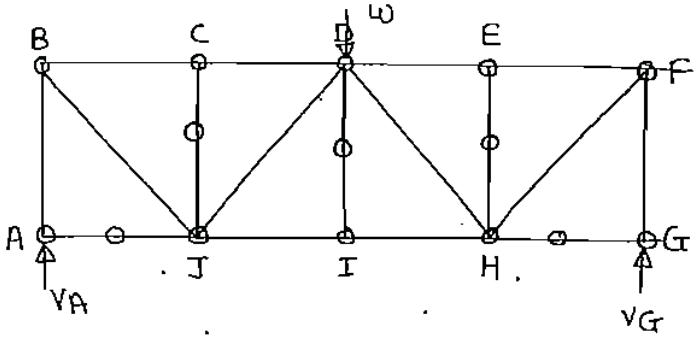
$\Rightarrow +VA + VD - 10\sin 45° = 0$

$\boxed{VD = \frac{10}{\sqrt{2}}\ KN}$

From F.B.D at A

$\boxed{F_{AD} = \frac{10}{\sqrt{2}}\ KN\ (T)}$

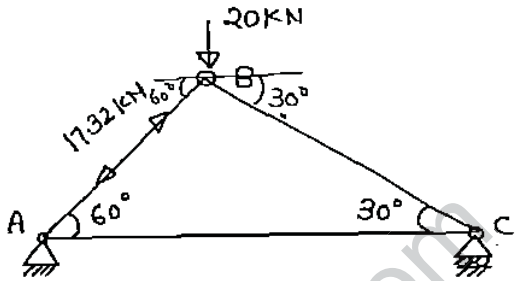
(5) For the truss shown in figure, the members having zero force are



$F_{AJ}, F_{CJ}, F_{DI}, F_{EH}, F_{GH} = 0$

(6) Find AC —

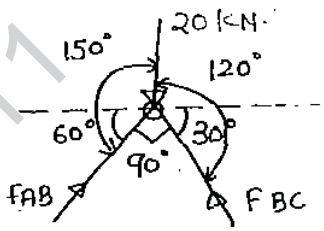
2 Marks.



Note :-

(1) Since the lengths of the members are not known, we can not find support reaction directly. So, 1st consider F.B.D of Joint B & Find the force F_{AB}. Then consider F.B.D of Joint A to find FAC.

F.B.D of Joint B



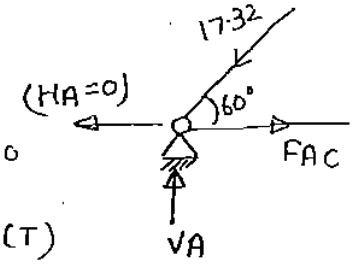
Use Sine Rule —

$$\frac{F_{AB}}{\sin 120^\circ} = \frac{F_{BC}}{\sin 150^\circ} = \frac{20}{\sin 90^\circ}$$

$\Rightarrow F_{AB} = 20 \cdot \sin 120^\circ$

$\Rightarrow \boxed{F_{AB} = 17.32\ KN}$ (comp.)

F.B.D of Joint A



$\Sigma X = 0 \Rightarrow -17.32 \cos 60^\circ + F_{AC} = 0$

$\left[\underset{+ve}{\rightarrow}\ \underset{-ve}{\leftarrow}\right] \Rightarrow F_{AC} = 8.66\ KN\ (T)$

Note :

If only 3 forces are meeting at a joint use sine Rule to find the unknowns quickly. In the above case at joint 'B', if we use $\Sigma X=0$ & $\Sigma Y=0$, we have to solve 2 simultaneous equation to find the F_{AB}. It will waste our time.

$$\Sigma X=0 \Rightarrow +F_{AB}\cdot\cos 60^\circ - F_{BC}\cdot\cos 30^\circ = 0 \quad -(1)$$

$$\Sigma Y=0 \Rightarrow +F_{AB}\cdot\sin 60 + F_{BC}\sin 30^\circ - 20 = 0 \quad -(2)$$

(b) Method of Sections :-

(i) Equilibrium of a section of a truss is considered in method of sections.

(ii) The advantage of Method of Sections is that force in any intermediate member can be found directly without finding forces in any other members.

(iii) Procedure :-

Step-1

Find the support reactions considering equilibrium of the entire truss.

Step-2

cut the member under consideration by a section ①-① and consider equilibrium of either L.H.S of ①-① or R.H.S of ①-① and use $\Sigma X=0$, $\Sigma Y=0$, $\Sigma M=0$, to find the unknown forces.

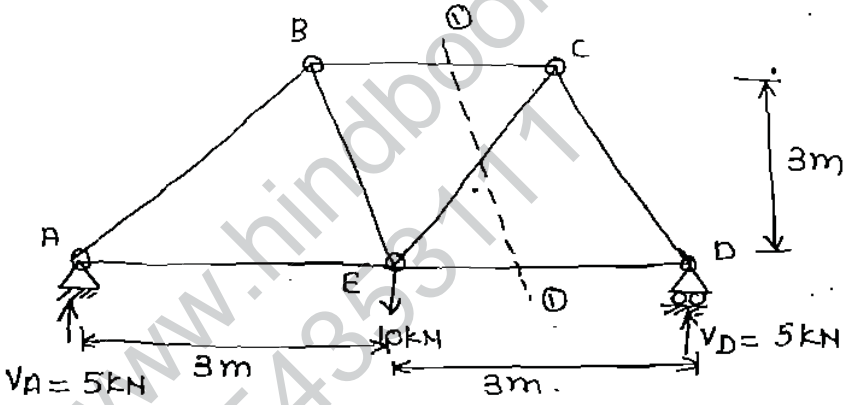
Note

(1) Cut the members such that entire truss is divided into 2 separate parts.

(2) Preferably, don't cut more than 3 members (b/c, in method of sections we have only 3 eq^{n}s. of equilibrium)

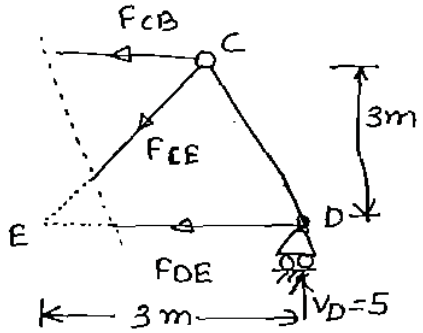
(3) Cut the members such that all the cut members do not meet at one joint. (If they meet at one joint, then $\Sigma M = 0$ becomes useless eq^n & it becomes a method of Joints Problem)

Ques: For the truss shown in fig. Force in the member BC is.



Cut BC by ①-①

Consider equilibrium of R.H.S of ①-①



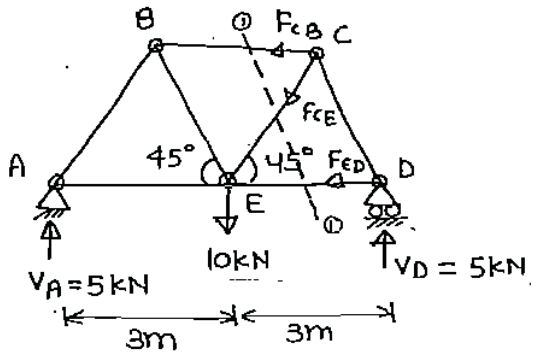
$\Sigma M_E = 0 \Rightarrow -F_{CB} \times 3 - 5 \times 3 = 0$

$\left[\begin{smallmatrix}\curvearrowright & \curvearrowleft \\ (+) & (-)\end{smallmatrix}\right]$ $\Rightarrow \boxed{F_{CB} = -5\ kN}$

{-ve sign implies that our assumed dir^n. for F_{BC} is wrong. So, arrow must be towards joint

So $F_{CB} = 5\ kN$ (compr^n)

Ques (2) Find F_{CE}.



Cut CE by ①-①

equil^m of R.H.S. of ①-①

{Then, keep arrow marks on R.H.S. of ①-① only}

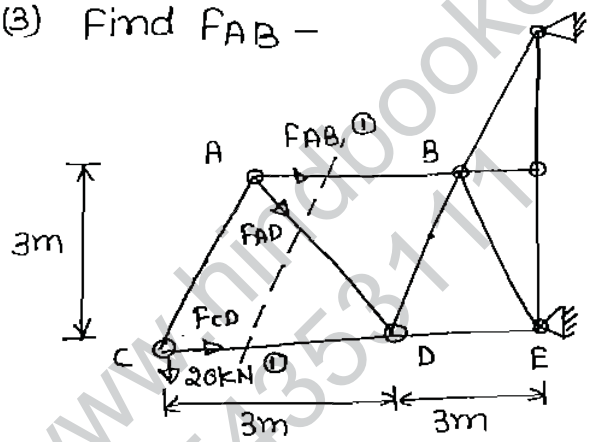
$\Sigma Y = 0$ $\Rightarrow +5 - F_{CE}\sin 45^\circ = 0$ {$\Sigma Y = 0$ is used b/c F_{CB}, F_{ED} are eliminated in the expression}

$[\uparrow +\ \downarrow -]$

$\Rightarrow F_{CE} = \frac{5}{\sin 45^\circ}$

$\Rightarrow \boxed{F_{CE} = 5\sqrt{2}\ kN\ (Tension)}$

Ques (3) Find F_{AB} –



Cut AB by ①-①

equil^m of L.H.S. of ①-① {So arrow are kept at L.H.S of ①-①}

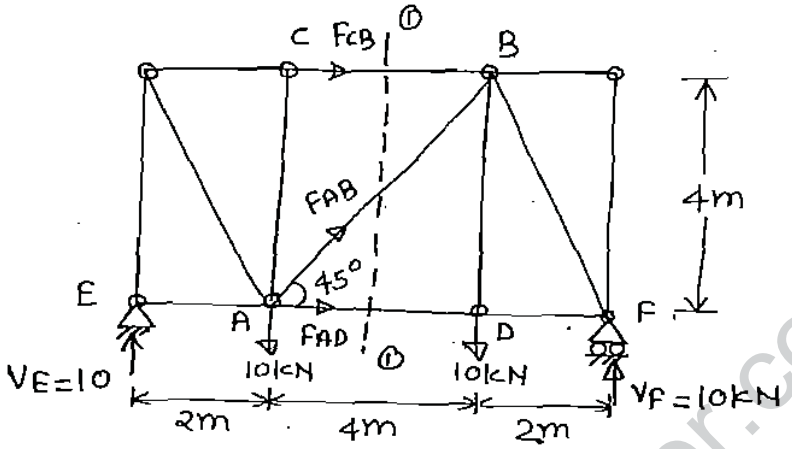
$\Sigma M_D = 0$

$[\circlearrowright +ve\ \ \circlearrowleft -ve]$

$\Rightarrow +F_{AB} \times 3 - 20 \times 3 = 0$

$\boxed{F_{AB} = 20\ kN\ (Tension)}$

Ques: 4 Find F_{AB}.



Always use method of sections to find force in intermediate member

Cut AB by ①-①

L.H.S of ①-①

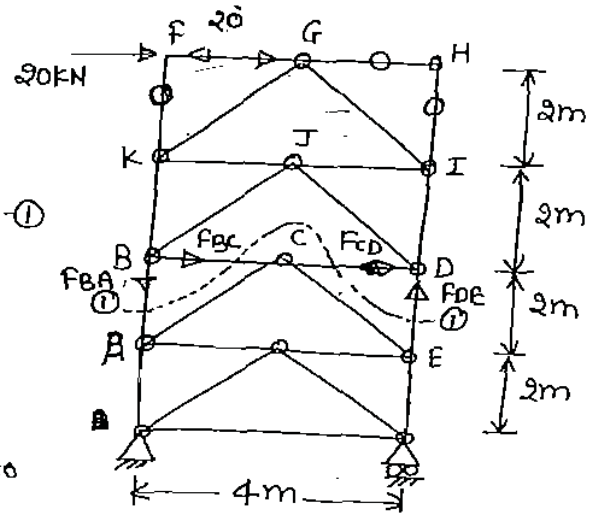
$\Sigma Y = 0$

$[\uparrow\downarrow\ (+)\ (-)]$ $\Rightarrow \underbrace{+10}_{E} \underbrace{-10}_{A} + F_{AB}\sin 45° = 0$

$\sin 45° \neq 0$

$F_{AB} = 0$ *

Ques: 5 Find F_{AB}.



Cut AB aby ①-①

Equilm of upper side of ①-①

(So, arrows are kept upper side of ①-①)

$\Sigma M_D = 0$

$[\circlearrowleft\ \circlearrowright\ (+)\ (-)]$ $\Rightarrow +20\times4 - F_{AB}\times4 = 0$

$F_{AB} = 20\,kN\,(T)$

F_{BC}, F_{CD}, F_{DE} produce zero Moment about O.

Note

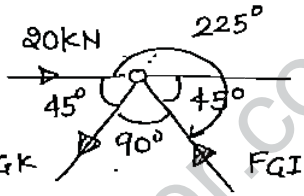
(1) $F_{GH} = F_{HI} = 0$

(2) $F_{FK} = 0$, $F_{FG} = 20\,kN$ (comp.)

(3) $F_{GK} = ?$, $F_{GI} = ?$

F.B.D of Joint 'G'

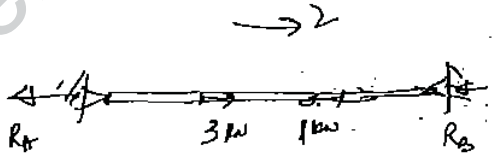
$$\frac{F_{GK}}{\sin 225^\circ} = \frac{F_{GI}}{\sin 45^\circ} = \frac{20}{\sin 90^\circ}$$



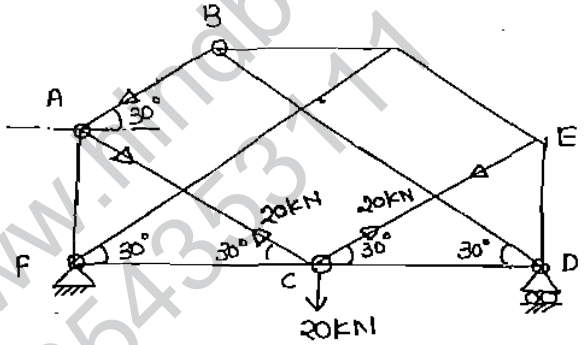
(Ignore (-ve sign) already considered)

$F_{GK} = 20 \cdot \sin 225^\circ = 14.14\,kN$ (Tension).

$F_{GI} = 20 \cdot \sin 45^\circ = 14.14\,kN$ (compⁿ).



Ques (6) Find AB



Notes

(1) Since all the joints have a minᵐ of three members, method of joints can not be used directly.

(2) Method of sections also can not be used directly b/c the minᵐ of 4 members ge are getting cut & unwanted members are not meeting at one joints.