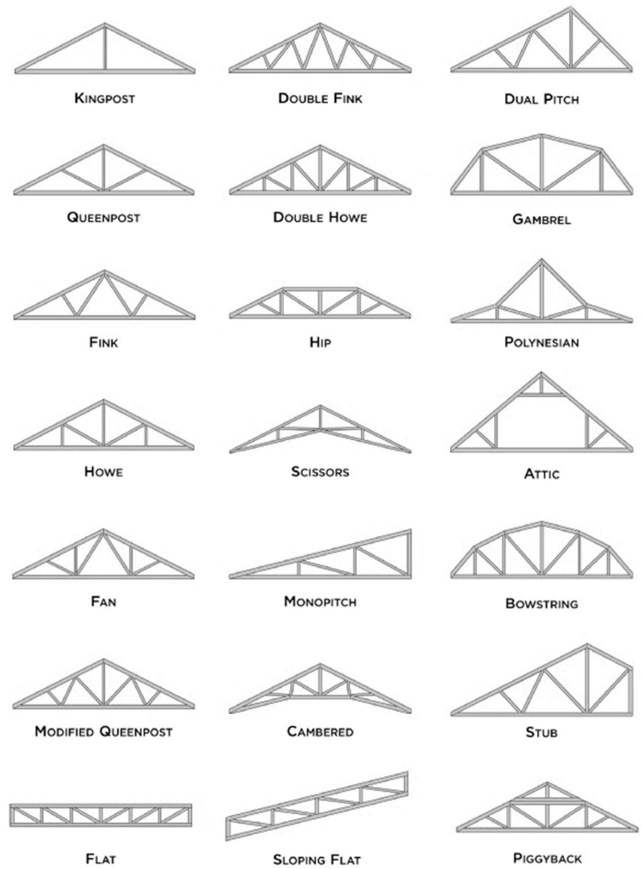
Architecture 314

Structures I

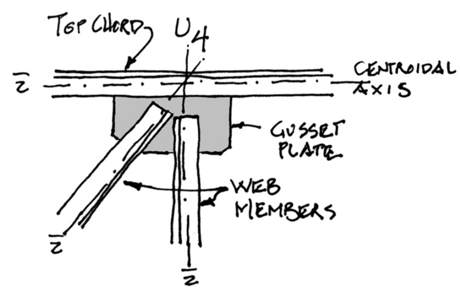
Trusses by Sections

Analysis by sections

Examples



Definitions and Assumtions of Truss Systems



2 Force Members

Pinned Joints

Concurrent Member Centroids at Joints

Joint Loaded

Straight Members

Small Deflections

Bullring Covering, Xàtiva, Spain
Kawaguchi and Engineers, 2007

Qualitative T or C

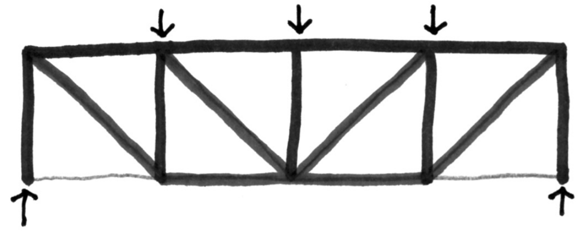
For typical gravity loading:
(tension=red compression=blue)

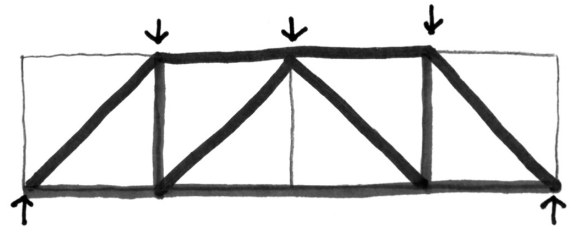
Top chords are in compression

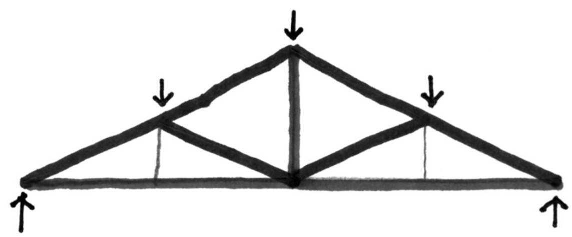
Bottom chords are in tension

Diagonals down toward center are in tension (usually)

Diagonals up toward center are in compression (usually)





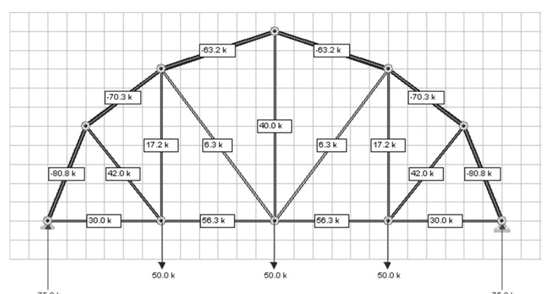


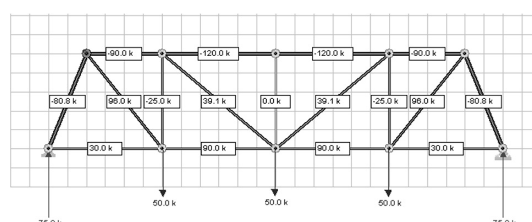
Qualitative Force

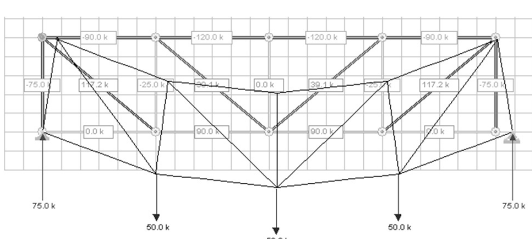
For spanning trusses with uniform loading: (tension=blue compression=red)

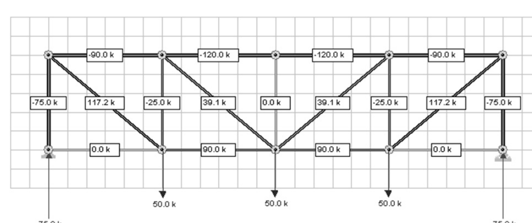
Top and bottom chords greatest at center when flat (at maximum curvature or moment)

Diagonals greatest at ends (near reactions, i.e. greatest shear)









Truss Analysis

Method of Joints

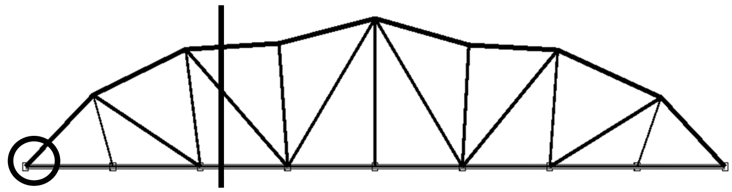
Method of Sections

Graphic Methods

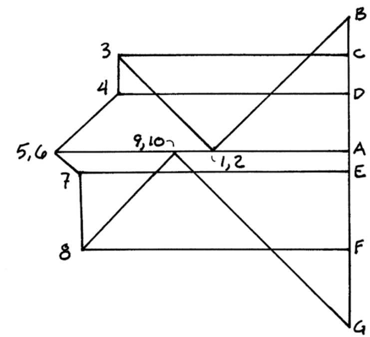
- James Clerk Maxwell 1869
- M. Williot 1877
- Otto Mohr 1887
- Heinrich Müller-Breslau 1904
- William Baker, SOM

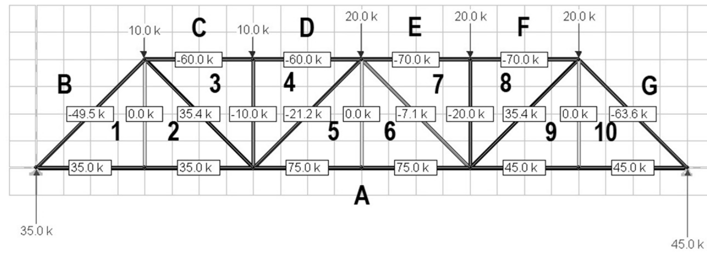
Computer Programs

- Dr. Frame (2D)
- STAAD Pro (2D or 3D)
- West Point Bridge Designer

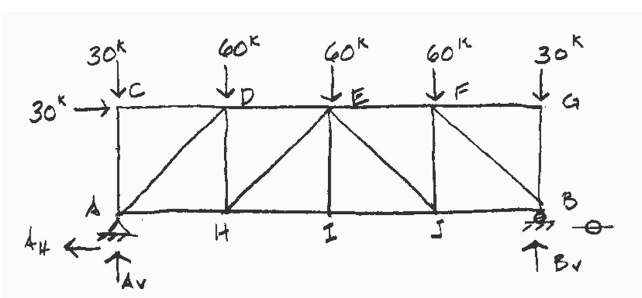


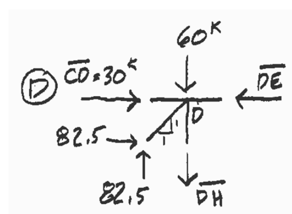
James Clerk Maxwell

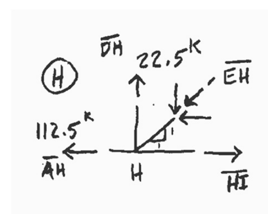


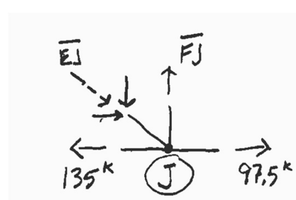


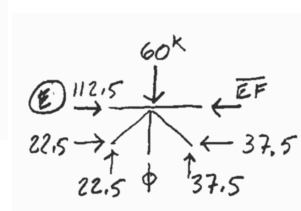
Method of Joints – procedure

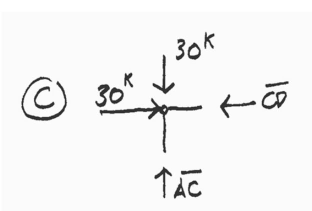


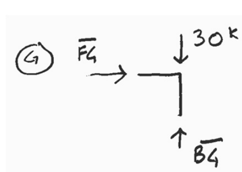


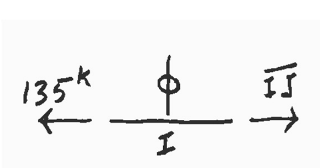


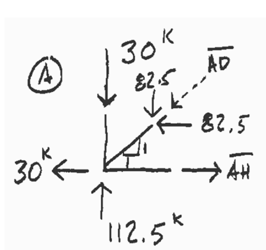


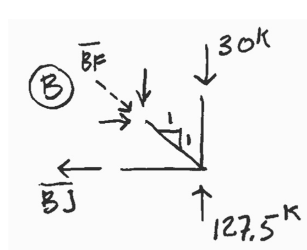




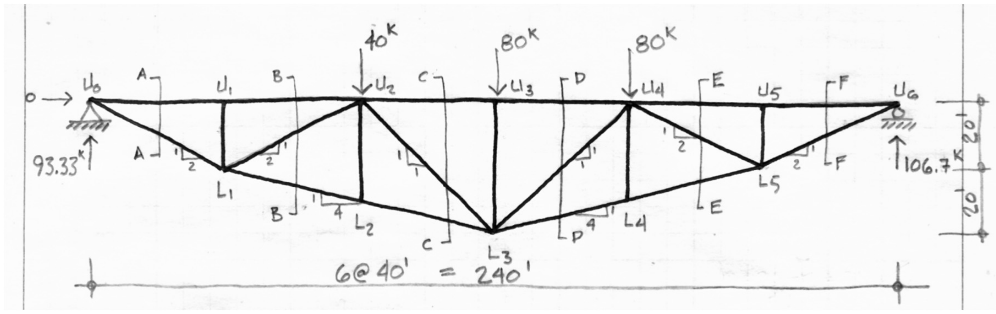




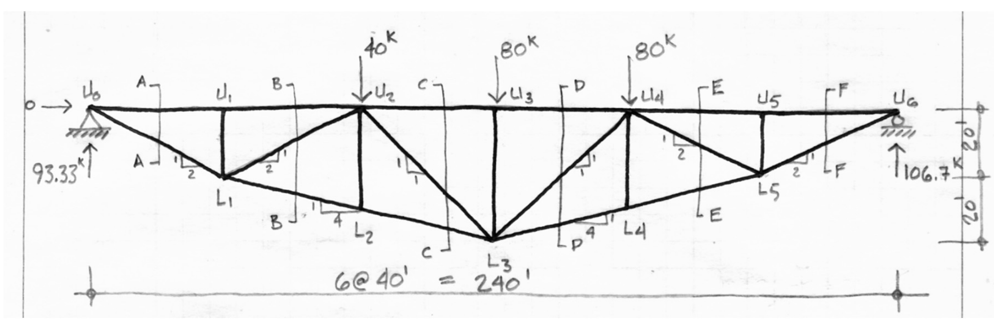




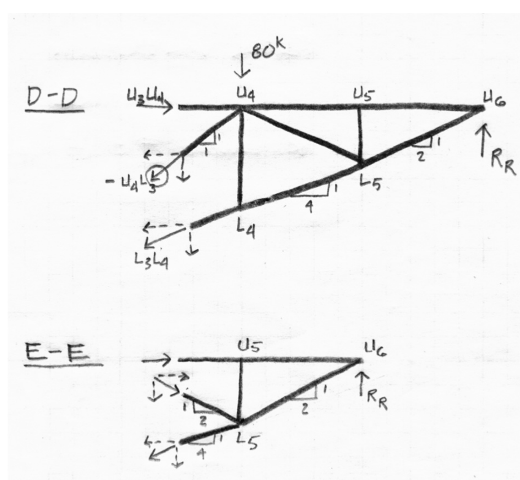
Method of Sections - procedure



Method of Sections - procedure



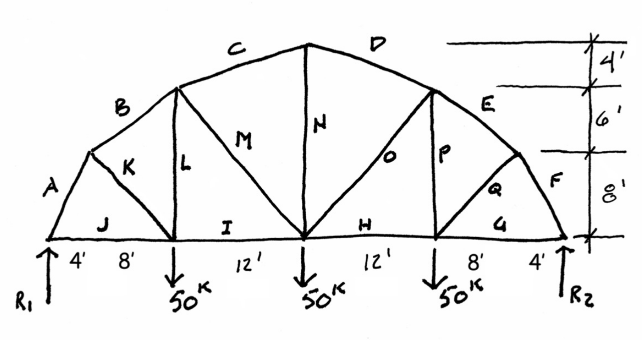
1. Solve Reactions
2. Cut section through truss
3. Choose point **where all but one of the unknown forces cross** and ΣM
4. Continue with ΣF_H and ΣF_V



Method of Sections - example

1. Solve the external reactions for the whole truss.

   Sum moments about each end. Or using symmetry, divide vertical forces evenly between reactions



REACTIONS:

$$\Sigma M_{R1} = 0 = 50^K(12') + 50^K(24') + 50^K(36') - R_2(48')$$

$$R_2(48') = 3600^{K-'}$$

$$R_2 = 75^K$$

$$\Sigma M_{R2} = 0 = R_1(48') - 50^K(36') - 50^K(24') - 50^K(12')$$

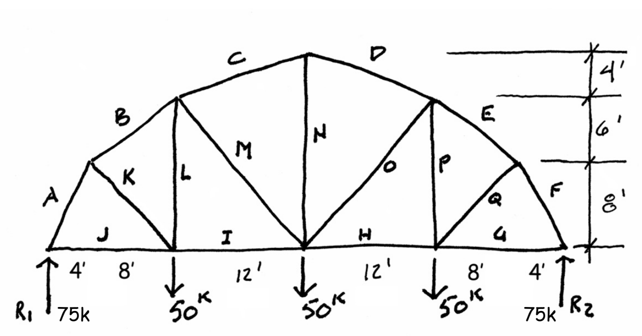
$$R_1(48') = 3600^{K-'}$$

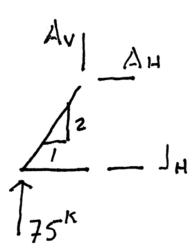
$$R_1 = 75^K$$

Method of Sections - example

2. Solution proceeds by cutting FBDs of either joints or sections of the truss.

   Member forces are shown as horizontal and vertical force components at each cut section.





$$\Sigma F_V = 0 = 75 - A_V$$

$$A_V = 75^K \downarrow$$

$$A_H = 37.5^K \leftarrow$$

$$\Sigma F_H = 0 = -37.5^K + J_H$$

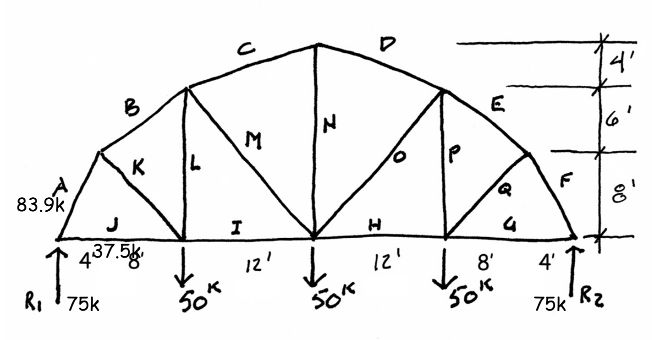
$$J_H = 37.5^K \rightarrow T$$

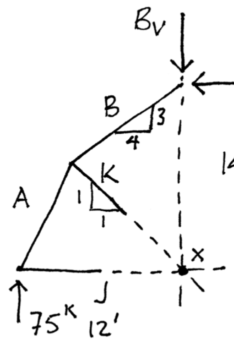
Method of Sections - example

2. Solution proceeds by cutting FBDs of either joints or sections of the truss.

   Member forces are shown as horizontal and vertical force components at each cut section.

3. Choose a point where all but one of the forces cross and sum moments.





$$\Sigma M_x = 0 = 75^K(12') - B_H(14')$$

$$B_H = 64.28^K \leftarrow$$

$$\frac{3}{4} : \frac{B_V}{64.28}$$

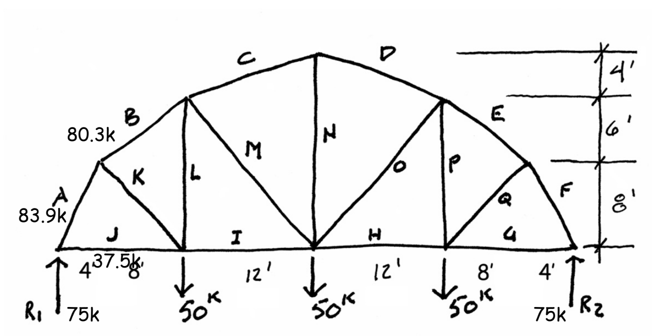
$$B_V = 48.21^K \downarrow$$

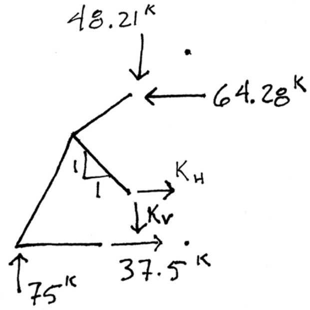
$$B = 80.35^K \text{ C}$$

Method of Sections - example

4. Continue with ΣF_H and ΣF_V

   Member forces are shown as horizontal and vertical force components at each cut section.





$$\Sigma F_H = 0 = +37.5 - 64.28 + K_H$$

$$K_H = 26.78^K \rightarrow$$

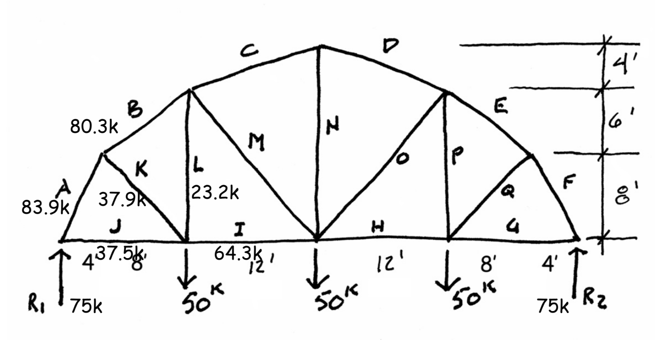
$$K_V = 26.78^K \downarrow$$

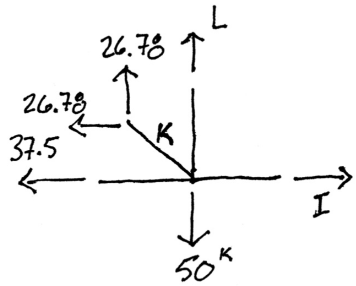
$$K = 37.87^K \text{ T}$$

Method of Sections - example

4. Continue with ΣF_H and ΣF_V

Member forces are shown as horizontal and vertical force components at each cut section.





$$\Sigma F_V = 0 = 26.78^K - 50^K + L$$
$$L = 23.22^K \ T$$

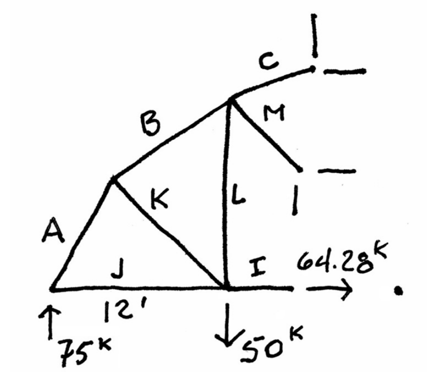
$$\Sigma F_H = 0 = -37.5 - 26.78 + I$$
$$I = 64.28^K \ T$$

Method of Sections - example

2. Solution proceeds by cutting FBDs of either joints or sections of the truss.

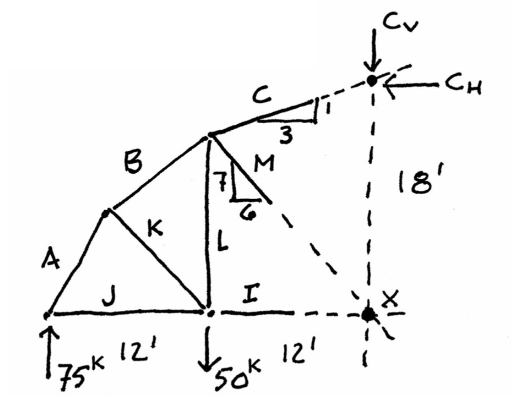
   Member forces are shown as horizontal and vertical force components at each cut section.

3. Choose a point where all but one of the forces cross and sum moments.



$$\Sigma M_X = 0$$
$$= 75^K(24') - 50^K(12') - C_H(18')$$
$$C_H(18) = 1200$$
$$C_H = 66.67^K \leftarrow$$

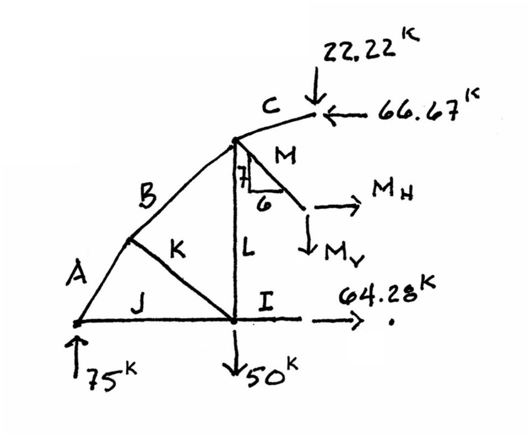
$$C_V = 22.22^K \downarrow$$
$$C = 70.27^K C$$



Method of Sections - example

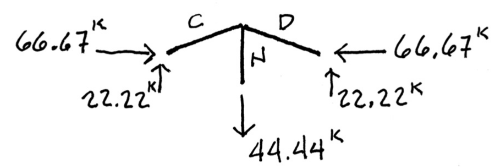
4. Continue with ΣF_H and ΣF_V

Member forces are shown as horizontal and vertical force components at each cut section.



$$\Sigma F_V = 0 = 75 - 50 - 22.22 - M_V$$
$$M_V = 2.78^K \downarrow$$
$$M_H = 2.38^K \rightarrow$$

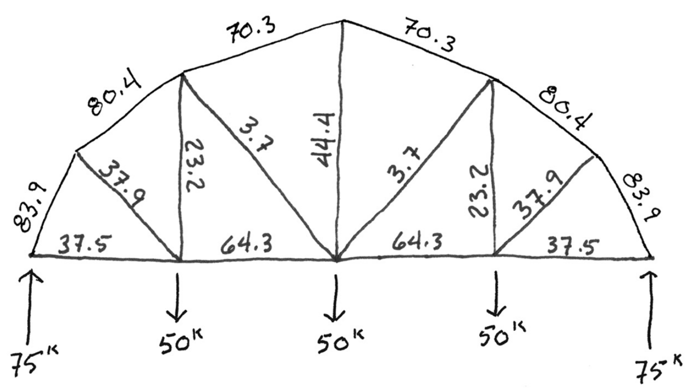
$$M = \underline{3.66^K\ T}$$



$$\Sigma F_H = 0 = -66.67 + 2.38 + I$$
$$I = \underline{64.29^K\ T}$$

Method of Sections - example

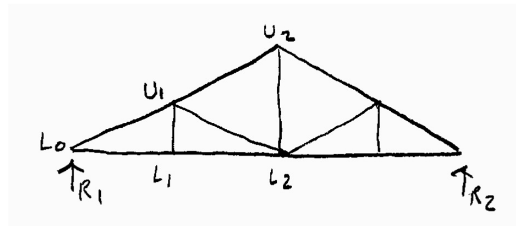
5. Make final qualitative check of solution.

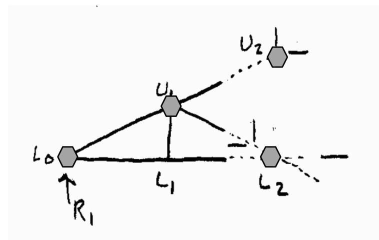


Tips on Sections

Howe Truss

1. Cut a panel with diagonals
2. ΣM at L_2 and resolve upper chord force at U_2. This gives U_1U_2H
3. ΣM at U_1 to find L_1L_2
4. ΣM at U_2 and resolve U_1L_2 at L_2 to find U_1L_2H
5. ΣM at L_0 and resolve U_1L_2 at L_2 to find U_1L_2V
6. U_1U_2V can now be found by ΣF_V

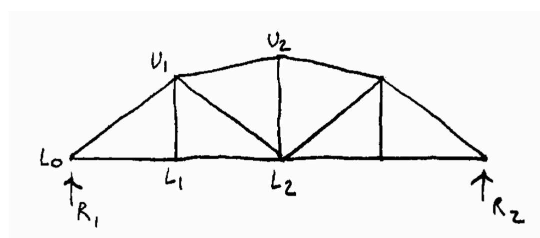


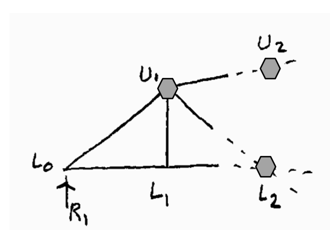


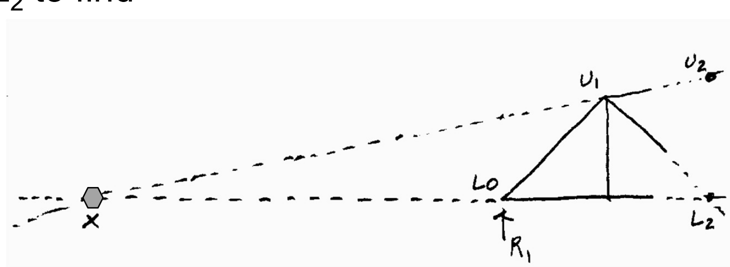
Tips on Sections

Parker Truss

1. Cut a panel with diagonals and ΣM at L_2 to solve U_1U_2H as before.
2. ΣM at U_1 to find L_1L_2
3. ΣM at U_2 and resolve U_1L_2 at L_2 to find U_1L_2H
4. Find point x in line with U_1U_2. ΣM at x and resolve U_1L_2 at L_2 to find U_1L_2V
5. U_1U_2V can now be found by ΣF_V

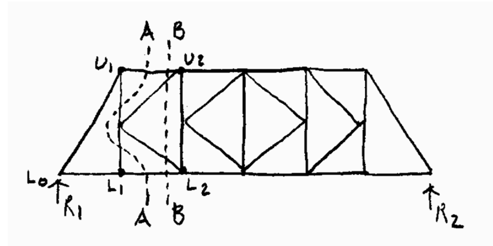




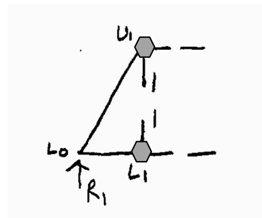


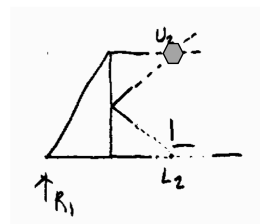
Tips on Sections

K Truss



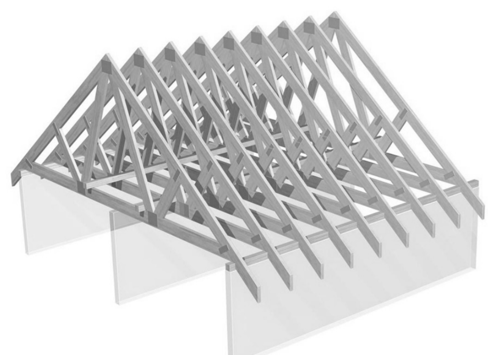
1. Make cut A-A to avoid the mid panel joint
2. ΣM at U_1 to get L_1L_2
3. ΣM at L_1 to get U_1U_2
4. The vertical web forces can be solved using joints
5. Cut B-B through the diagonals
6. ΣM at U_2 and resolve lower diagonal at L_2 to find its H component. The V component can be found by slope triangle. Top and bottom chords are known from steps 2. & 3.
7. Repeat step 6 by ΣM at L_2 to find other diagonal.





Examples of Trusses

Timber Frame



Light Frame – dimensioned lumber

Hamburg Airport – steel tube truss

Concrete Truss – Kilburn Rd. Bridge, Calif.

Trussed Lateral Bracing

Diagrid Towers

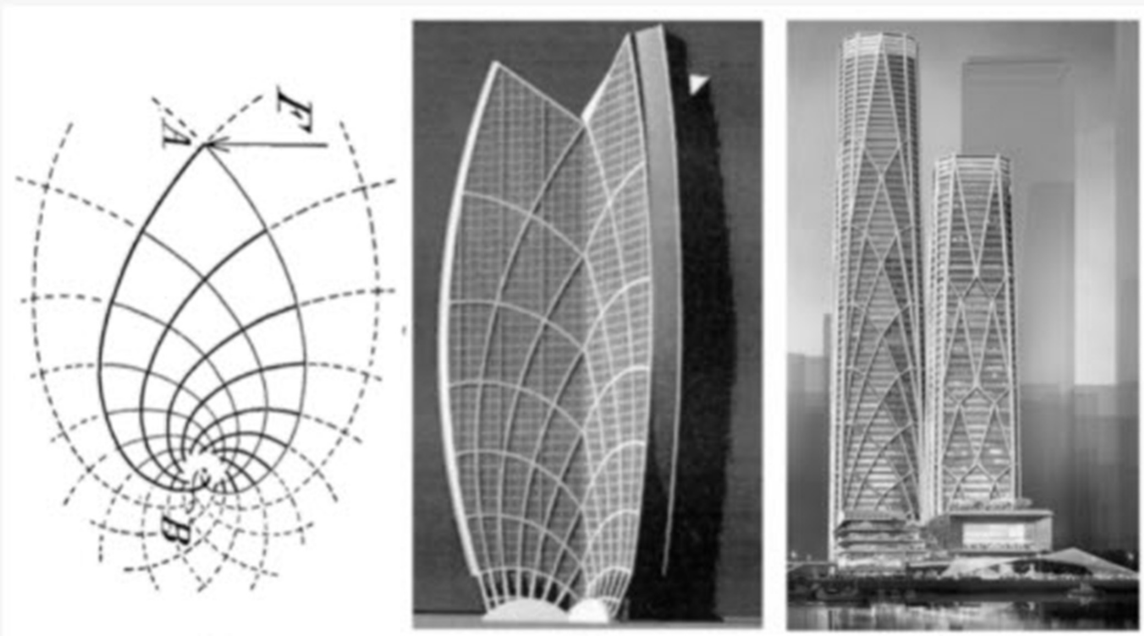
(a) (b) (c) (d)

(a) Hearst Tower in NY (b) Poly International Plaza tower in Chaoyang Qu
(c) Capital Gate tower in Abu Dhabi (d) 30 St. Mary Axe in London

John Handcock Tower - 1968
875 North Michigan Avenue, Chicago
Fazlur Kahn, SOM

Optimized Principal Stress Grid

Figure 1. (**a**) Original Michell's minimum frame [9], (**b**) structural design by Zalewski and Załocki [105], and (**c**) CITIC financial centre in Shenzhen by SOM [105]. William Baker



(a) (b) (c)