Baylor University
Engineering & Computer Science

Analysis of Structures

Truss Bridges

The truss is a simple skeletal structure. In design theory, the individual members of a simple truss are only subject to tension (pulling) and compression (pushing) forces and not bending forces.

This is the Washington Ave. Bridge in Waco, Texas. It is the longest and oldest single span truss still in continuous use in Texas.

There are both simple and continuous trusses. The small size of individual parts of a truss make it the ideal bridge for places where large parts or sections cannot be shipped. Because the truss is a hollow skeletal structure, the roadway may pass over or even through the structure allowing for clearance below the bridge often not possible with other bridge types.

Suspension Bridges

- Note that a suspension bridge like the Golden Gate also uses truss structures in the design.

- What are the Advantages in the suspension bridge design?
- What are the Disadvantages in the suspension bridge design?

The famous Waco Suspension Bridge was designed by the John Roebling Co. which later built the Brooklyn Bridge.

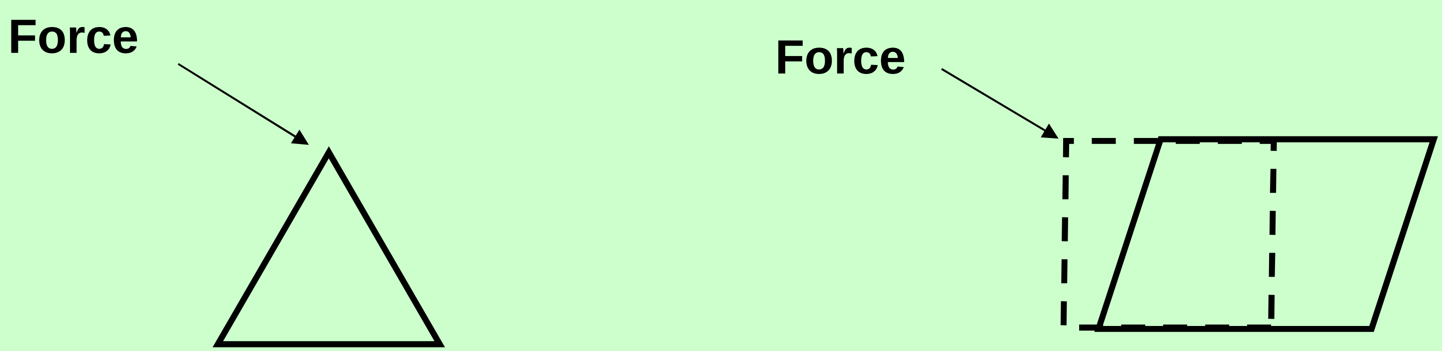
This was the first bridge across the Brazos and was an important link in the Chisholm Trail.

World’s Longest Truss Bridge
Pont de Quebec

- This bridge was designated as an international historical monument by the Canadian Society for Civil Engineering and the American Society of Civil Engineers. The Pont de Québec is formed by a 549 m (1702’) suspended span located between two main pillars, which makes this bridge the longest cantilever bridge in the world. While the bridge was under construction, the suspended span collapsed on two occasions (in 1907 and 1916), killing many workers. Trains began using the bridge in 1917 while automobiles were only allowed on it in 1929.

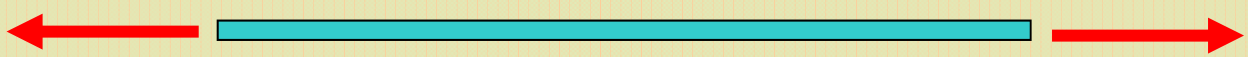
Why Structures Are Built With Triangles

- Pinned triangles are naturally rigid
- Joint strength becomes less critical
- High stiffness can be achieved for small amount of material used
- Ease of construction

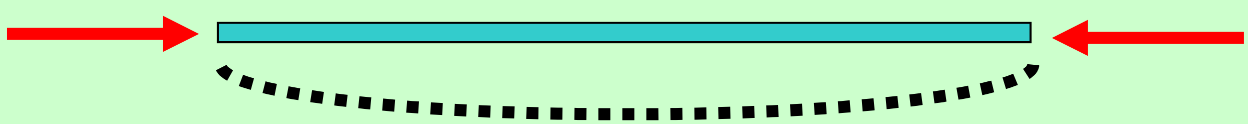


Members in Tension and Compression

- Tension Forces on 2-Force members tend to pull the member apart
  - the member tends to “stretch:
  - a cable or wire can be a 2-Force member in Tension
  - more economical, can be made lighter/thinner.

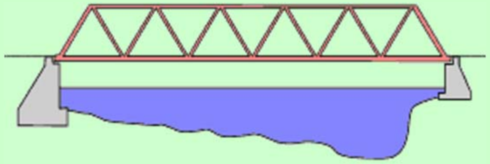


- Compressive forces tend to “squeeze” the member.
  - long slender members “buckle” easily, carry much less load.
  - shorter members can carry higher compressive loads

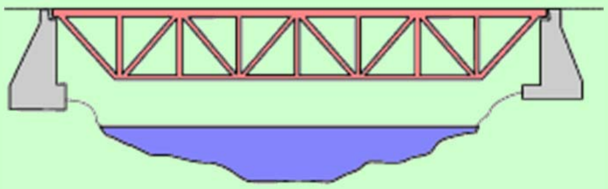


Truss Bridges

Trusses are constructed using triangles and are also classified by the basic design used.



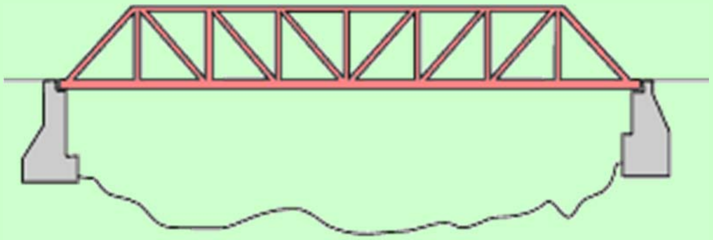
The **Warren** truss is perhaps the most common truss for both simple and continuous trusses. For smaller spans, no vertical members are used lending the structure a simple look. For longer spans vertical members are added providing extra strength.



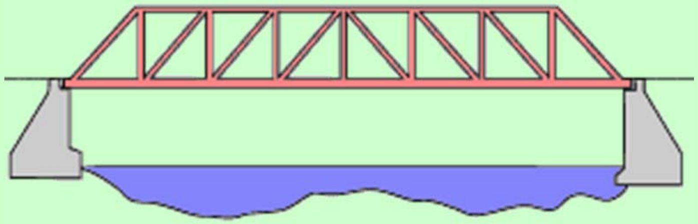
Warren trusses are typically used in spans of between 50-100m.

Truss Bridges

- **Pratt -** The Pratt truss is identified by its diagonal members which, except for the very end ones, all slant down and in toward the center of the span. Except for those diagonal members near the center, all the diagonal members are subject to tension forces only while the shorter vertical members handle the compressive forces. This allows for thinner diagonal members resulting in a more economic design.

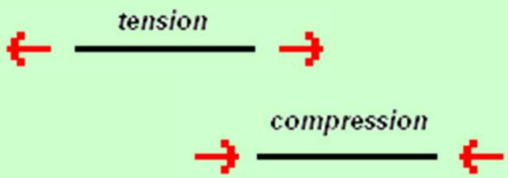


- **Howe -** The Howe truss is the opposite of the Pratt truss. The diagonal members face in the opposite direction and handle compressive forces (requiring thicker elements. This makes it very uneconomic design for steel bridges and its use is rarely seen.



Concepts & Assumptions for Static Analysis of Truss Bridges

- Sum of forces at each joint, or node, must equal zero
- Each element is a "two-force" member (i.e., the direction of the force is along the axis)
  - If an element is in tension, it will **pull** on both joints
  - If an element is in compression, it will **push** on both joints



- Joints are pinned and frictionless (i.e., pins will not support a moment)
- A force cannot be applied at any point, just at the ends; i.e. no bending.
- No deformation occurs to change dimensions
- The external reactions are statically determinant, and the supports are frictionless:

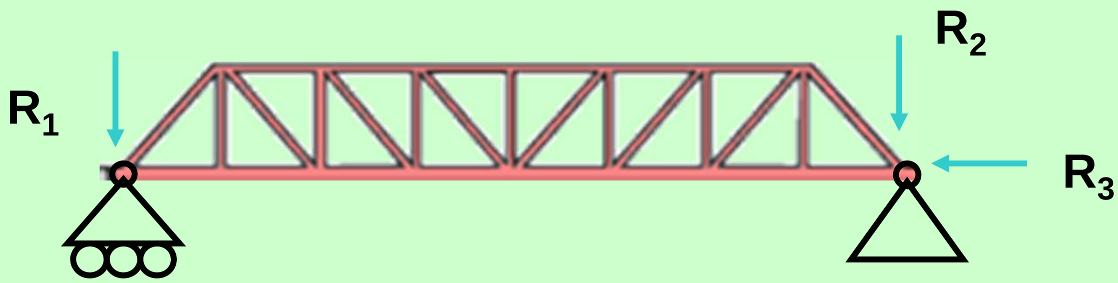


Figure 6.3

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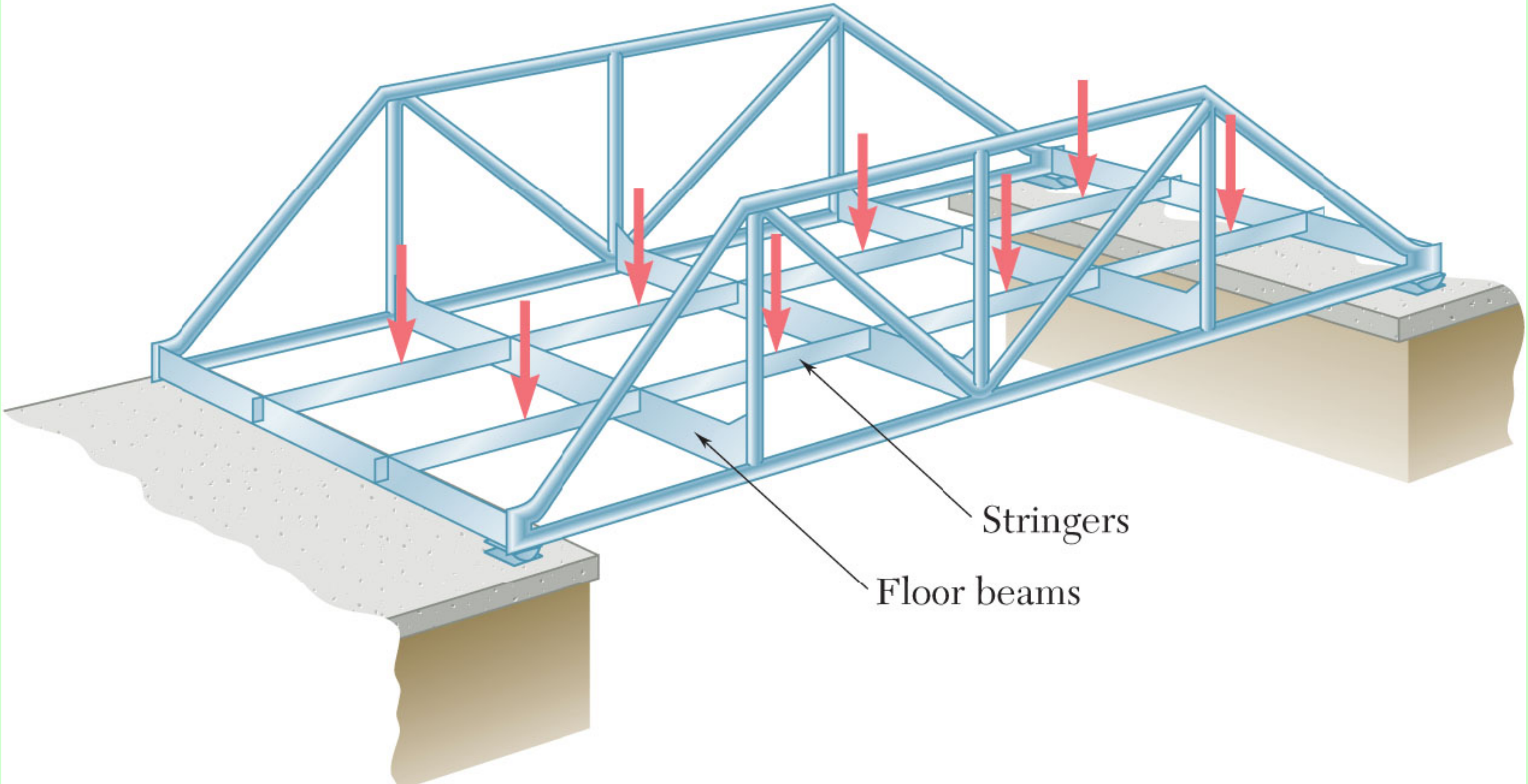


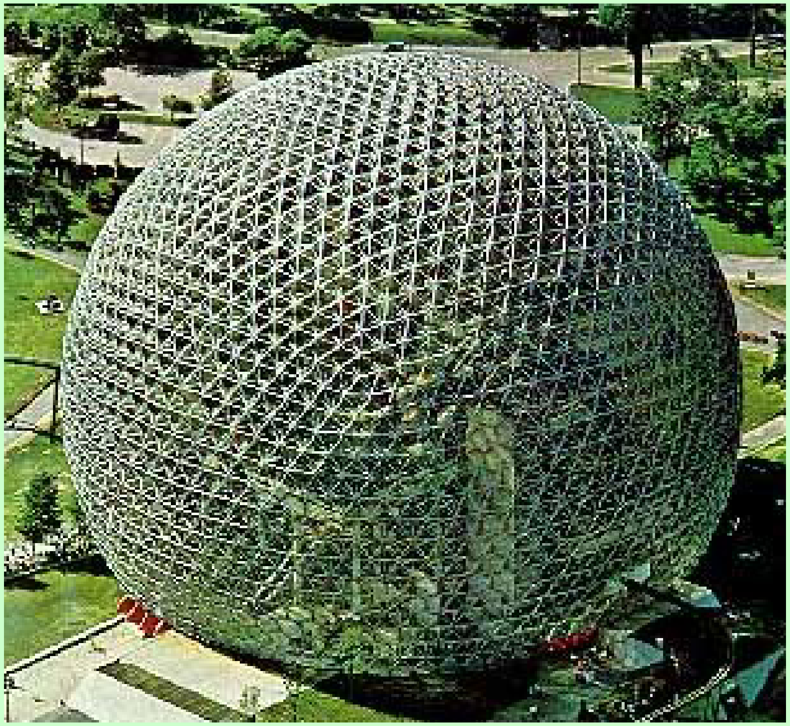
Fig. 6.3
Vector Mechanics For Engineers, Beer & Johnston

TX HWY 130 Sign Supports – Note the use of Pratt Truss construction

- Long thin members in tension
- Short thick members in compression
- Top and Bottom are Warren trusses to take wind loads in either direction

But Trusses are not just Bridges

Architecture



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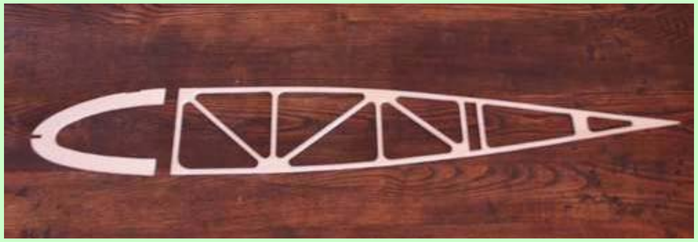
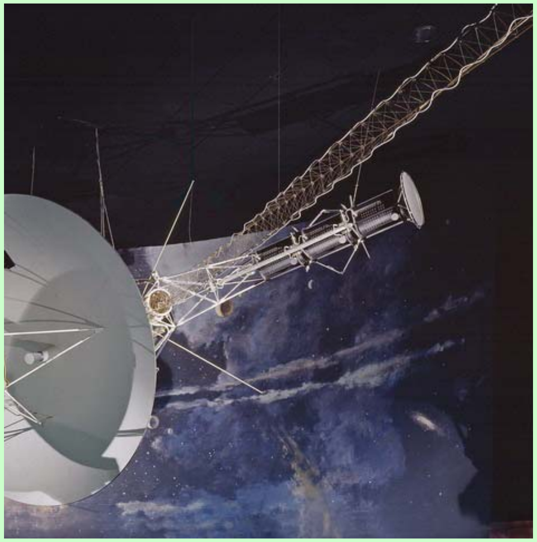
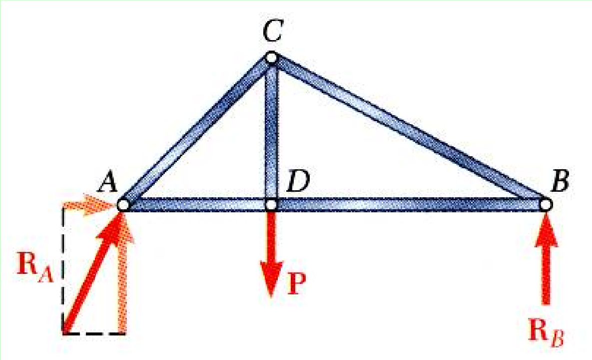
Trusses in Aerospace

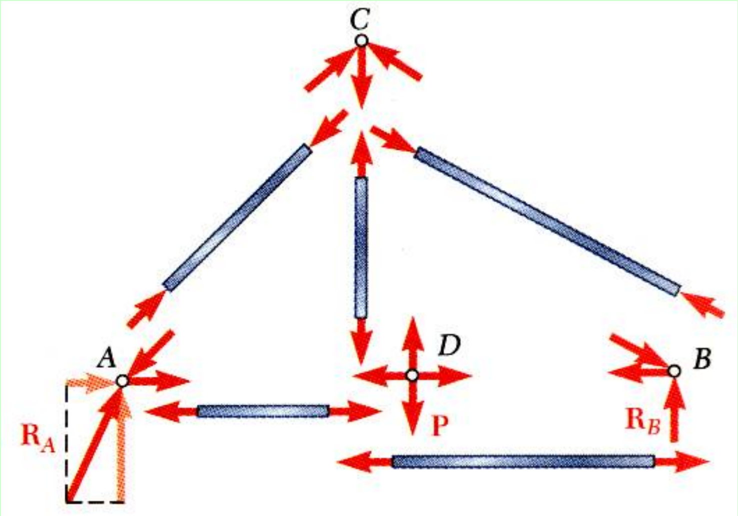




Analysis of Trusses by the Method of Joints

From Vector Mechanics For Engineers by Beer and Johnston, 9th Edition

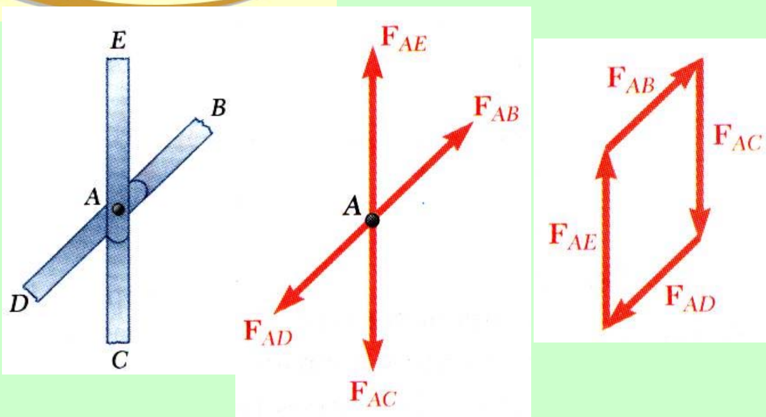


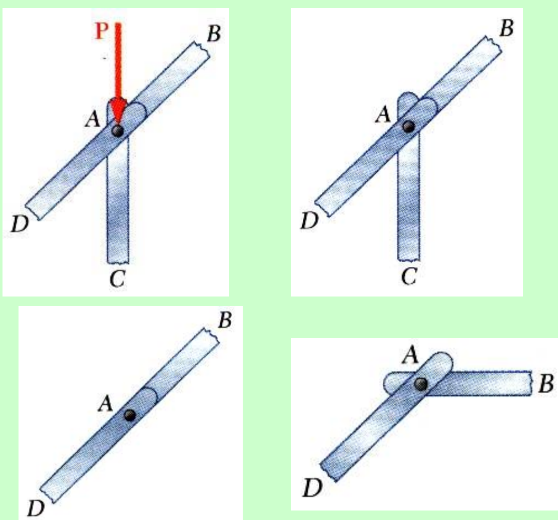


- Draw FBD of entire truss and determine reactions at supports
- Locate a joint with only two members, and draw the FBD of that pin. Determine the unknown forces at that joint.
- Next, locate a member where the forces in only two members are still unkown. Draw a FBD of this joint and solve for the unknowns.
- Repeat this process until all member forces are known.

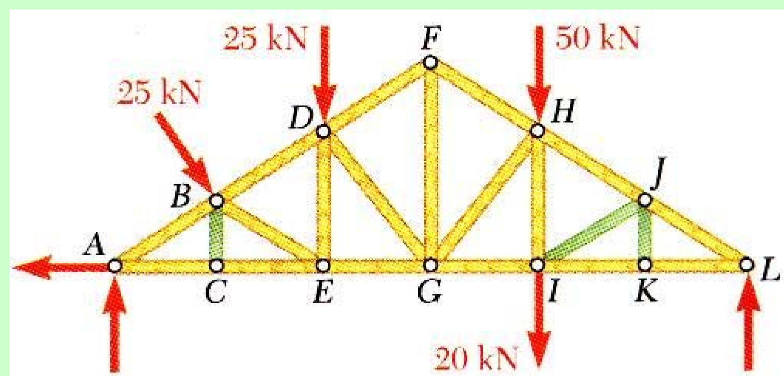
Joints Under Special Loading Conditions

From Vector Mechanics For Engineers by Beer and Johnston, 9th Edition

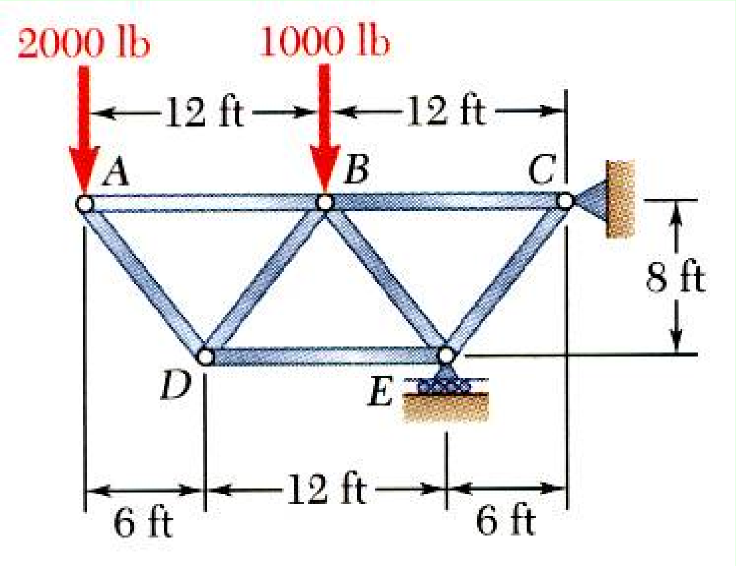




- Forces in opposite members intersecting in two straight lines at a joint are equal.
- The forces in two opposite members are equal when a load is aligned with a third member. The third member force is equal to the load (including zero load).
- The forces in two members connected at a joint are equal if the members are aligned and zero otherwise.
- Recognition of joints under special loading conditions simplifies a truss analysis.



Sample Problem

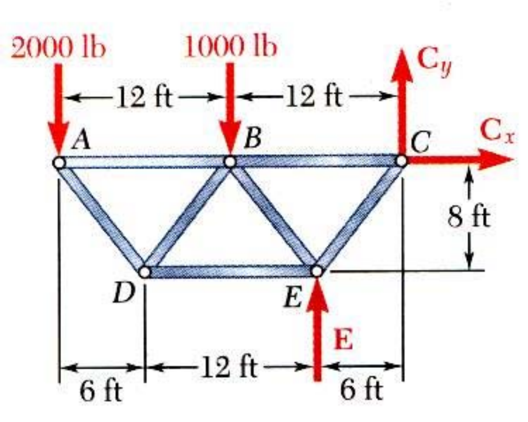


Using the method of joints, determine the force in each member of the truss.

SOLUTION:

- Based on a free-body diagram of the entire truss, solve the 3 equilibrium equations for the reactions at *E* and *C*.
- Joint *A* is subjected to only two unknown member forces. Determine these from the joint equilibrium requirements.
- In succession, determine unknown member forces at joints *D*, *B*, and *E* from joint equilibrium requirements.
- All member forces and support reactions are known at joint *C*. However, the joint equilibrium requirements may be applied to check the results.

Sample Problem



SOLUTION:

- Based on a free-body diagram of the entire truss, solve the 3 equilibrium equations for the reactions at *E* and *C*.

$$\sum M_C = 0$$

$$= (2000\text{ lb})(24\text{ ft}) + (1000\text{ lb})(12\text{ ft}) - E(6\text{ ft})$$

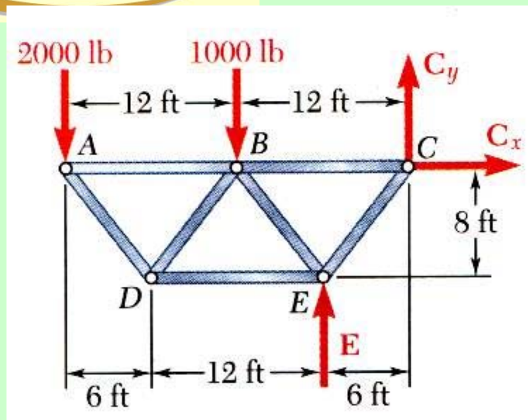
$$E = 10{,}000\text{ lb} \uparrow$$

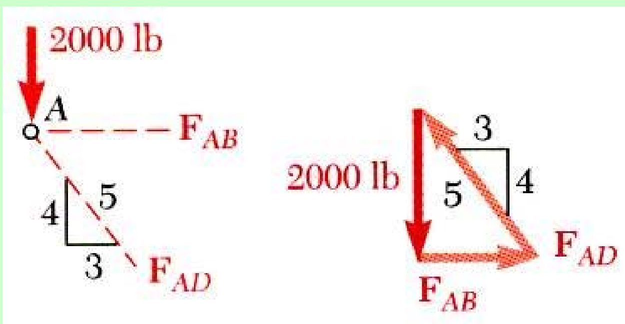
$$\sum F_x = 0 = C_x \qquad C_x = 0$$

$$\sum F_y = 0 = -2000\text{ lb} - 1000\text{ lb} + 10{,}000\text{ lb} + C_y$$

$$C_y = 7000\text{ lb} \downarrow$$

Sample Problem

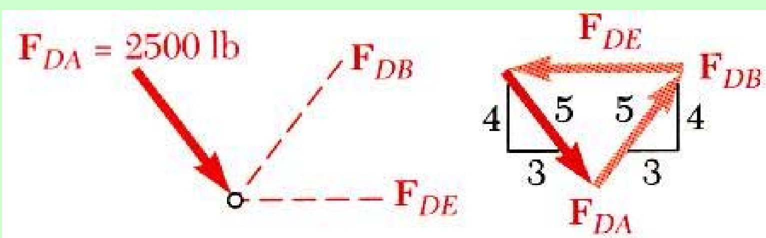




- Joint *A* is subjected to only two unknown member forces. Determine these from the joint equilibrium requirements.

$$\frac{2000\,\text{lb}}{4} = \frac{F_{AB}}{3} = \frac{F_{AD}}{5}$$

$$F_{AB} = 1500\,\text{lb} \;\; T$$
$$F_{AD} = 2500\,\text{lb} \;\; C$$

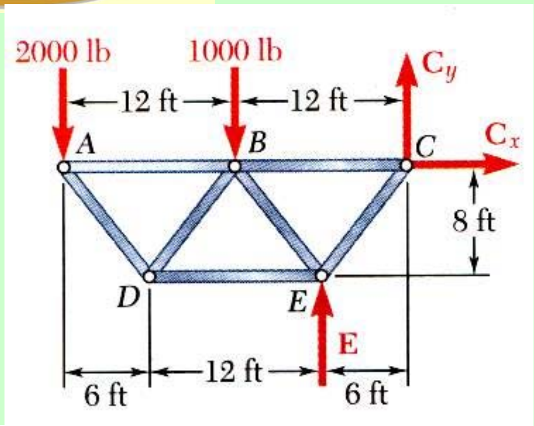


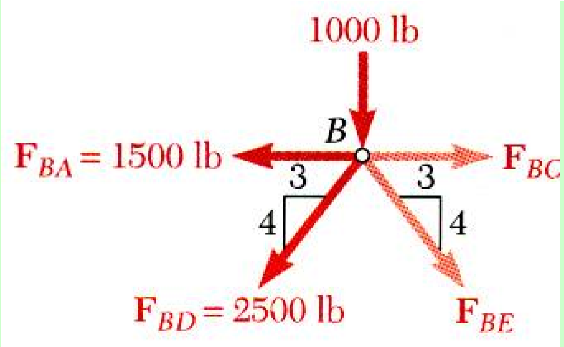
- There are now only two unknown member forces at joint D.

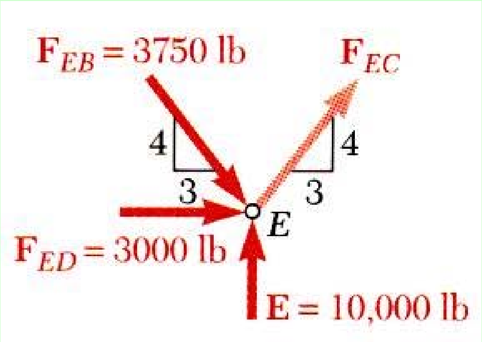
$$F_{DB} = F_{DA}$$
$$F_{DE} = 2\left(\tfrac{3}{5}\right)F_{DA}$$

$$F_{DB} = 2500\,\text{lb} \;\; T$$
$$F_{DE} = 3000\,\text{lb} \;\; C$$

Sample Problem







- There are now only two unknown member forces at joint B. Assume both are in tension.

$$\sum F_y = 0 = -1000 - \tfrac{4}{5}(2500) - \tfrac{4}{5} F_{BE}$$

$$F_{BE} = -3750\,\text{lb}$$

$$\boxed{F_{BE} = 3750\,\text{lb}\ \ C}$$

$$\sum F_x = 0 = F_{BC} - 1500 - \frac{3}{5}(2500) - \frac{3}{5}(3750)$$

$$F_{BC} = +5250\,\text{lb}$$

$$\boxed{F_{BC} = 5250\,\text{lb}\ \ T}$$

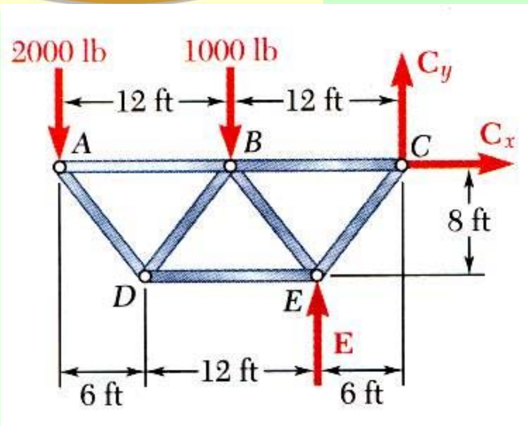
- There is one unknown member force at joint *E*. Assume the member is in tension.

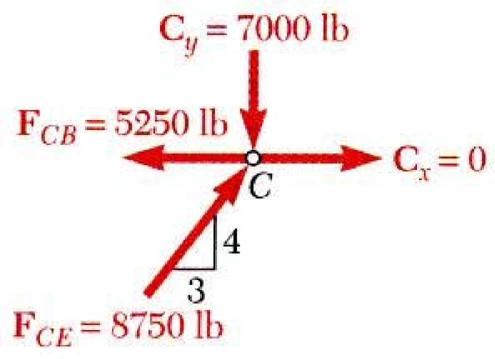
$$\sum F_x = 0 = \frac{3}{5} F_{EC} + 3000 + \frac{3}{5}(3750)$$

$$F_{EC} = -8750\,\text{lb}$$

$$\boxed{F_{EC} = 8750\,\text{lb}\ \ C}$$

Sample Problem





- All member forces and support reactions are known at joint *C*. However, the joint equilibrium requirements may be applied to check the results.

$$\sum F_x = -5250 + \tfrac{3}{5}(8750) = 0 \quad (\text{checks})$$

$$\sum F_y = -7000 + \tfrac{4}{5}(8750) = 0 \quad (\text{checks})$$