ME 164 - STATICS OF SOLID MECHANICS / ME 162 - BASIC MECHANICS

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LECTURE 2

Static Equilibrium of Particles and Rigid Bodies
Analysis of Planar Trusses and Frames

Static Equilibrium Of Particles And Rigid Bodies

Static Equilibrium
Procedure for analyzing static equilibrium problems
Free Body Diagrams

Static Equilibrium

- A particle or body is said to be in equilibrium if the resultant force and moment acting on it is zero. In other words, the sum of forces (or moments) **must** be equal to zero.

- For particles;

$$\vec{R} = \sum F = 0$$

$$\Rightarrow \sum F_x = 0 \qquad \sum F_y = 0 \qquad \sum F_z = 0$$

- For bodies;

$$\vec{R} = \sum F = 0$$

$$\Rightarrow \sum F_x = 0 \qquad \sum F_y = 0 \qquad \sum F_z = 0$$

$$\vec{M} = \sum M = 0$$

$$\Rightarrow \sum M_x = 0 \qquad \sum M_y = 0 \qquad \sum M_z = 0$$

Solving Static Equilibrium Problems

➢ Involves three main steps;

✓ Sketch a free body diagram for the problem

✓ Sum up forces and moments to obtain the **equations of equilibrium** for the problem.

✓ Solve the equations and interpret your results.

Sketching Free Body Diagrams

- Select the extent of the body that is of interest, detach it from the ground and all other bodies and supports, and (basically) sketch the outline of the "free-body".

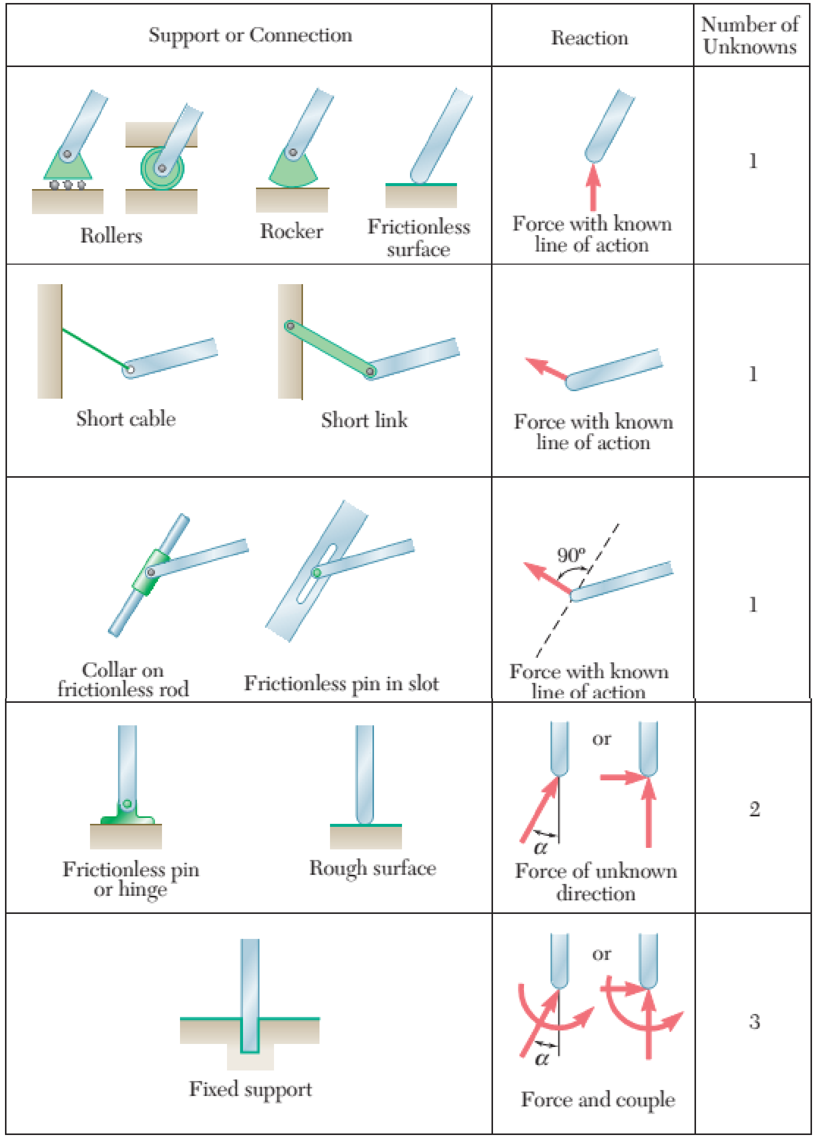
- Indicate force reactions which the ground and other supports exert on the "free-body".

- Indicate external forces and moments, including the rigid body weight where it cannot be ignored at their points of application.

- Include the required dimensions to compute the moments of the forces where necessary.

Free Body Diagrams: Support Reactions

➢ Reactions at Supports and Connections for Two-Dimensional Structures



Support or Connection	Reaction	Number of Unknowns
Rollers; Rocker; Frictionless surface	Force with known line of action	1
Short cable; Short link	Force with known line of action	1
Collar on frictionless rod; Frictionless pin in slot	90° Force with known line of action	1
Frictionless pin or hinge; Rough surface	or α Force of unknown direction	2
Fixed support	or α Force and couple	3

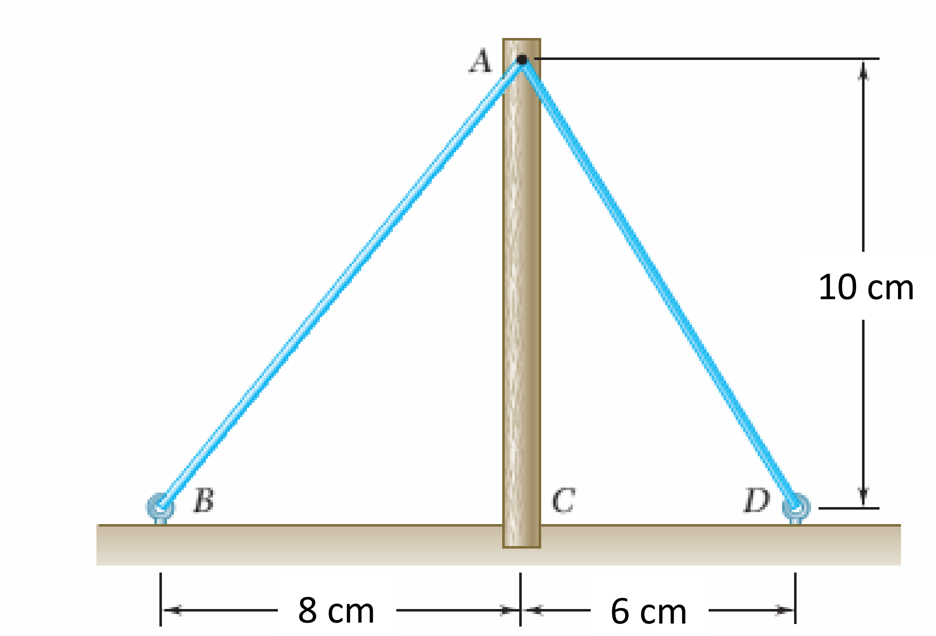
- Reactions equivalent to a force with known line of action.
- Reactions equivalent to a force of unknown direction and magnitude.
- Reactions equivalent to a force of unknown direction and magnitude and a couple of unknown magnitude

Source: Vector Mechanics for Engineers, Beer *et al.*

Free Body Diagrams

Example

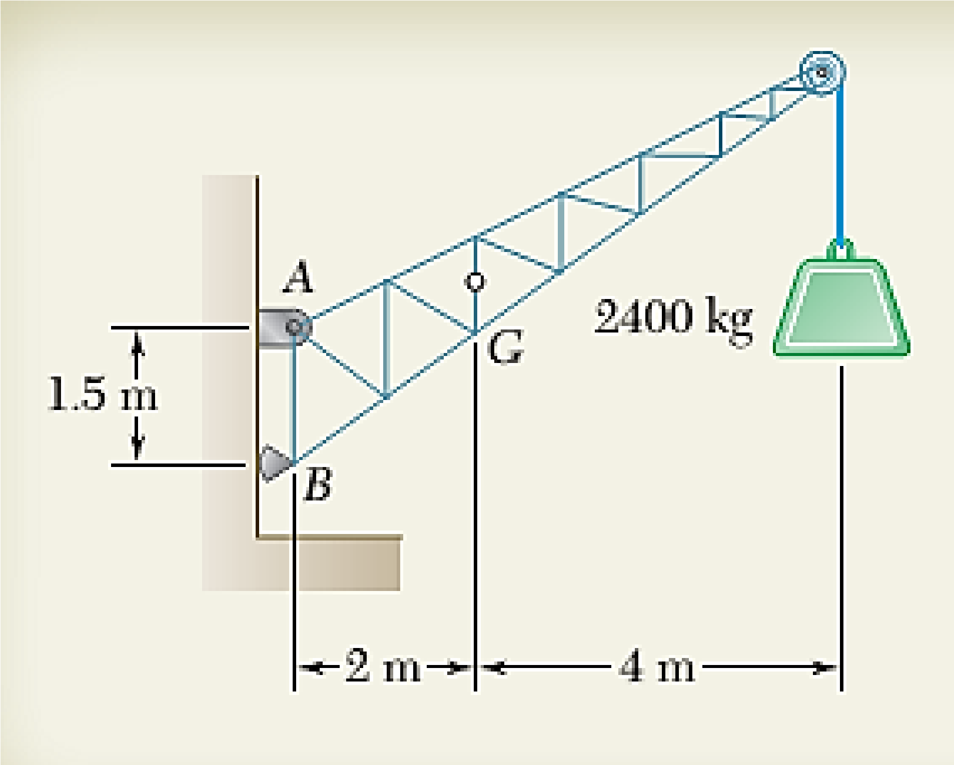
Cables AB and AD help support pole AC. Knowing that the tension is 120 N in AB and 40 N in AD, sketch the free body diagram for the pole.

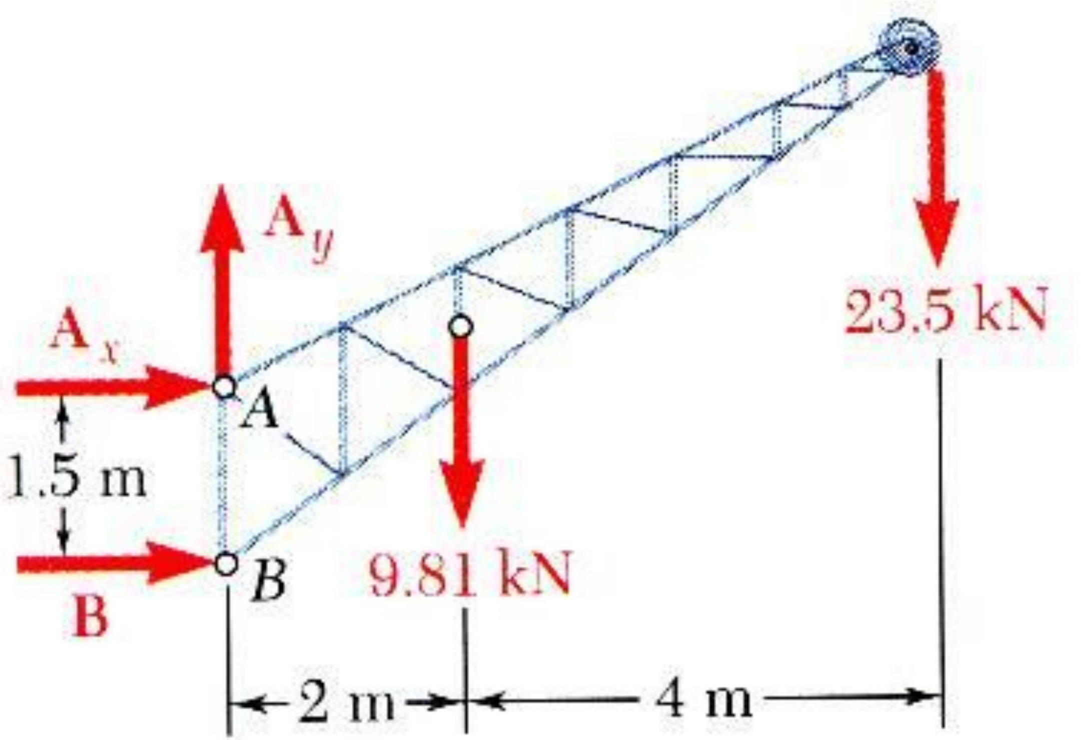


Sketching Free Body Diagrams

- Example

A fixed crane has a mass of 1000 kg and is used to lift a 2400 kg crate. It is held in place by a pin at A and a rocker at B. The center of gravity of the crane is located at G. Sketch the free body diagram for the crane.

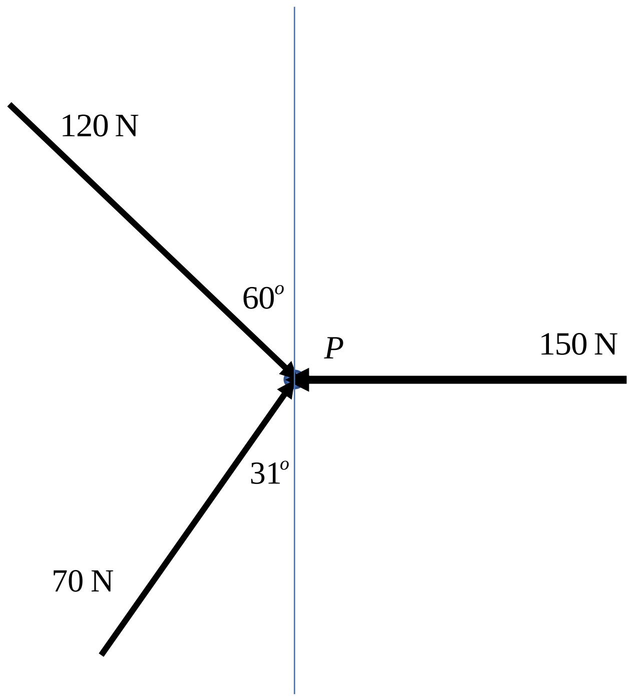




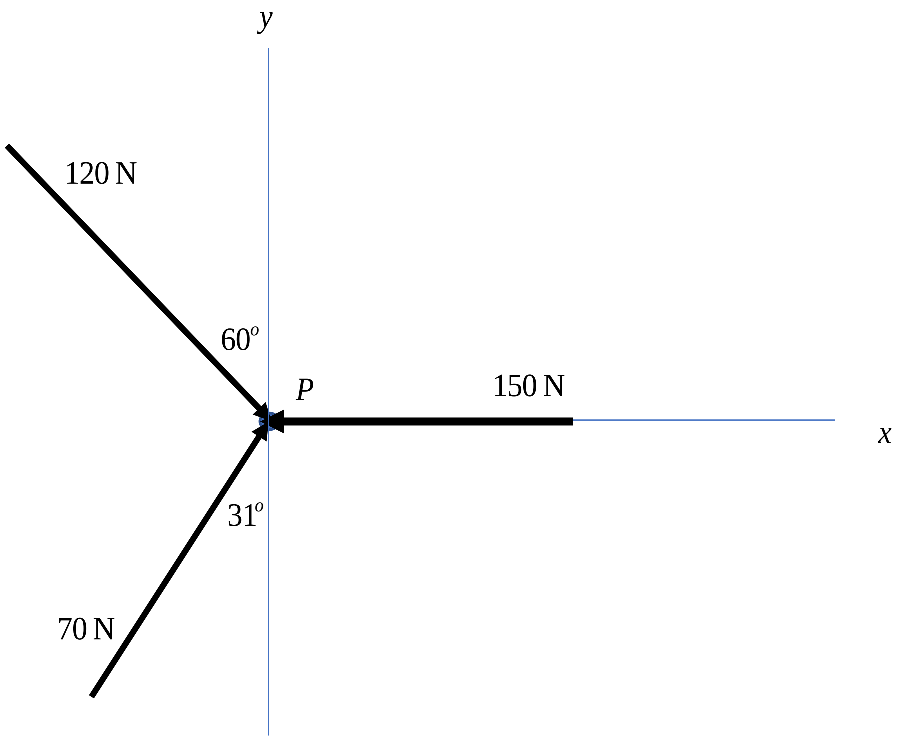
Static Equilibrium - Particles

Example

Determine if the particle P is in equilibrium under the influence of the forces shown.



- Solution



Equations of Equilibrium

$$\overset{+}{\rightarrow}\sum F_x = 120\sin 60^o + 70\sin 31^o - 150 = -11.02 \text{ N}$$

$$+\uparrow\sum F_y = -120\cos 60^o + 70\cos 31^o = -0.0017 \text{ N} = 0.00 \text{ N}$$

For equilibrium, $\sum F_x = 0 = \sum F_y$

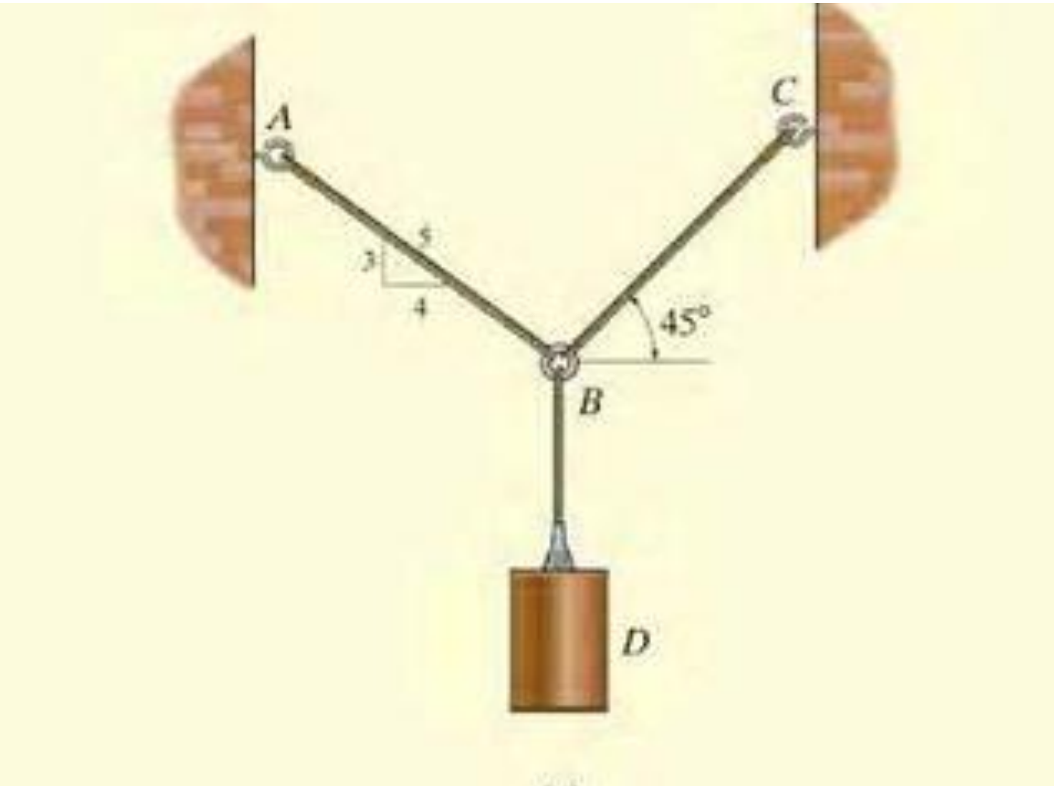
But $\sum F_x \neq 0$

Hence, P is not in equilibrium

Static Equilibrium - Particles

- Example

Determine the tensions required in cables BC and BA to keep the ring at B in equilibrium.

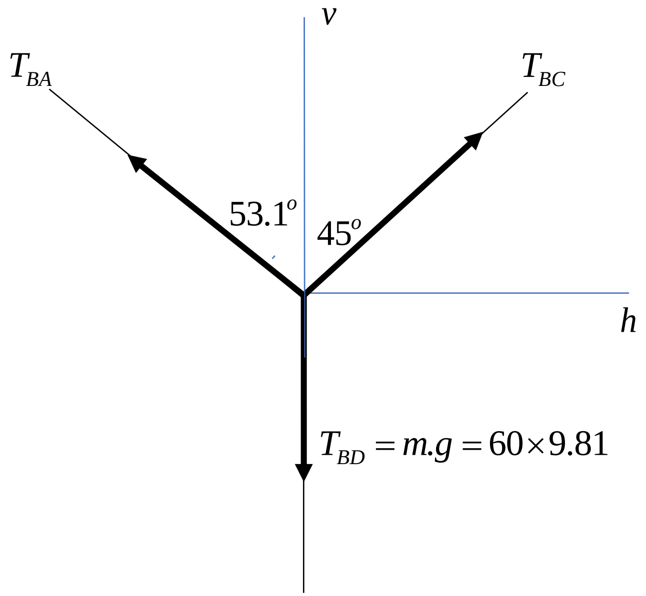


(a)

Static Equilibrium - Particles

- Solution

FBD



Equations of Equilibrium

$$\overset{+}{\rightarrow} \sum F_h = 0 : T_{BC} \sin 45^o - T_{BA} \sin 53.1^o = 0 \qquad \text{---} \quad (1)$$

$$+\uparrow \sum F_v = 0 : T_{BC} \cos 45^o + T_{BA} \cos 53.1^o - T_{BD} = 0$$

$$= T_{BC} \cos 45^o + T_{BA} \cos 53.1^o = 588.6 \text{ N} \qquad \text{---} \quad (2)$$

Solving (1) and (2) simultaneously,

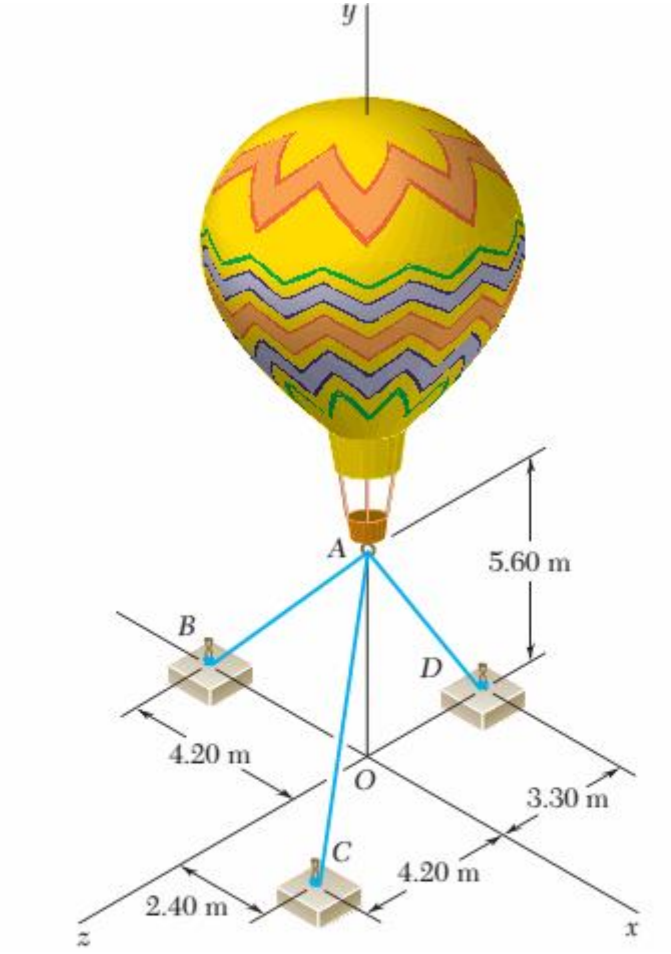
$T_{BC} = 475.41$ N

$T_{BA} = 420.43$ N

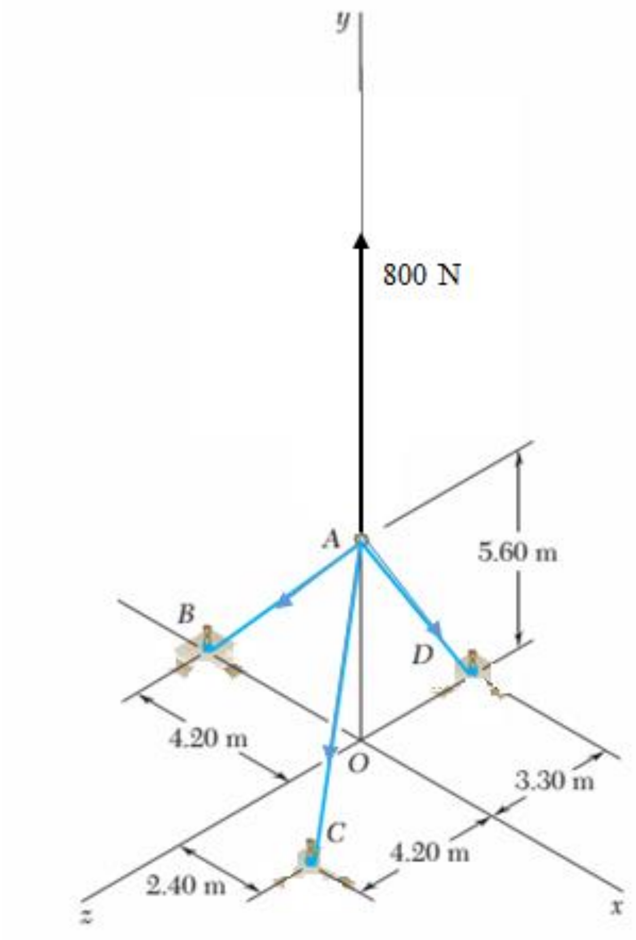
Static Equilibrium - Particles

Example

Three cables are used to tether a balloon as shown. Knowing that the balloon exerts an 800-N vertical force on the ring at A, determine the tension in each cable assuming equilibrium.



Solution



Equations of Equilibrium

$$\vec{T}_{AB} = T_{AB}\frac{-4.2\vec{i} - 5.6\vec{j}}{\sqrt{4.2^2 + 5.6^2}} = -0.6T_{AB}\vec{i} - 0.8T_{AB}\vec{j}$$

$$\vec{T}_{AC} = T_{AC}\frac{2.4\vec{i} - 5.6\vec{j} + 4.2\vec{k}}{\sqrt{2.4^2 + 5.6^2 + 4.2^2}} = 0.37T_{AC}\vec{i} - 0.87T_{AC}\vec{j} + 0.65T_{AC}\vec{k}$$

$$\vec{T}_{AD} = T_{AD}\frac{-5.6\vec{j} - 3.3\vec{k}}{\sqrt{5.6^2 + 3.3^2}} = -0.86T_{AD}\vec{j} - 0.51T_{AD}\vec{k}$$

$$F_{Ay} = 800 \text{ N}\vec{j}$$

$$\sum F_x = -0.6T_{AB} + 0.37T_{AC} = 0 \qquad \text{---} \quad (1)$$

$$\sum F_y = -0.8T_{AB} - 0.87T_{AC} - 0.86T_{AD} + 800 = 0 \qquad \text{---} \quad (2)$$

$$\sum F_z = 0.65T_{AC} - 0.51T_{AD} = 0 \qquad \text{---} \quad (3)$$

Solving (1), (2) and (3) simultaneously,

$T_{AB} = 200.6$ N

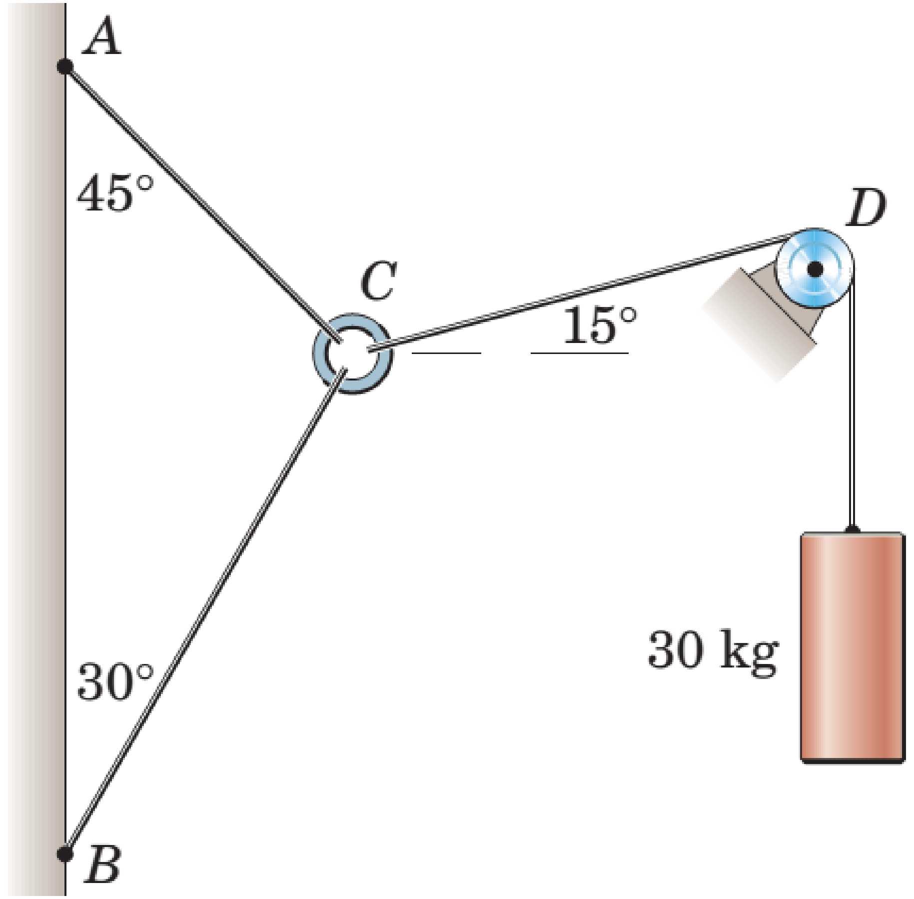
$T_{AC} = 325.3$ N

$T_{AD} = 414.6$ N

Static Equilibrium - Particles

Example

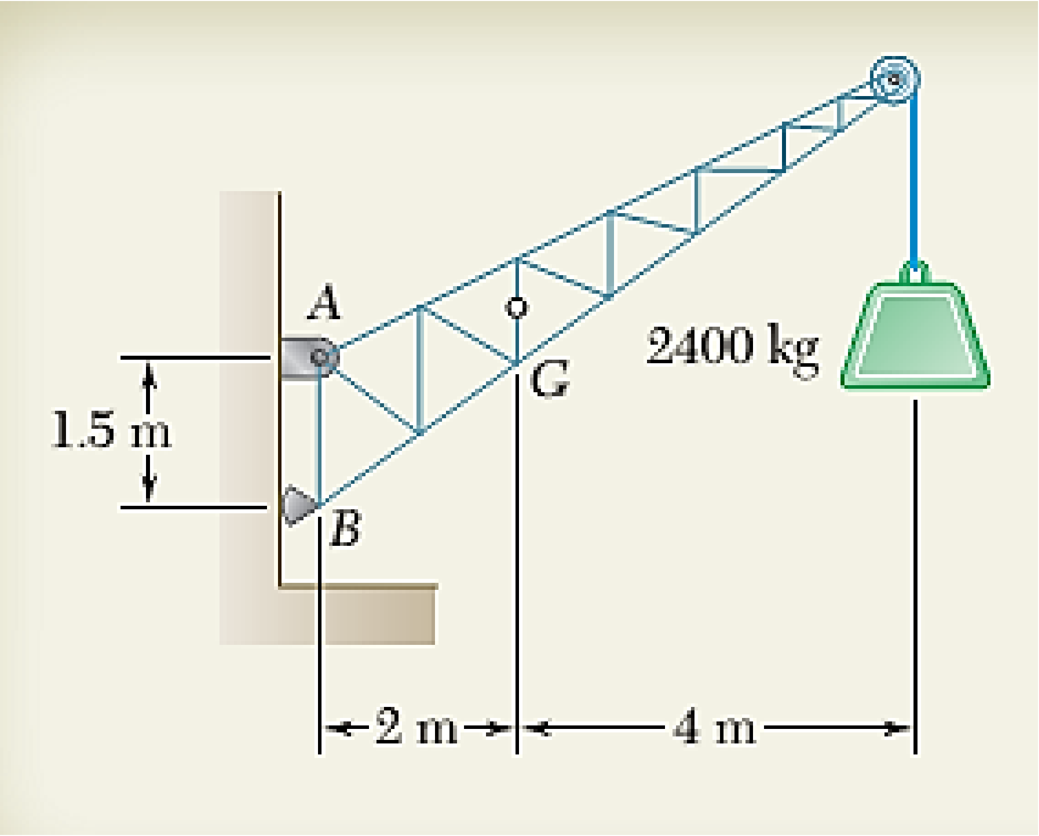
Three cables are joined at the junction ring, *C*. Determine the magnitudes of the tensions in cables *AC* and *BC* on the ring.



Static Equilibrium – Rigid Bodies

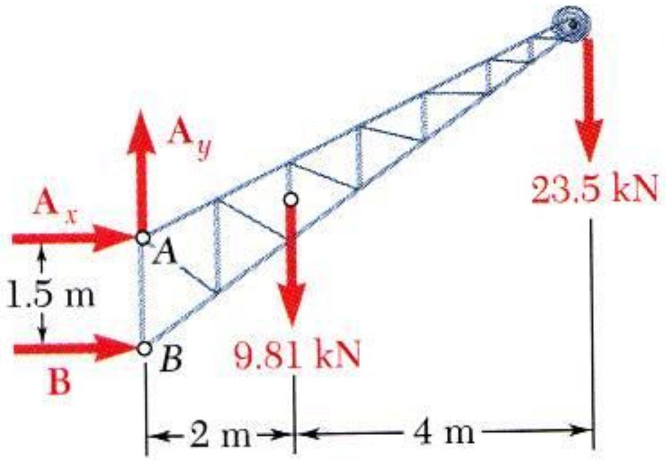
➢Example

A fixed crane has a mass of 1000 kg and is used to lift a 2400 kg crate. It is held in place by a pin at A and a rocker at B. The center of gravity of the crane is located at G. Determine the components of the reactions at A and B.



Static Equilibrium – Rigid Bodies

➢ Solution



At A,

$$\overset{+}{\rightarrow}\sum F_x = 0: \quad A_x + B = 0$$

$$+\uparrow\sum F_y = 0: \quad A_y - 9.81\,\text{kN} - 23.5\,\text{kN} = 0$$

$$A_y = +33.3\,\text{kN}$$

Taking moments about A,

$$+\sum M_A = 0: \quad +B(1.5\text{m}) - 9.81\,\text{kN}(2\text{m}) - 23.5\,\text{kN}(6\text{m}) = 0$$

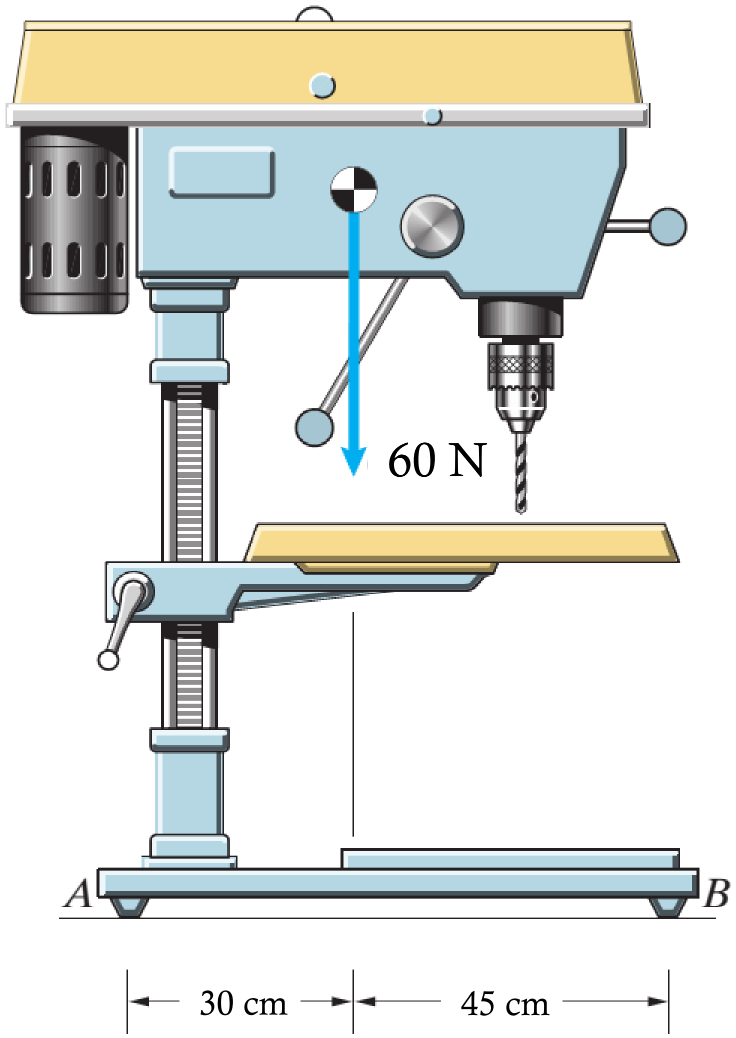
$$B = +107.1\,\text{kN}$$

$$\therefore A_x = -107.1\,\text{kN}$$

Static Equilibrium – Rigid Bodies

➢Example

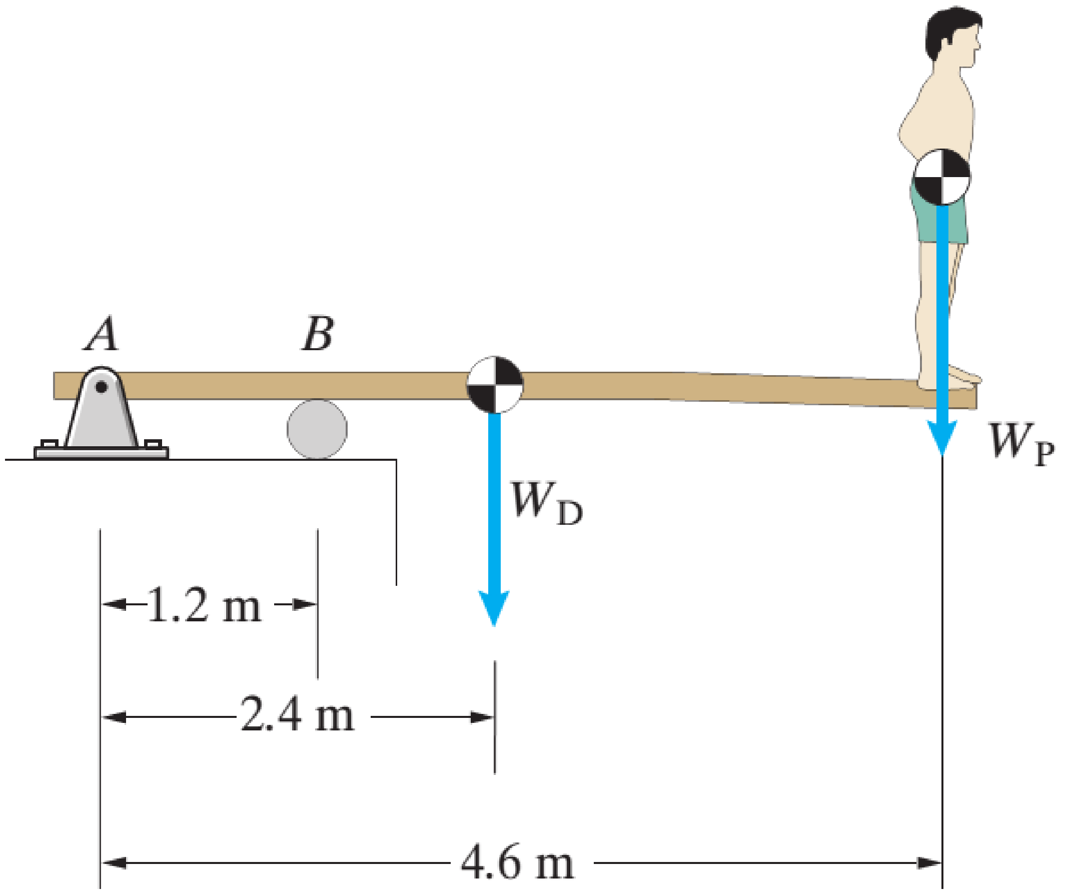
Determine the reactions at A and B. Assume that the surfaces at A and B are frictionless.



Static Equilibrium – Rigid Bodies

The masses of the man and the diving board are 54 kg and 36 kg, respectively. Assume that they are in equilibrium.

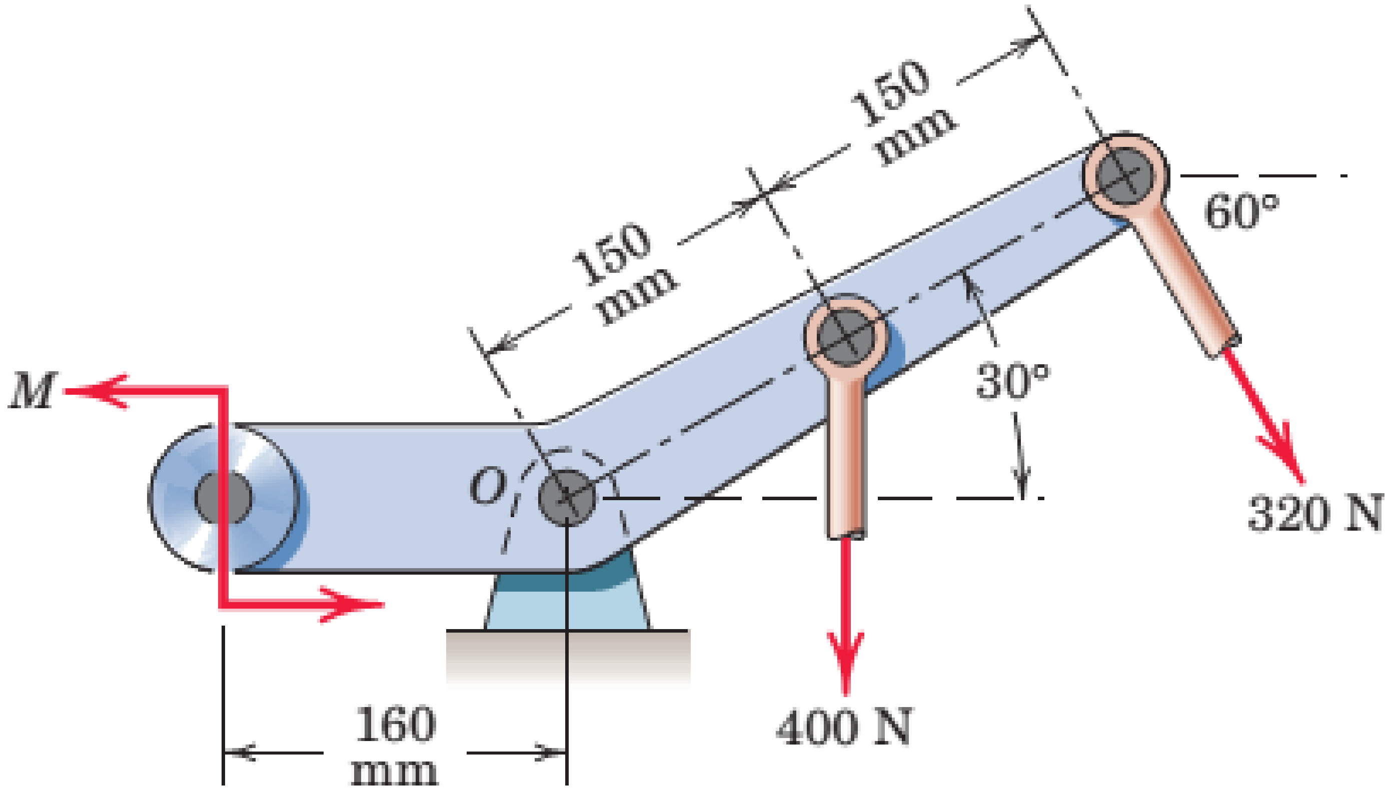
(a) Sketch the free-body diagram of the diving board.
(b) Determine the reactions at the supports A and B.



Static Equilibrium – Rigid Bodies

Example

Neglecting weight, determine *M* if the link is in equilibrium.



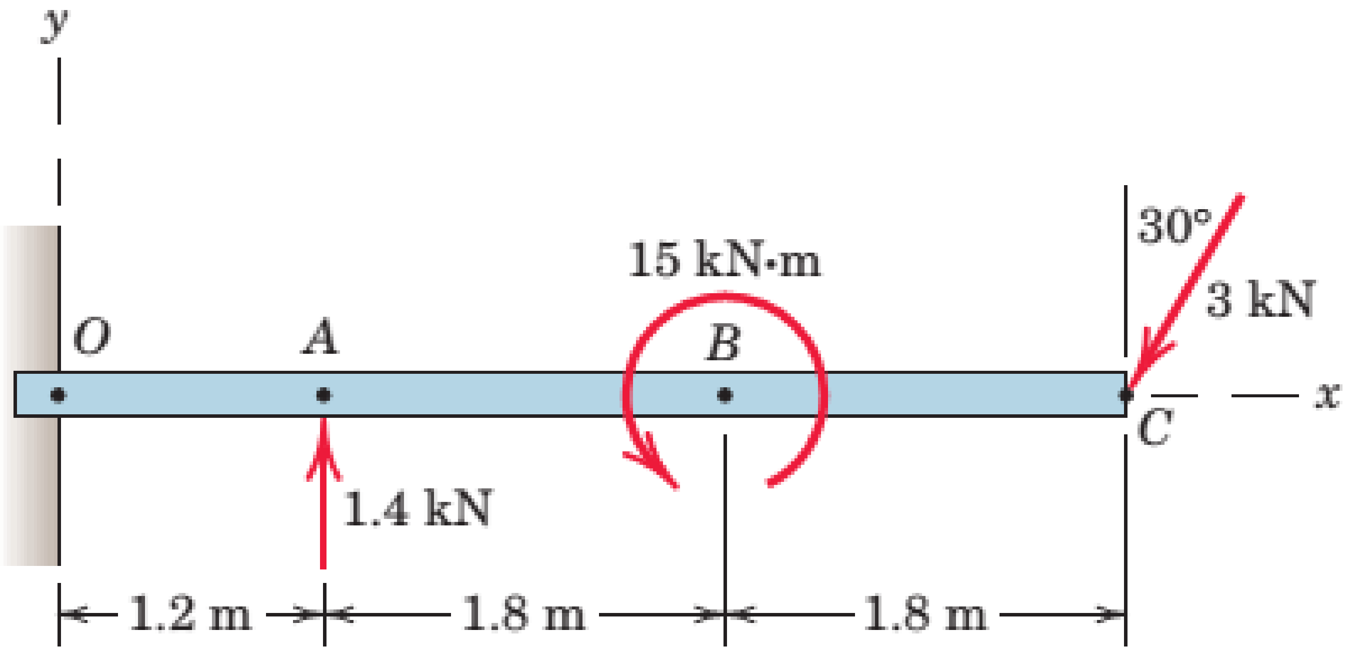
Ans:

M = 147.96 Nm

Static Equilibrium – Rigid Bodies

Example

The 500 kg uniform beam is subjected to the three external loads shown. Compute the reactions at the support point *O*.



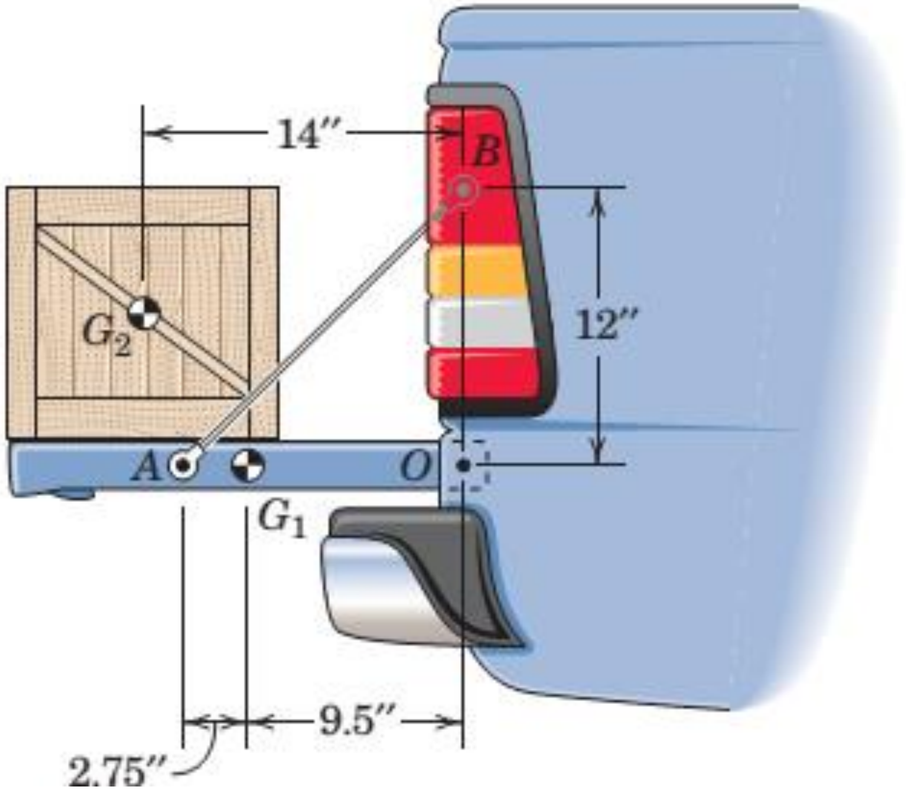
Ans:

F_x = 1.5 kN, F_y = -1.198 kN, M_O = 0.85 kNm (clockwise)

Static Equilibrium – Rigid Bodies

Example

A 150 N crate rests on the 100 N pickup tailgate as shown. Calculate the tension T in each of the two restraining cables, one of which is shown. The centres of gravity are at G_1 and G_2. Assume the crate is located midway between the two cables.



Static Equilibrium Applications:

Analysis of Planar Trusses and Frames

Analysis of Planar Trusses

- Engineering structures basically, are designed to support or transfer forces safely. They normally comprise of a number of structural elements of members connected to form a main structure.

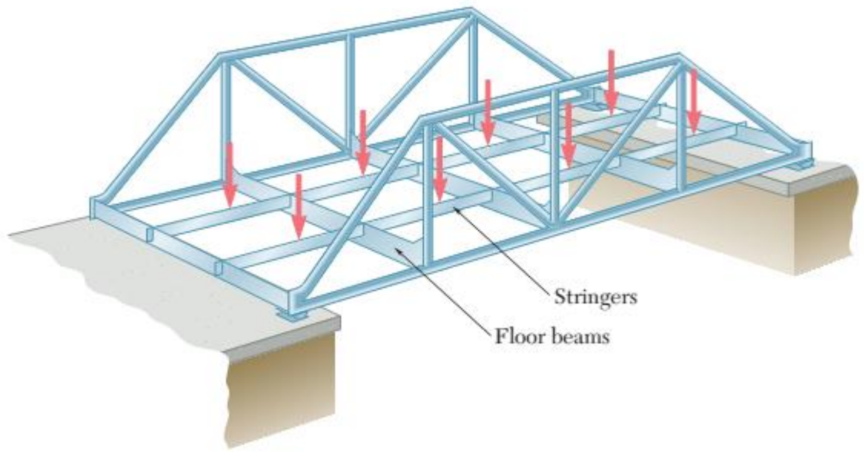
- Trusses are designed to transmit forces over long distances and comprise straight, **slender** bars that are joined to often form pattern of triangles.

- The loads on trusses are always applied at the joints, while in frames, loads may not necessarily be applied at the joints. Also, members of trusses are normally two force members, whereas in frames, at least one member is a sustains more than two forces.

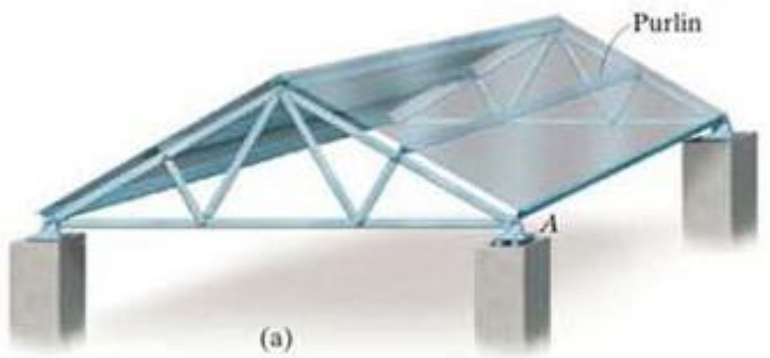
- In designing a structure, it is desirable to know the force each individual member must sustain.

Analysis of Planar Trusses

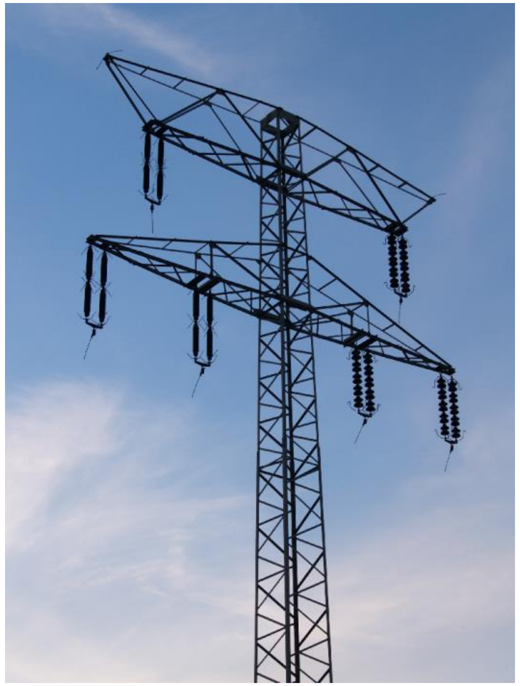
- Common applications are roofs, bridges and power pylons.



Bridge Truss
Source: Mechanics for Engineers by Beet *et al*



Roof Supporting Truss
Source: Engineering Mechanics Statics by Hiebbler

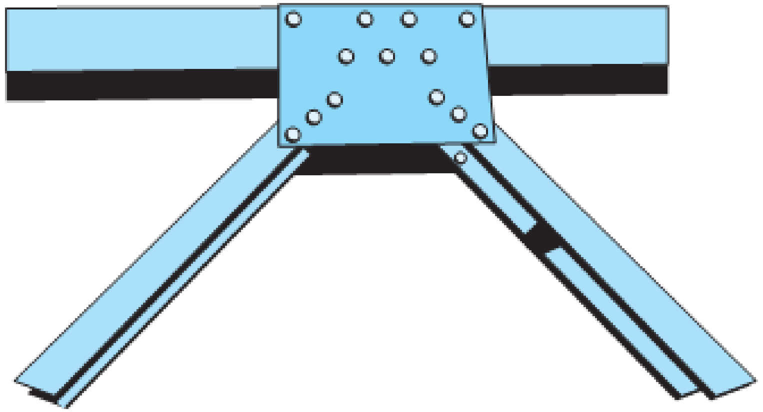


Power Pylon
Source: http://upload.wikimedia.org/wikipedia/commons/7/7e/Electricity_pylon_power_outage.jpg

Analysis of Planar Trusses

➢ **Assumptions:**

- The weights of the slender bars/members are negligible.
- Forces act at the ends of the members such that they are in either tension or compression.
- All joints are pins.



Truss members welded or riveted to a gusset plate
Source: Engineering Mechanics – Statics by Pytel

Analysis of Planar Trusses – Zero Force Members

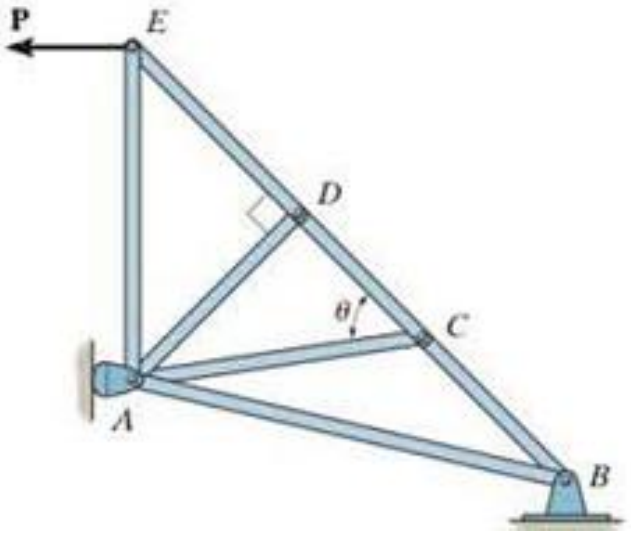
- It is possible that some members of a Truss do not experience any external forces. Such members are referred to as ***Zero Force Members.***

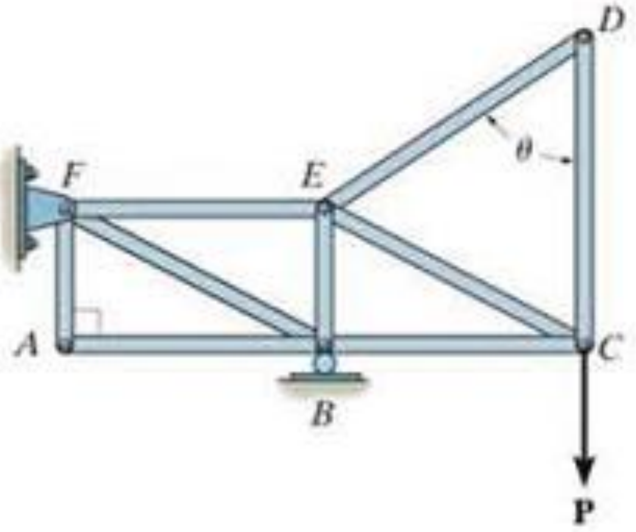
- Identifying of such members can significantly make analysis of planar trusses easier.

- Two rules of thumb for identifying such members are;

  1. *if* ***three members*** *form a truss joint and* ***two of the members are collinear****, the third member may be a zero force member provided no external force or support reaction is applied to that joint (See top right Figure).*

  2. *if a* ***joint*** *is formed by* ***only two members*** *and there is* ***no external load or support reactions at the joint****, then the two members may be zero force members (Bottom right Figure).*





Analysis of Planar Trusses – The Method of Joints

- This involves an equilibrium analysis on each joint to determine the forces being exerted on the end of each member at that joint.

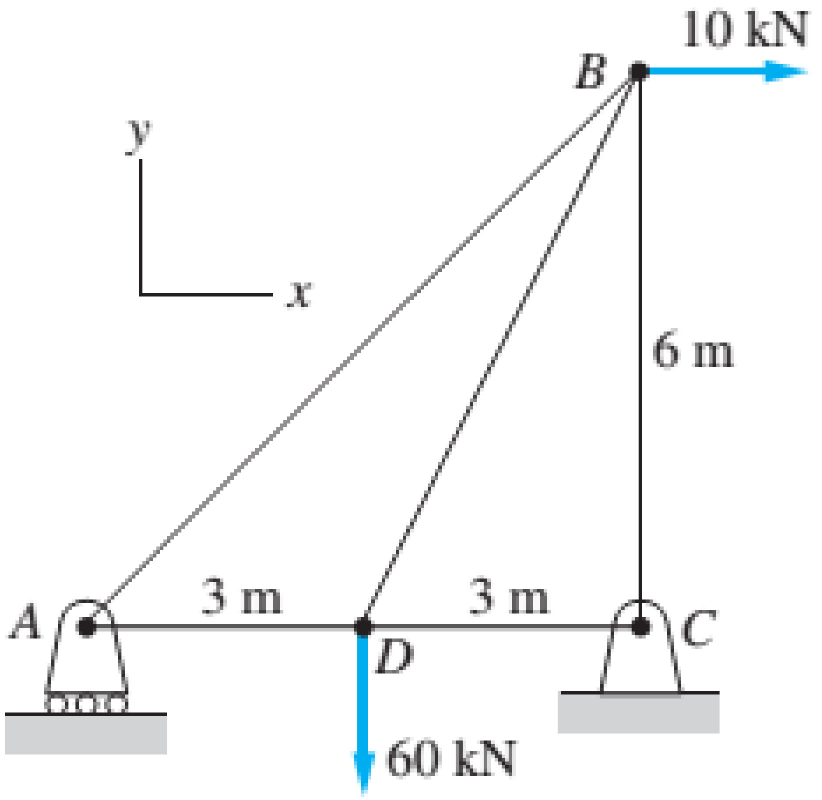
- It is based on the assumption that if the whole truss is in equilibrium, each of its members or joints are also in equilibrium.

- Analysis is done in two main steps:
  - Determine all support reactions on the entire truss.
  - Conduct an equilibrium analysis at each joint/pin to determine the forces in each member.

Analysis of Planar Trusses

Example

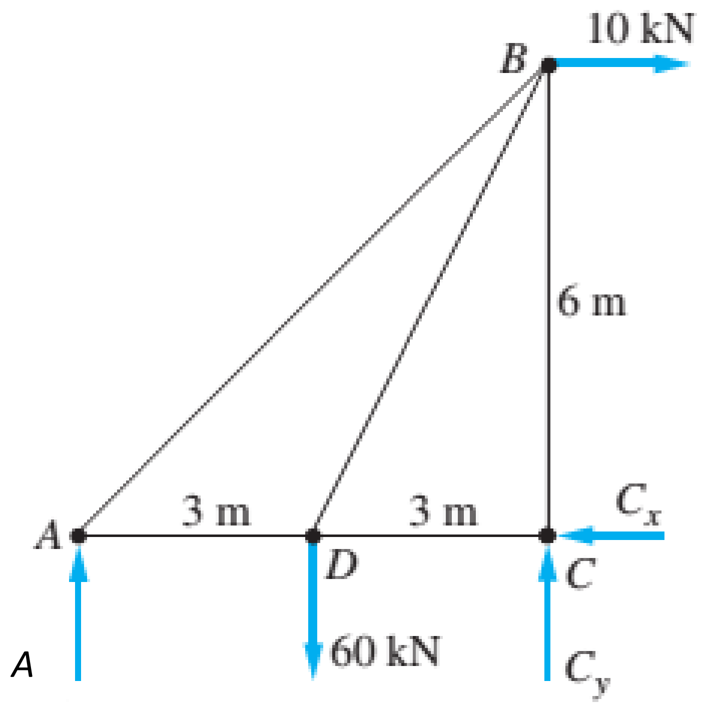
Determine the force in each member of the truss shown below using the method of joints. Indicate whether each member is in tension or compression



Analysis of Planar Trusses

Example

Equilibrium analysis of the whole structure to determine support reactions



For equilibrium,

$$+\rightarrow \sum F_x = 0: -C_x + 10\text{ kN} = 0$$

$$+\uparrow \sum F_y = 0: C_y + A - 60\text{ kN} = 0$$

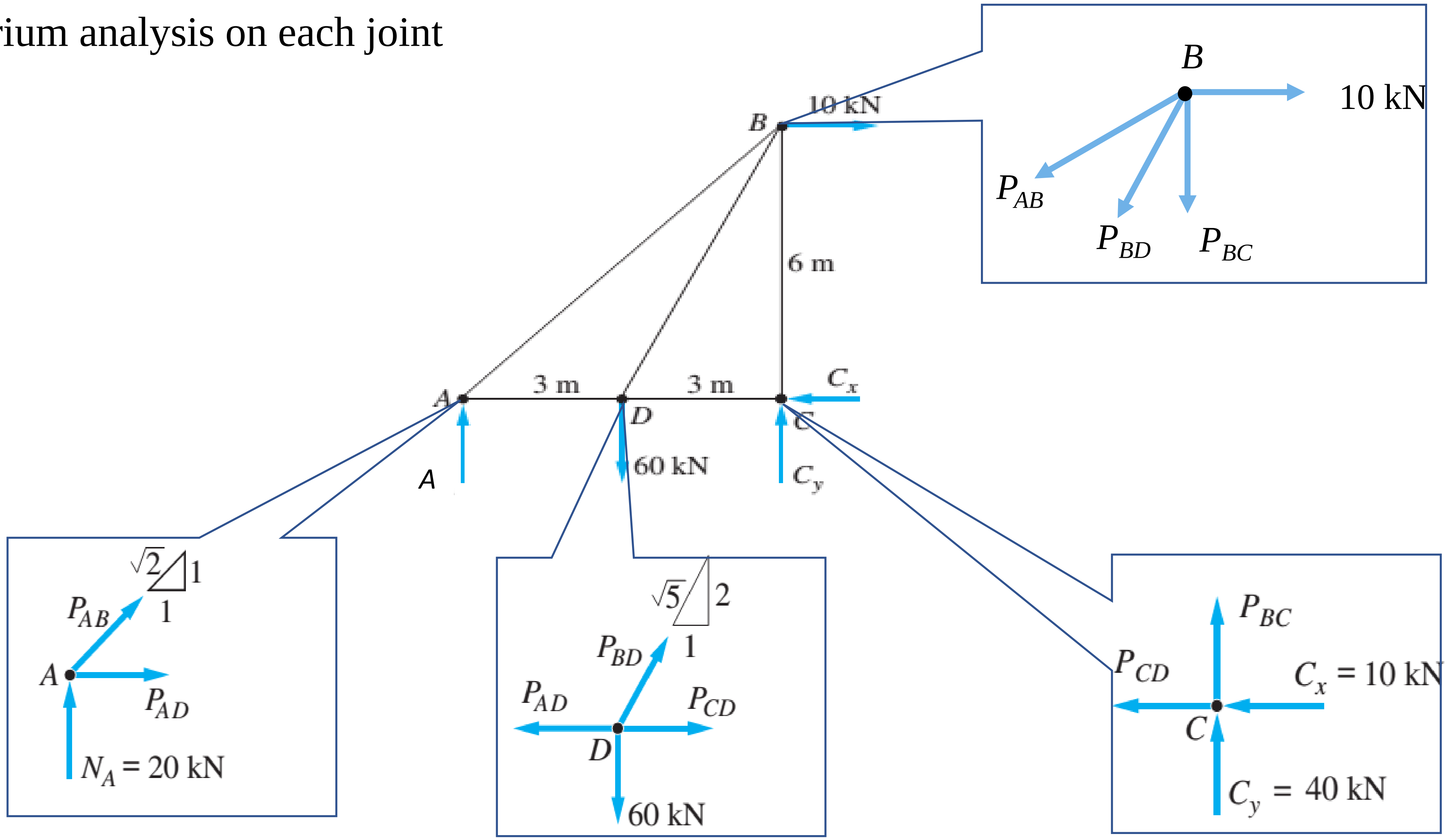
$$\circlearrowleft + \sum M_C = 0: A(6\text{ m}) + (10\text{ kN})(6\text{ m}) - (60\text{ kN})(3\text{ m}) = 0$$

$$A = 20\text{ kN}$$

$$\therefore C_y = 40\text{ kN}$$

Analysis of Planar Trusses

Equilibrium analysis on each joint

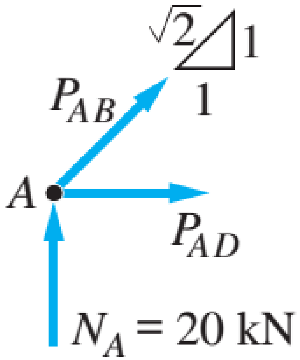


Analysis of Planar Trusses

- Solution

Equilibrium analysis on the joints

Joint A



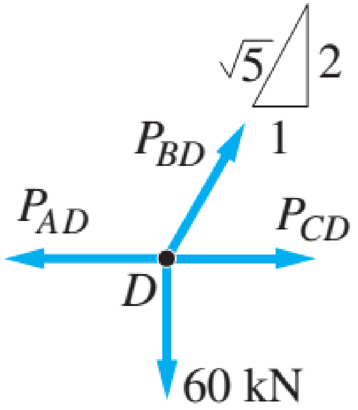
For equilibrium,

$$+\rightarrow \sum F_x = 0 : P_{AD} + \frac{1}{\sqrt{2}} P_{AB} = 0 \qquad \text{-----} \ (1)$$

$$+\uparrow \sum F_y = 0 : 20\ \text{kN} + \frac{1}{\sqrt{2}} P_{AB} = 0 \qquad \text{------}(2)$$

$P_{AB} = -28.3\ \text{kN (Compression)}$ $\qquad P_{AD} = 20\ \text{kN (Tension)}$

Joint D



For equilibrium,

$$+\rightarrow \sum F_x = 0 : -P_{AD} + \frac{1}{\sqrt{5}} P_{BD} + P_{CD} = 0 \qquad \text{-----} \ (1)$$

$$+\uparrow \sum F_y = 0 : -60\ \text{kN} + \frac{2}{\sqrt{5}} P_{BD} = 0 \qquad \text{------}(2)$$

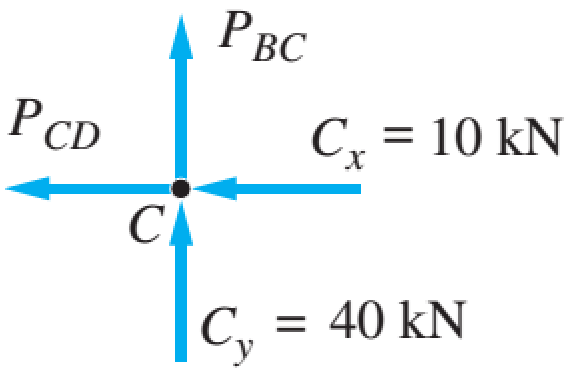
$P_{BD} = 67.1\ \text{kN (Tension)}$ $\qquad P_{CD} = -10\ \text{kN (Compression)}$

Analysis of Planar Trusses

- Solution

Equilibrium analysis on the joints

Joint C



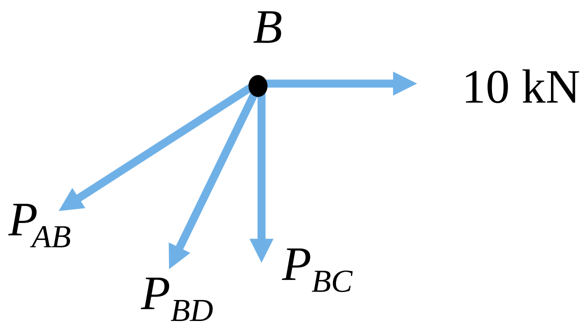
For equilibrium,

$$+\rightarrow \sum F_x = 0: -P_{CD} - 10\text{ kN} = 0 \qquad \text{-----} \ (1)$$

$$+\uparrow \sum F_y = 0: 40\text{ kN} + P_{BC} = 0 \qquad \text{------} (2)$$

$$P_{BC} = -40\text{ kN (Compression)}$$

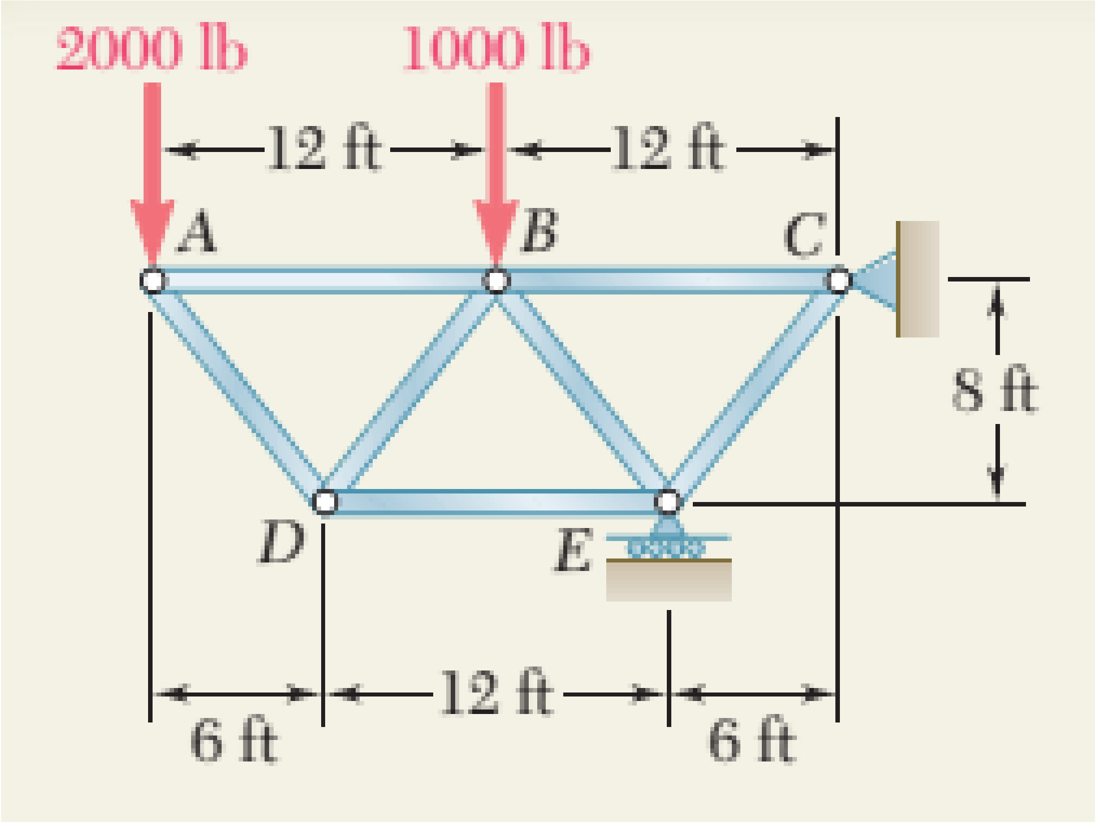
Joint B



Analysis of Planar Trusses

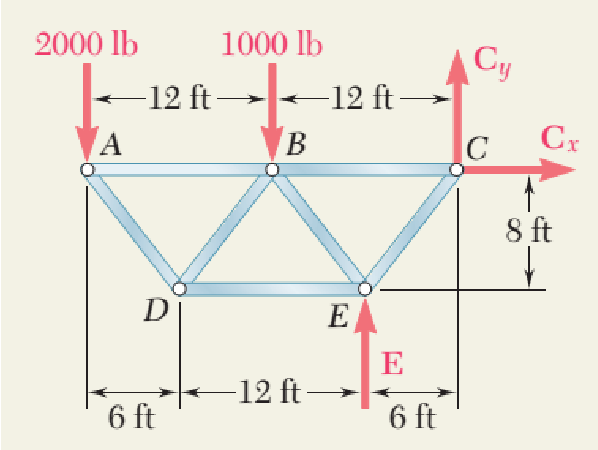
- Example

Determine the force in each member of the truss shown below using the method of joints.



Analysis of Planar Trusses

- Solution
  - Equilibrium analysis on the entire truss to determine the support reactions



For equilibrium,

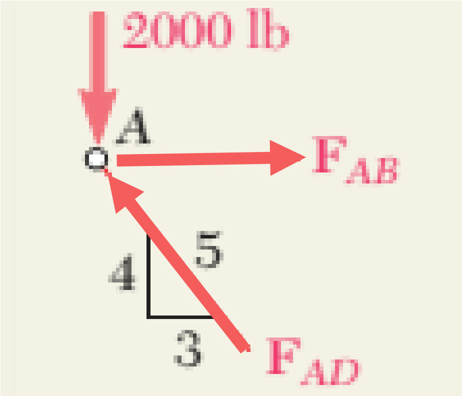
$$+\rightarrow \sum F_x = 0 : C_x = 0$$

$$+\uparrow \sum F_y = 0 : C_y + E = 3000\,\text{lb}$$

$$\sum M_C = 0 : (6\,\text{ft})E - (2000\,\text{lb})(24\,\text{ft}) - (1000\,\text{lb})(12\,\text{ft}) = 0$$

$$E = 10000\,\text{lb}\uparrow$$

  - Equilibrium analysis on the individual joints



For equilibrium,

$$+\rightarrow \sum F_x = 0 : F_{AB} - \frac{3}{5}F_{AD} = 0 \qquad ----(1)$$

$$+\uparrow \sum F_y = 0 : \frac{4}{5}F_{AD} - 2000\,\text{lb} = 0 \qquad ----(2)$$

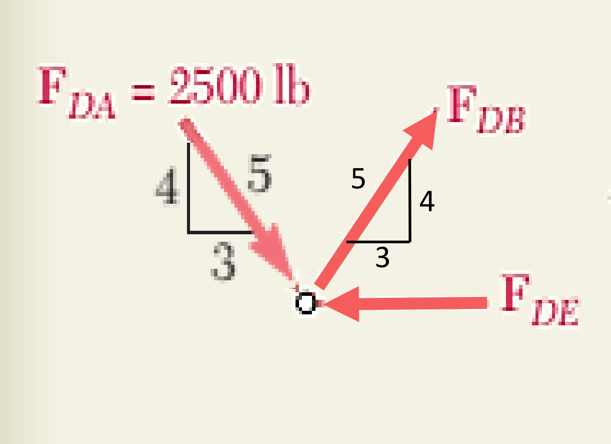
Solving (1) and (2) simultaneously,

$F_{AD} = 2500\,\text{lb} \qquad F_{AB} = 1500\,\text{lb}$

Analysis of Planar Trusses - The Method of Joints

➢Solution

Joint D



For equilibrium,

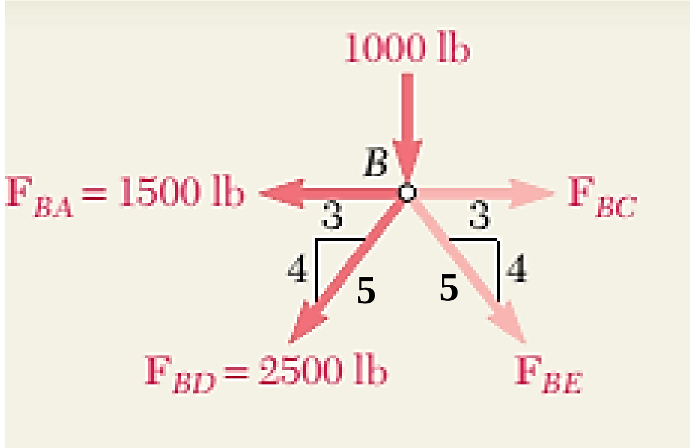
$$+\rightarrow \sum F_x = 0: \frac{3}{5}(2500\,\text{lb}) - F_{DE} + \frac{3}{5}F_{DB} = 0 \qquad ----(1)$$

$$+\uparrow \sum F_y = 0: \frac{4}{5}F_{DB} - \frac{4}{5}(2000\,\text{lb}) = 0 \qquad ----(2)$$

Solving (1) and (2) simultaneously,

$F_{DB} = 2500\,\text{lb} \qquad F_{DE} = 3000\,\text{lb}$

Joint B



For equilibrium,

$$+\rightarrow \sum F_x = 0: -\frac{3}{5}(2500\,\text{lb}) - 1500\,\text{lb} + F_{BC} + \frac{3}{5}F_{BE} = 0 \qquad ----(1)$$

$$+\uparrow \sum F_y = 0: -1000\,\text{lb} - \frac{4}{5}(2000\,\text{lb}) - \frac{4}{5}F_{BE} = 0 \qquad ----(2)$$

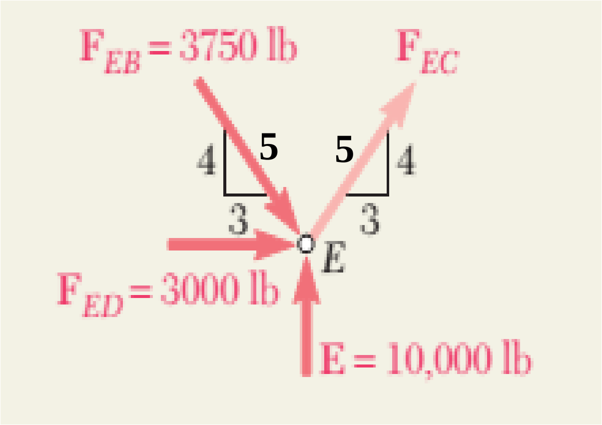
Solving (1) and (2) simultaneously,

$F_{BE} = 3750\,\text{lb} \qquad F_{BC} = 5250\,\text{lb}$

Analysis of Planar Trusses - The Method of Joints

➢ Solution

Joint E



For equilibrium,

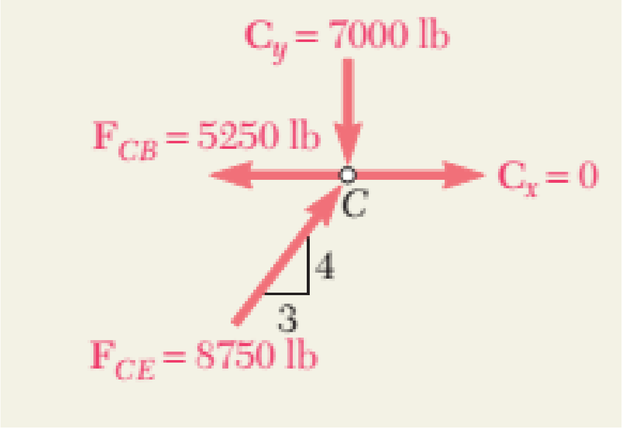
$$+\rightarrow \sum F_x = 0: \frac{3}{5}(3750\text{ lb}) + 3000\text{ lb} + \frac{3}{5}F_{EC} = 0 \qquad \text{----}(1)$$

$$+\uparrow \sum F_y = 0: -\frac{4}{5}(3750\text{ lb}) + \frac{4}{5}F_{EC} + 10000\text{ lb} = 0 \qquad \text{----}(2)$$

Solving (1) and (2) simultaneously,

$$F_{DB} = 2500\text{ lb} \qquad F_{DE} = 3000\text{ lb}$$

Joint C



For equilibrium,

$$+\rightarrow \sum F_x = 0: \frac{3}{5}(8750\text{ lb}) - 5250\text{ lb} + 0 = 0$$

$$+\uparrow \sum F_y = 0: -7000\text{ lb} - \frac{4}{5}(8750\text{ lb}) = 0$$

Analysis of Planar Trusses – The Method of Sections

- This method is useful if it is desired to find the forces in only a few members.

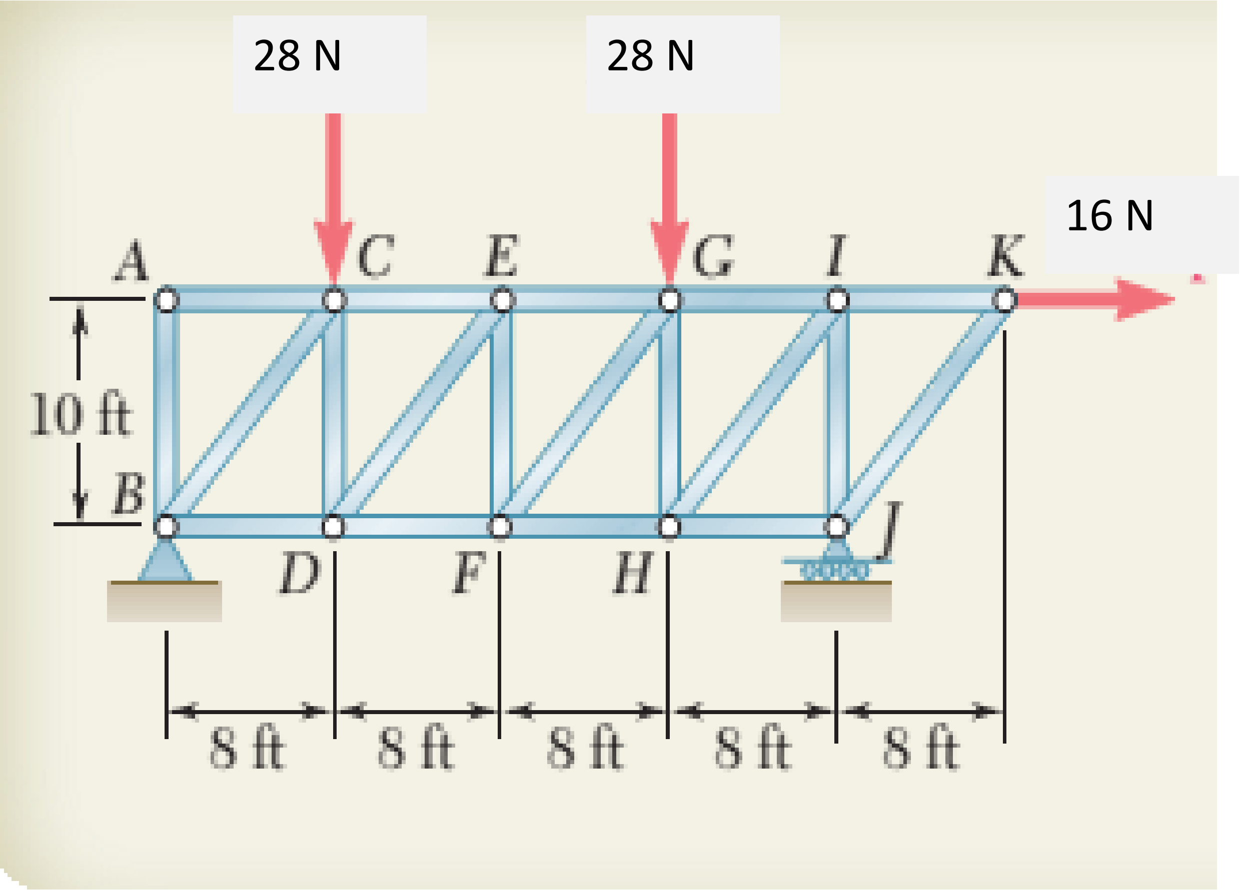
- It is based on the assumption that if the whole truss is in equilibrium, any section of it must also be in equilibrium.

- Analysis in the following steps:
  - Perform an equilibrium analysis to determine all support reactions on the truss.
  - Draw a line which divides the truss into two separate portions, intersecting the member of interest in the process.
  - Perform an equilibrium analysis on one of the sections to determine the force on the member of interest.

Analysis of Planar Trusses

➢Example

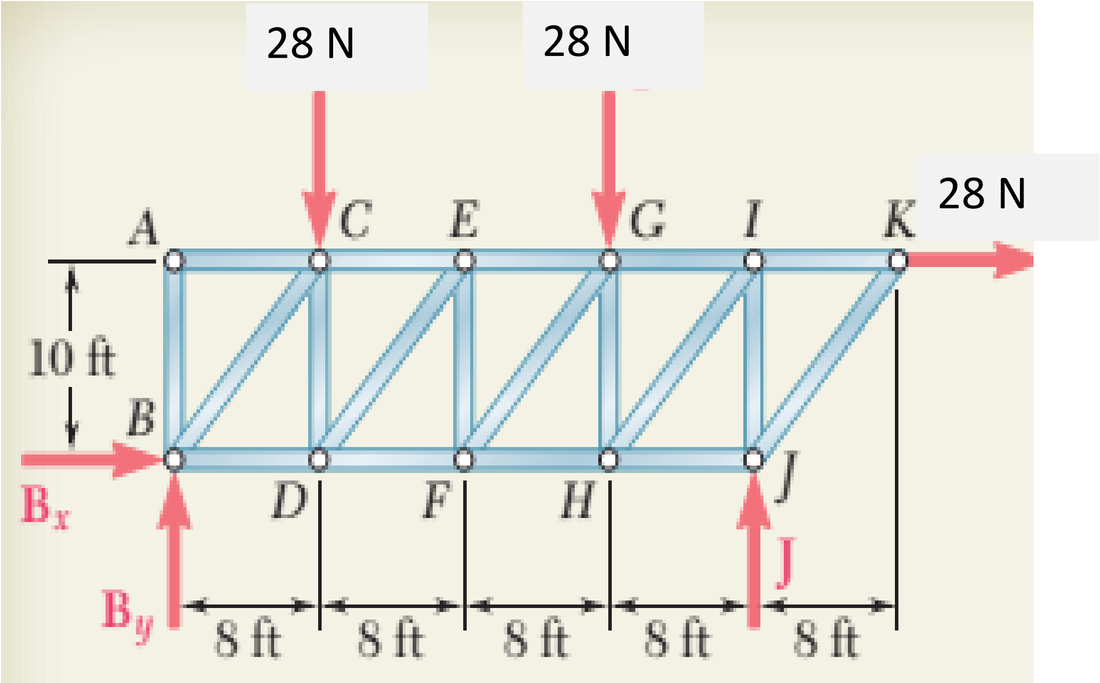
Determine the force in members *EF* and *GI* of the truss shown



Analysis of Planar Trusses

➢Example Solution

Equilibrium analysis on the whole truss to determine support reactions.



For equilibrium,

$$+\rightarrow\sum F_x = 0: B_x + 16\text{ N} = 0$$

$$+\uparrow\sum F_y = 0: B_y + J - 28\text{ N} - 28\text{ N} = 0$$

$$\circlearrowleft + \sum M_B = 0: 28\text{ N}(8\text{ ft}) + 28\text{ N}(24\text{ ft}) + 16\text{ N}(10\text{ ft}) - J(32\text{ ft}) = 0$$

$$J = 33\text{ N}$$

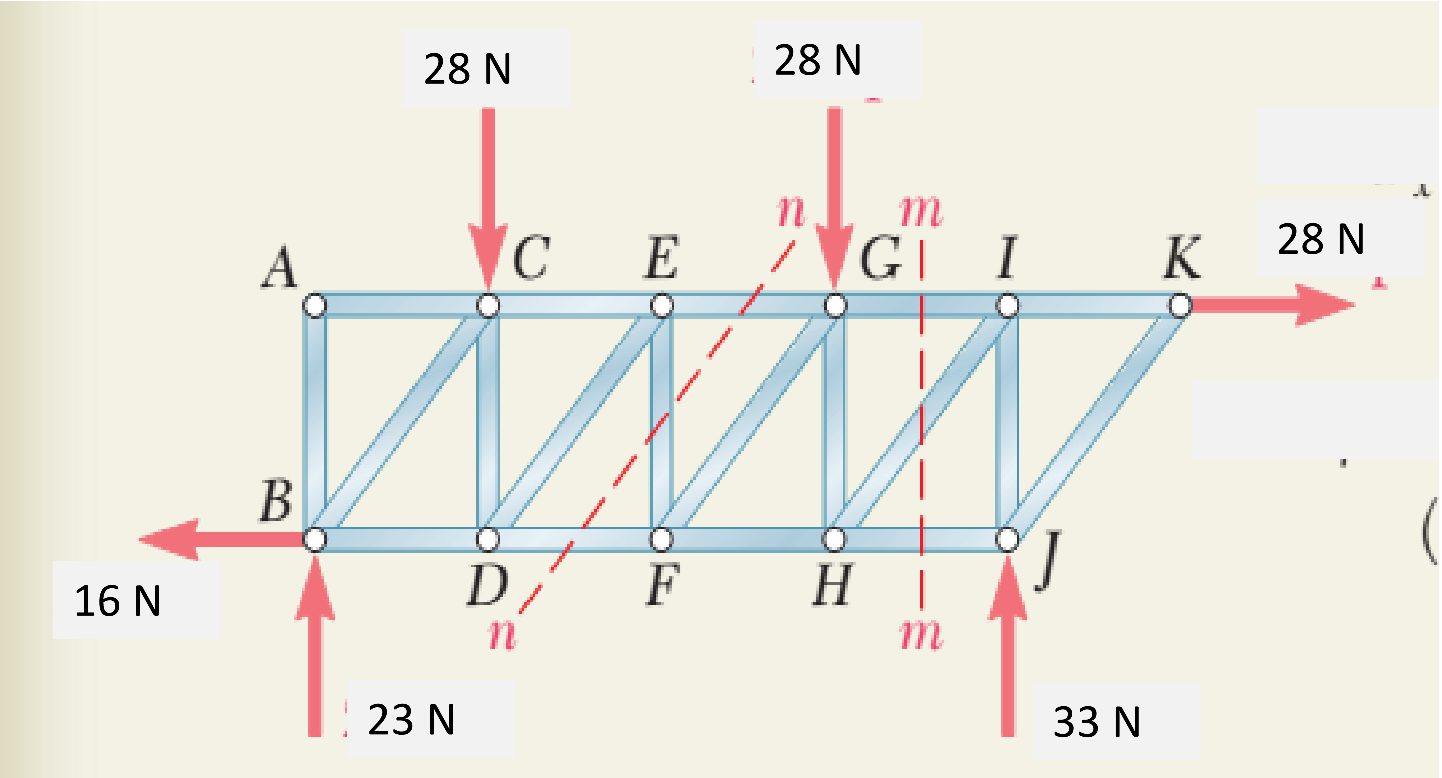
$$B_x = -16\text{ N}$$

$$B_y = 23\text{ N}$$

Analysis of Planar Trusses

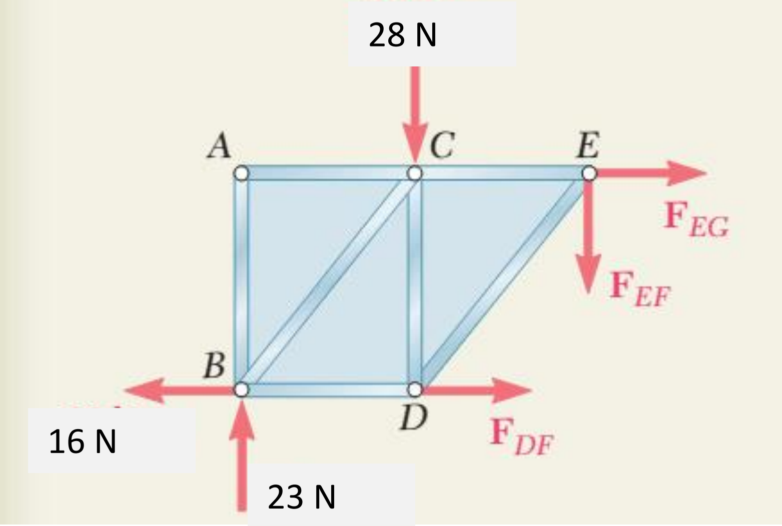
Example - Solution

Dividing the truss into two with line *nn* (to solve for member *EF*), then with *mm* (to solve for *GI*)



Analysis of Planar Trusses - The Method of Sections

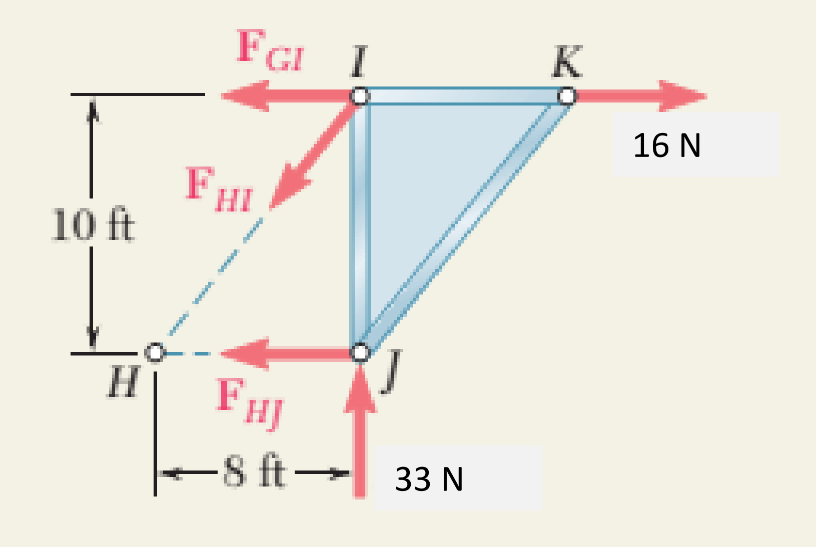
➢Example - Solution



Performing an equilibrium analysis on the left side of *nn* to obtain *EF*,

$$+\uparrow \sum F_y = 0: 23\text{ N} - 28\text{ N} - F_{EF} = 0$$

$$F_{EF} = -5\text{ N}$$



Performing an equilibrium analysis on the right side of *mm* to obtain *GI*,

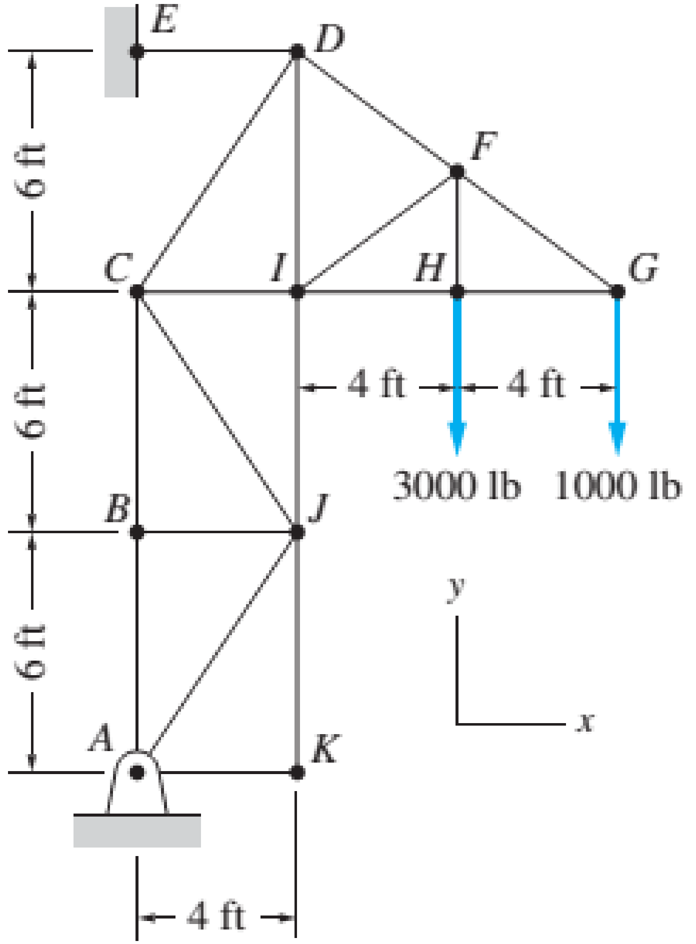
$$\circlearrowleft+ \sum M_H = 0: -F_{GI}(10\text{ ft}) - 33\text{ N}(8\text{ ft}) + 16\text{ N}(10\text{ ft}) = 0$$

$$F_{GI} = -10.4\text{ N}$$

Analysis of Planar Trusses

➢Example

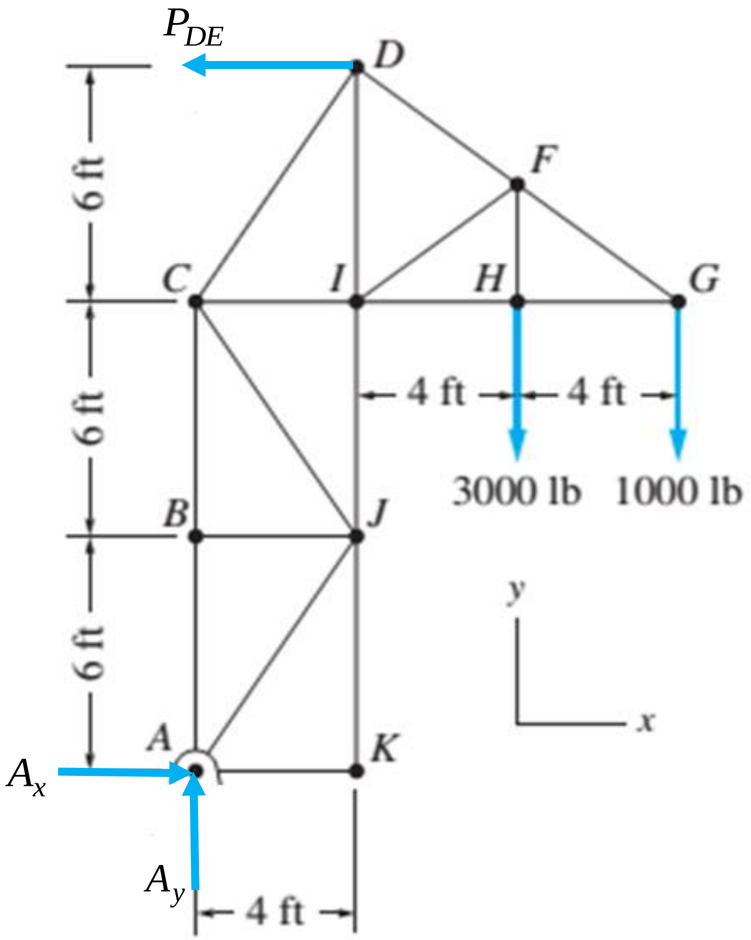
Determine the forces in members *FI* and *JC* of the truss shown. Indicate tension or compression.



Analysis of Planar Trusses - The Method of Sections

Example - Solution

Equilibrium analysis on the whole truss to determine support reactions gives.



$$P_{DE} = 2000\,\text{lb}$$

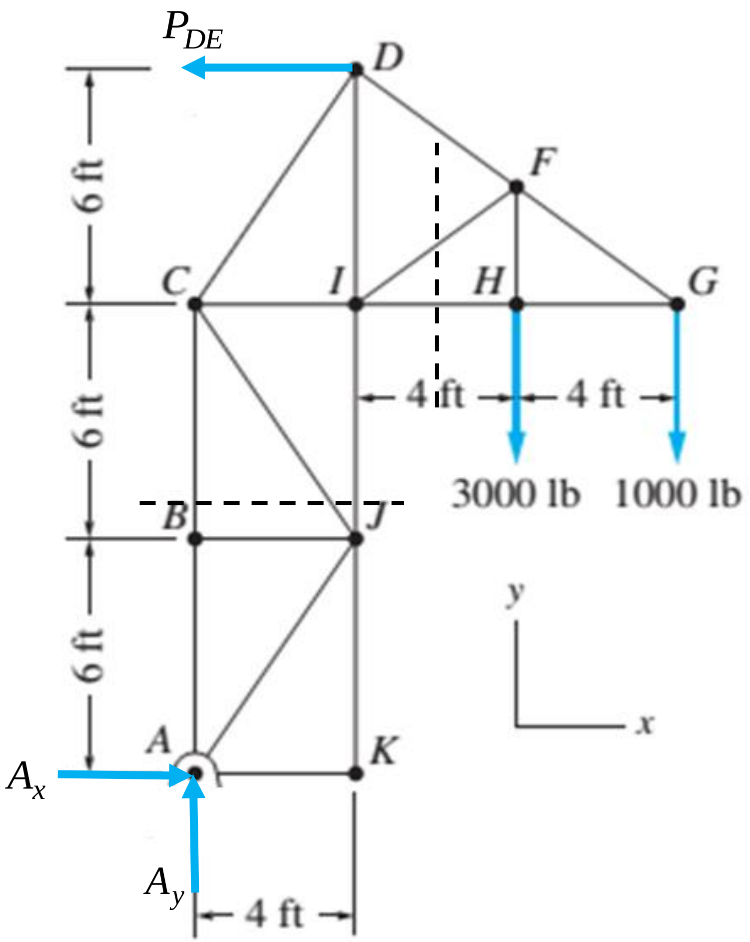
$$A_x = 2000\,\text{lb}$$

$$A_y = 4000\,\text{lb}$$

Analysis of Planar Trusses

- Example - Solution

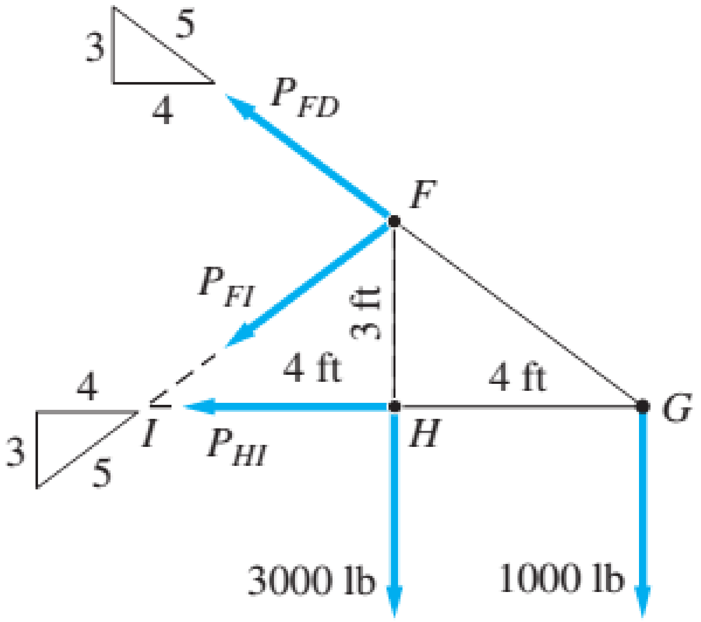
The truss is divided into 2 tie lines so *FI* and *JC* can be determined.



Analysis of Planar Trusses

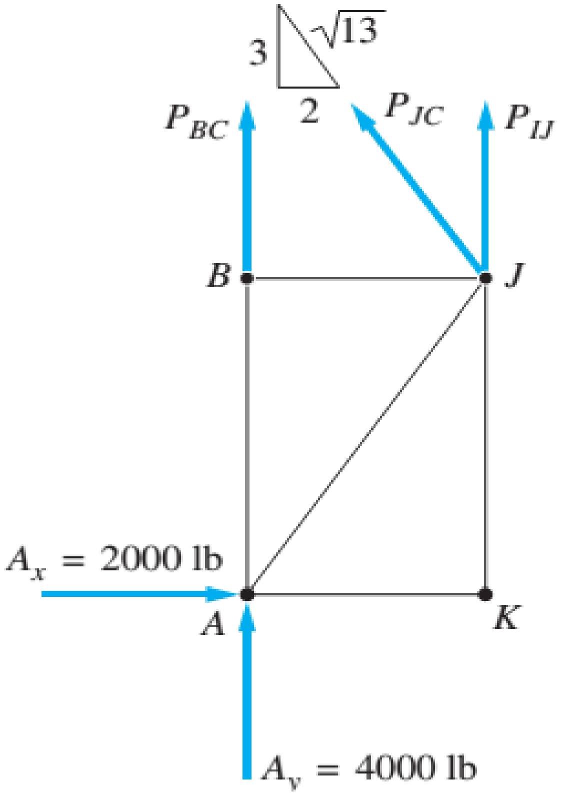
- Example - Solution

For *FI*



$$P_{FI} = -2500\,\text{lb}$$

For *JC*



$$P_{JC} = -3610\,\text{lb}$$

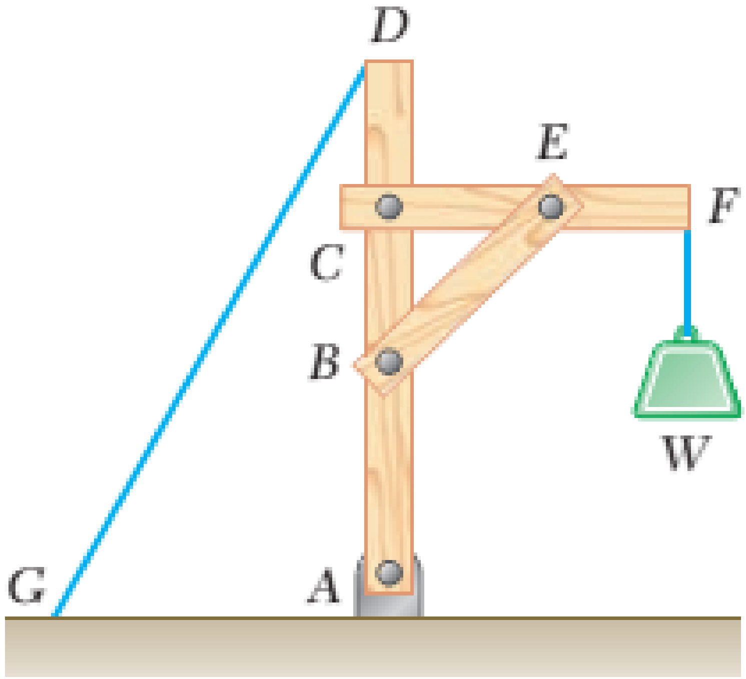
Analysis of Planar Frames

- Frames and Machines are structures in which at least one member is acted upon by at least three or more forces member.

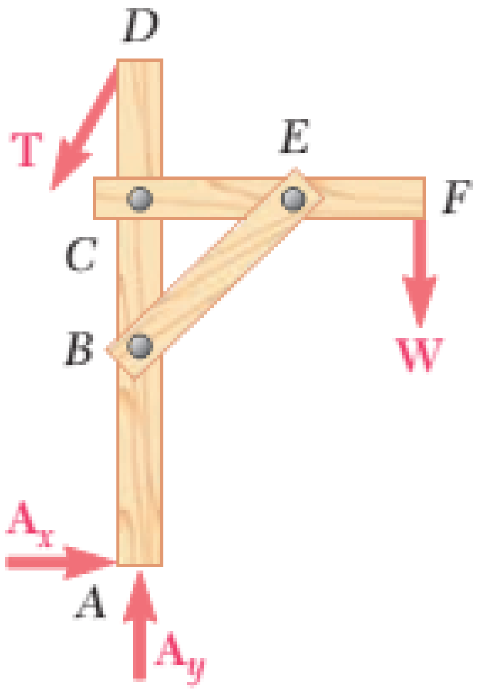
- In addition, forces can act on any point of a frame member (not just the ends)

- Analysis procedure is similar to what is used in trusses;
  - An equilibrium analysis is first carried out on the entire structure.
  - An equilibrium analysis is then carried out on the individual members of the frame to determine all forces acting on each of them (It is sometimes easier if this is done first on the two force, then three force members).

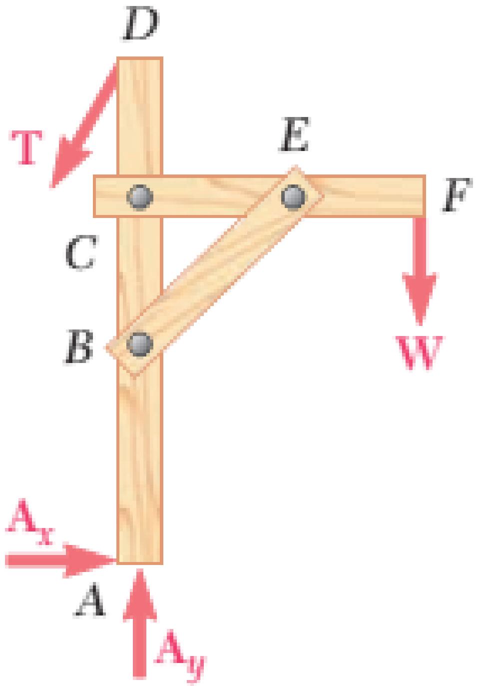
Analysis of Planar Frames



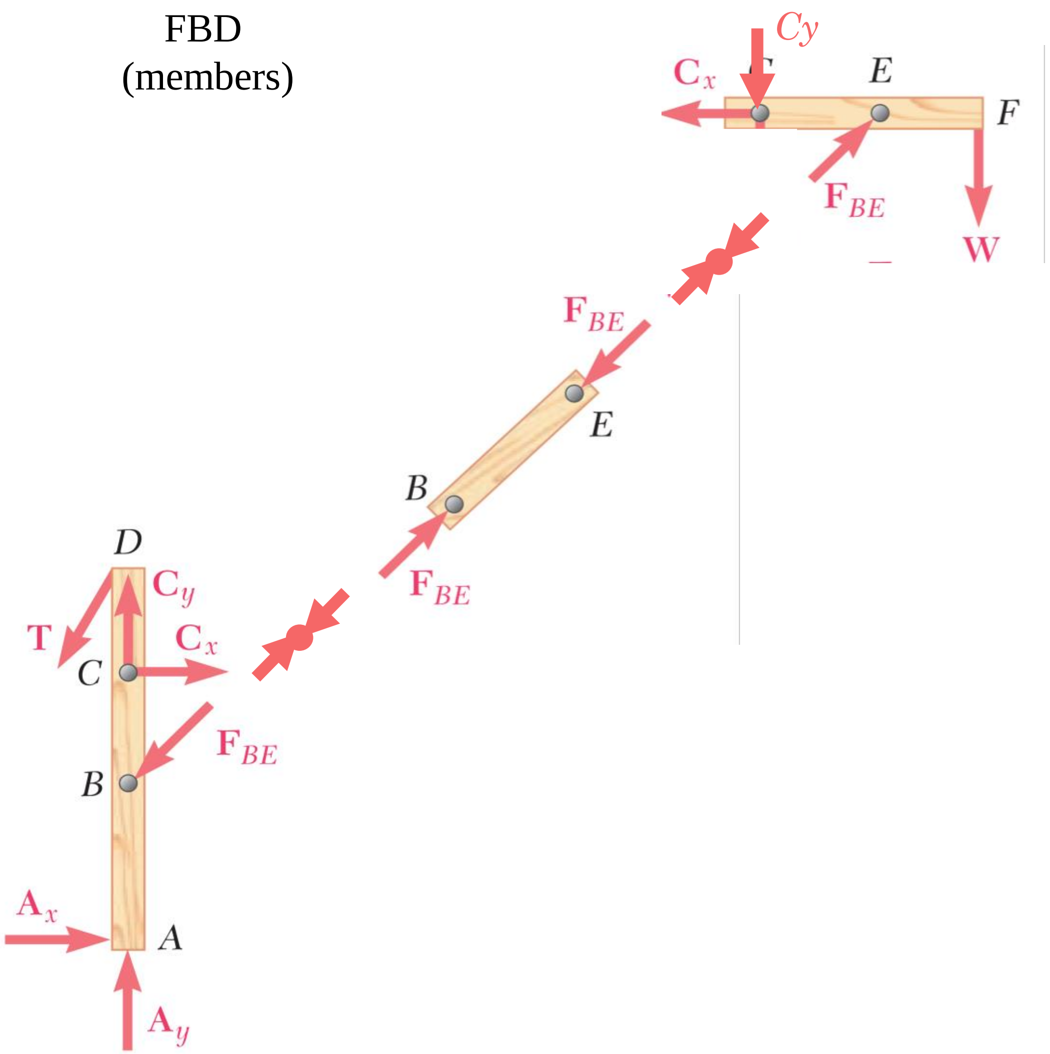
FBD
(entire structure)



Analysis of Planar Frames



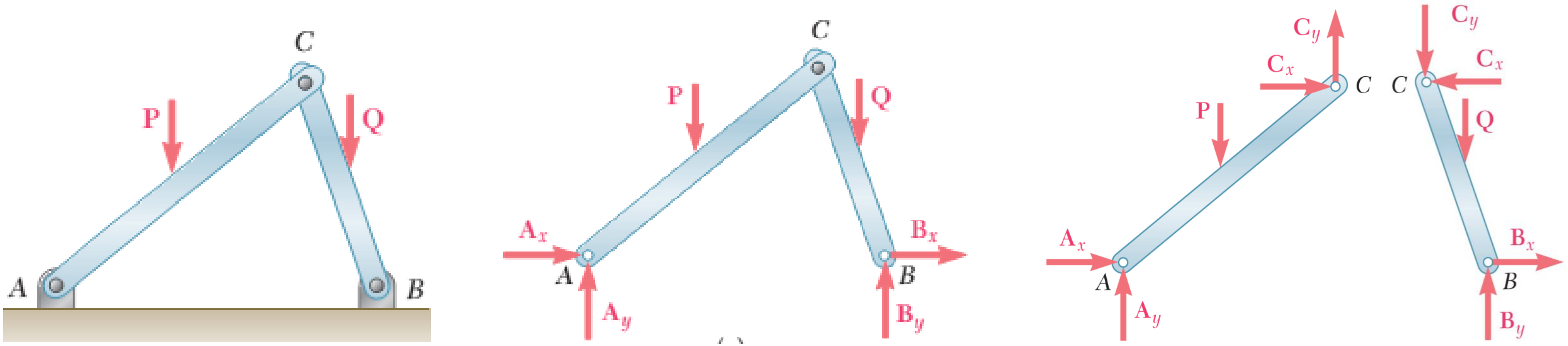
FBD
(members)



Analysis of Planar Frames

Analysis of Frames

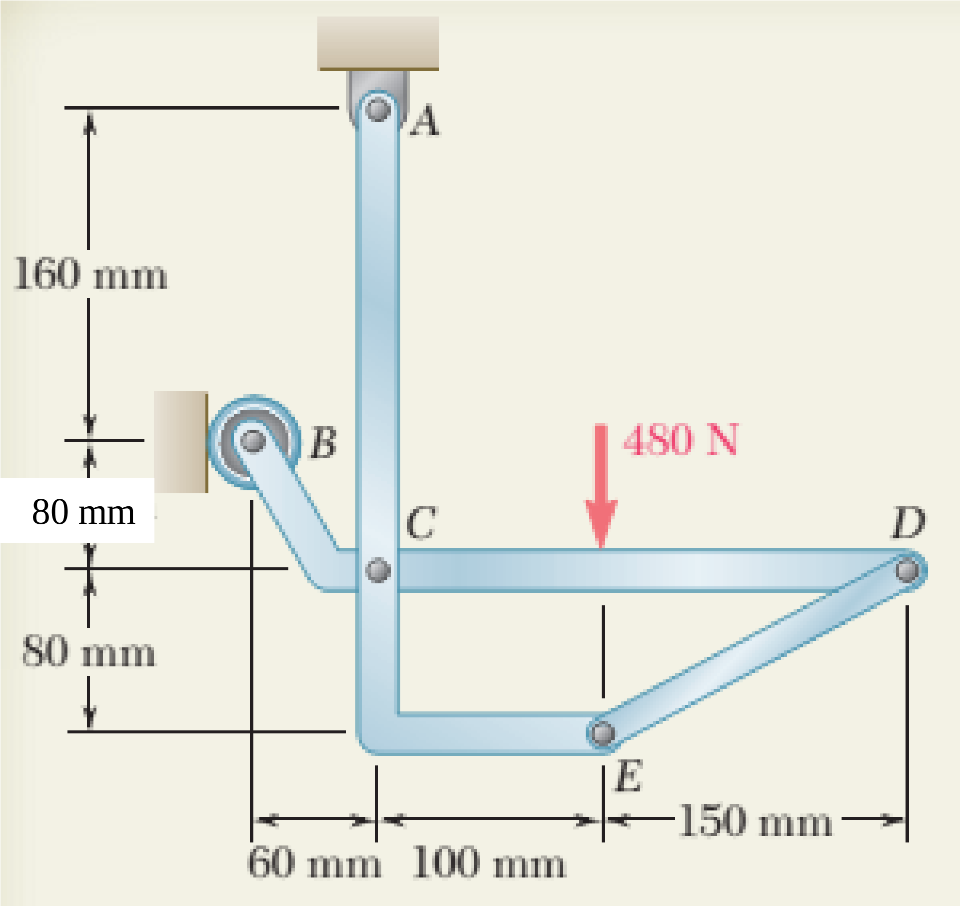
➢ During analysis of non-rigid frames, the individual members of frame are considered as rigid members.



Analysis of Planar Frames

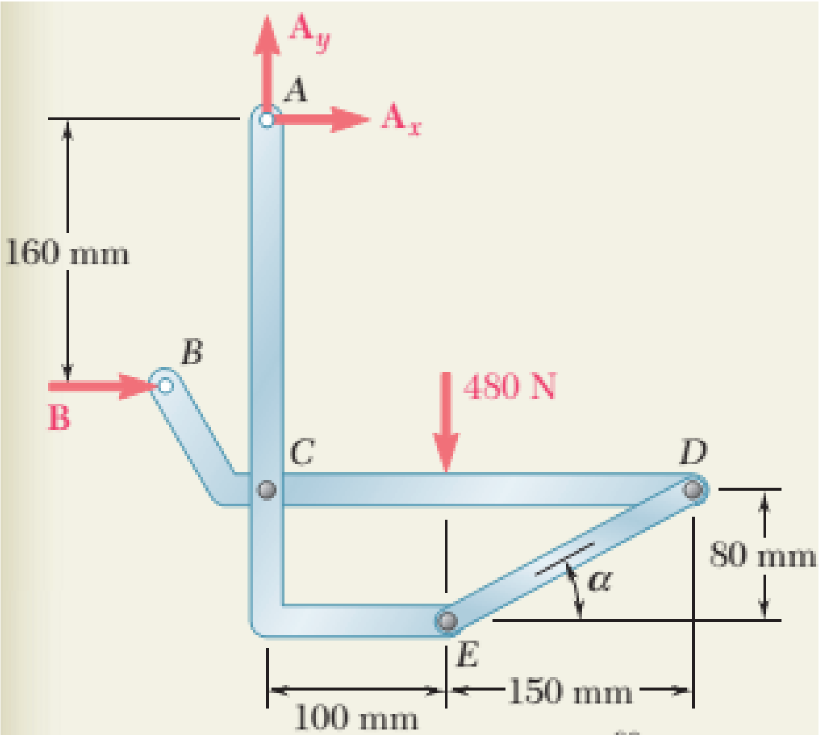
➢Example

In the frame shown, members *ACE* and *BCD* are connected by a pin at *C* and by the link *DE*. For the loading shown, determine the force in link *DE* and the components of the force exerted at *C* on member *BCD*. Is link *DE* tension or compression?



Analysis of Planar Frames

Equilibrium analysis on the entire structure



For equilibrium,

$$\xrightarrow{+} \sum F_x = 0: B + A_x = 0$$

$$+\uparrow \sum F_y = 0: A_y = 480\text{ N}$$

$$\circlearrowleft + \sum M_A = 0: -B(160\text{ mm}) + 480\text{ N}(100\text{ mm}) = 0$$

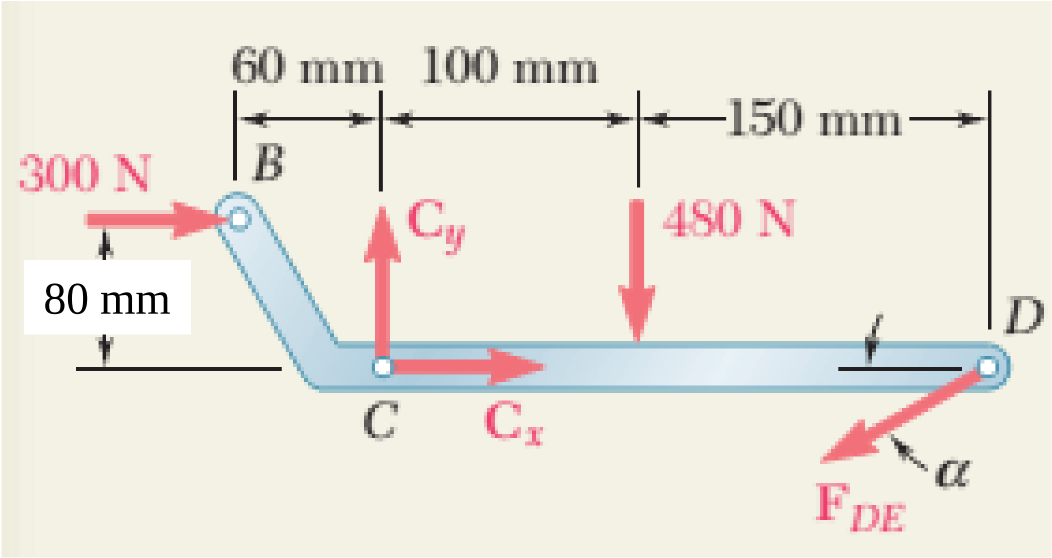
$$B = 300\text{ N}$$

So,

$$A_x = -300\text{ N}$$

Analysis of Planar Frames

Example – Solution (Equilibrium analysis on individual links)



For equilibrium,

$$+\rightarrow\sum F_x = 0: 300\ \mathrm{N} + C_x - F_{DEx} = 0$$

$$+\uparrow\sum F_y = 0: C_y - 480\ \mathrm{N} - F_{DEy} = 0$$

$$\circlearrowleft + \sum M_C = 0: 300\ \mathrm{N}(80\ \mathrm{mm}) + 480\ \mathrm{N}(100\ \mathrm{mm}) + F_{DEy}(250\ \mathrm{mm}) = 0$$

$$F_{DEy} = -288\ \mathrm{N} \qquad C_y = -192\ \mathrm{N}$$

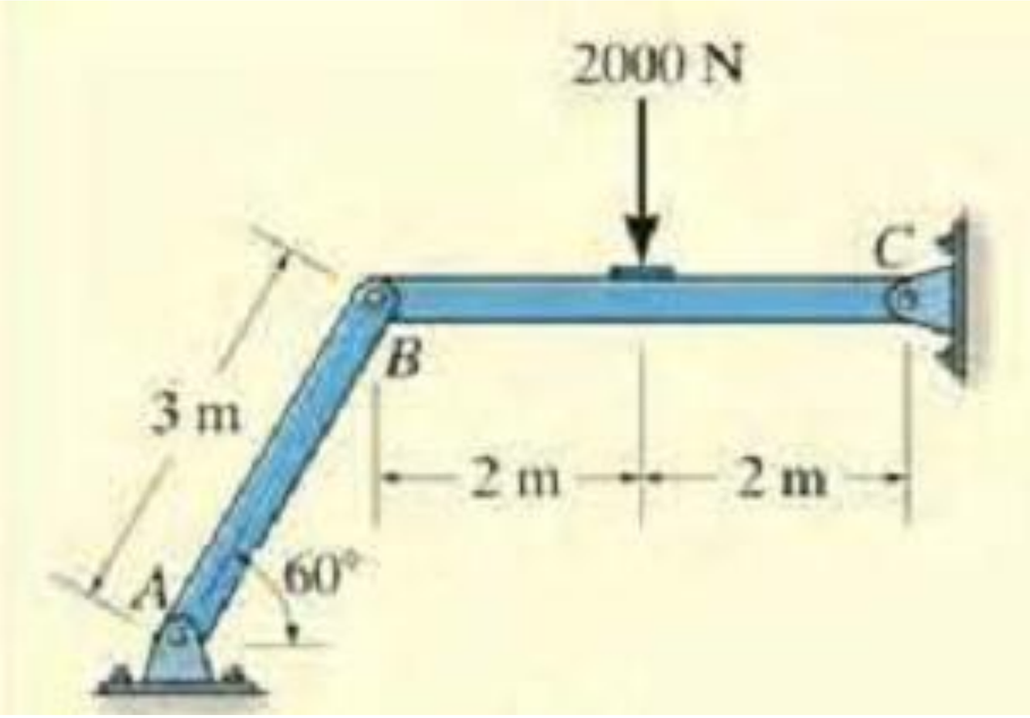
$$\alpha = \tan^{-1}\left(\frac{80}{150}\right)$$

$$F_{DE} = -612\ \mathrm{N} \qquad F_{DEx} = -\ \mathrm{N} \qquad C_x = -\ \mathrm{N}$$

Analysis of Planar Frames

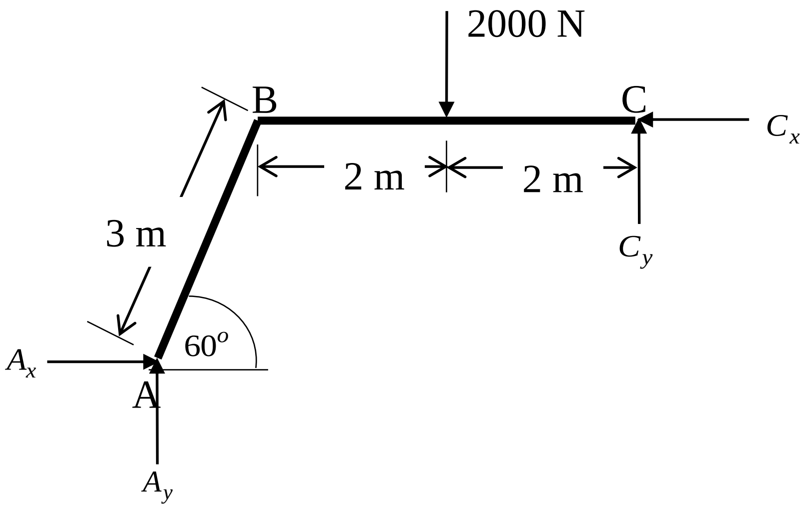
- Example

Determine the horizontal and vertical components of the force which the pin at *C* exerts on member *BC* of the frame shown below. Also determine the forces acting on both members at *B*



Analysis of Planar Frames

- Example - Solution



For equilibrium,

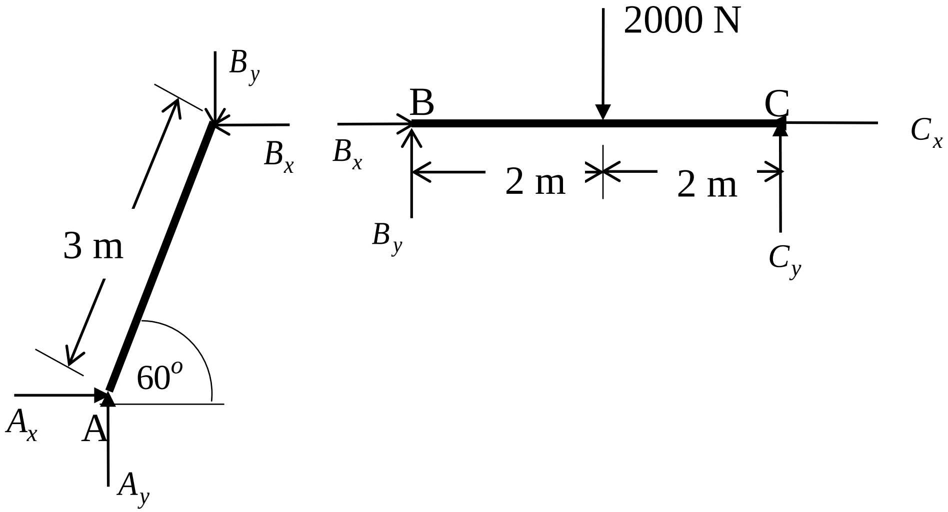
$$+\rightarrow \sum F_x = 0: A_x - C_x = 0$$

$$+\uparrow \sum F_y = 0: A_y + C_y - 2000\text{ N} = 0$$

$$\circlearrowleft + \sum M_C = 0: -A_y(4 + 3\cos 60^o) + A_x(3\sin 60^o) + 2000\text{ N}(2\text{ m}) = 0$$

$$\circlearrowleft + \sum M_A = 0: -C_y(4 + 3\cos 60^o)\text{m} + C_x(3\sin 60^o)\text{m} + 2000\text{ N}(2 + 3\cos 60^o)\text{m} = 0$$

$$A_x = C_x = 577\text{ N} \qquad A_y = C_y = 1000\text{ N}$$



Taking member BC, for equilibrium,

$$+\rightarrow \sum F_x = 0: B_x - C_x = 0$$

$$+\uparrow \sum F_y = 0: B_y + C_y - 2000\text{ N} = 0$$

$$B_x = 577\text{ N}$$

$$B_y = 1000\text{ N}$$

For member AB,

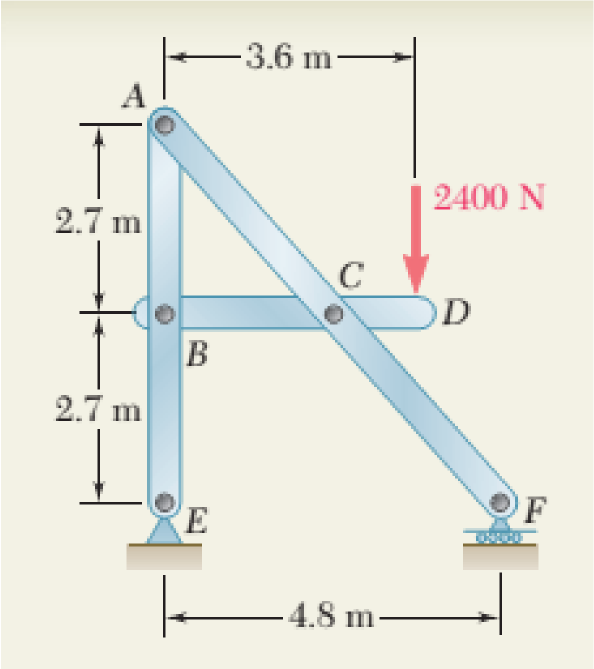
$$B_x = 577\text{ N} \leftarrow$$

$$B_y = 1000\text{ N} \downarrow$$

Analysis of Planar Frames

➢Example

Determine the components of the forces acting on each member of the frame shown.



$F = 1800 \text{ N}$

$E_y = 600 \text{ N}$

$E_x = 0 \text{ N}$

$A_x = 0 \text{ N}$

$A_y = 1800 \text{ N}$

$B_x = 0 \text{ N}$

$B_y = 1200 \text{ N}$

$C_x = 0 \text{ N}$

$C_y = 1000 \text{ N}$