CHAPTER

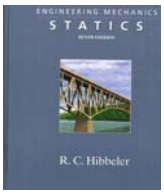
6c

Engineering Mechanics: Statics Tenth Edition

STRUCTURAL ANALYSIS

UMBC

•College of Engineering •Department of Mechanical Engineering



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SPRING 2007

ENES 110 – Statics

Department of Mechanical Engineering
University of Maryland, Baltimore County

Frames and Machines (Section 6.6)

Lecture's Objectives:

Students will be able to:

a) Draw the free body diagram of a frame or machine and its members.

b) Determine the forces acting at the joints and supports of a frame or machine.

In-Class Activities:

- Reading quiz
- Applications
- Analysis of a frame/machine
- Concept quiz
- Problem solving (Ex.2)
- Attention quiz

Reading Quiz

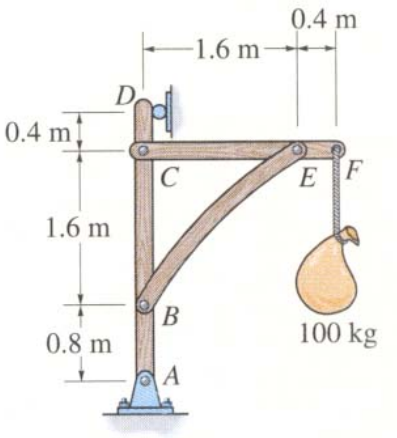
1. Frames and machines are different as compared to trusses since they have _____.

   A) only two-force members
   B) only multiforce members
   C) at least one multiforce member
   D) at least one two-force member

2. Forces common to any two contacting members act with _____ on the other member.

   A) equal magnitudes but opposite sense
   B) equal magnitudes and the same sense
   C) different magnitudes but opposite sense
   D) different magnitudes but the same sense

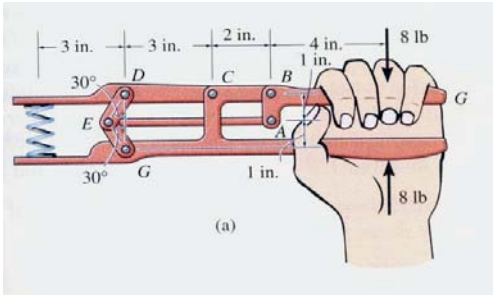
Applications



Frames are commonly used to support various external loads.

How is a frame different than a truss? How can you determine the forces at the joints and supports of a frame?

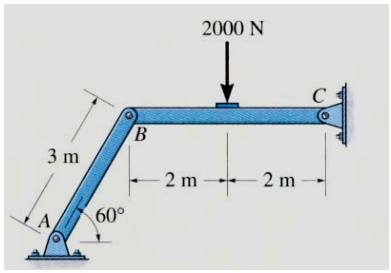
Applications (cont'd)

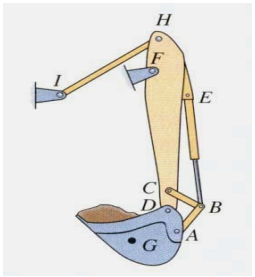


Machines, like these above, are used in a variety of applications. How are they different from trusses and frames?

How can you determine the loads at the joints and supports? These forces and moments are required when designing the machine members.

Frames and Machines: Definitions



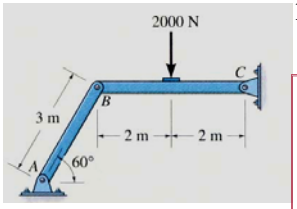


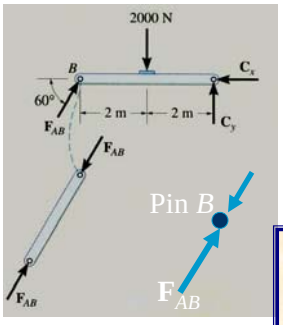
Frames and machines are two common types of structures that have at least one multi-force member. (Recall that trusses have nothing but two-force members).

Frames are generally stationary and support external loads.

Machines contain moving parts and are designed to alter the effect of forces.

Steps for Analyzing a Frame or Machine





1. Draw the FBD of the frame or machine and its members, as necessary.

Hints:

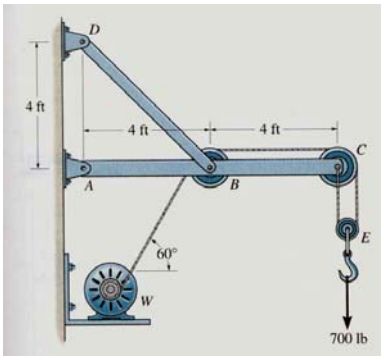
a) Identify any two-force members, b) Forces on contacting surfaces (usually between a pin and a member) are equal and opposite, and,

c) For a joint with more than two members or an external force, it is advisable to draw a FBD of the pin.

2. Develop a strategy to apply the equations of equilibrium to solve for the unknowns.

Problems are going to be challenging since there are usually several unknowns. A lot of practice is needed to develop good strategies.

Example 1



Given: The wall crane supports an external load of 700 lb.

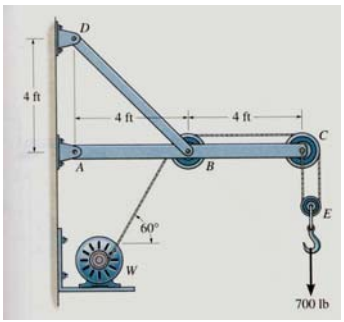
Find: The force in the cable at the winch motor *W* and the horizontal and vertical components of the pin reactions at *A*, *B*, *C*, and *D*.

Plan:

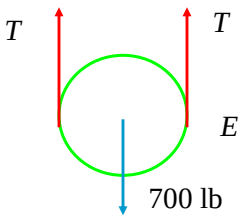
a) Draw FBDs of the frame's members and pulleys.

b) Apply the equations of equilibrium and solve for the unknowns.

Example 1 (cont'd)



FBD of the Pulley *E*



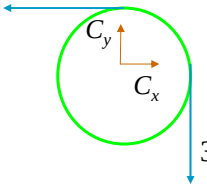
Necessary Equations of Equilibrium:

$$\uparrow + \sum F_y = 2T - 700 = 0$$

$$T = 350 \text{ lb}$$

Example 1 (cont'd)

350 lb



$$\rightarrow + \sum F_x = C_x - 350 = 0$$

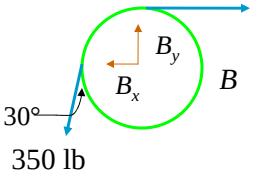
$$C_x = 350 \text{ lb}$$

$$\uparrow + \sum F_y = C_y - 350 = 0$$

$$C_y = 350 \text{ lb}$$

A FBD of pulley *C*

350 lb



350 lb

$$\rightarrow + \sum F_x = -B_x + 350 - 350 \sin 30° = 0$$

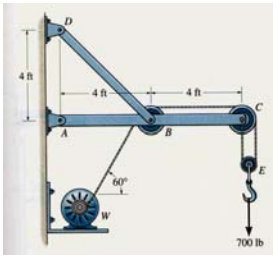
$$B_x = 175 \text{ lb}$$

$$\uparrow + \sum F_y = B_y - 350 \cos 30° = 0$$

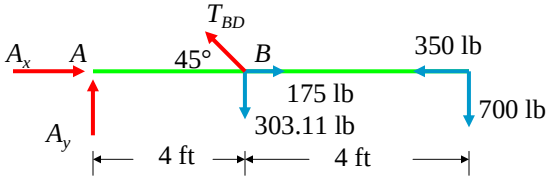
$$B_y = 303.1 \text{ lb}$$

A FBD of pulley *R*

Example 1 (cont'd)



Please note that member *BD* is a two-force member.



A FBD of member *ABC*

$$\curvearrowleft + \sum M_A = T_{BD} \sin 45° (4) - 303.1 (4) - 700 (8) = 0$$

$$T_{BD} = 2409 \text{ lb}$$

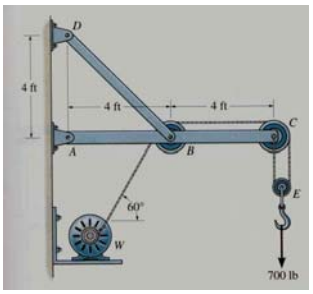
$$\uparrow + \sum F_y = A_y + 2409 \sin 45° - 303.1 - 700 = 0$$

$$A_y = -700 \text{ lb}$$

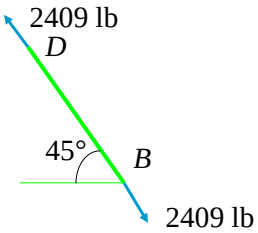
$$\rightarrow + \sum F_x = A_x - 2409 \cos 45° + 175 - 350 = 0$$

$$A_x = 1880 \text{ lb}$$

Example 1 (cont'd)



A FBD of member *BD*

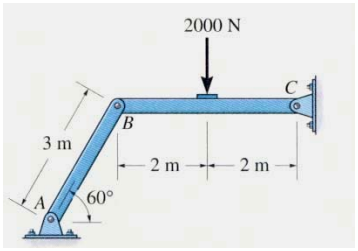


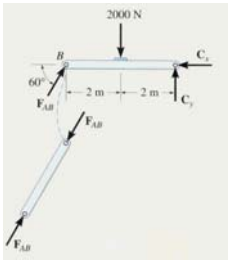
At *D*, the *x* and *y* component are

$$\rightarrow + D_x = -2409 \cos 45° = -1700 \text{ lb}$$

$$\uparrow + D_y = 2409 \sin 45° = 1700 \text{ lb}$$

Concept Quiz

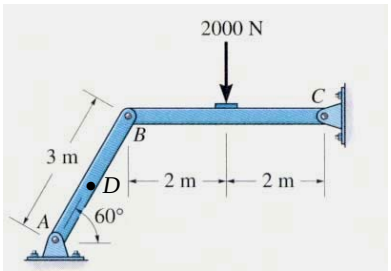


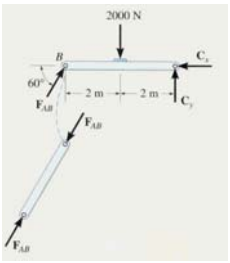


1. The figures show a frame and its FBDs. If an additional couple moment is applied at *C*, then how will you change the FBD of member *BC* at *B*?

   A) No change, still just one force (F_{AB}) at *B*.
   B) Will have two forces, B_x and B_y, at *B*.
   C) Will have two forces and a moment at *B*.
   D) Will add one moment at *B*.

Concept Quiz (cont'd)

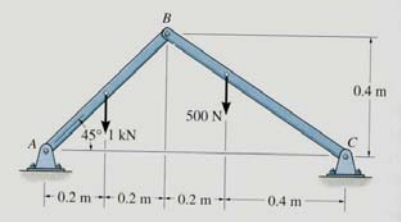




2. The figures show a frame and its FBDs. If an additional force is applied at *D*, then how will you change the FBD of member *BC* at *B*?

   A) No change, still just one force (F_{AB}) at *B*.
   B) Will have two forces, B_x and B_y, at *B*.
   C) Will have two forces and a moment at *B*.
   D) Will add one moment at *B*.

Example 2



Given: A frame and loads as shown.

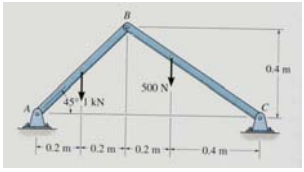
Find: The reactions that the pins exert on the frame at *A*, *B* and *C*.

Plan:

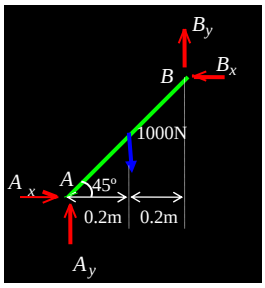
a) Draw a FBD of members *AB* and BC.

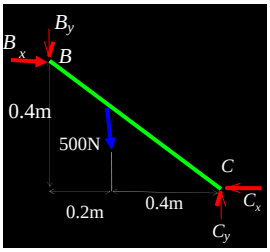
b) Apply the equations of equilibrium to each FBD to solve for the six unknowns. Think about a strategy to easily solve for the unknowns.

Example 2 (cont'd)



FBDs of members *AB* and *BC*:





Equating moments at *A* and *C* to zero, we get:

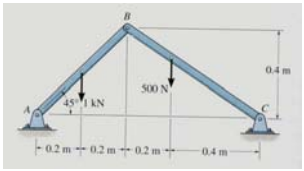
$$\circlearrowright + \sum M_A = B_x(0.4) + B_y(0.4) - 1000(0.2) = 0$$

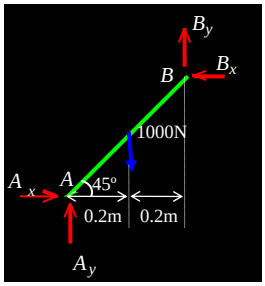
$$\circlearrowright + \sum M_C = -B_x(0.4) + B_y(0.6) + 500(0.4) = 0$$

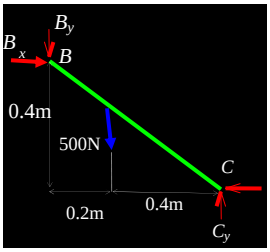
$B_y = 0$ and $B_x = 500$ N

Example 2 (cont'd)

FBDs of members *AB* and *BC*:







Applying EofE to bar *AB*:

$\rightarrow + \sum F_x = A_x - 500 = 0$; $A_x = 500$ N

$\uparrow + \sum F_y = A_y - 1000 + 0 = 0$; $A_y = 1000$ N

Consider member *BC*:

$\rightarrow + \sum F_x = 500 - C_x = 0$; $C_x = 500$ N

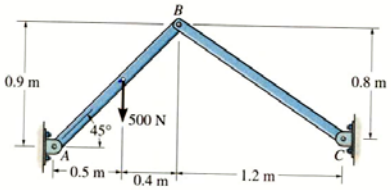
$\uparrow + \sum F_y = C_y - 500 = 0$; $C_y = 500$ N

Attention Quiz

1. When determining the reactions at joints *A*, *B*, and *C*, what is the minimum number of unknowns for solving this problem?

   A) 3 B) 4

   C) 5 D) 6



2. For the above problem, imagine that you have drawn a FBD of member *AB*. What will be the easiest way to directly solve for the first unknown?

   A) $\sum M_C = 0$ B) $\sum M_B = 0$

   C) $\sum M_A = 0$ D) $\sum F_x = 0$