FRAMES AND MACHINES

Objectives:

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.

APPLICATIONS

Frames are commonly used to support various external loads.

How is a frame different than a truss?

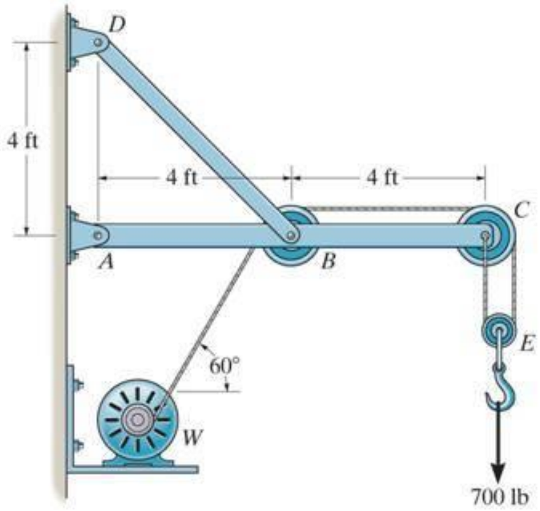
To be able to design a frame, you need to determine the forces at the joints and supports.

APPLICATIONS (continued)

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

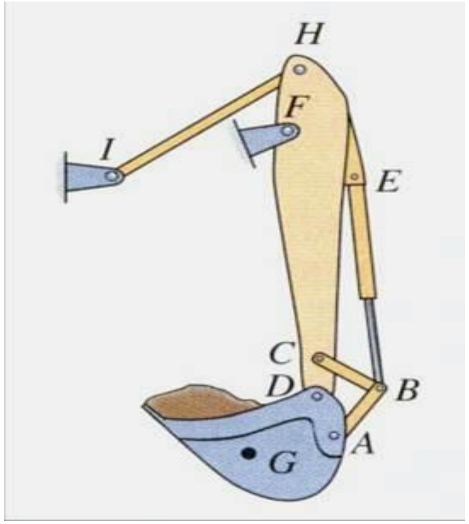
How can you determine the loads at the joints and supports? These forces and moments are required when designing the machine’s members.

FRAMES AND MACHINES: DEFINITIONS



← Frame

Machine →

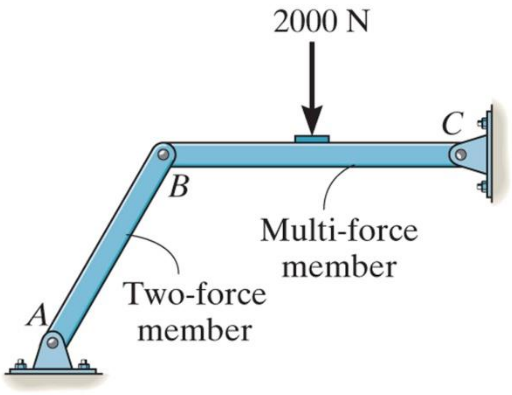


Frames and machines are two common types of structures that have at least one multi-force member. (Recall that trusses have nothing but two-force members).

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



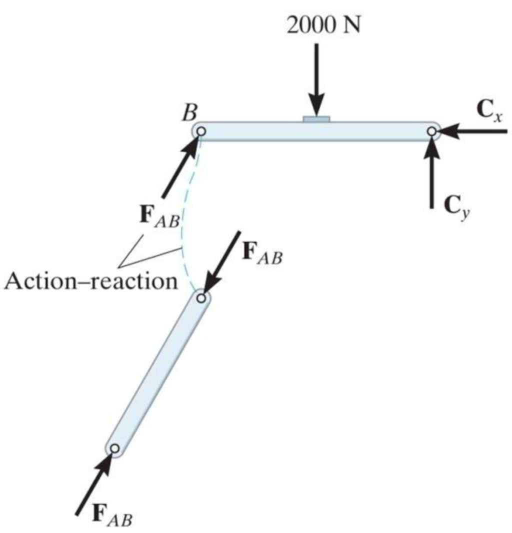
1. Draw a FBD of the frame or machine and its members, as necessary.

Hints:

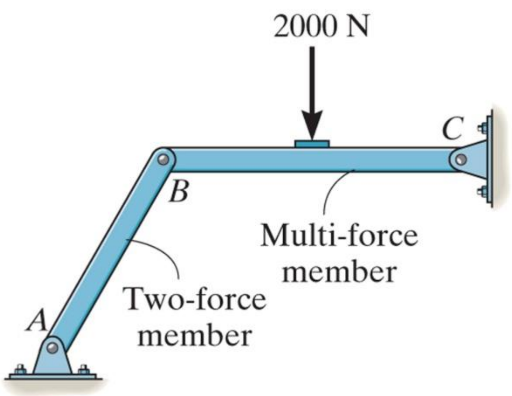
a) Identify any two-force members,

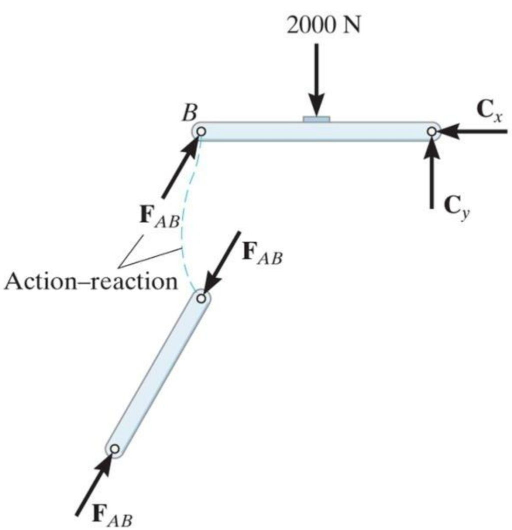
b) Note that forces on contacting surfaces (usually between a pin and a member) are equal and opposite, and,

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



STEPS FOR ANALYZING A FRAME OR MACHINE

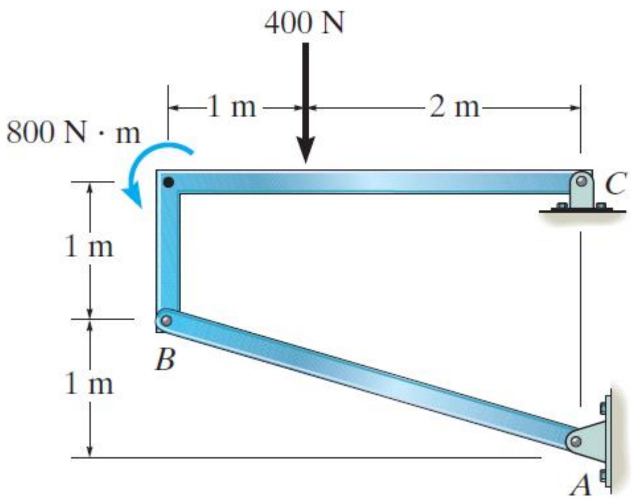




2. Develop a strategy to apply the equations of equilibrium to solve for the unknowns. Look for ways to form single equations and single unknowns.

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

EXAMPLE I



Given: The frame supports an external load and moment as shown.

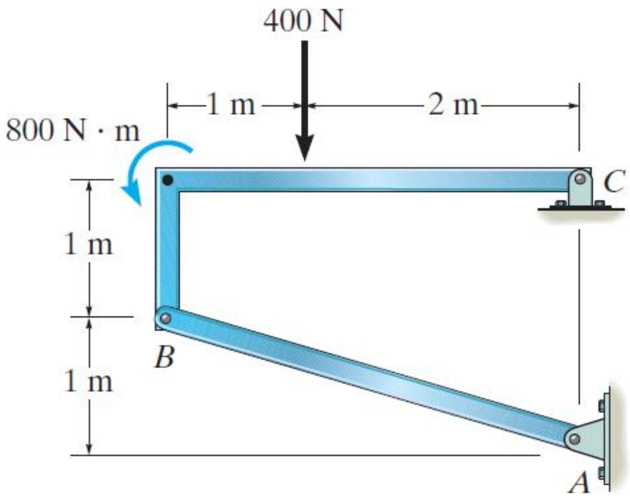
Find: The horizontal and vertical components of the pin reactions at C and the magnitude of reaction at B.

Plan:

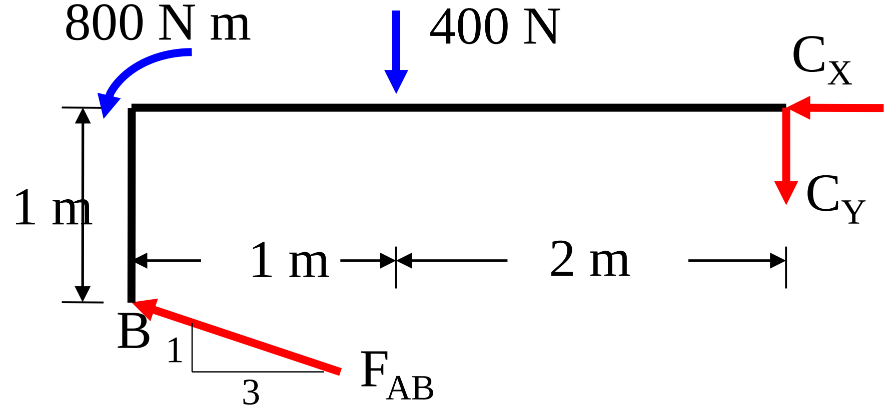
a) Draw a FBD of frame member BC. Why pick this part of the frame?

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

EXAMPLE I (continued)



FBD of member BC



Note that member AB is a two-force member.

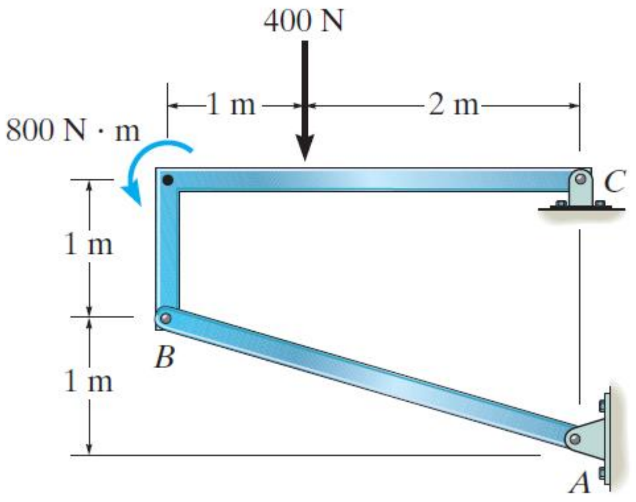
Equations of Equilibrium:

Start with $\sum M_C$ since it yields one unknown.

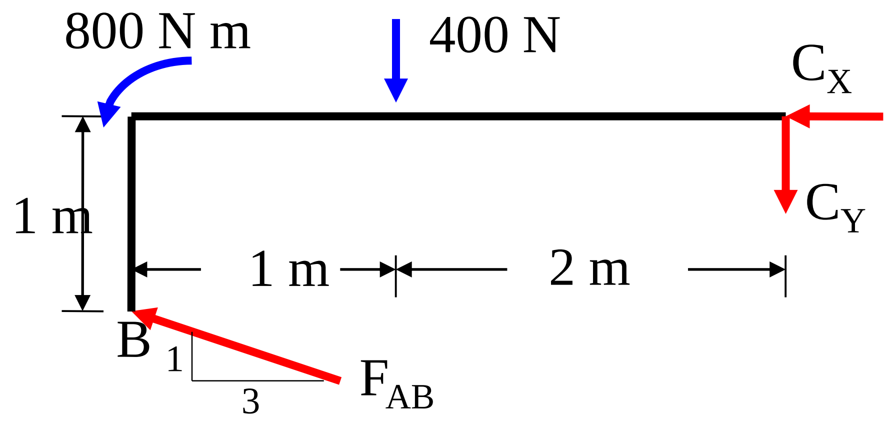
$$\curvearrowleft + \sum M_C = -F_{AB}\,(3/\sqrt{10})\,(1) - F_{AB}\,(1/\sqrt{10})\,(3) + 800 + 400\,(2) = 0$$

$F_{AB} = 843.3 = 843\ \text{N}$

EXAMPLE I (continued)



FBD of member BC



Now use the x and y-direction Equations of Equilibrium:

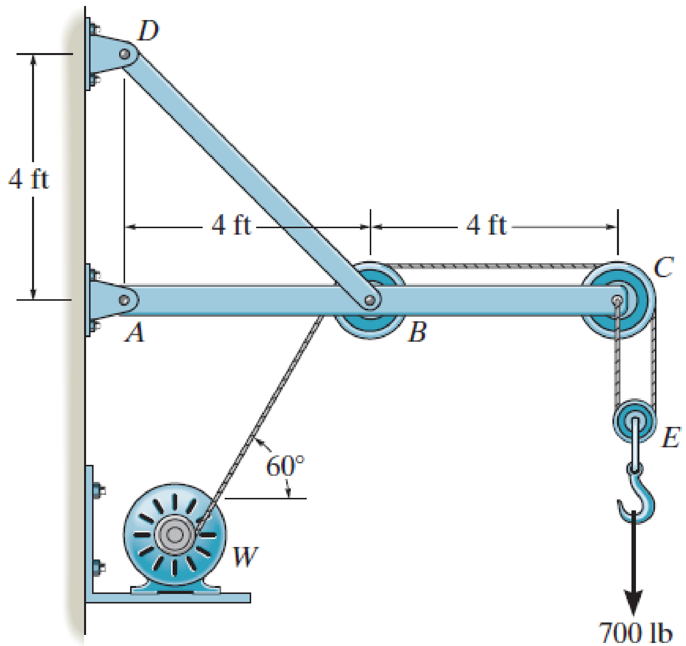
$$\rightarrow + \sum F_X = -C_X - 843.3\,(3/\sqrt{10}) = 0$$

$$C_X = -800\text{ N} = \underline{800\text{ N} \rightarrow}$$

$$\uparrow + \sum F_Y = -C_Y + 843.3\,(1/\sqrt{10}) - 400 = 0$$

$$C_Y = -133\text{ N} = \underline{133\text{ N} \uparrow}$$

EXAMPLE II



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

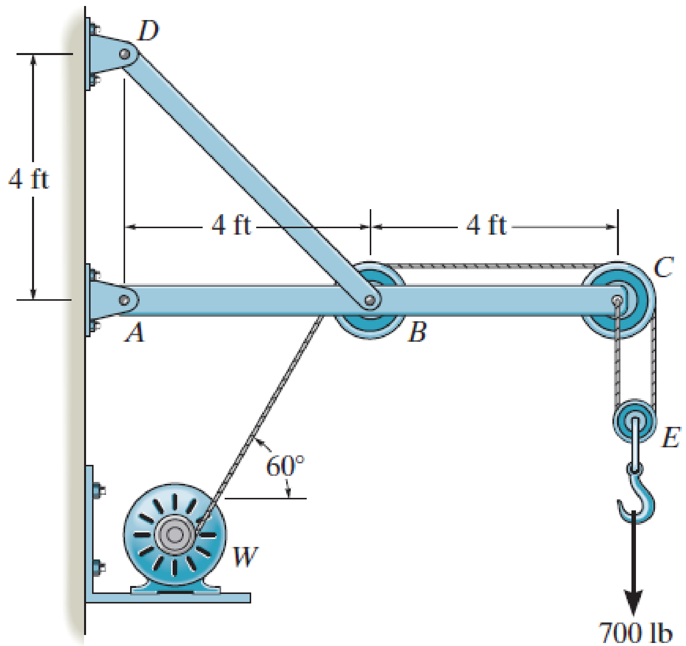
Find: The force in the cable at winch motor W and the horizontal and vertical components of pin reactions at A, B, C, and D.

Plan:

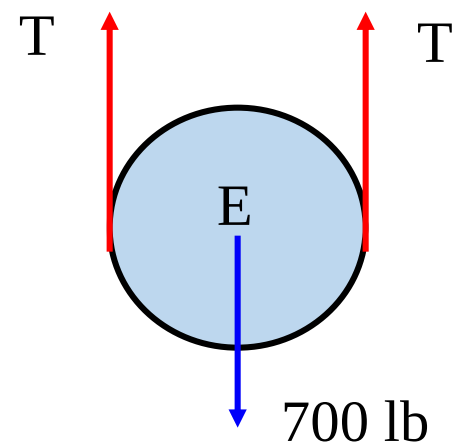
a) Draw FBDs of the frame's members and pulleys.

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

EXAMPLE II (continued)



FBD of the Pulley E

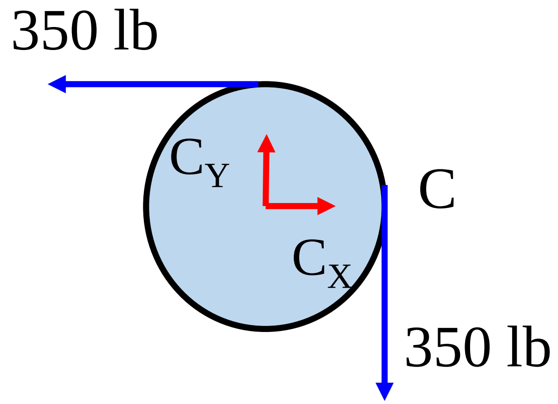


Necessary Equations of Equilibrium:

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

$T = 350$ lb

EXAMPLE II (continued)



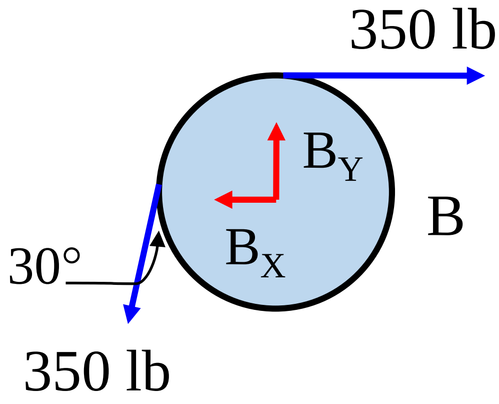
FBD of pulley C

$$\rightarrow + \sum F_X = C_X - 350 = 0$$

$C_X = 350$ lb

$$+\uparrow \sum F_Y = C_Y - 350 = 0$$

$C_Y = 350$ lb



FBD of pulley B

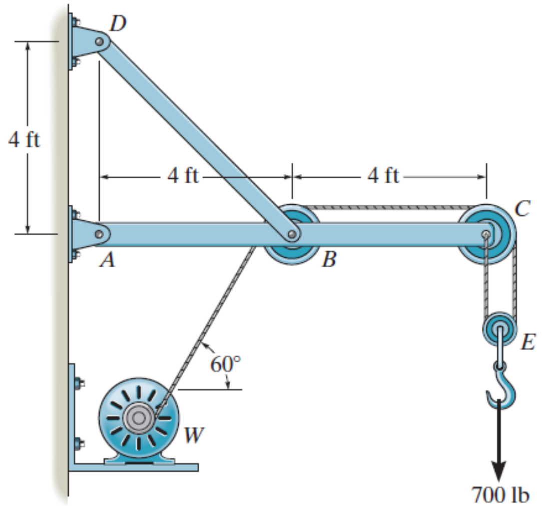
$$\rightarrow + \sum F_X = - B_X + 350 - 350 \sin 30° = 0$$

$B_X = 175$ lb

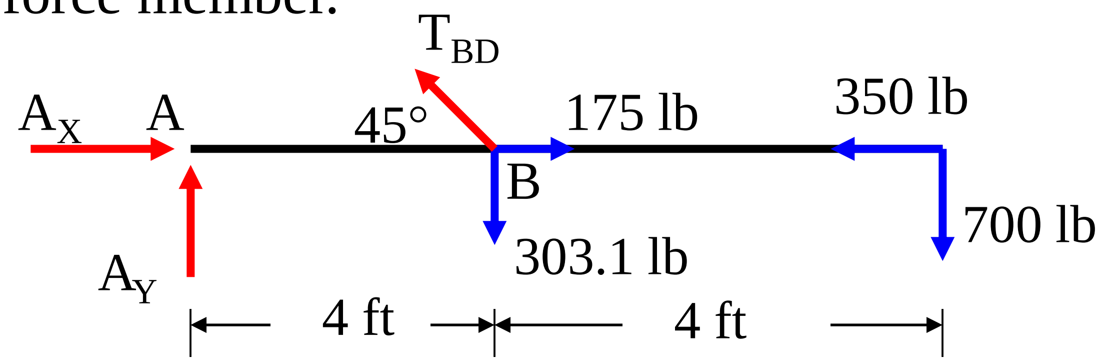
$$\uparrow + \sum F_Y = B_Y - 350 \cos 30° = 0$$

$B_Y = 303.1$ lb

EXAMPLE II (continued)



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



FBD of member ABC

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

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

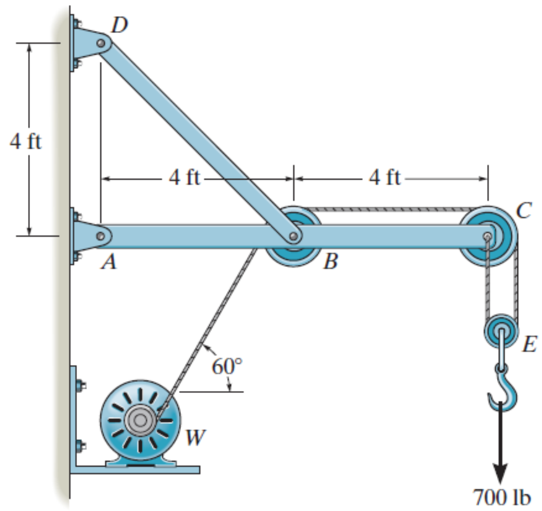
$$\rightarrow + \sum F_X = A_X - 2409 \cos 45° + 175 - 350 = 0$$

$$\underline{A_X = 1880 \text{ lb}}$$

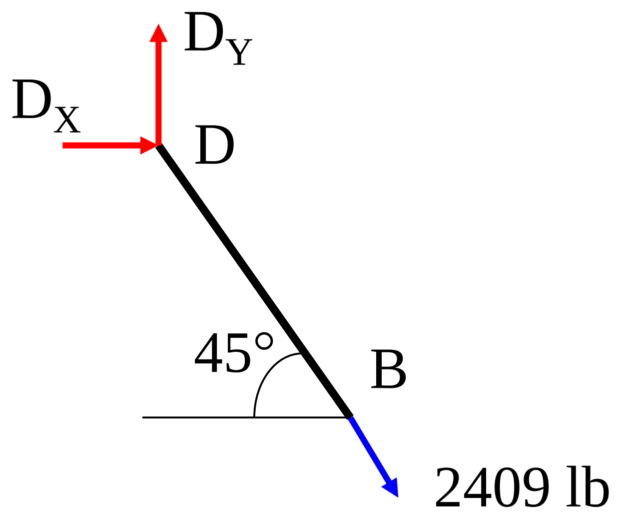
$$\uparrow + \sum F_Y = A_Y + 2409 \sin 45° - 303.1 - 700 = 0$$

$$\underline{A_Y = -700 \text{ lb}}$$

EXAMPLE II (continued)



FBD of member BD



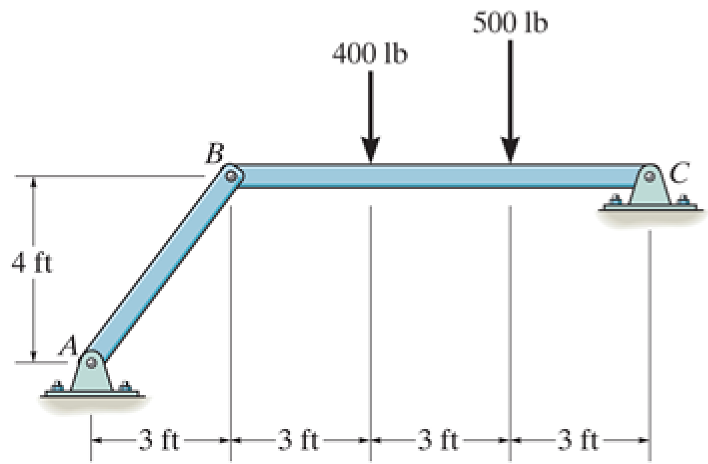
At D, the X and Y component are

$\rightarrow + \; D_X = -2409 \cos 45° = \underline{-1700 \text{ lb}}$

$\uparrow + \; D_Y = 2409 \sin 45° = \underline{1700 \text{ lb}}$

QUIZ

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



A) 6 B) 5

C) 4 D) 3

2. For the above problem, imagine that you have drawn a FBD of member BC. What will be the easiest way to write an equation involving unknowns at B?

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

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