FRAMES AND MACHINES

<u>Today's Objectives</u>:

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.

<u>In-Class Activities</u>:

- Check Homework, if any
- Reading Quiz
- Applications
- Analysis of a Frame/Machine
- Concept Quiz
- Group Problem Solving
- 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

Frames and Machines

- at least one member is **not** a two-force body.

Frame – designed to remain stationary and support loads

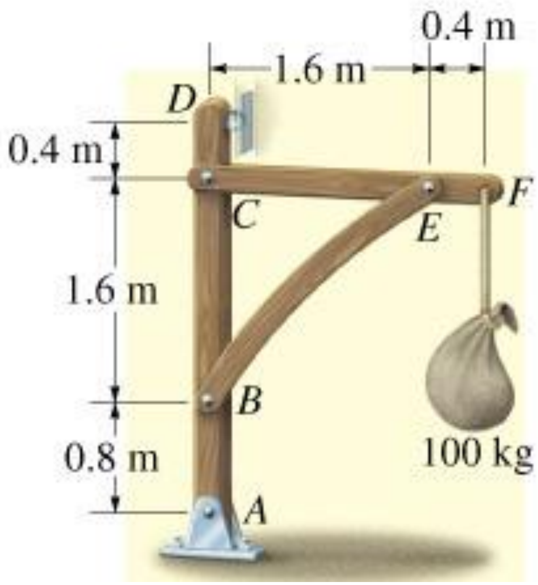
Machine – designed to move and apply loads

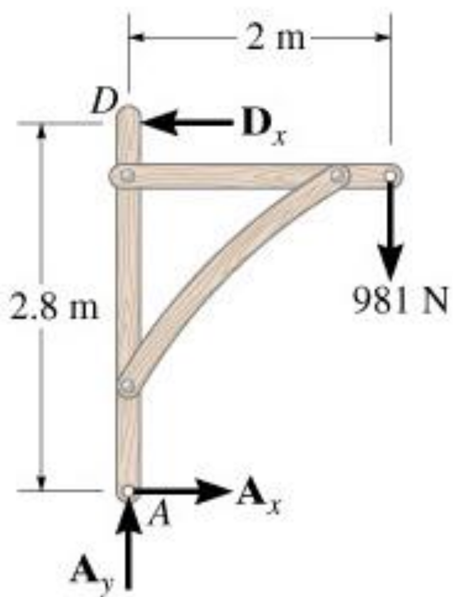
Steps in Analysis:

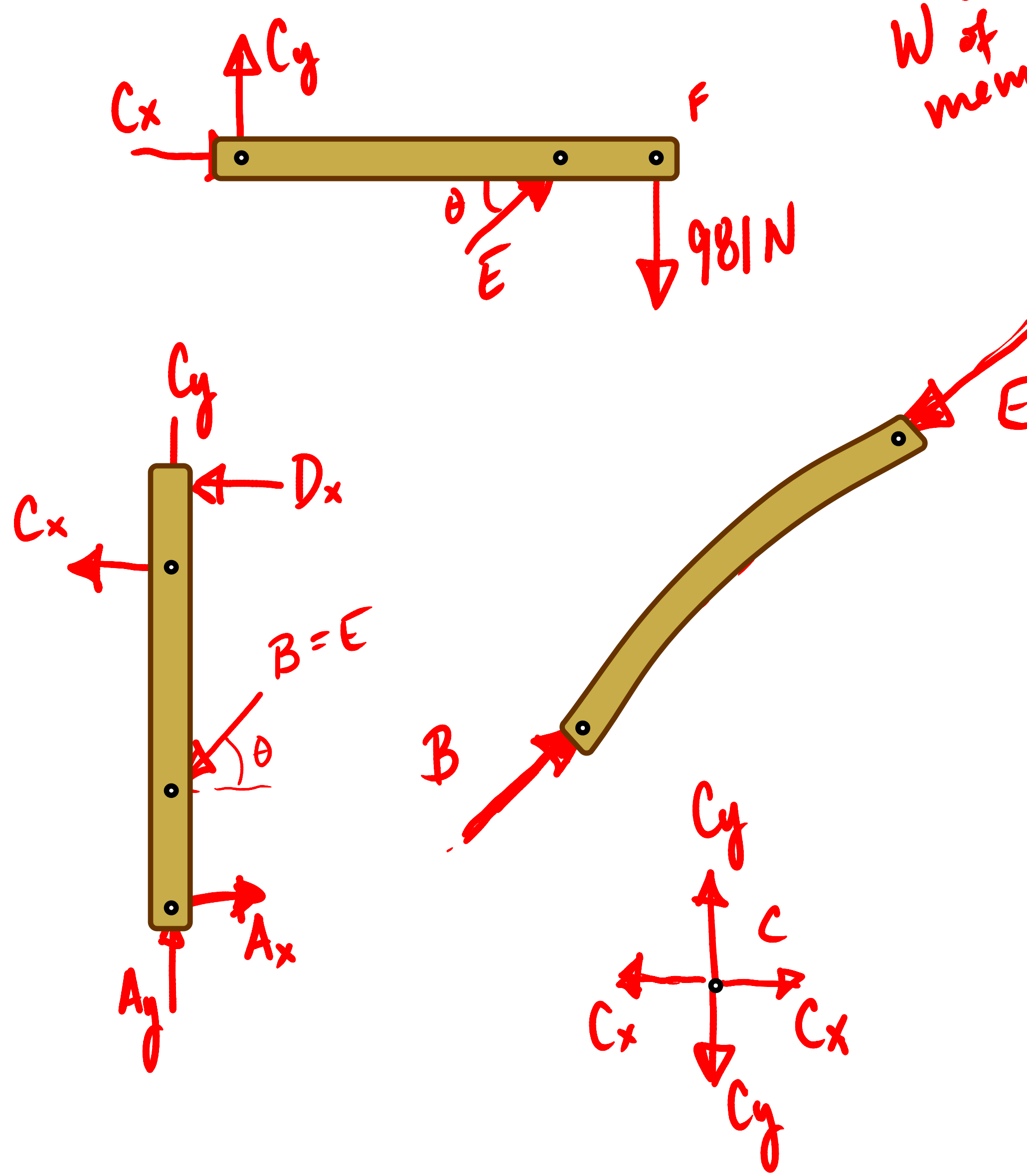
1. Take note of all two-force members.
2. FBD of entire frame – determine as many external reactions as possible
3. Take frame apart to look at FBD's of individual members:
   - Use two-force members to reduce unknowns
   - Observe **Newton's 3rd Law** (Action-Reaction)
   - Start with FBD's with 3 or less unknowns (in 2D)

Example 1. FBD for a Frame.

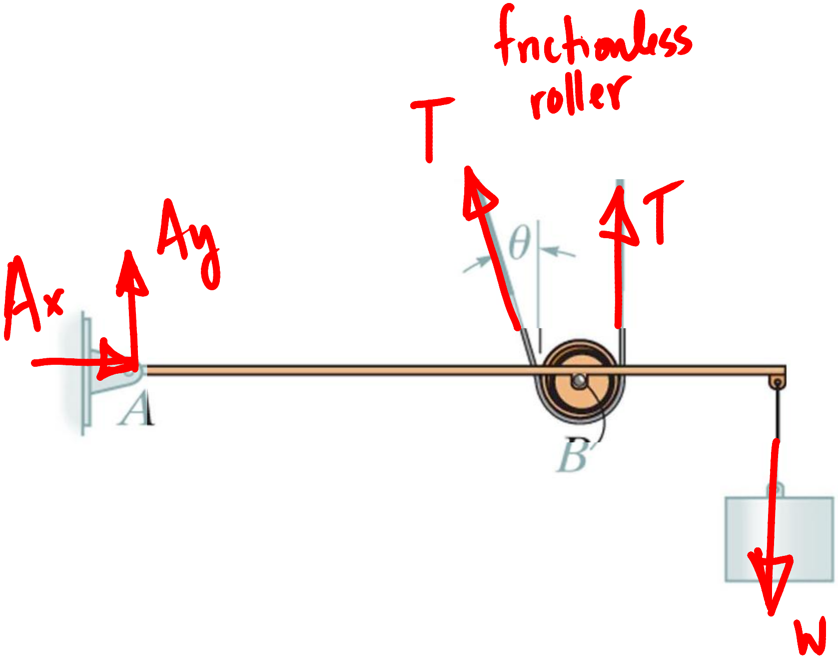
Neglect W of members

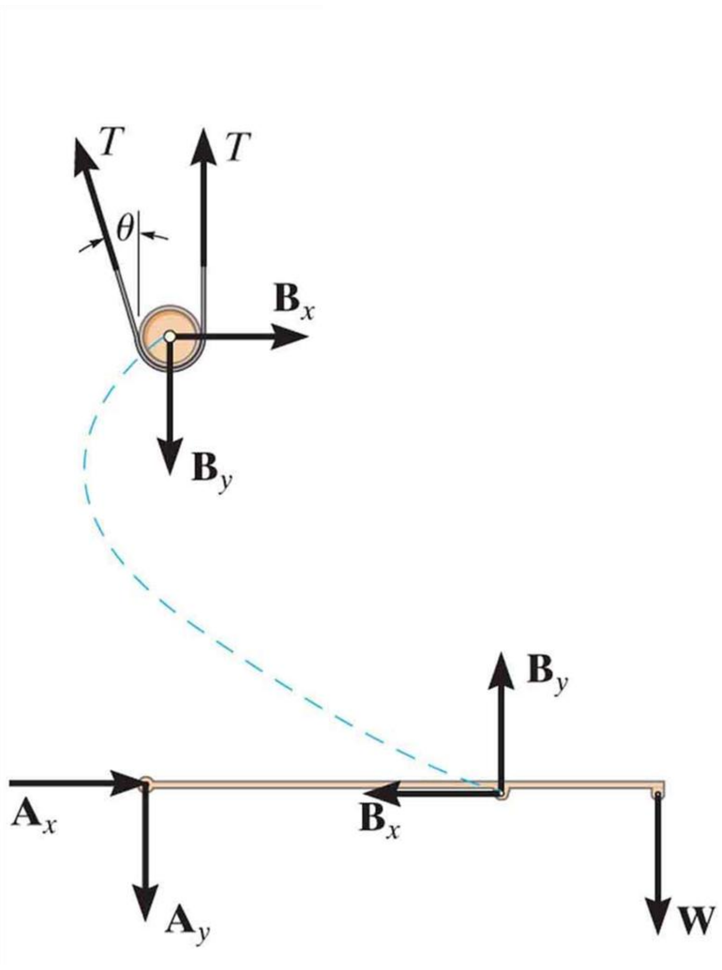




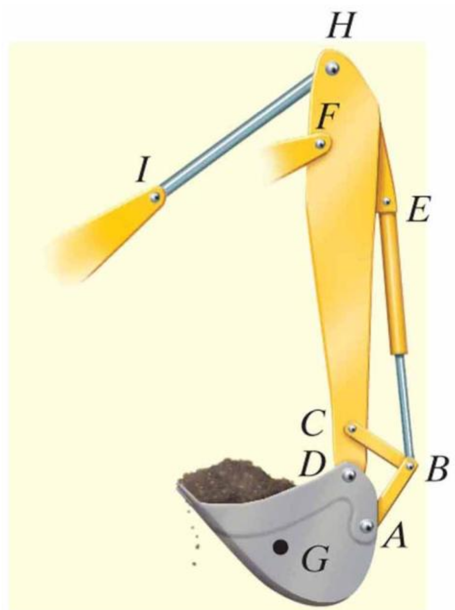


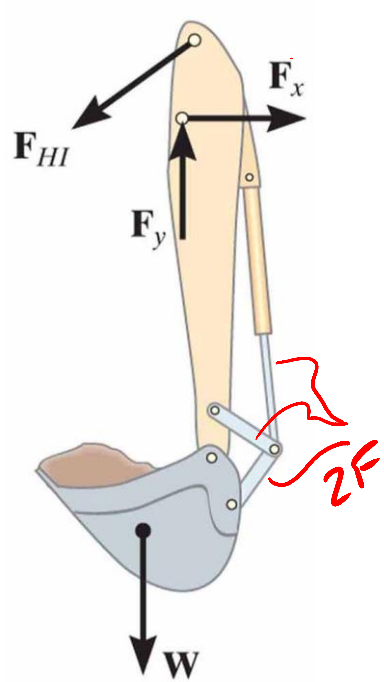
Example 2. FBD for a Machine.

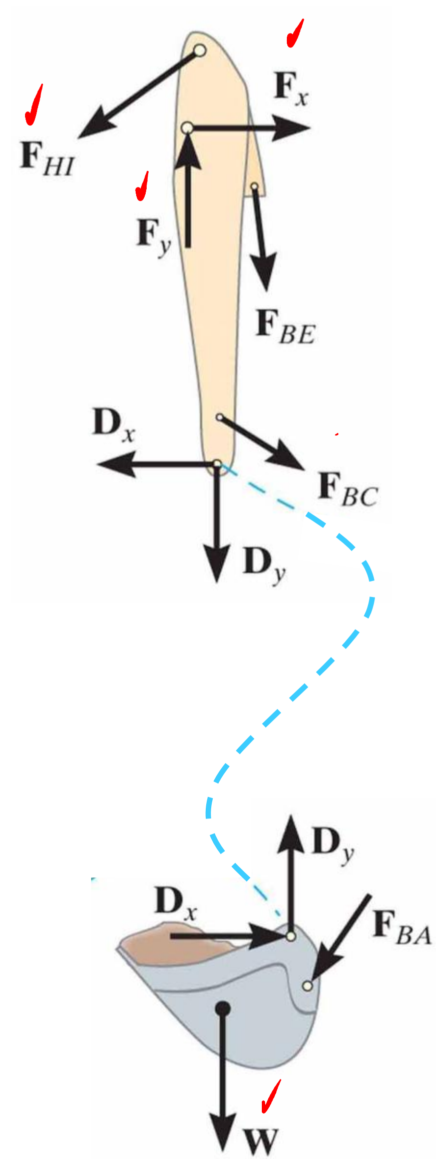


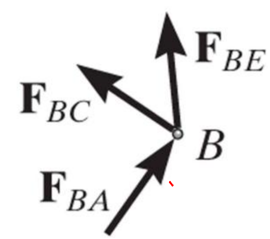


Example 3. FBD for a Machine.

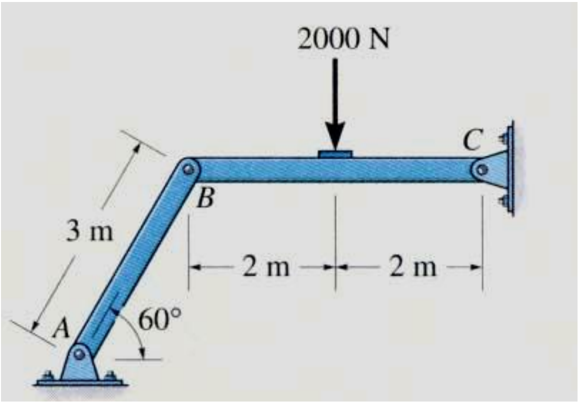








STEPS FOR ANALYZING A FRAME OR MACHINE

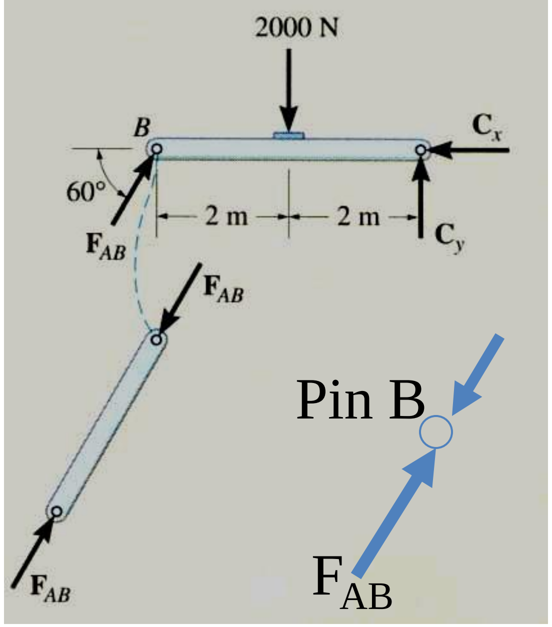


1. Draw the FBD of the frame or machine and its members, as necessary.

Hints:

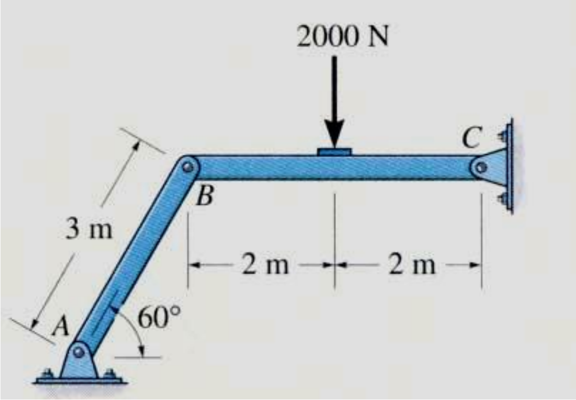
a) Identify any two-force members, b) Forces on contacting surfaces (usually between a pin and a member) are equal and opposite, and,

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

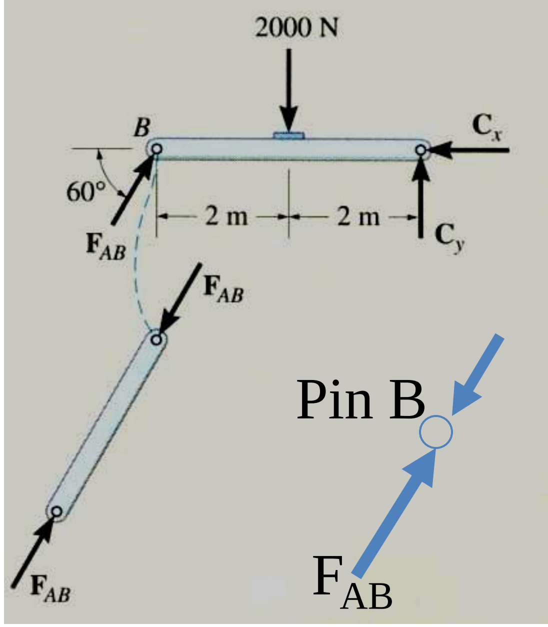


2. Develop a strategy to apply the equations of equilibrium to solve for the unknowns.

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



Example 4



Solving for Member BC

$$+\ \sum M_B = \quad Cy\,(4) - 2000\,(2) = 0$$

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

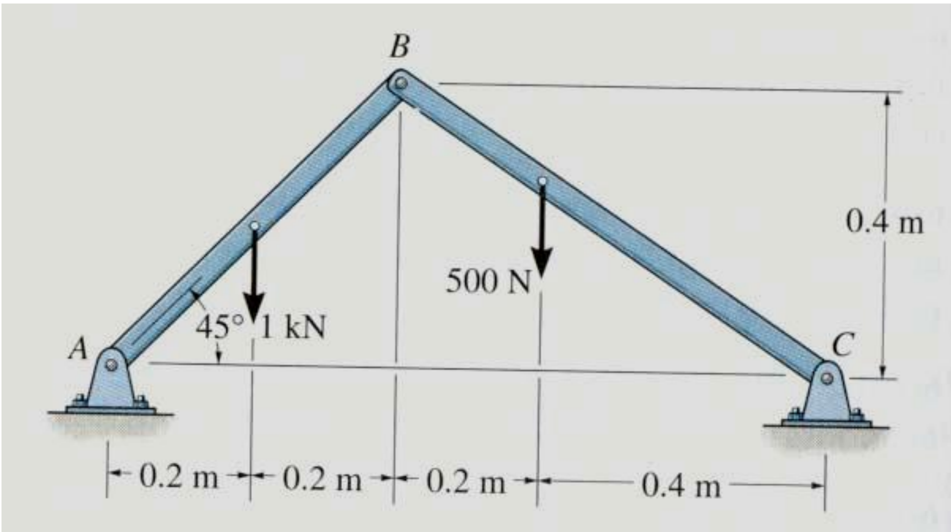
$$+\ \sum Fy = \quad Fab\sin(60) - 2000 + Cy = 0$$

$$Fab = 1000/.866 = 1150$$

$$+\ \sum Fx = \quad Fab\cos(60) - Cx = 0$$

$$Cx = Fab\cos(60) = 577$$

Example 5



Given: A frame and loads as shown.

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

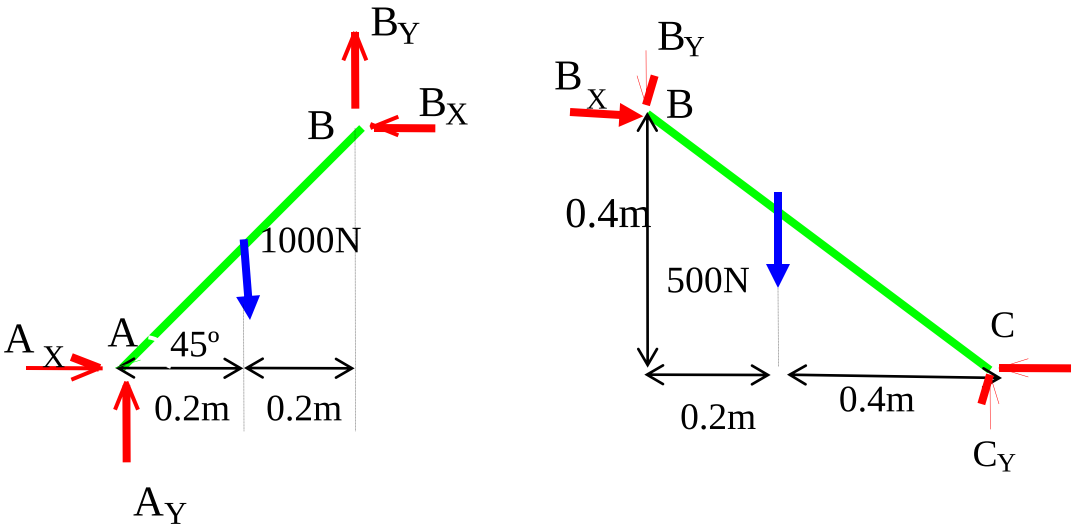
Plan:

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 5 (continued)

FBDs of members AB and BC:



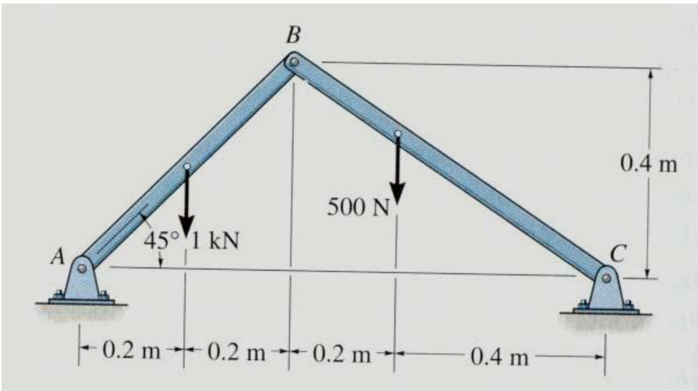
Equating moments at A and C to zero, we get:

$$+ \quad \sum M_A = B_X\,(0.4) + B_Y\,(0.4) - 1000\,(0.2) = 0$$

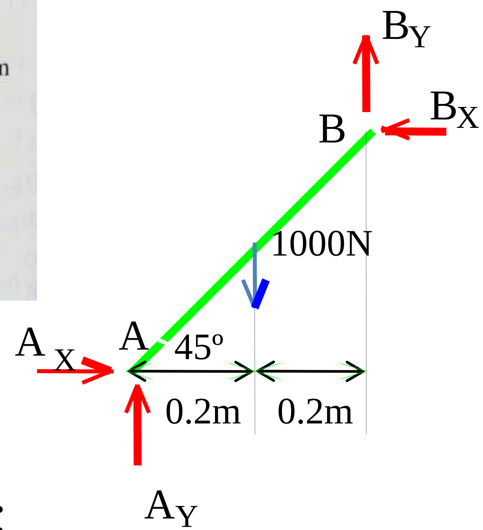
$$+ \quad \sum M_C = -B_X\,(0.4) + B_Y\,(0.6) + 500\,(0.4) = 0$$

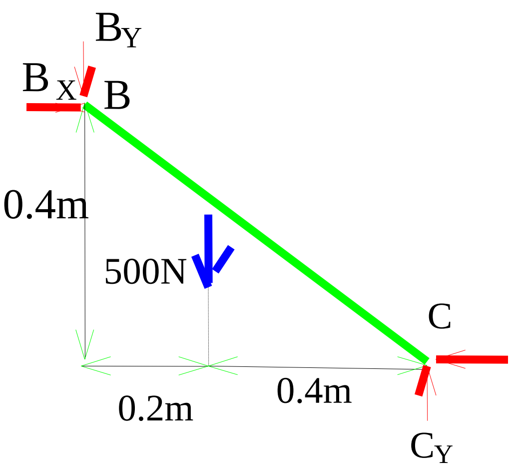
$\underline{B_Y = 0}$ and $\underline{B_X = 500\ N}$

EXAMPLE 5 (continued)



FBDs of members AB and BC:





Applying E-of-E to bar AB:

$\rightarrow + \sum F_X = A_X - 500 = 0$; $\quad$ $A_X = 500$ N

$\uparrow + \sum F_Y = A_Y - 1000 = 0$; $\quad$ $A_Y = 1{,}000$ N

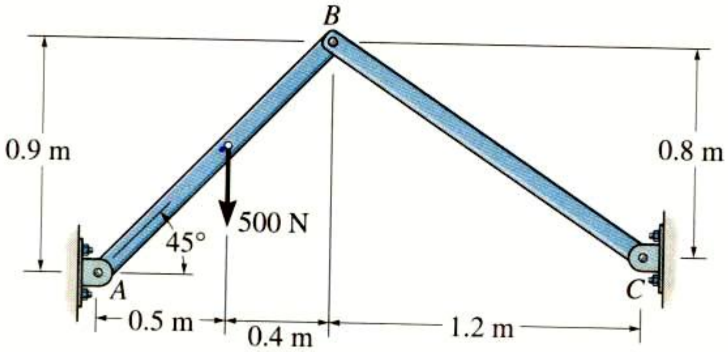
Consider member BC:

$\rightarrow + \sum F_X = 500 - C_X = 0$; $\quad$ $C_X = 500$ N

$\uparrow + \sum F_Y = C_Y - 500 = 0$; $\quad$ $C_Y = 500$ 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

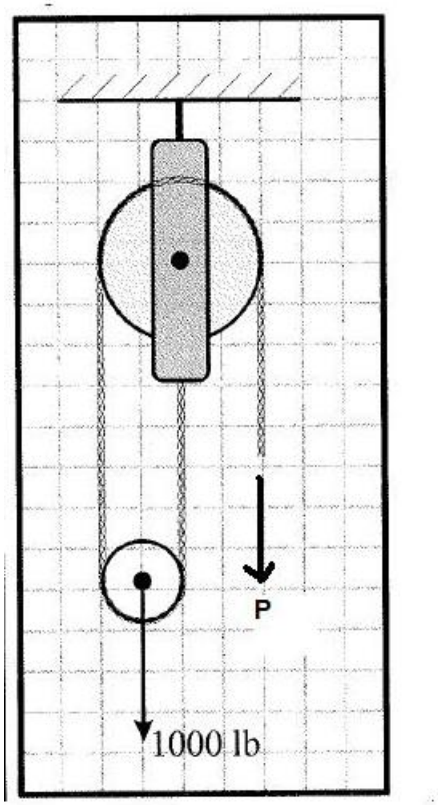
C) 5 D) 6

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

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

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

SIMPLE PULLEY EXAMPLE, EX 6



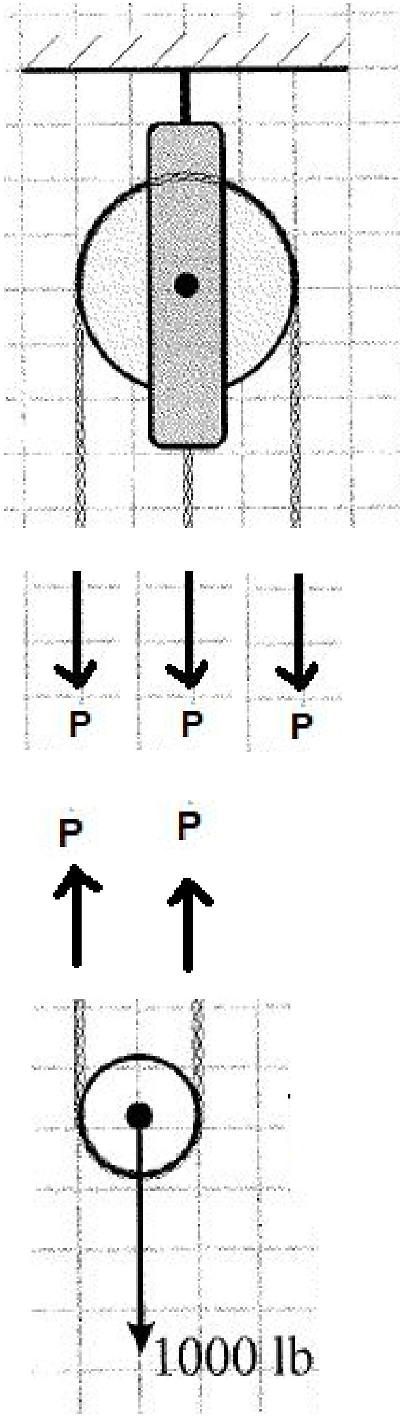
Given: The Block and tackle supports a 1000 lb load.

Find: The force P necessary for equilibrium.

Plan:

a) Draw FBDs of the two pulleys.

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



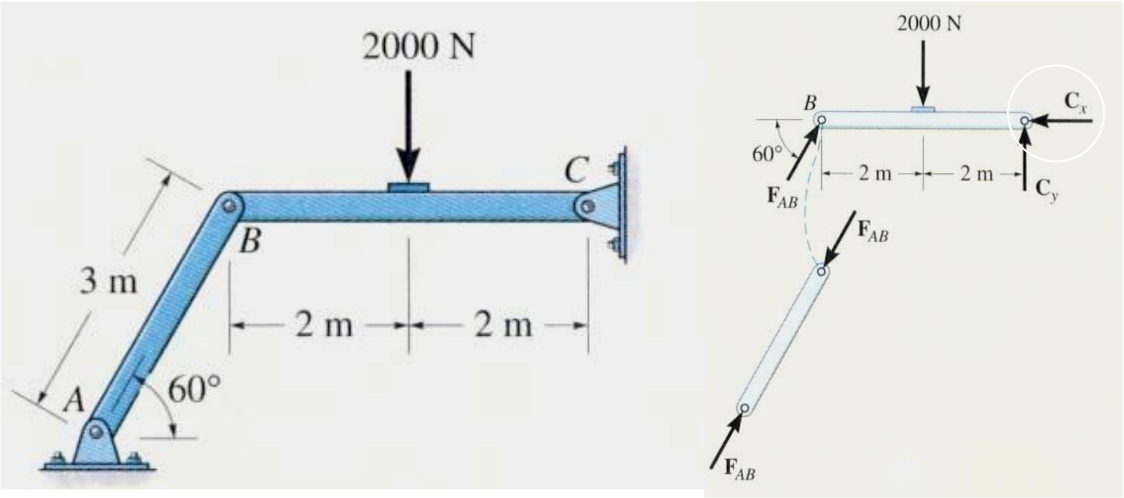
SIMPLE PULLEY EXAMPLE 6 -- Solved

Note that the tension of a cable around a frictionless pulley is the same on both sides

$+ \quad \sum F_y = \qquad 2P - 1000 = 0$

$P = 500$

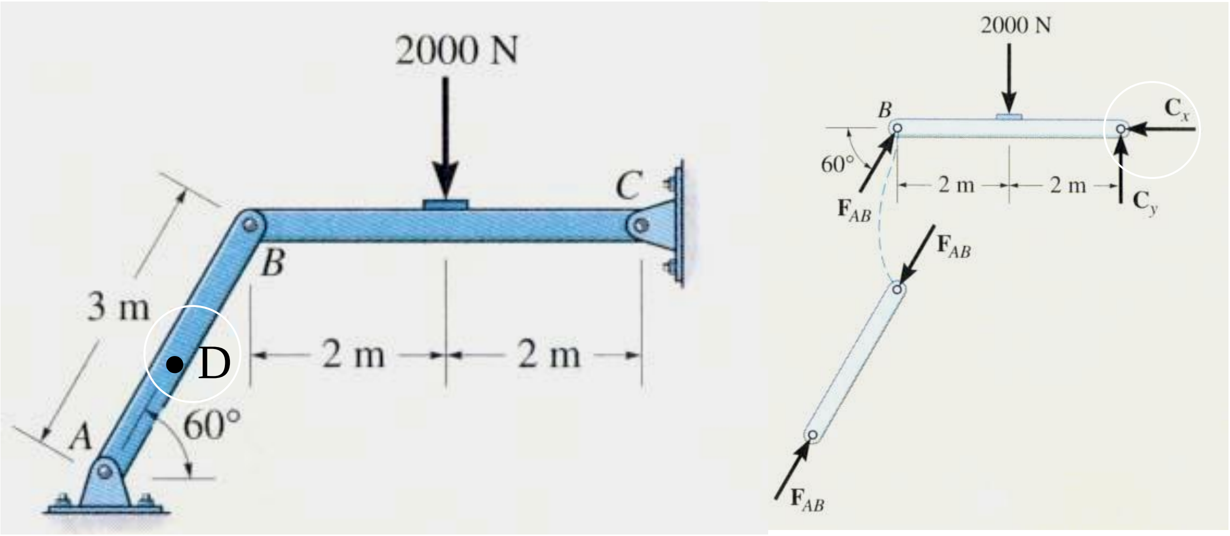
CONCEPT QUIZ



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 **<u>BC at B</u>**?

   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.

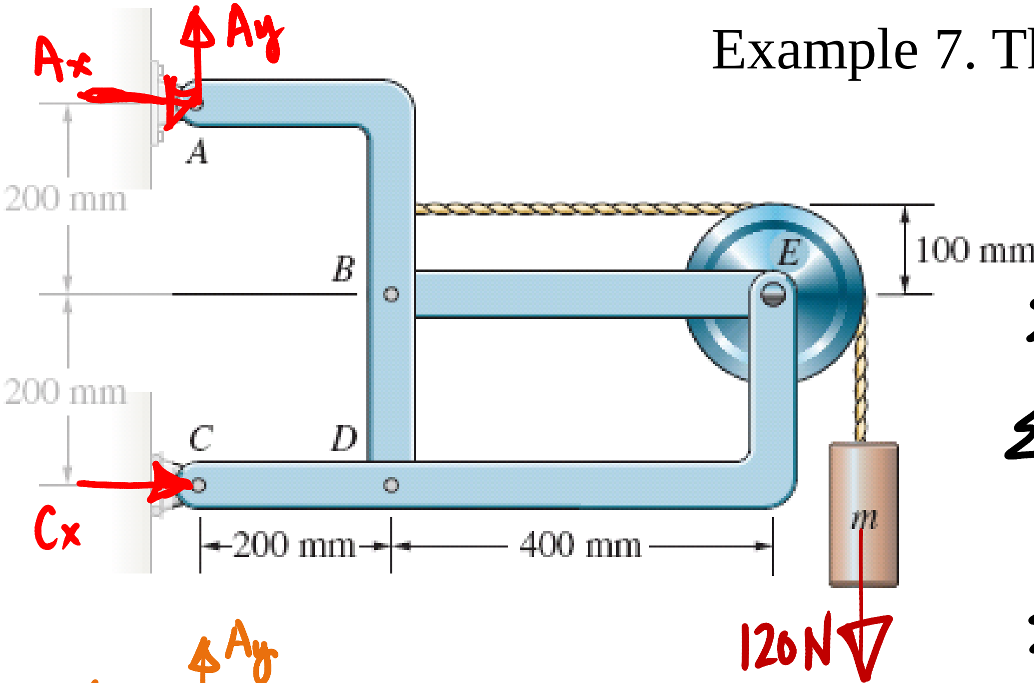
CONCEPT QUIZ (continued)



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 7. The weight of m is 120 N. Find the forces on member CDE.



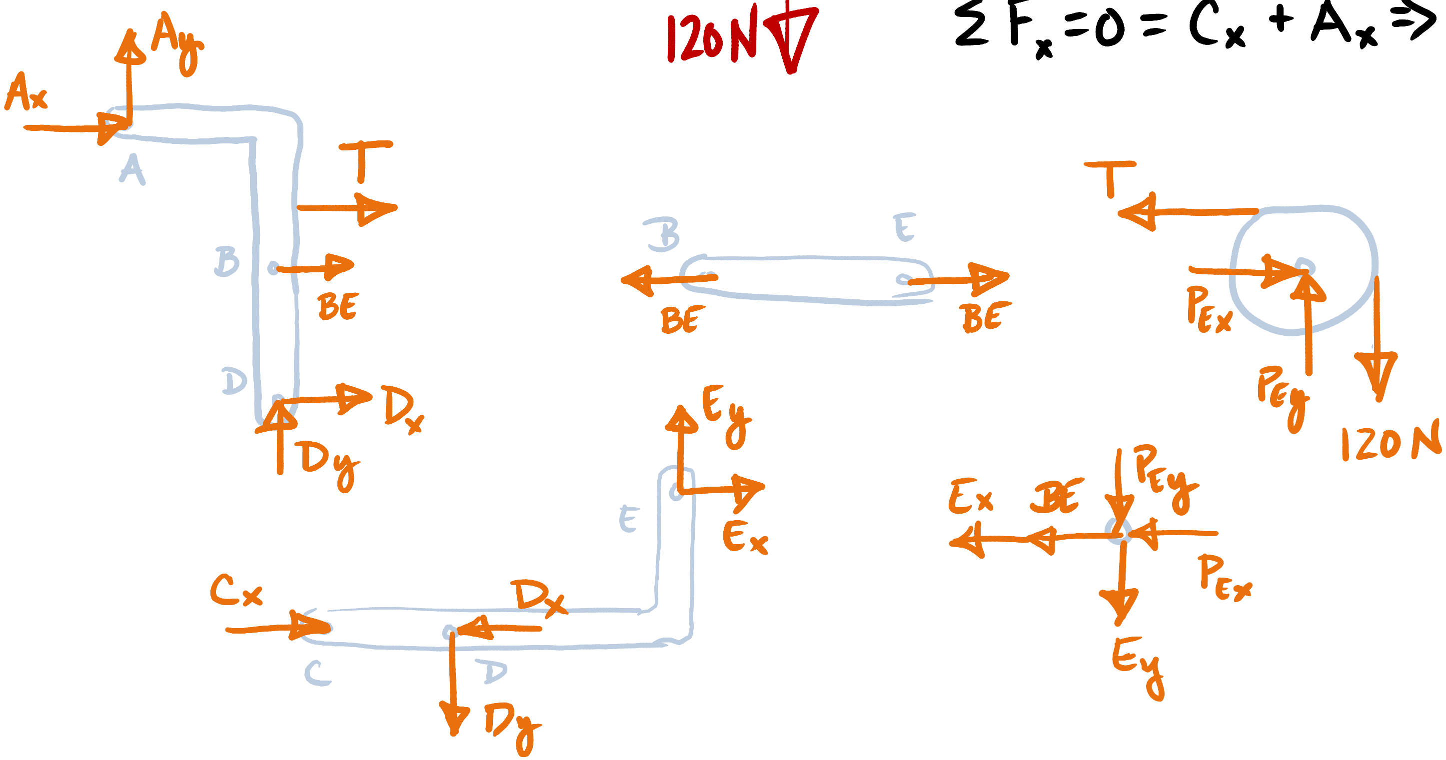
① FBD for whole frame ② Analyze

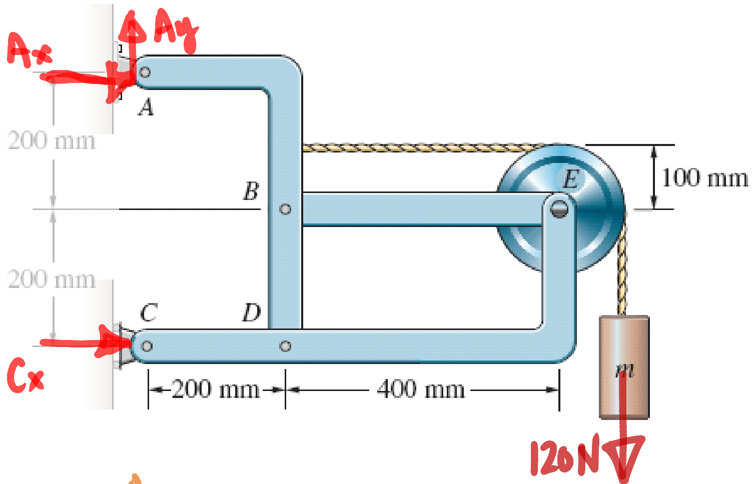
$$\Sigma F_y = 0 = A_y - 120N \Rightarrow A_y = 120N$$

$$\Sigma M_A = 0 = C_x(0.4m) - 120N(0.6m)$$

$$\Rightarrow C_x = 180\ N$$

$$\Sigma F_x = 0 = C_x + A_x \Rightarrow A_x = -180N$$



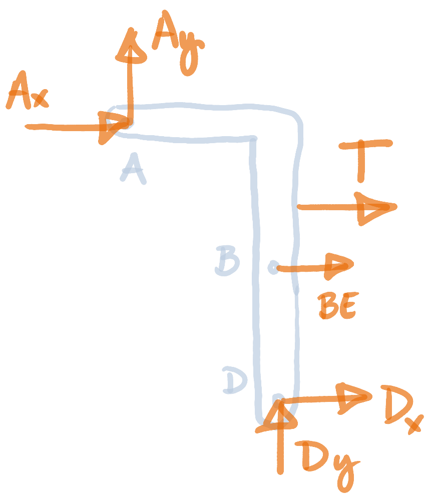


$$\Sigma F_y = 0 = A_y - 120\text{N} \Rightarrow A_y = 120\text{N}$$

$$\Sigma M_A = 0 = C_x(0.4\text{m}) - 120\text{N}(0.6\text{m})$$

$$\Rightarrow C_x = 180\text{ N}$$

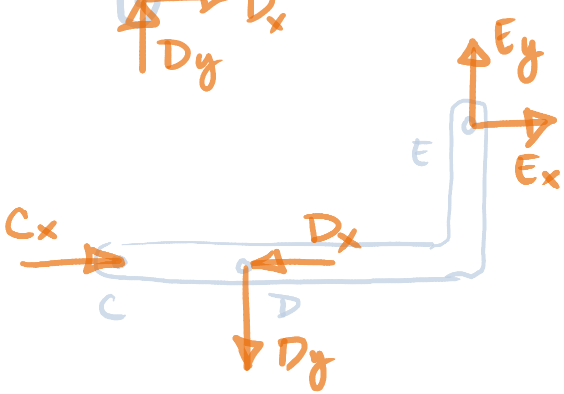
$$\Sigma F_x = 0 = C_x + A_x \Rightarrow A_x = -180\text{N}$$



Member ABD

$$\Sigma F_y = 0 = A_y + D_y \Rightarrow D_y = -120\text{ N}$$

Member CDE



$$\Sigma M_E = 0 = C_x(0.2\text{m}) + D_y(0.4\text{m}) - D_x(0.2\text{m})$$

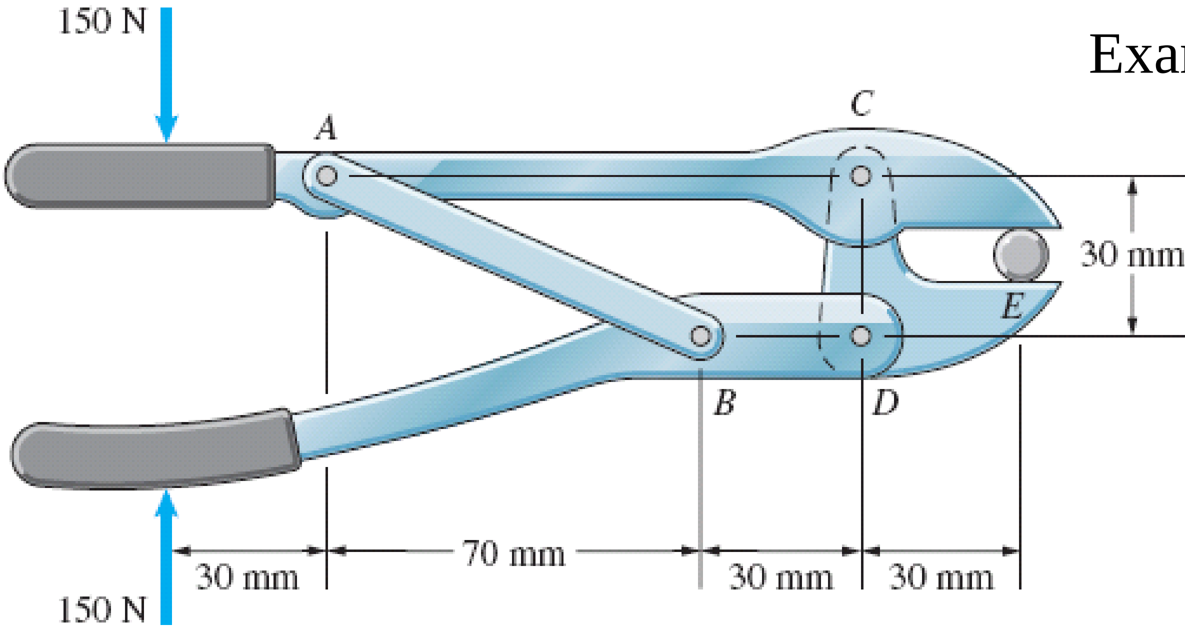
$$\Rightarrow D_x = [180(0.2) + (-120)(0.4)]/0.2$$

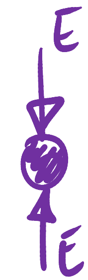
$$\Rightarrow D_x = -60\text{ N}$$

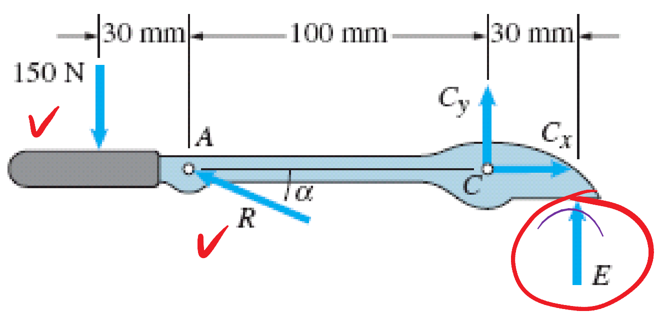
$$\Sigma F_x = 0 = C_x - D_x + E_x \Rightarrow E_x = -240\text{N}$$

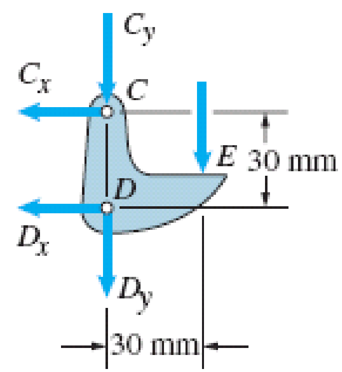
$$\Sigma F_y = 0 = E_y - D_y \Rightarrow E_y = -120\text{ N}$$

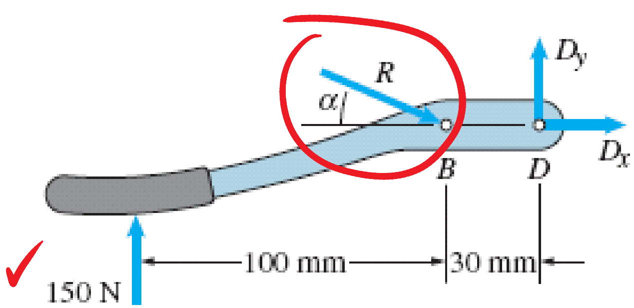
Example 8. Find forces on the bolt at E.









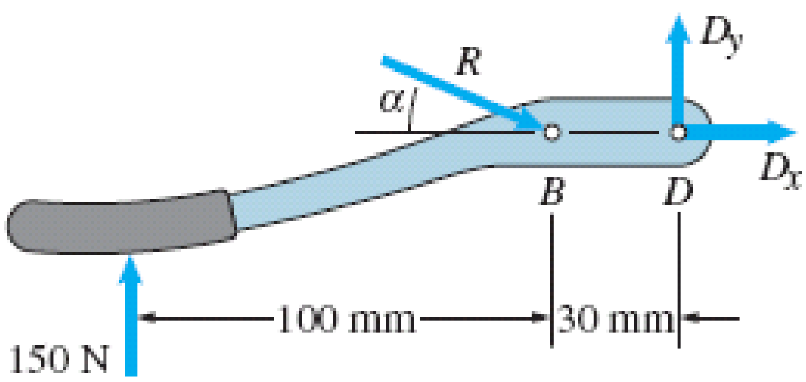


BD:

$\Sigma M_D = 0 \Rightarrow R$

ACE:

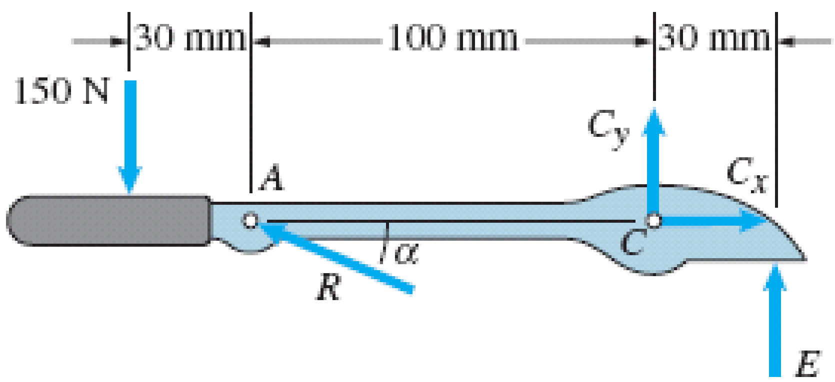
$\Sigma M_C = 0 \Rightarrow E$



BD:

$$\Sigma M_D = -150(130) + R_y(30) = 0$$

$$R_y = 150(130)/30 = 650\text{N}$$



ACE:

$$\Sigma M_C = 0 = 150(130) - R_y(100) + E(30)$$

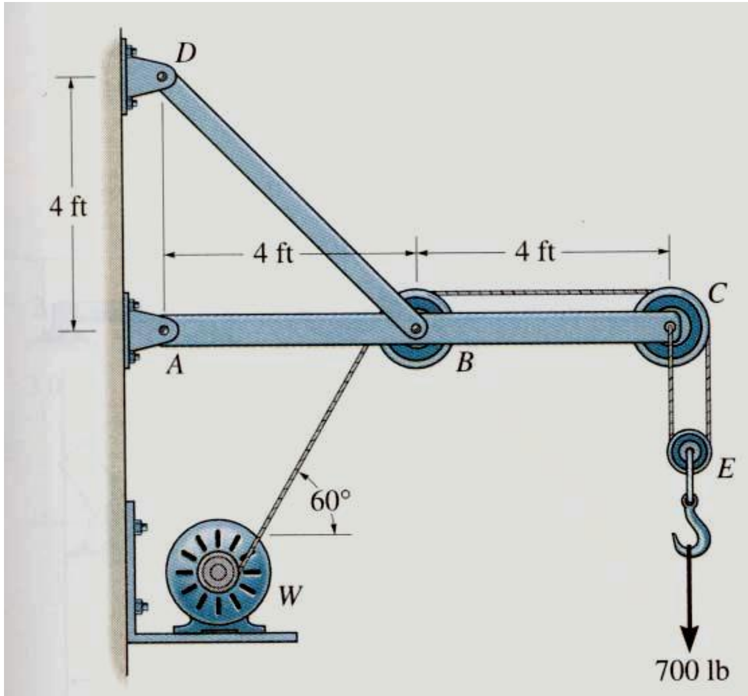
$$E = [R_y(100) - 150(130)]/30$$

$$\underline{E = 1516\text{ N}}$$

Mechanical advantage:

$$= \frac{1516\text{ N}}{150\text{ N}} \approx \underline{10:1}$$

Example 9



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

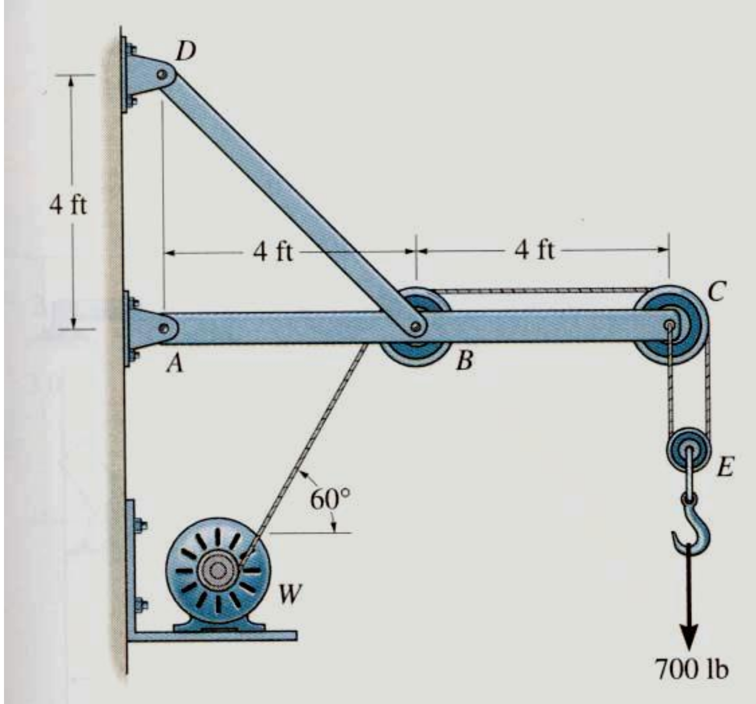
Find: The force in the cable at the winch motor W and the horizontal and vertical components of the pin reactions at A, B, C, and D.

Plan:

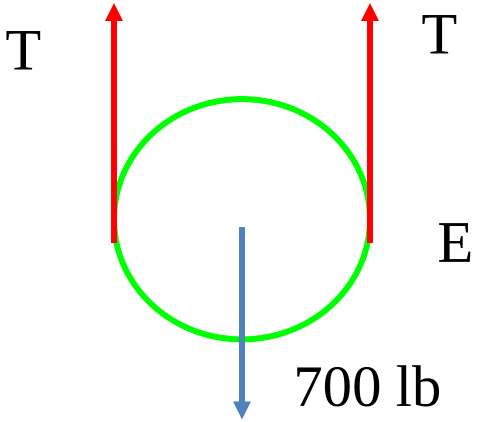
a) Draw FBDs of the frame's members and pulleys.

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

EXAMPLE 9 (continued)



FBD of the Pulley E

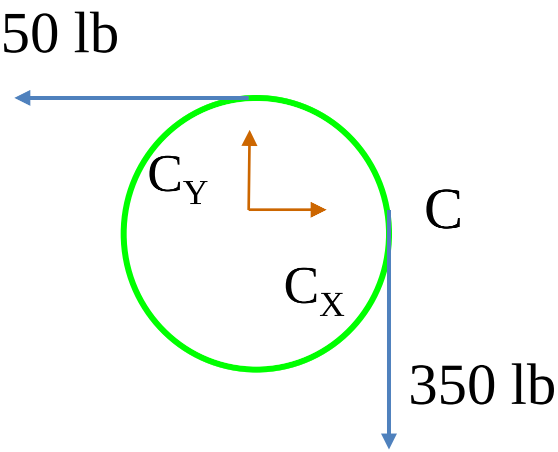


Necessary Equations of Equilibrium:

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

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

EXAMPLE 9 (continued)



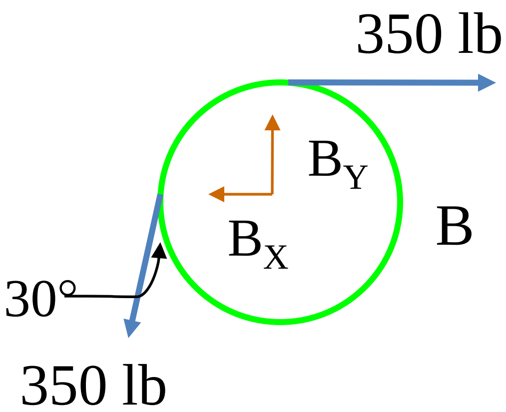
$$\rightarrow + \sum F_X = C_X - 350 = 0$$

$$\underline{C_X = 350 \text{ lb}}$$

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

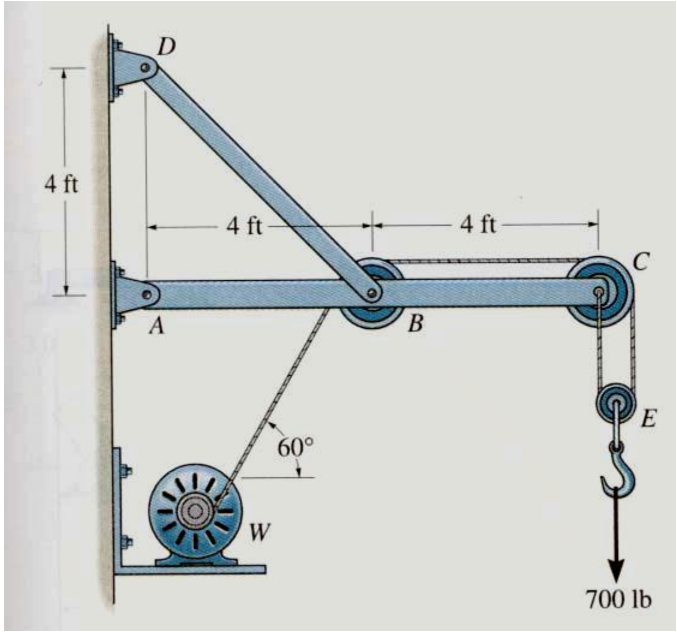
$$\underline{C_Y = 350 \text{ lb}}$$

<u>A FBD of pulley C</u>



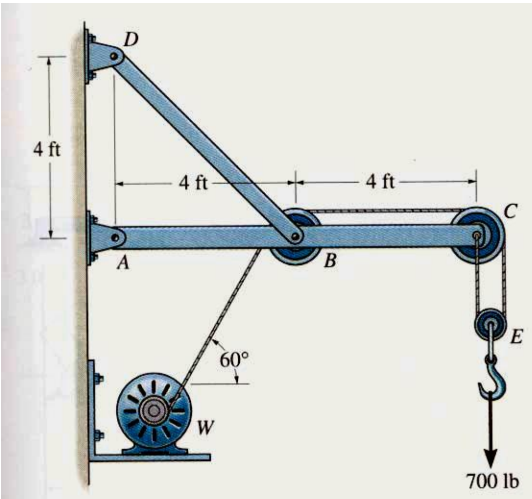
$\rightarrow + \sum F_X$ 30° = 0

$\uparrow + \sum F_Y$ 0

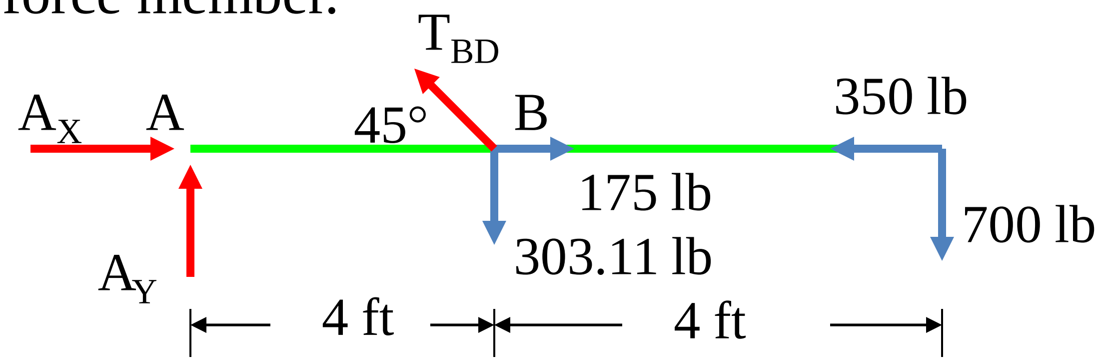


<u>A FBD of pulley B</u>

EXAMPLE 9 (continued)



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



<u>A FBD of member ABC</u>

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

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

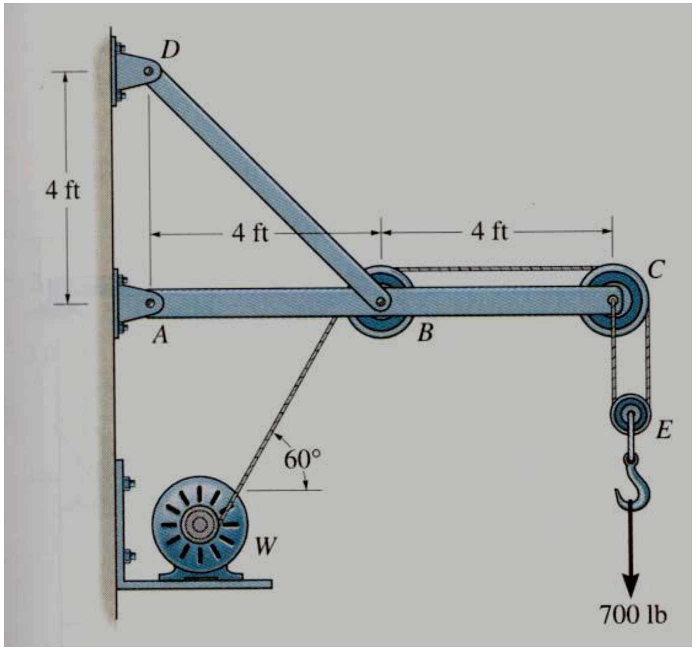
$$\uparrow + \ \sum F_Y = A_Y + 2409 \sin 45° - 303.1 - 700 = 0$$

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

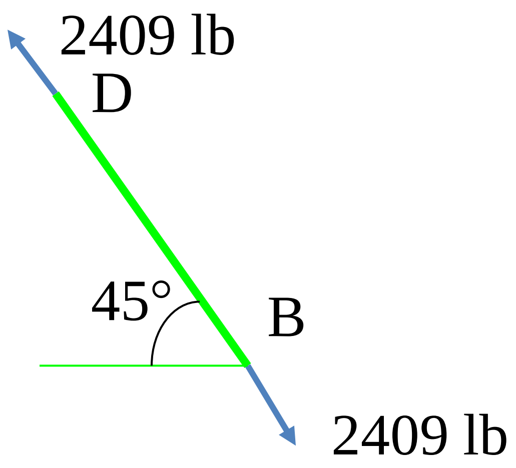
$$\rightarrow + \ \sum F_X = A_X - 2409 \cos 45° + 175 - 350 = 0$$

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

EXAMPLE 9 (continued)



A FBD of member BD



At D, the X and Y component are

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

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

End of the Lecture

Let Learning Continue