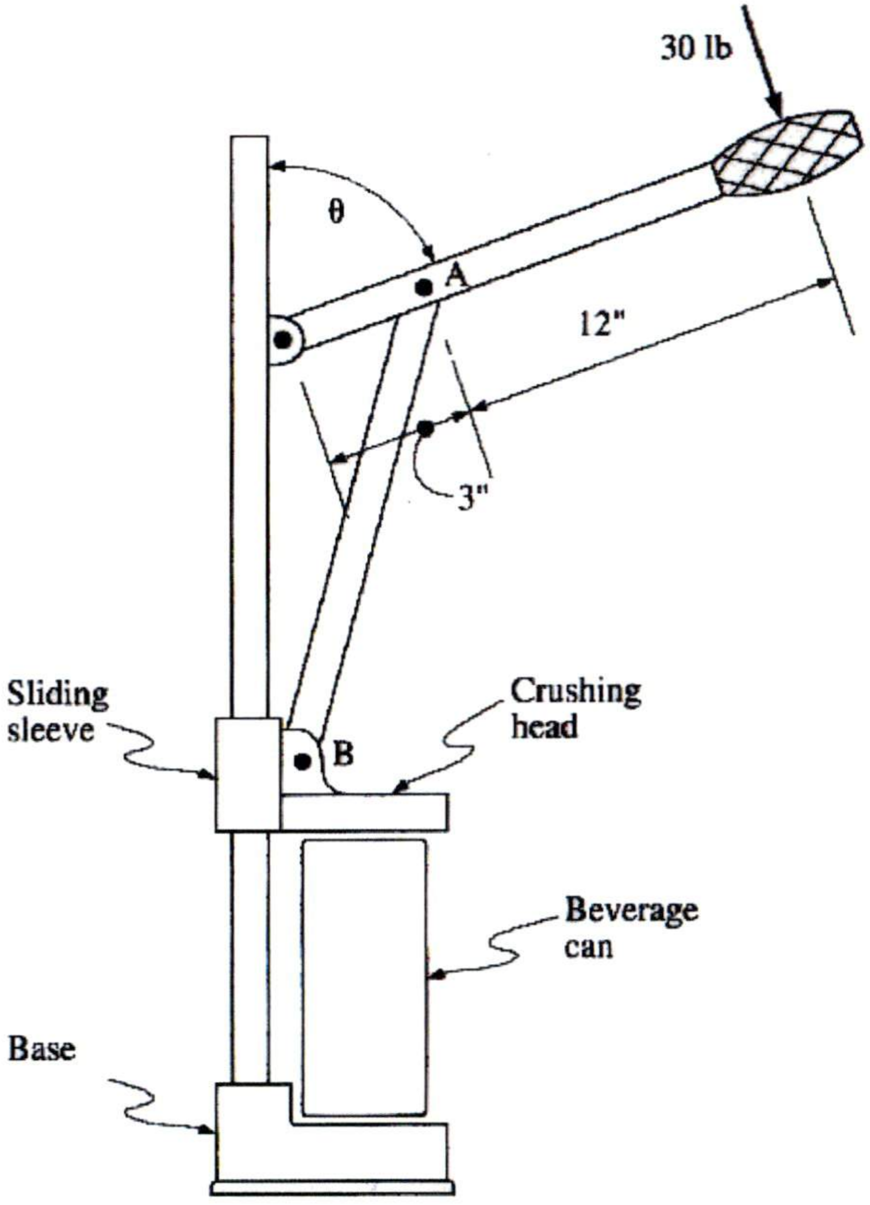
Frame
A pin-connected frame differs from a truss in that the members may no longer be connected at their ends and the loads may be applied at any point to the structure.

At least one of the members must be acted on by three or more forces. Thus the forces at the joints that hold the frame together must have x and y components.

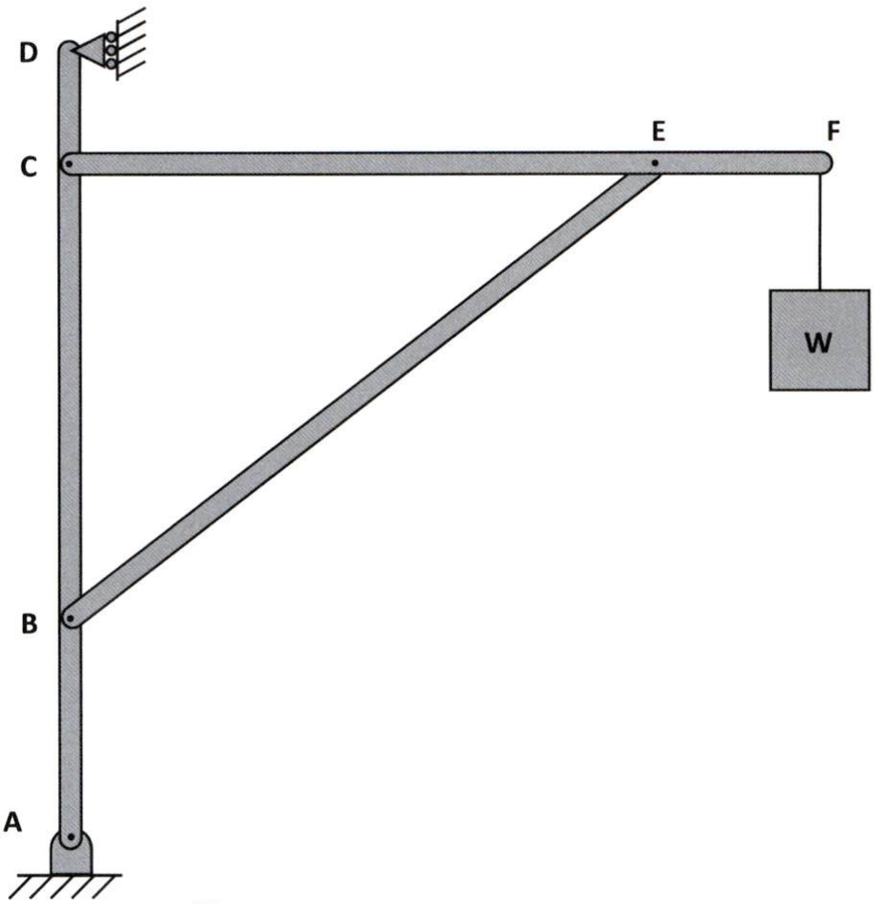
Machine
A machine differs from a pin-connected frame in that it is designed to transmit and transform input forces into output forces rather than support loads.

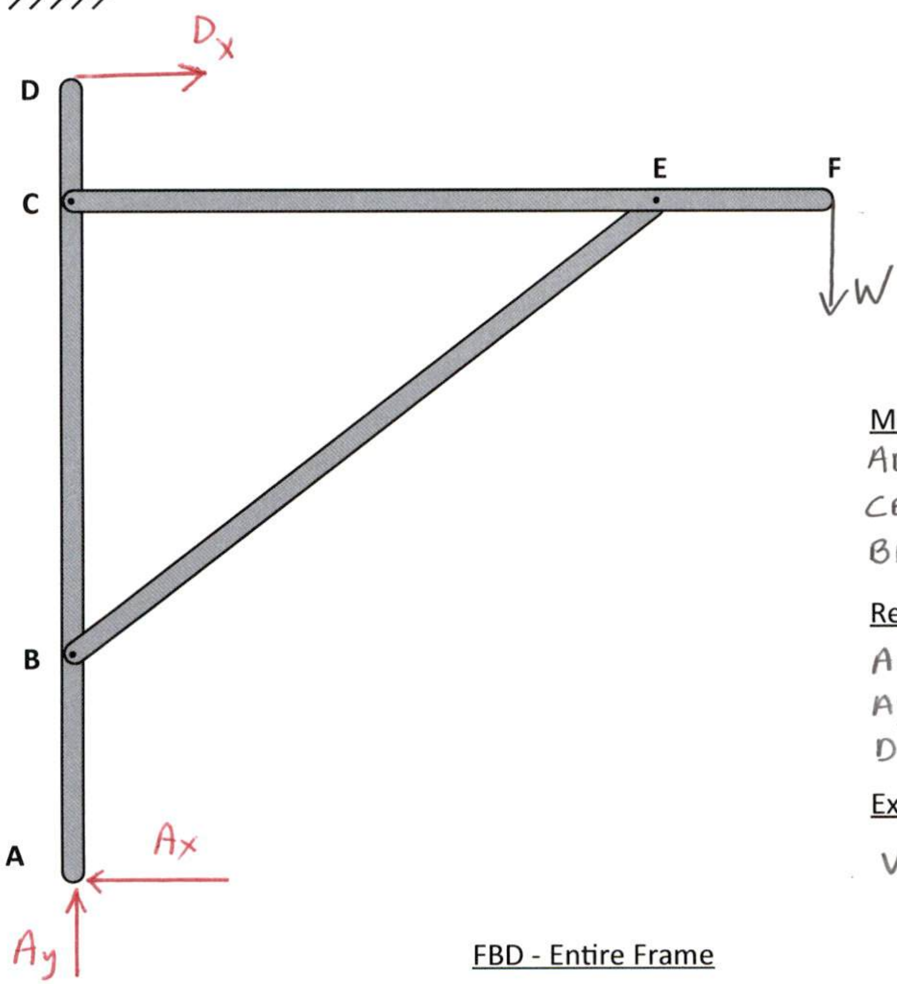
Frames are rigid structures while machines are nonrigid structures.

In machines, we will be concerned with the relationship between input and output forces necessary for equilibrium.



Frame





Members

ABCD

CEF

BE (TFM)

Reactions

A_x

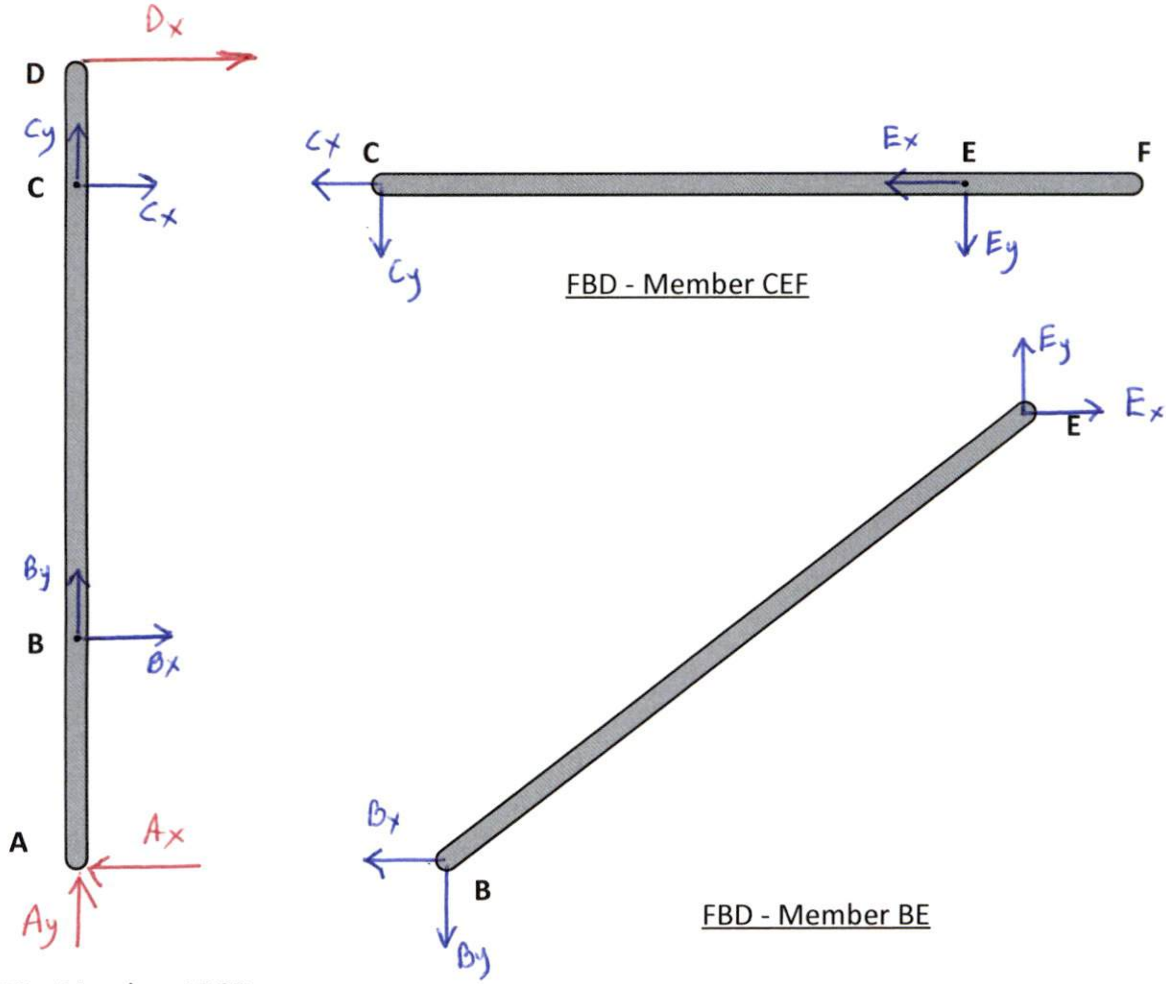
A_y

D_x

External Load

W

FBD - Entire Frame



FBD - Member CEF

FBD - Member BE

FBD - Member ABCD

Free Body Diagrams for the three members of the frame

Newton's Third Law – action and reaction
Must be observed when forces are drawn on the FBD's of the connected members.

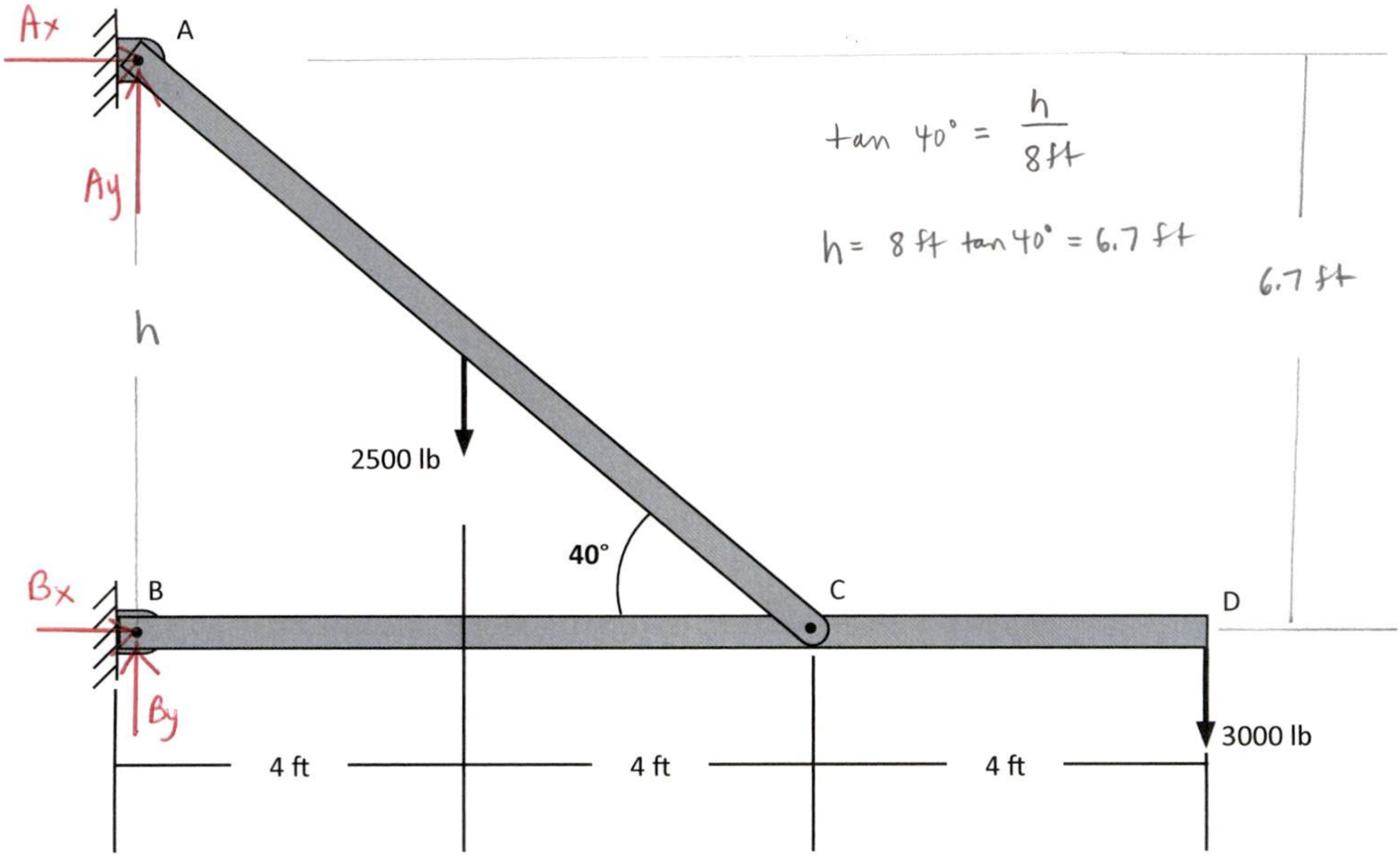
Member BE is a Two-Forec Member (TFM) and the force in the member acts along the member.

How do you check you correctly drew the forces on each FBD?

If the three free-body diagrams for the parts of the frame are combined, the forces at B, C, and E cancel and we have a FBD for the entire frame.

Example 1

A bracket is pin connected at points A, B, and D and is subjected to the loads shown. Calculate the pin reactions. Neglect the weights of the members.



Solution.

FBD- Entire Frame

CCW +M
CW − M

Equilibrium Equations

$[\Sigma M_A = 0]$ $\quad B_x(6.7\text{ ft}) - 2500\text{ lb}(4\text{ ft}) - 3000\text{ lb}(12\text{ ft}) = 0$

$$B_x = \frac{46{,}000\text{ lb}\cdot\text{ft}}{6.7\text{ ft}} = 6866\text{ lb} \rightarrow$$

$[\Sigma F_x = 0]$ $\quad A_x + B_x = 0$

$$A_x = -B_x = -6866\text{ lb} \rightarrow$$

and $\boxed{A_x = 6866\text{ lb} \leftarrow}$

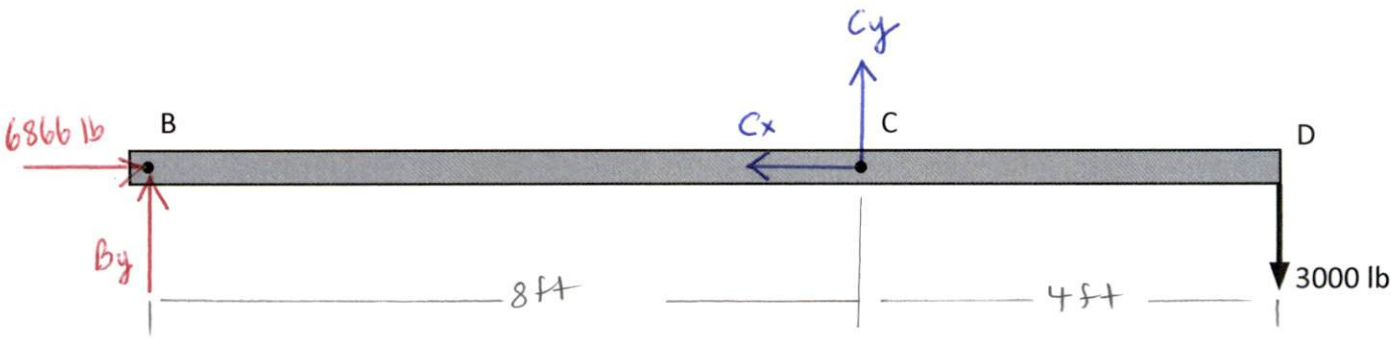
$[\Sigma F_y = 0]$ $\quad A_y + B_y - 2500\text{ lb} - 3000\text{ lb} = 0$

$$A_y + B_y = 5500\text{ lb}$$

(Can't solve yet)

EQN (1)

Member BCD



FBD - Member BCD

ccw +M
cw −M

Equilibrium Equations

$[\Sigma M_c = 0]$ $\quad -B_y(8\,ft) - 3000\,lb\,(4\,ft) = 0$

$$B_y = -\frac{12{,}000\,lb\cdot ft}{8\,ft} = -1500\,lb \uparrow$$

and $\boxed{B_y = 1500\,lb \downarrow}$

$[\Sigma F_x = 0]$ $\quad 6866\,lb - C_x = 0$

$$C_x = \underline{\underline{6866\,lb}} \leftarrow$$

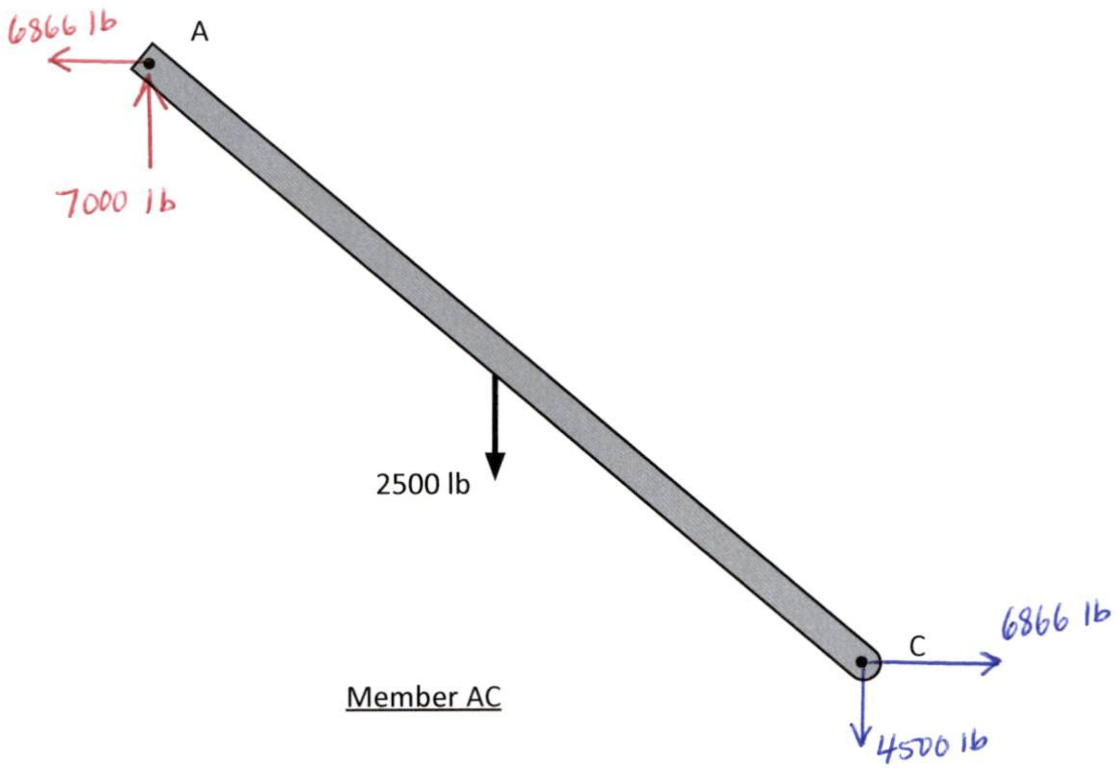
$[\Sigma F_y = 0]$ $\quad B_y + C_y - 3000\,lb = 0$

$$C_y = 3000\,lb - (-1500\,lb) = \underline{\underline{4500\,lb}} \uparrow$$

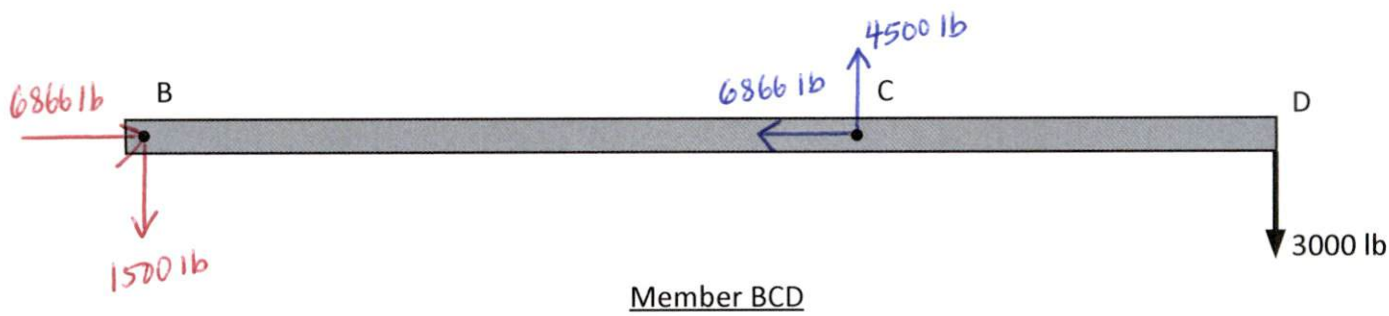
From Eqn (1) $\quad A_y + B_y = 5500\,lb$

$$A_y = 5500\,lb - (-1500\,lb) = 7000\,lb \uparrow$$

Summarize the Results



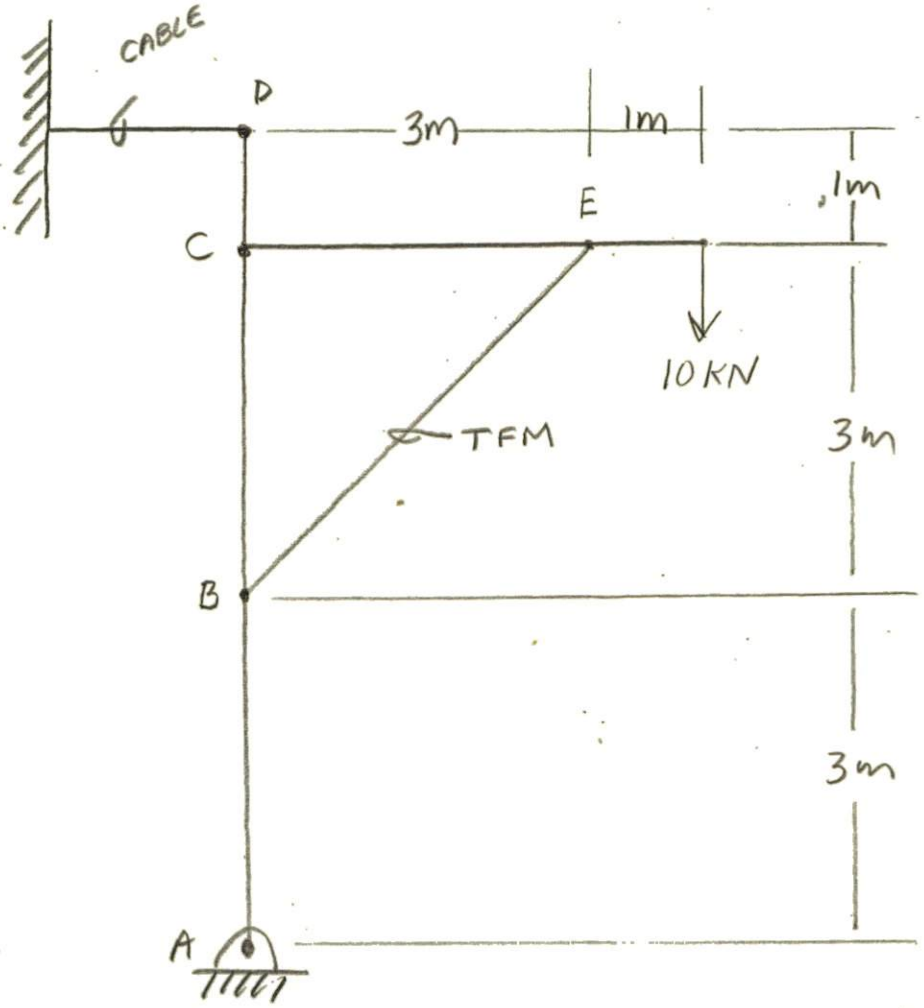
Member AC



Member BCD

Example 2. (solution #1)

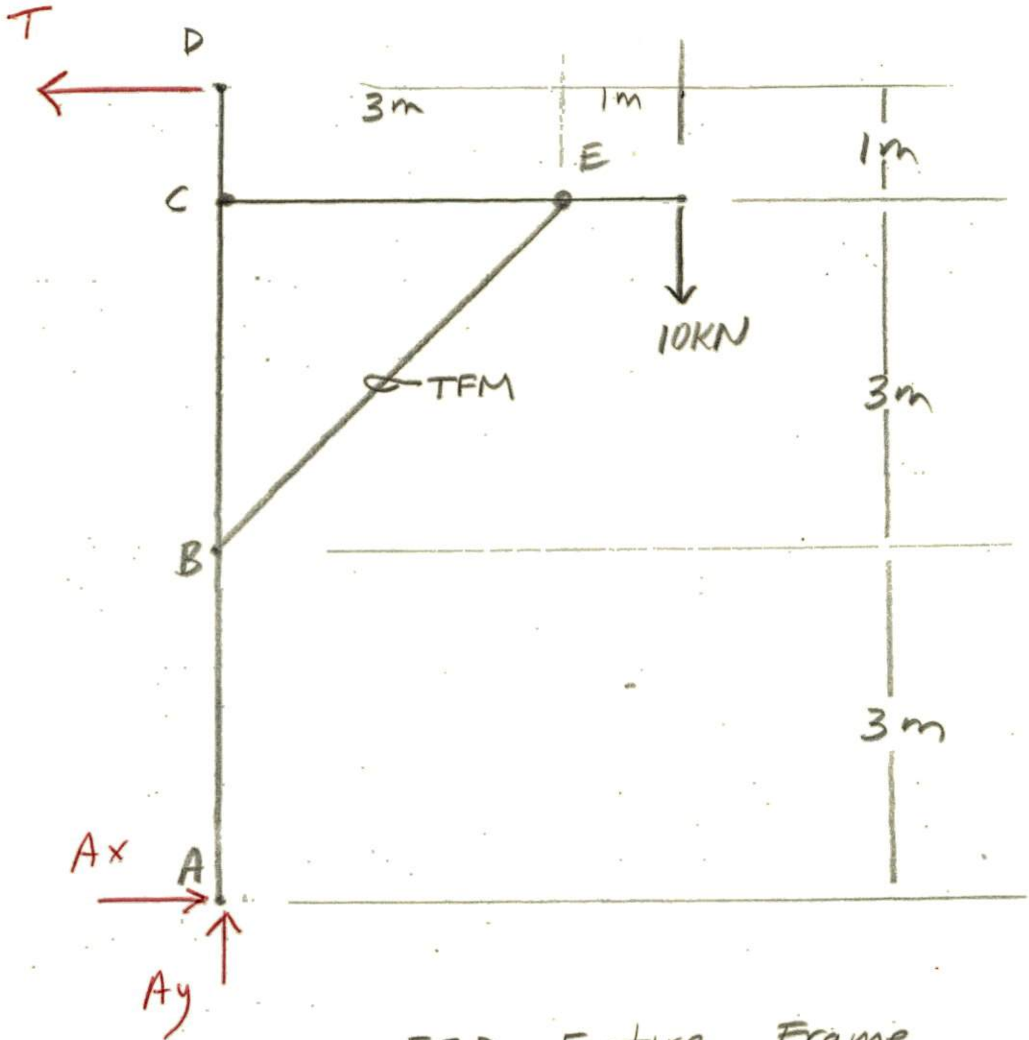
Determine the pin reactions for the frame shown.



Solution.

MULTI-FORCE MEMBERS	TFM
ABCD	BE
CE	

Step. 1. Use the FBD of the Entire Frame to solve for the support reactions.



FBD- Entire Frame

Equilibrium Equations

CCW +M
CW −M

$[\Sigma M_A = 0]$ $T(7m) - 10KN(4m) = 0$

$$T = \frac{40\ KN \cdot m}{7m}$$

$$T = \underline{\underline{5.71\ KN}} \leftarrow$$

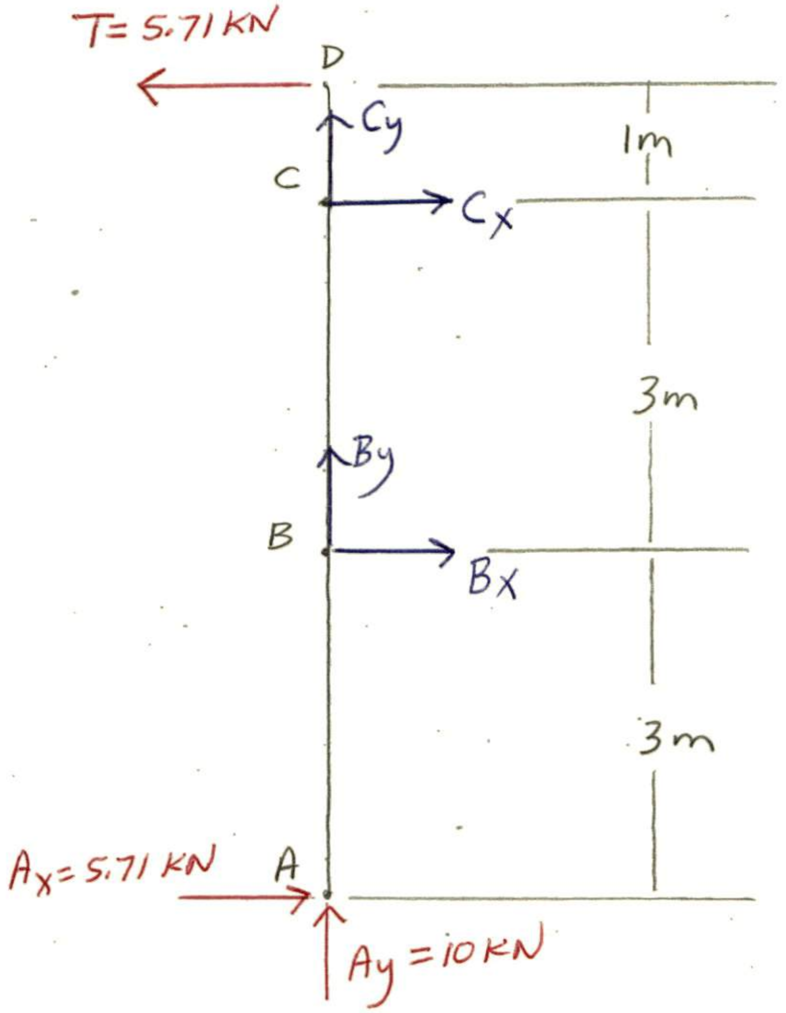
$[\Sigma F_x = 0]$ $Ax - T = 0$

$$Ax = \underline{\underline{5.71\ KN}} \rightarrow$$

$[\Sigma F_y = 0]$ $A_y - 10\,kN = 0$

$$A_y = \underline{\underline{10\,kN}} \uparrow$$

Member ABCD



FBD- member ABCD

Equilibrium Equations

$[\Sigma M_B = 0]$ $5.71\,kN(4m) + 5.71\,kN(3m) - C_x(3m) = 0$

$$C_x = \frac{39.97\,kN \cdot m}{3m} = \underline{\underline{13.3\,kN}} \rightarrow$$

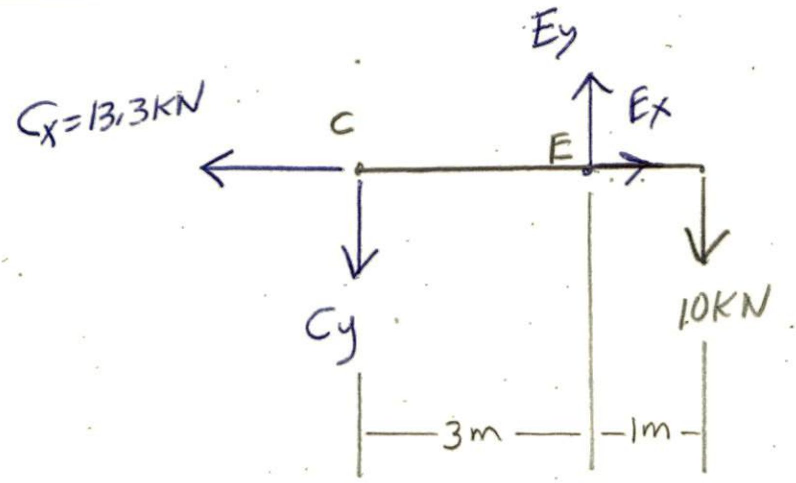
$[\Sigma F_x = 0]$ $5.71\,kN - 5.71\,kN + C_x + B_x = 0$

$$B_x = -13.3\,kN \rightarrow$$

or $\boxed{B_x = 13.3\,kN \leftarrow}$

$[\Sigma F_y = 0]$ $\quad C_y + B_y + 10\,KN = 0$ (EQN 1) (C.S.4)

Member CE



FBD- member CE

Equilibrium Equations

$[\Sigma M_c = 0]$ $\quad E_y(3m) - 10\,KN(4m) = 0$

$$E_y = \underline{\underline{13.3\ KN}} \uparrow$$

$[\Sigma F_x = 0]$ $\quad -13.3\,KN + E_x = 0$

$$E_x = \underline{\underline{13.3\ KN}} \rightarrow$$

$[\Sigma F_y = 0]$ $\quad -C_y + E_y - 10\,KN = 0$

$$C_y = 13.3\,KN - 10\,KN$$

$$C_y = \underline{\underline{3.3\ KN}} \downarrow$$

From (EQN.1)

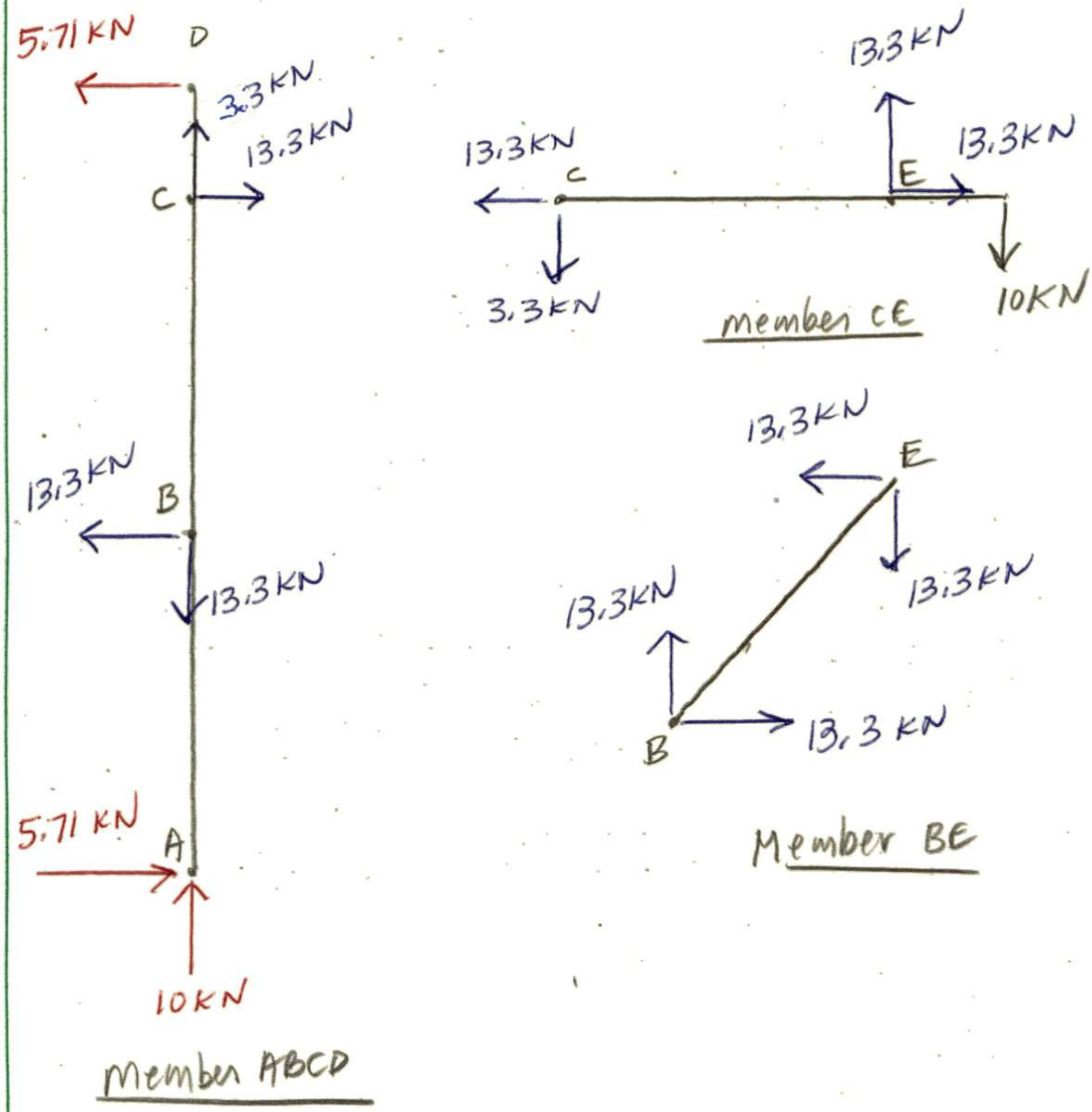
$$C_y + B_y + 10\,KN = 0$$

$$B_y = -3.3\,KN - 10\,KN$$

$$B_y = -13.3\,KN \uparrow$$

or $\boxed{B_y = 13.3\,KN \downarrow}$

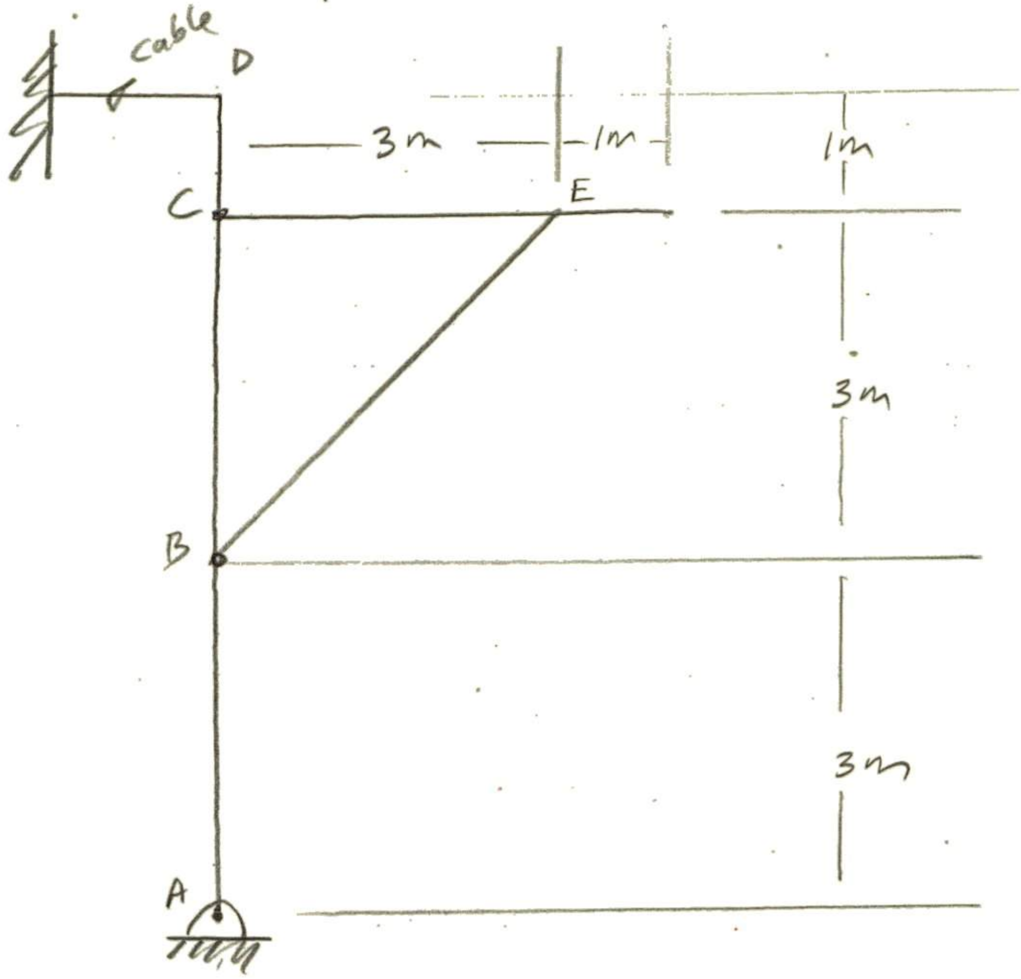
Summarize Results (No. Dimensions shown)



All Members are in Equilibrium!

Example 2. (solution #2)

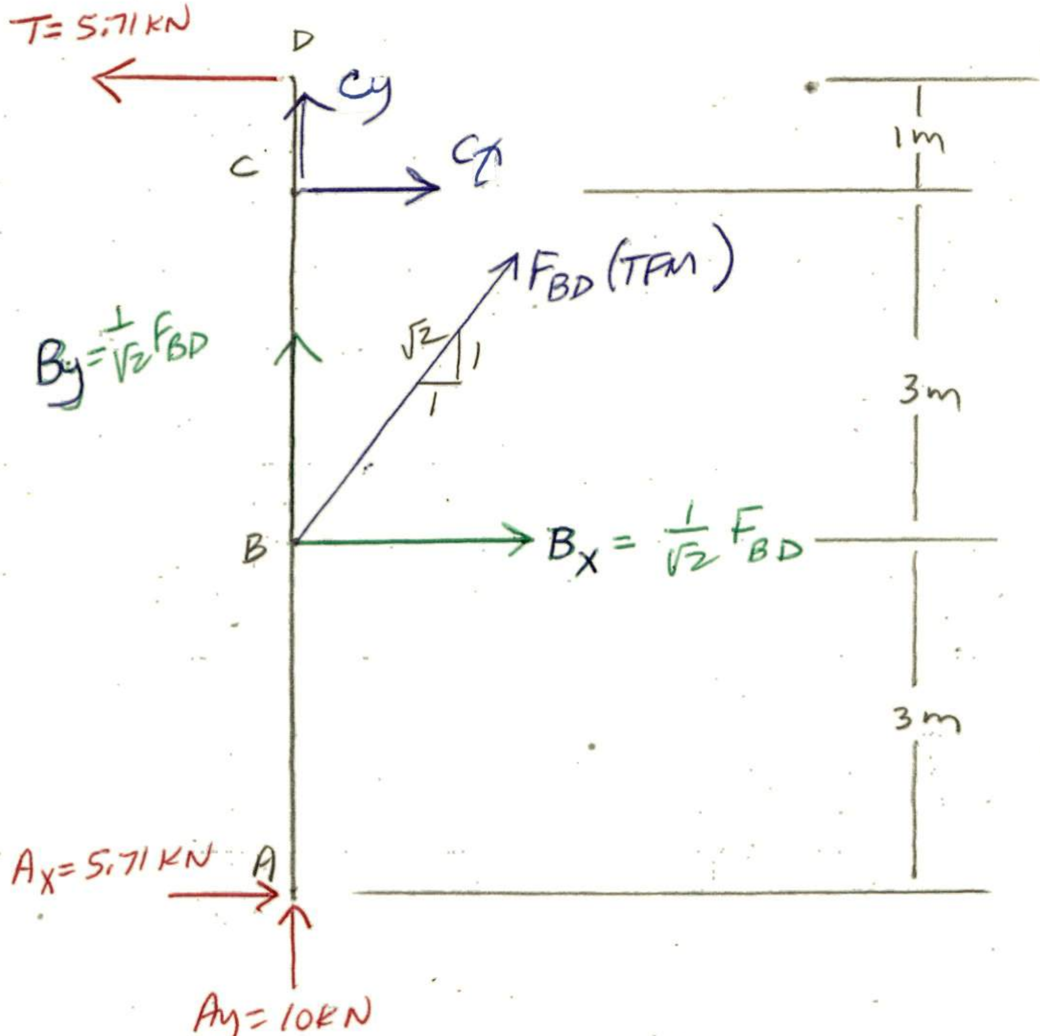
Determine the pin reactions for the frame shown.



Solution.

See Solution #1 to solve for the reactions at supports A and D.

Member ABCD



FBD- Member ABCD

Equilibrium Equations

$[\Sigma M_B=0]$ $5.71\,kN(4m) + 5.71\,kN(3m) - C_x(3m) = 0$

$C_x = 13.3\,kN \rightarrow$

$[\Sigma F_x=0]$ $-5.71\,kN + 5.71\,kN + C_x + \frac{1}{\sqrt{2}} F_{BD} = 0$

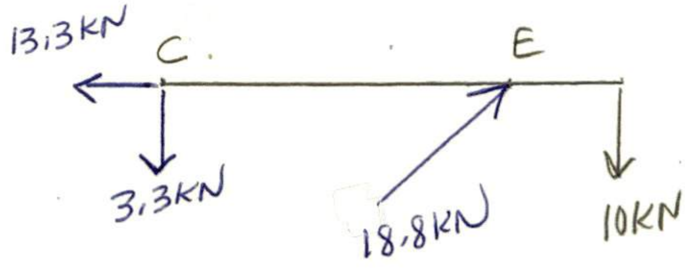
$F_{BD} = -13.3\,kN(\sqrt{2}) = -18.8\,kN\,(T)$

or $\boxed{F_{BD} = 18.8\,kN\,(C)}$

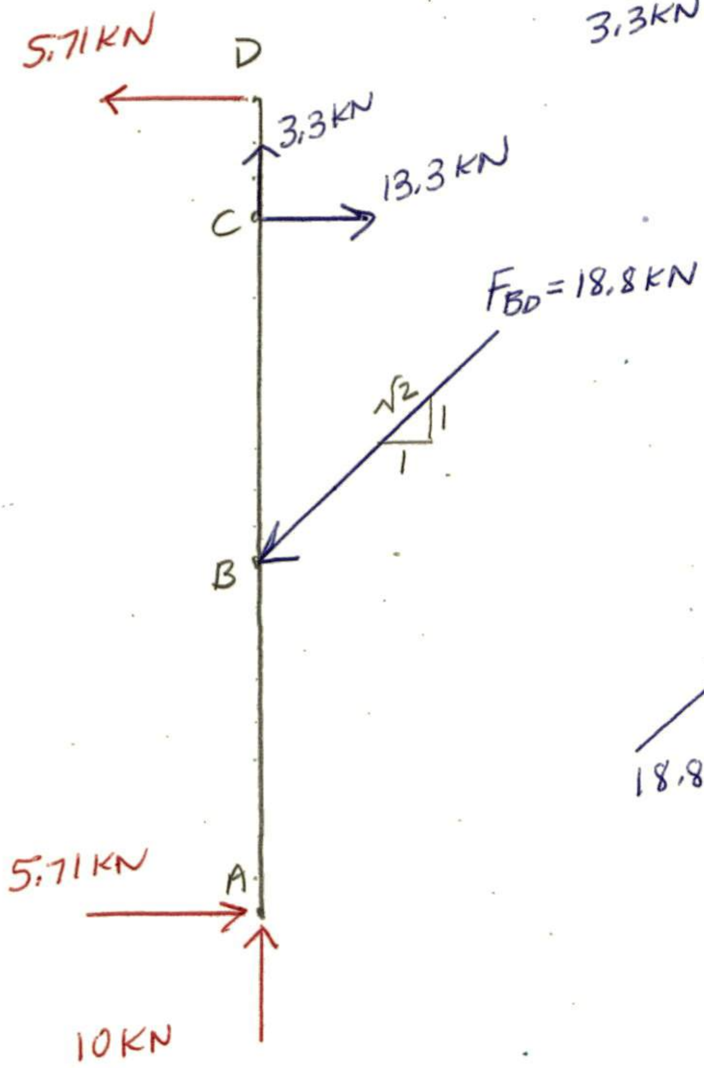
$[\Sigma F_y=0]$ $10\,kN + \frac{1}{\sqrt{2}} F_{BD} + C_y = 0$

$C_y = -10\,kN - \frac{1}{\sqrt{2}}(-18.8\,kN) = \underline{\underline{3.3\,kN}} \uparrow$

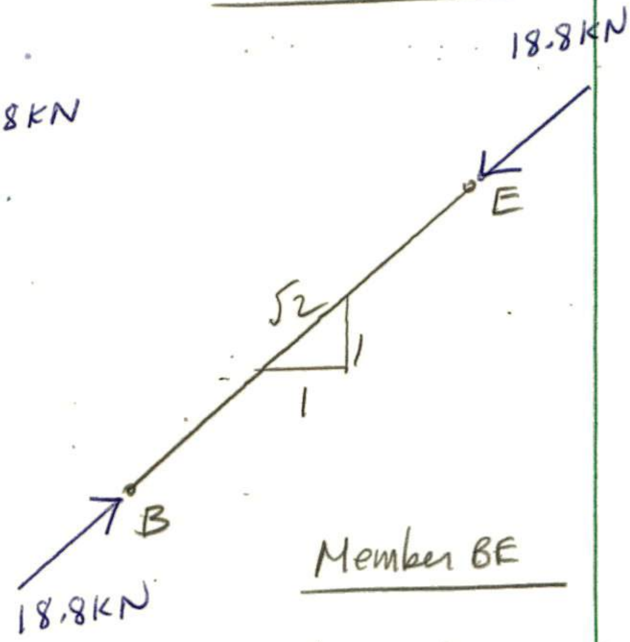
Summarize Results



member CE



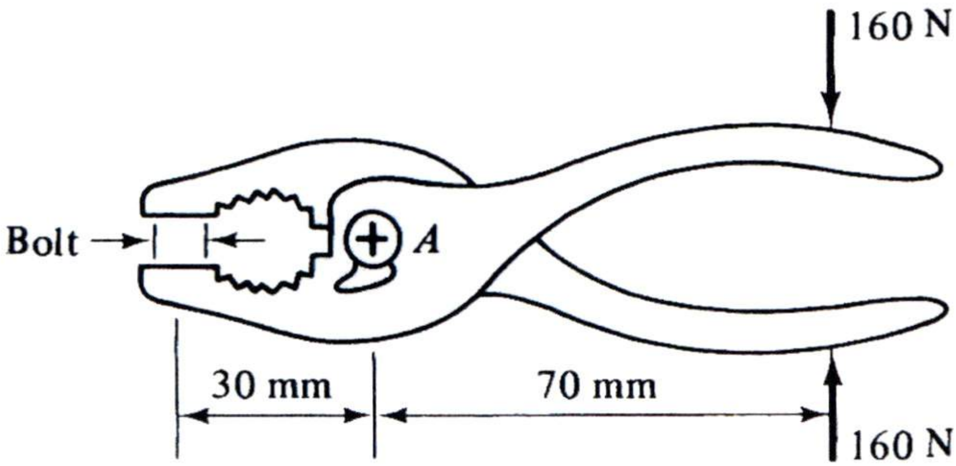
Member ABCD



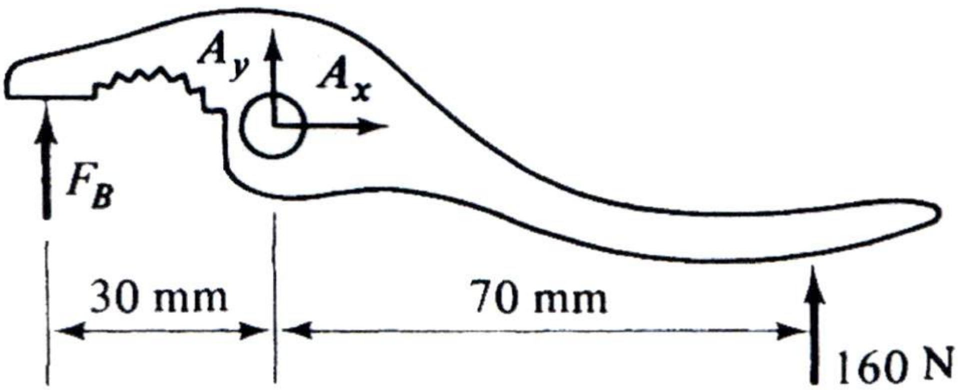
Member BE

Machines

Example 1
A force is applied to the handle of the pliers shown. Find the force applied to the bolt and the horizontal and vertical reactions at the hinge A.



Solution.



<u>Free-Body Diagram - Upper handle of Pliers</u>

CCW +M
CW − M

<u>Equilibrium Equations</u>

$[\Sigma M_A = 0]$ $\quad -F_B\,(30\text{mm}) + 160\text{N}\,(70\text{mm}) = 0$

$$F_B = \underline{\underline{373\ \text{N}}}$$

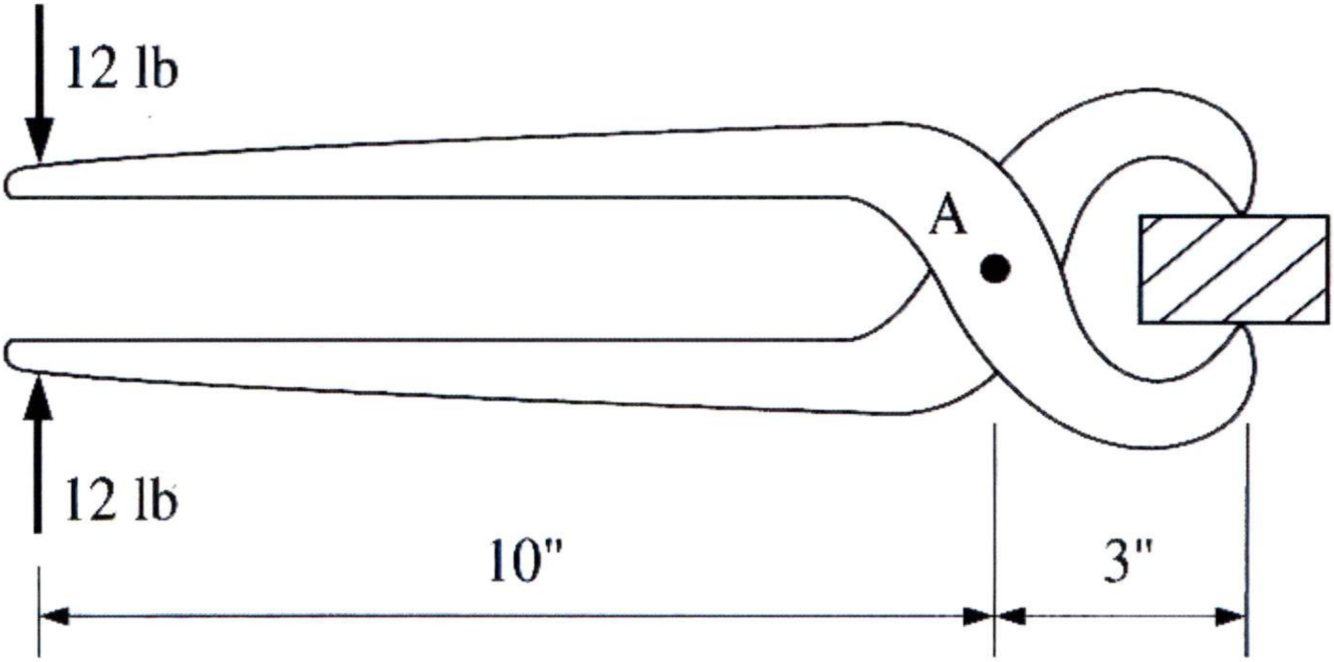
$[\Sigma F_x = 0]$ $\quad A_x = 0$

$[\Sigma F_y = 0]$ $\quad F_B + A_y + 160\text{N} = 0$

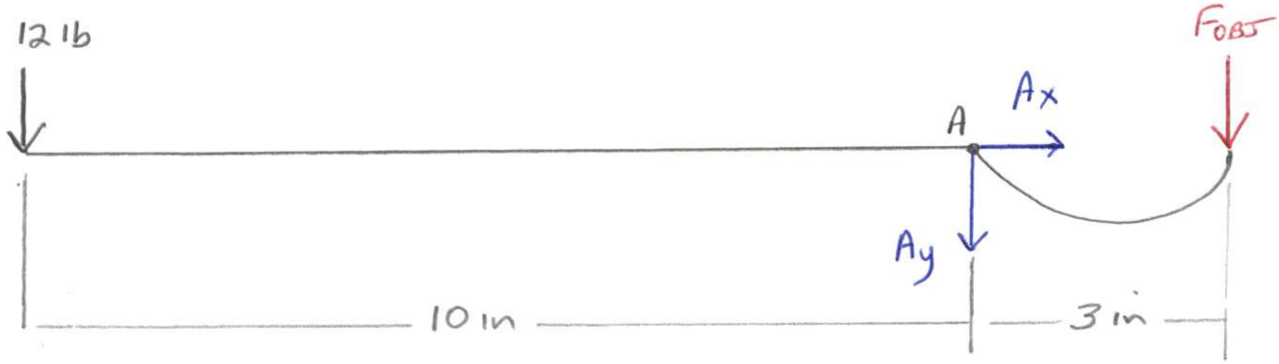
$$A_y = -373\text{N} - 160\text{N} = -533\ \text{N}\ \uparrow$$

and $\boxed{A_y = 533\ \text{N}\ \downarrow}$

Example 2
The tongs shown are used to grip an object. For an input force of 12 lb on each handle, determine the forces exerted on the object and the forces exerted on the pin at A.



Solution.



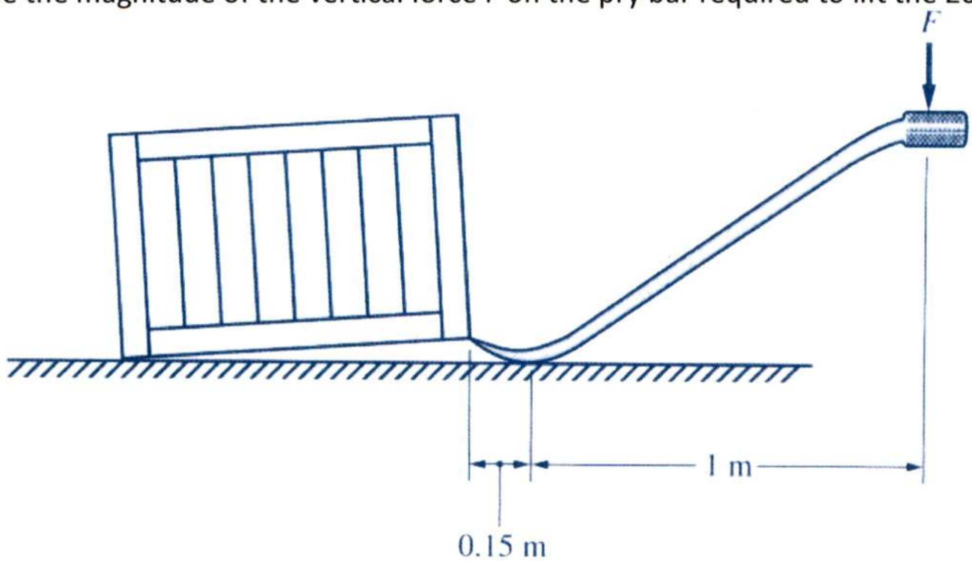
FBD- Upper member

Equilibrium Equations

$[\Sigma M_A = 0]$ $\quad 12 \text{ lb} (10 \text{ in}) - F_{OBJ} (3 \text{ in}) = 0$

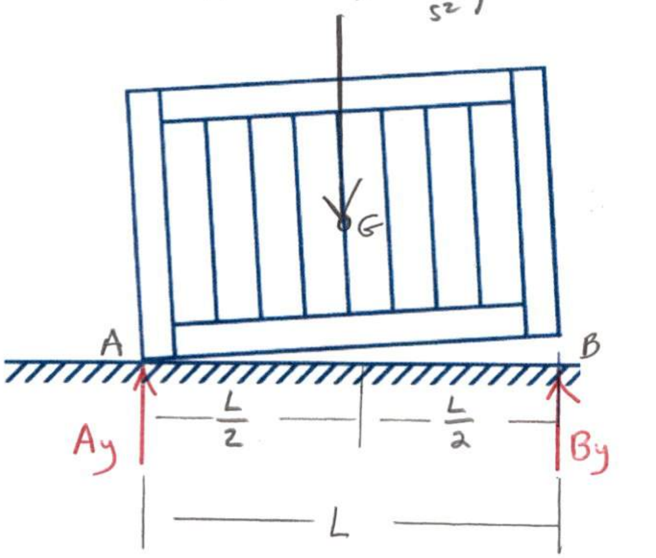
$$F_{OBJ} = \frac{120 \text{ lb}\cdot\text{in}}{3 \text{ in}} = \underline{\underline{40 \text{ lb}}} \downarrow$$

4-39 Determine the magnitude of the vertical force F on the pry bar required to lift the 2000-kg crate.

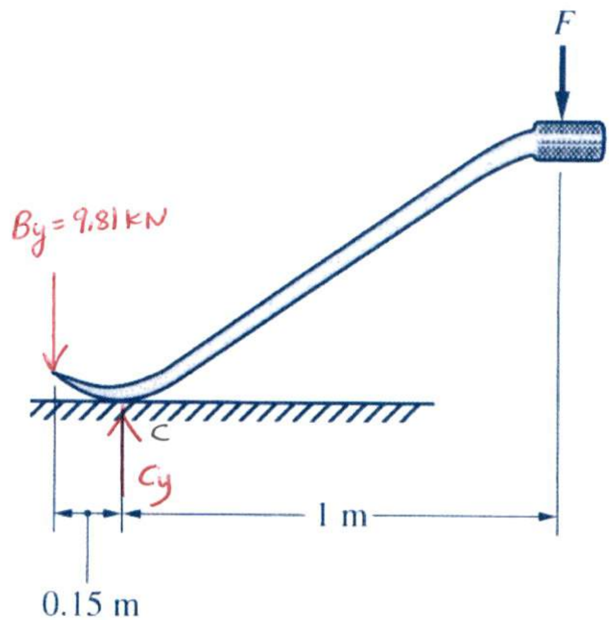


Solution.

$W = 2000\ kg \left(9.81 \frac{m}{s^2}\right) = 19.62\ kN$



FBD - Crate



FBD - Pry Bar

Equilibrium Equations

$[\Sigma M_A = 0]$

$-19.62\ kN\left(\frac{L}{2}\right) + B_y(L) = 0$

$B_y = \frac{19.62\ kN\left(\frac{L}{2}\right)}{L}$

$= \underline{\underline{9.81\ kN}} \uparrow$

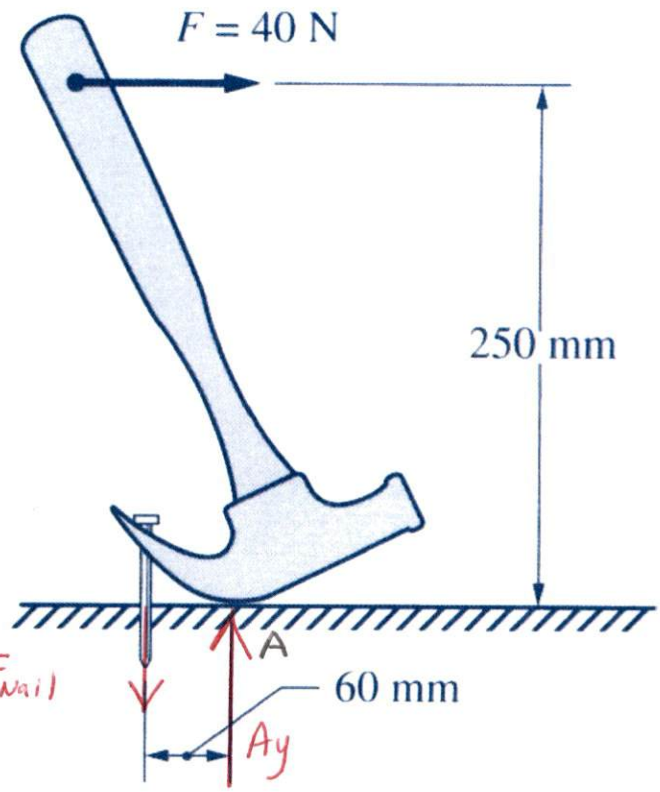
Equilibrium Equations

$[\Sigma M_C = 0]$

$9.81\ kN\,(0.15 m) - F\,(1 m) = 0$

$\underline{\underline{F = 1.47\ kN}} \downarrow$

4-40 A horizontal force F of 40N is applied to the claw hammer. Determine the force exerted on the nail by the claw hammer.



Solution.

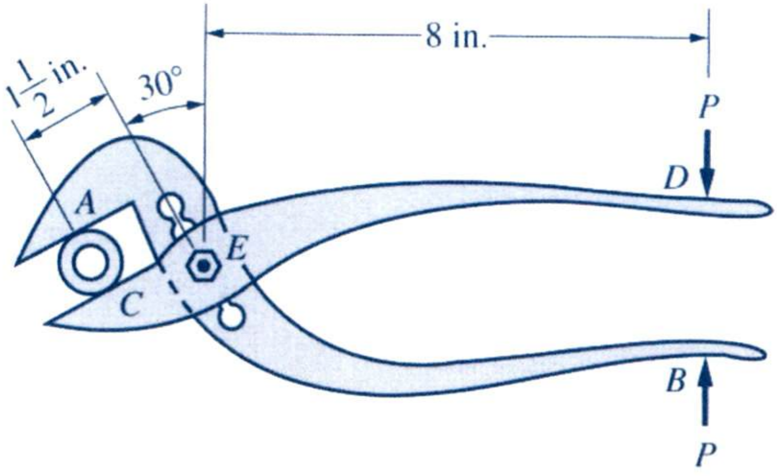
FBD

Equilibrium Equations

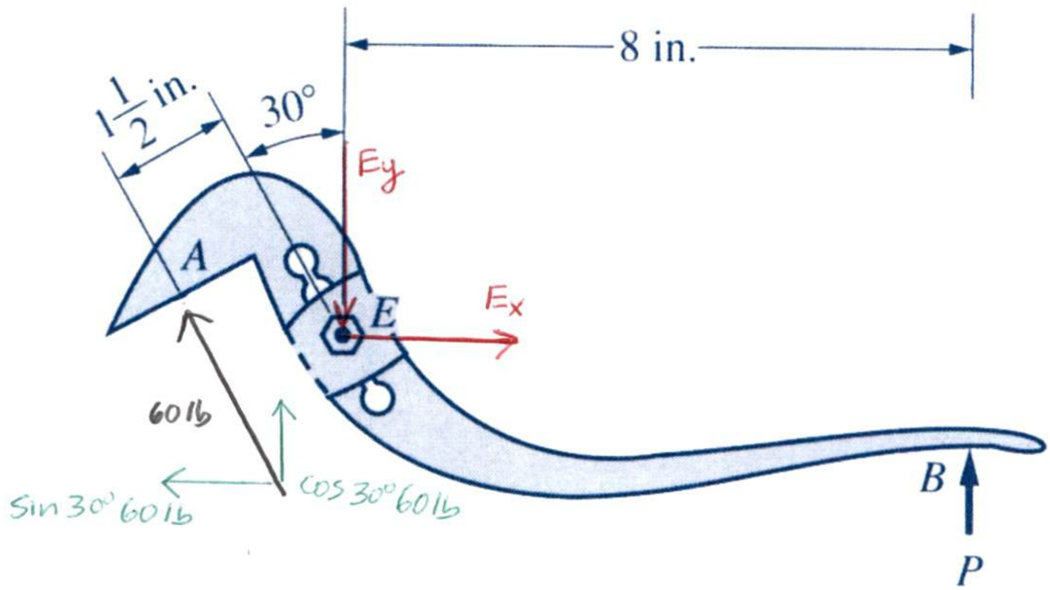
$[\Sigma M_A = 0]$ $\quad F_{NAIL}(60mm) - 40N(250mm) = 0$

$$F_{Nail} = \frac{40N(250mm)}{60mm} = \underline{\underline{167N}} \downarrow$$

4-41 The pipe is held by a joint plier with a clamping force of 60 lb. Determine (a) the force P applied to the handles and (b) the force exerted by the pin E on portion AB of the plier.



Solution.



FBD- member AEB

Equilibrium Eqns

(a)

$[\Sigma M_E = 0]$ $\quad P(8\text{in}) - 60\text{ lb}(1.5\text{in}) = 0$

$$P = \underline{11.25\text{ lb}} \uparrow$$

(b)

$[\Sigma F_x = 0]$ $\quad -\sin 30° \, 60\text{ lb} + E_x = 0$

$$E_x = \underline{30\text{ lb}} \rightarrow$$

$[\Sigma F_y = 0]$ $\quad \cos 30° \, 60\text{ lb} - E_y + 11.25\text{ lb} = 0$

$$E_y = \underline{62.3\text{ lb}} \downarrow$$