Carleton University * Faculty of Engineering and Design

Mechanics I

ECOR 1101

Lecture 14

FRAMES AND MACHINES

Section 7.1

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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.

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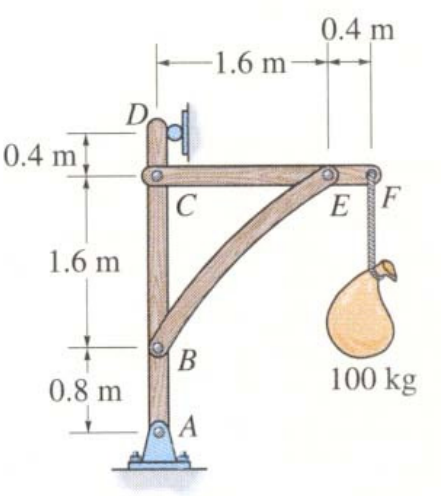
APPLICATIONS



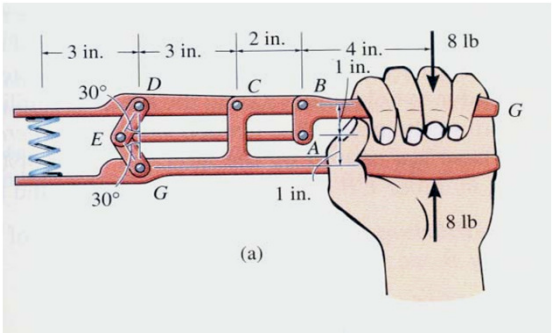
Frames are commonly used to support various external loads.

How is a frame different than a truss?

How can you determine the forces at the joints and supports of a frame?

3

APPLICATIONS (continued)



Machines, like these above, are used in a variety of applications.

How can you determine the loads at the joints and supports?

These forces and moments are required when designing the machine members.

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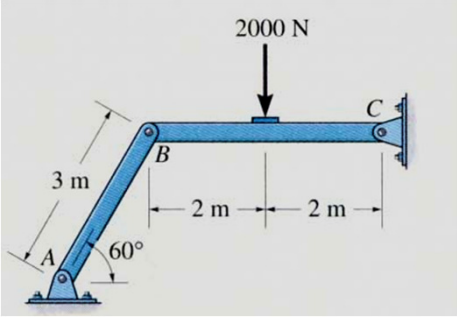
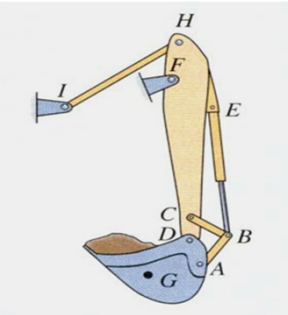
FRAMES AND MACHINES: DEFINITIONS





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.

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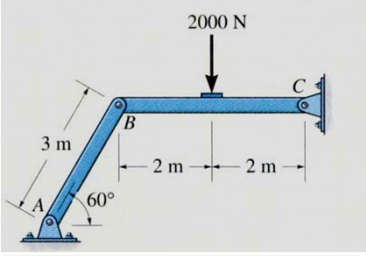
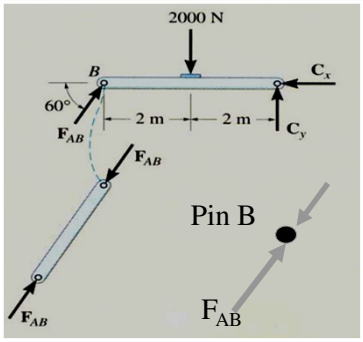
STEPS FOR ANALYZING A FRAME OR MACHINE





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.

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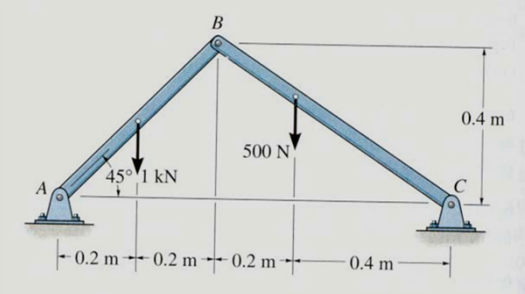
PROBLEM SOLVING



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.

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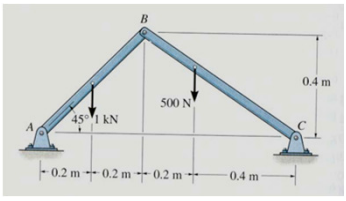
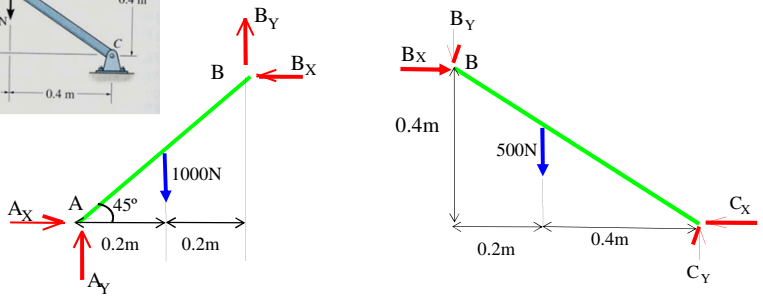
PROBLEM SOLVING (continued)



FBDs of members AB and BC:



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

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

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

$B_Y = 0$ and $B_X = 500$ N

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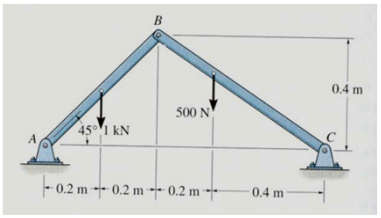
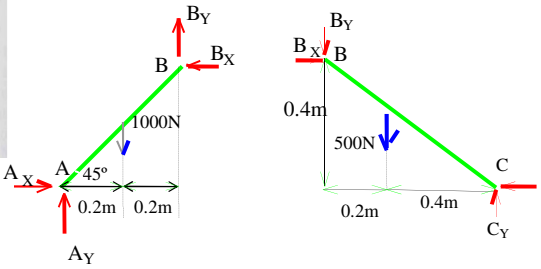
PROBLEM SOLVING (continued)



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

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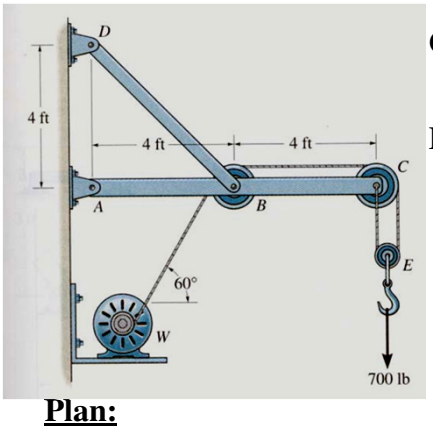
EXAMPLE



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.

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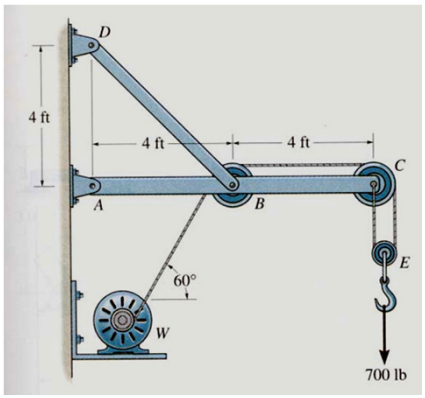
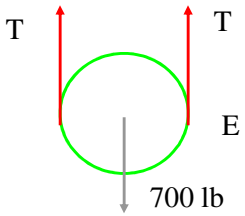
EXAMPLE (continued)



FBD of the Pulley E



Necessary Equations of Equilibrium:

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

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

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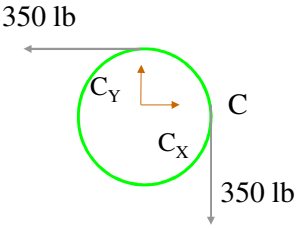
EXAMPLE (continued)



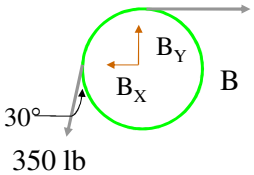
$$\rightarrow + \sum F_X = C_X - 350 = 0$$

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

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

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

A FBD of pulley C



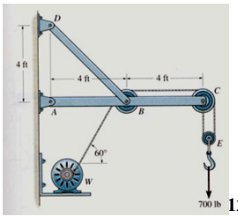
$$\rightarrow + \sum F_X = -B_X + 350 - 350 \sin 30° = 0$$

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

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

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

A FBD of pulley B



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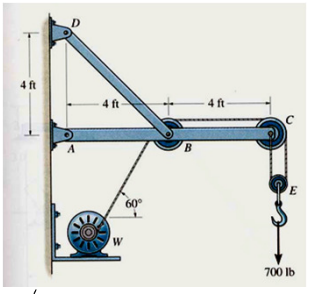
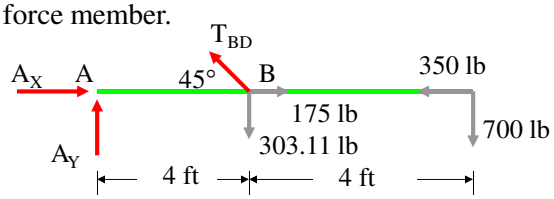
EXAMPLE (continued)



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



A FBD of member ABC

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

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

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

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

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

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

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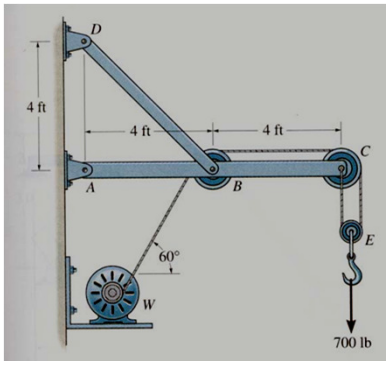
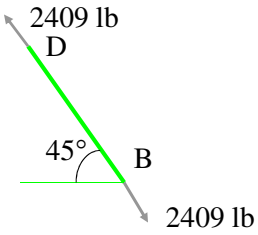
EXAMPLE (continued)



A FBD of member BD



At D, the X and Y component are

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

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

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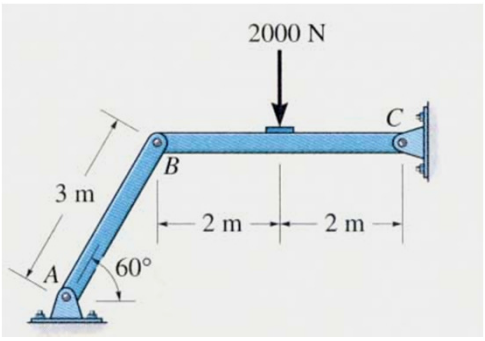
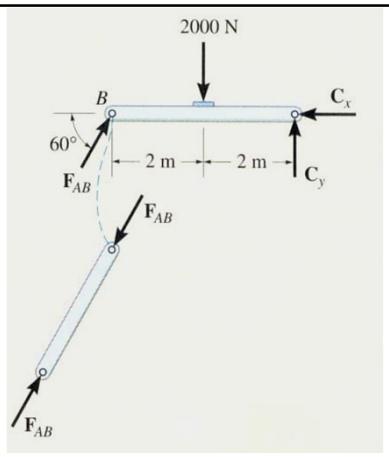
CONCEPT QUIZ





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.

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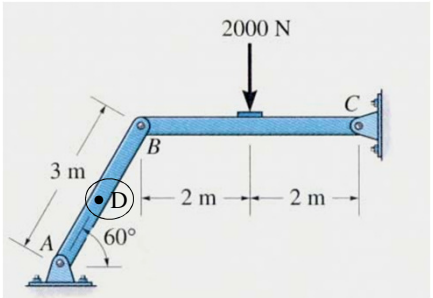
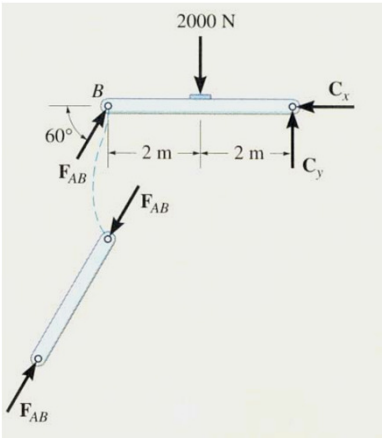
CONCEPT QUIZ (continued)





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.

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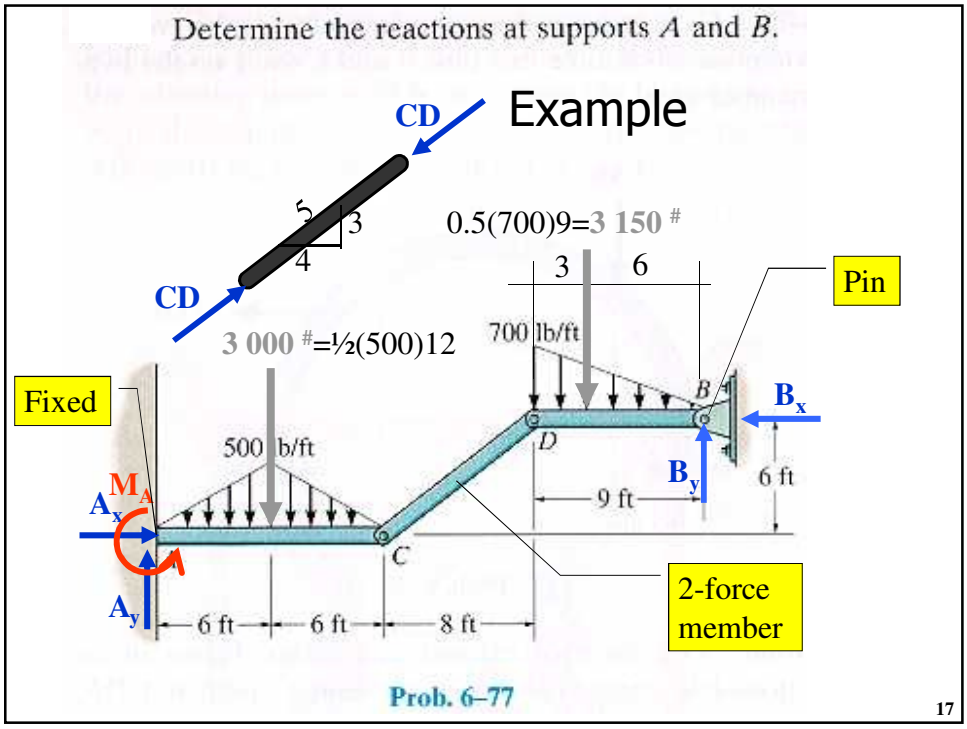
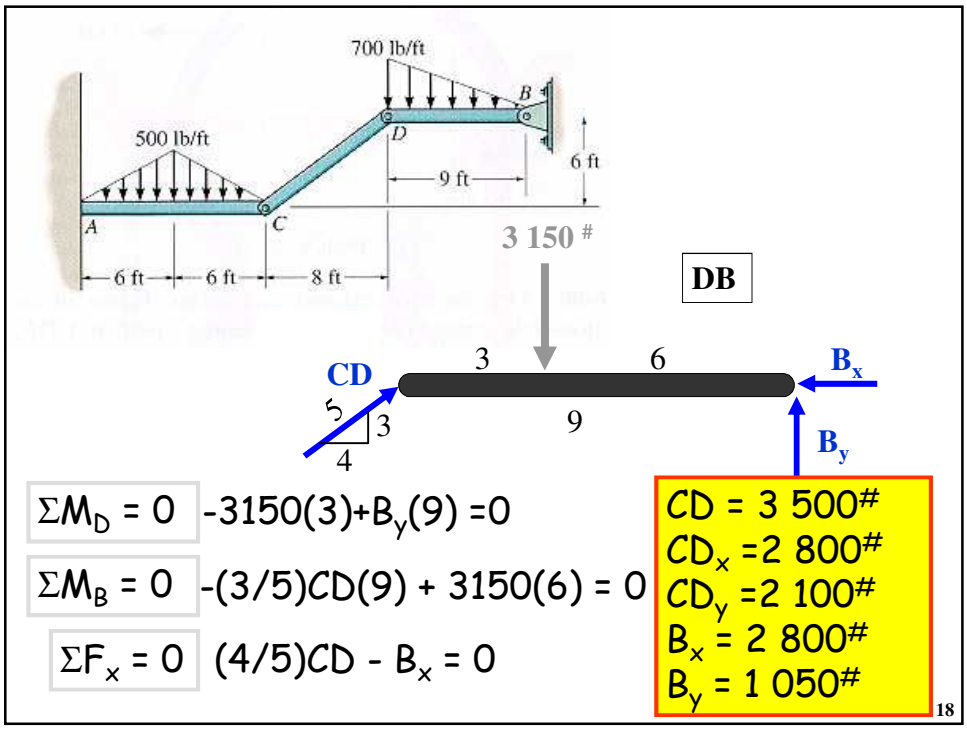
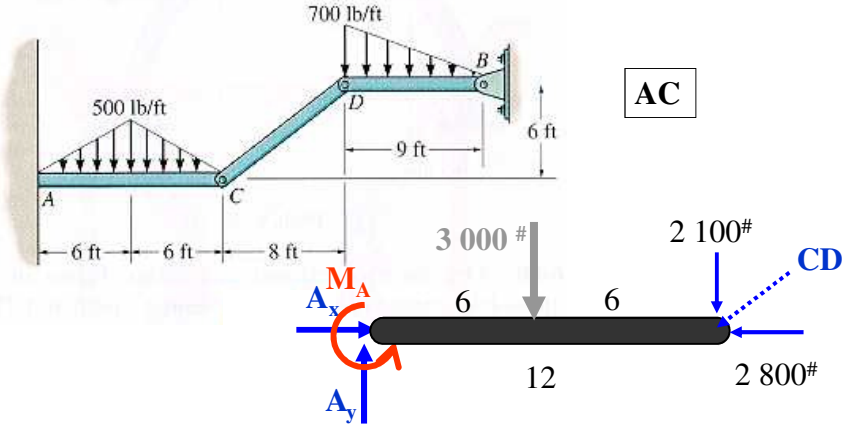

Determine the reactions at supports A and B.
Example
CD
5
3
4
CD
0.5(700)9=3 150 #
3
6
Pin
3 000 #=½(500)12
700 lb/ft
Fixed
B
Bx
500 lb/ft
D
By
9 ft
6 ft
MA
Ax
C
Ay
6 ft
6 ft
8 ft
2-force member
Prob. 6–77
17


700 lb/ft
B
500 lb/ft
D
9 ft
6 ft
A
C
6 ft
6 ft
8 ft
3 150 #
DB
CD
3
6
Bx
5
3
4
9
By
ΣMD = 0 -3150(3)+By(9) =0
ΣMB = 0 -(3/5)CD(9) + 3150(6) = 0
ΣFx = 0 (4/5)CD - Bx = 0
CD = 3 500#
CDx =2 800#
CDy =2 100#
Bx = 2 800#
By = 1 050#
18



$\Sigma M_A = 0$ M_A - 3000(6) - 2100(12) =0

$\Sigma F_x = 0$ A_x - 2800 = 0

$\Sigma F_y = 0$ A_y - 3000 - 2100 = 0

A_x = 2 800#
A_y = 5 100#
M_A= 43 200 # ft

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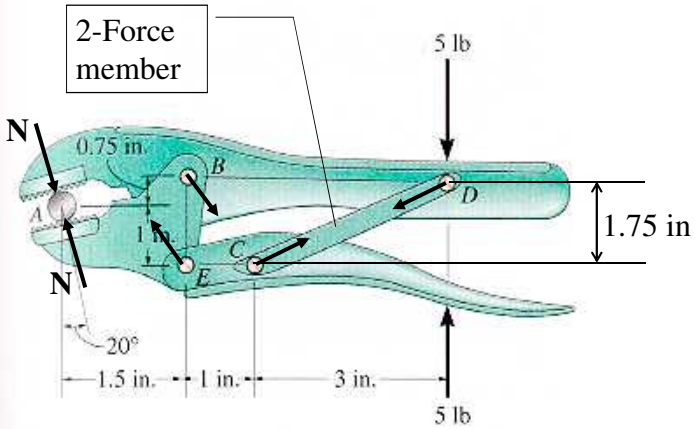
A 5-lb force is applied to the handles of the vise grip. Determine the compressive force developed on the smooth bolt shank *A* at the jaws.

Example



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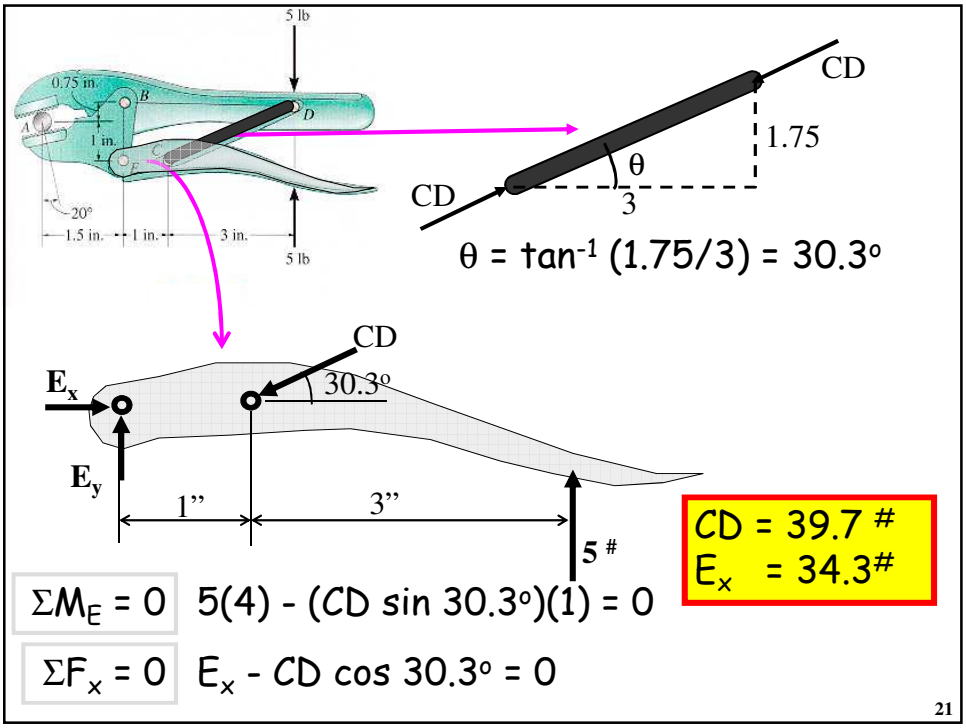
5 lb
0.75 in.
A
B
C
D
E
1 in.
20°
1.5 in.
1 in.
3 in.
5 lb
CD
1.75
θ
CD
3
θ = tan-1 (1.75/3) = 30.3°
CD
Ex
30.3°
Ey
1”
3”
5 #
CD = 39.7 #
Ex = 34.3#
ΣME = 0
5(4) - (CD sin 30.3°)(1) = 0
ΣFx = 0
Ex - CD cos 30.3° = 0
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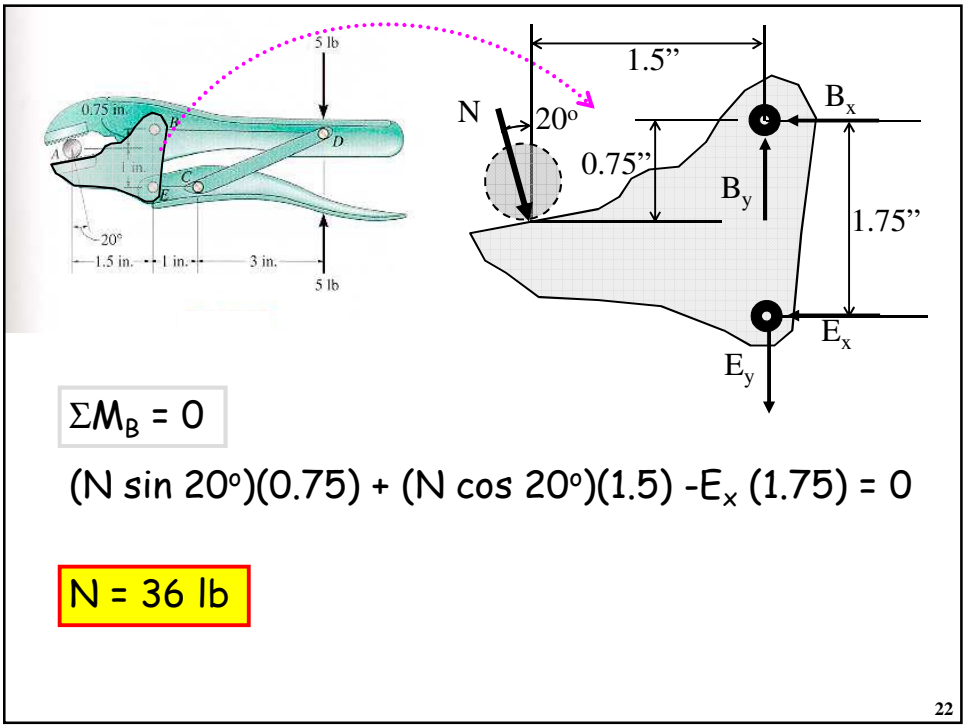
5 lb
0.75 in.
A
B
C
D
E
1 in.
20°
1.5 in.
1 in.
3 in.
5 lb
1.5”
N
20°
0.75”
Bx
By
1.75”
Ex
Ey
ΣMB = 0
(N sin 20°)(0.75) + (N cos 20°)(1.5) -Ex (1.75) = 0
N = 36 lb
22