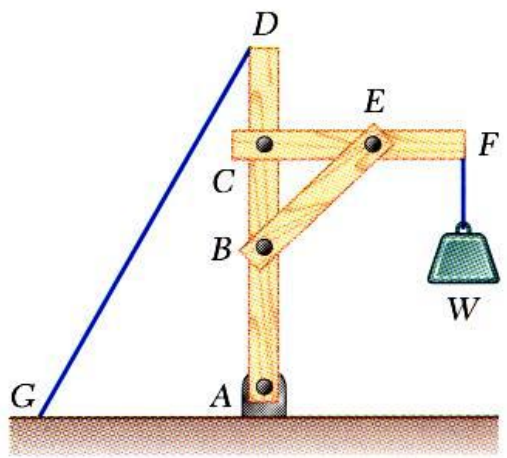
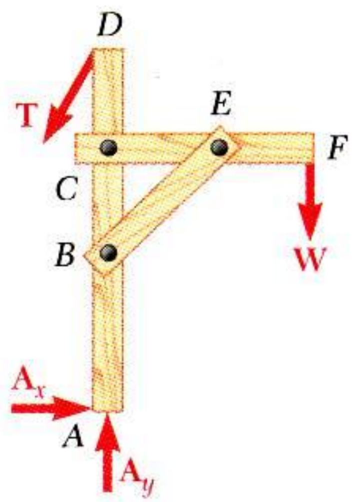
CHAPTER 4

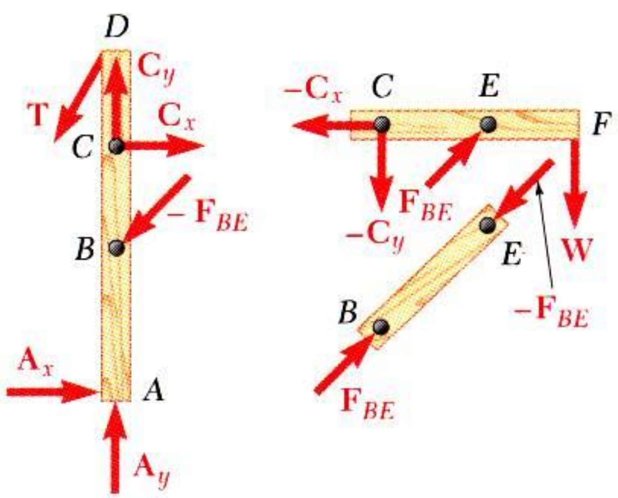
Frames and Machines

- *Frames* and *machines* are two types of structures which are often *composed* of *pin-connected* multiforce members, i.e., members that are subjected to *more* than *two forces*.
- *Frames* are used to *support loads*, whereas *machines* contains *moving parts* and are designed to *transmit* and *change* the effect of *forces*.

Analysis of Frames







- *Frames* and *machines* are structures with at least one *multiforce* member. Frames are designed to support loads and are usually stationary. Machines contain moving parts and are designed to transmit and modify forces.

- A free body diagram of the complete frame is used to determine the external forces acting on the frame.

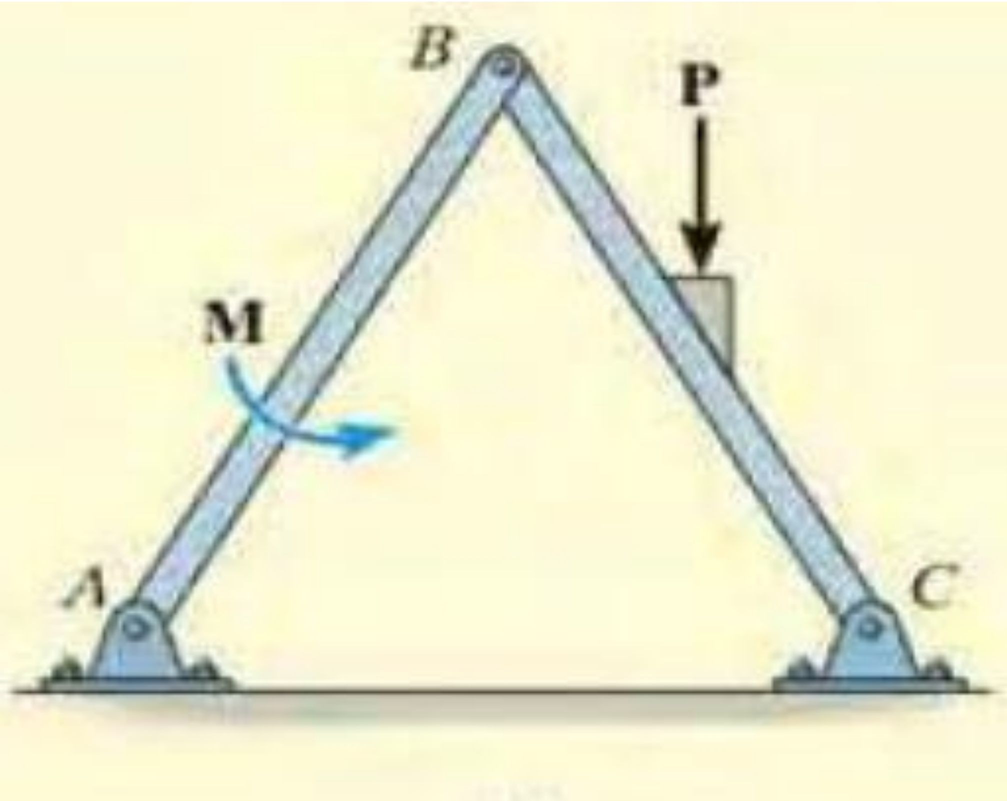
- Internal forces are determined by dismembering the frame and creating free-body diagrams for each component.

- Forces on two force members have known lines of action but unknown magnitude and sense.

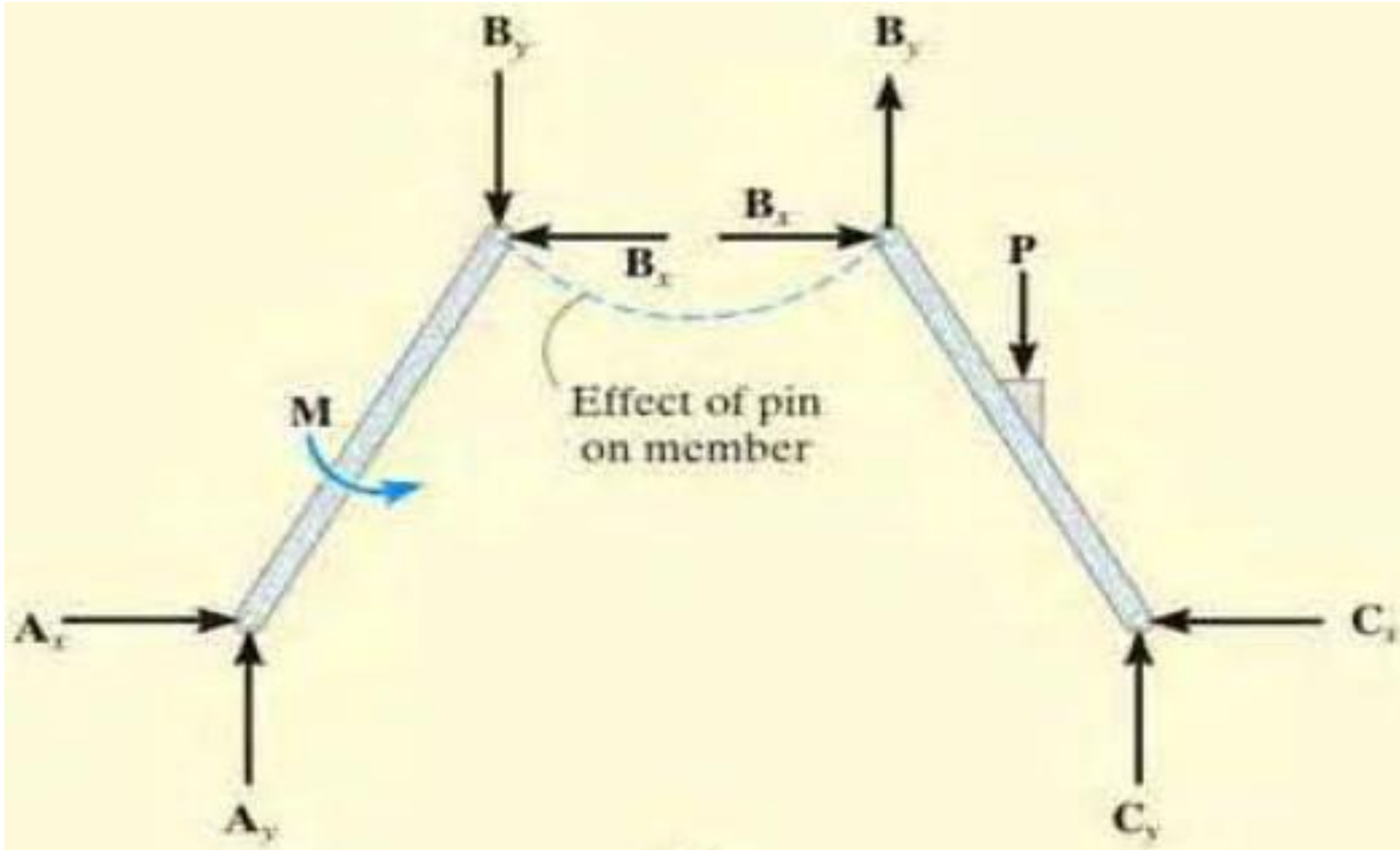
- Forces on multiforce members have unknown magnitude and line of action. They must be represented with two unknown components.

- Forces between connected components are equal, have the same line of action, and opposite sense.

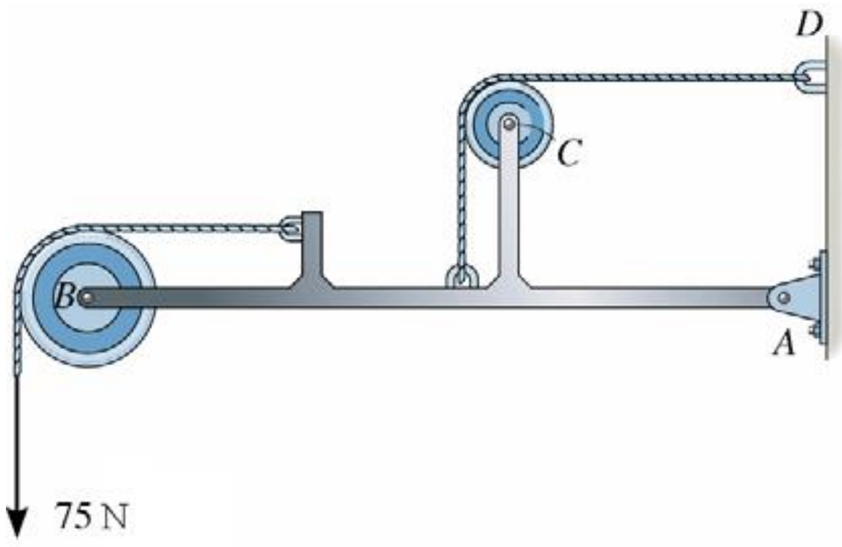
Examples

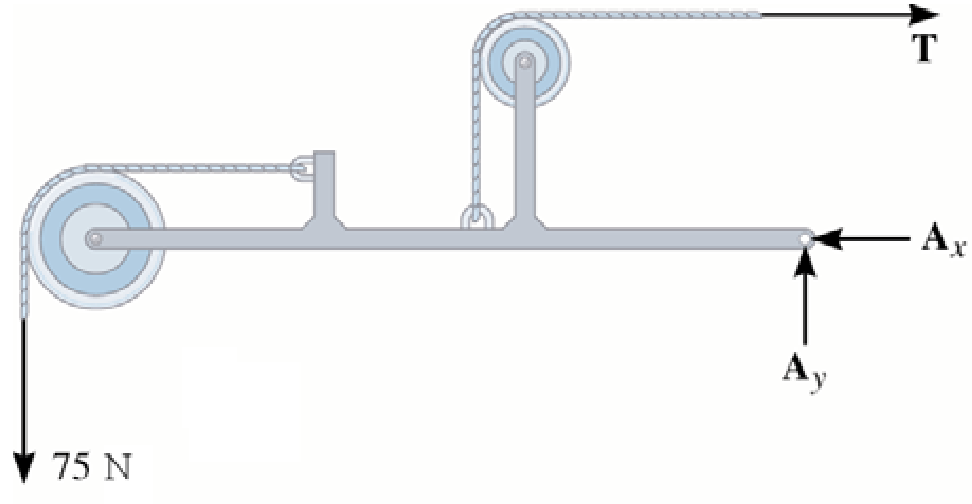


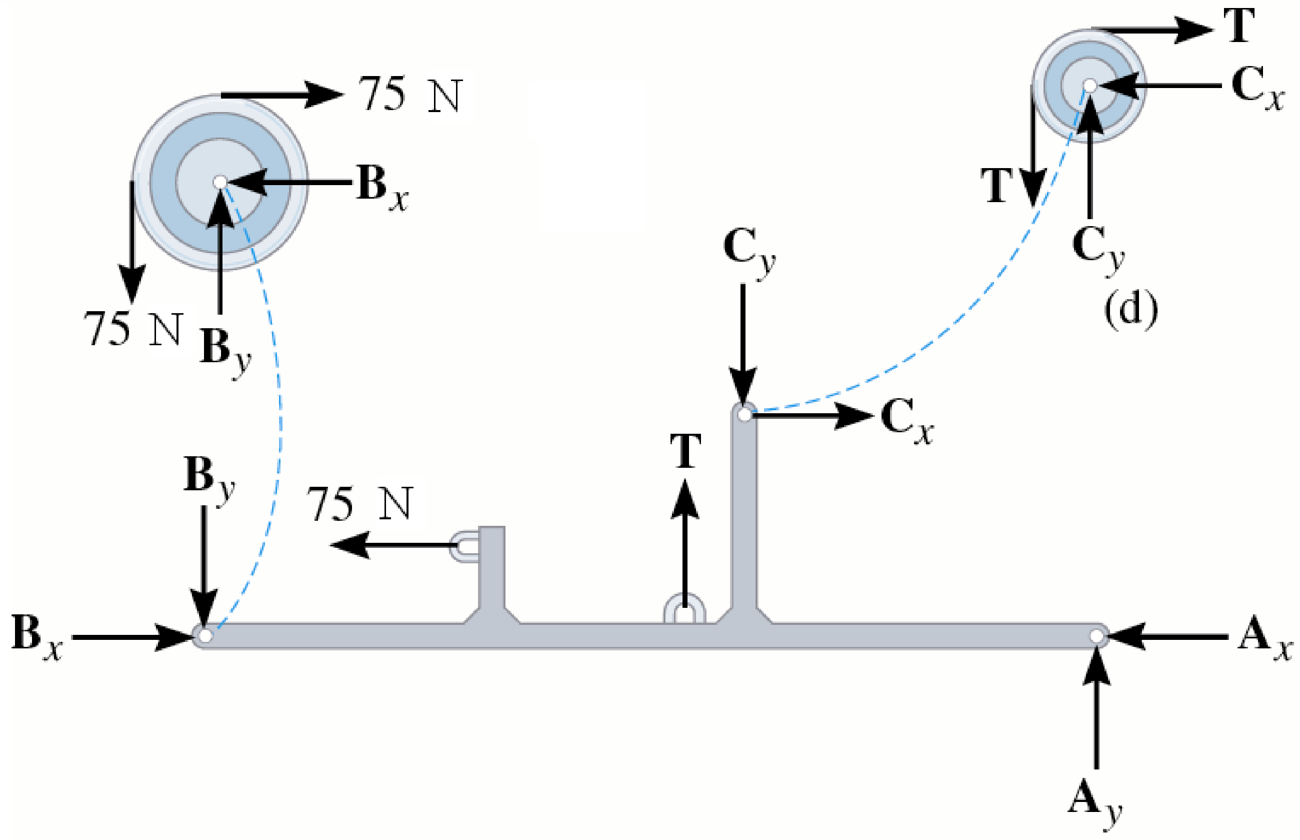
(a)

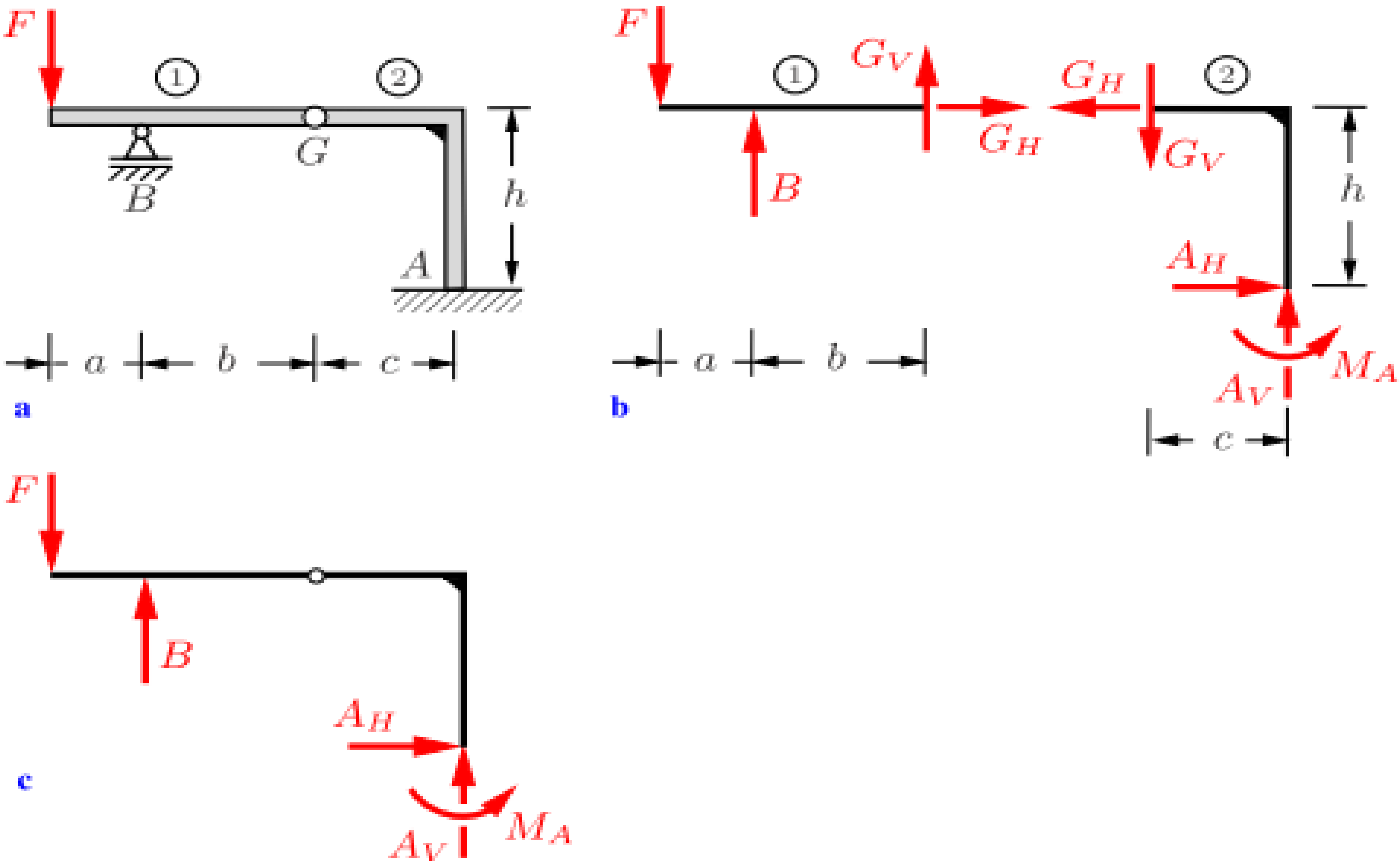


(b)

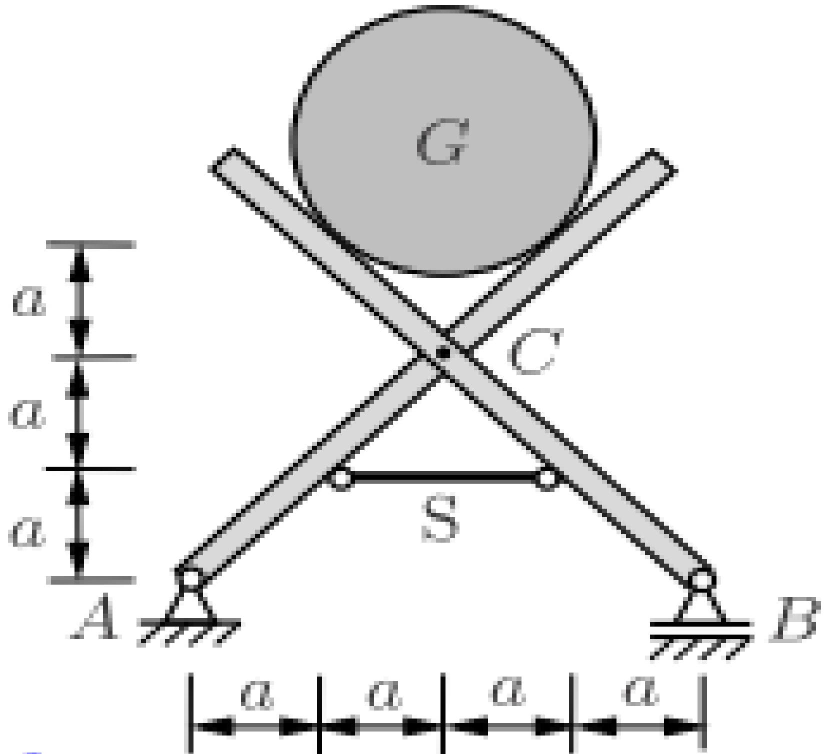

D
C
B
A
75 N


T
A_x
A_y
75 N

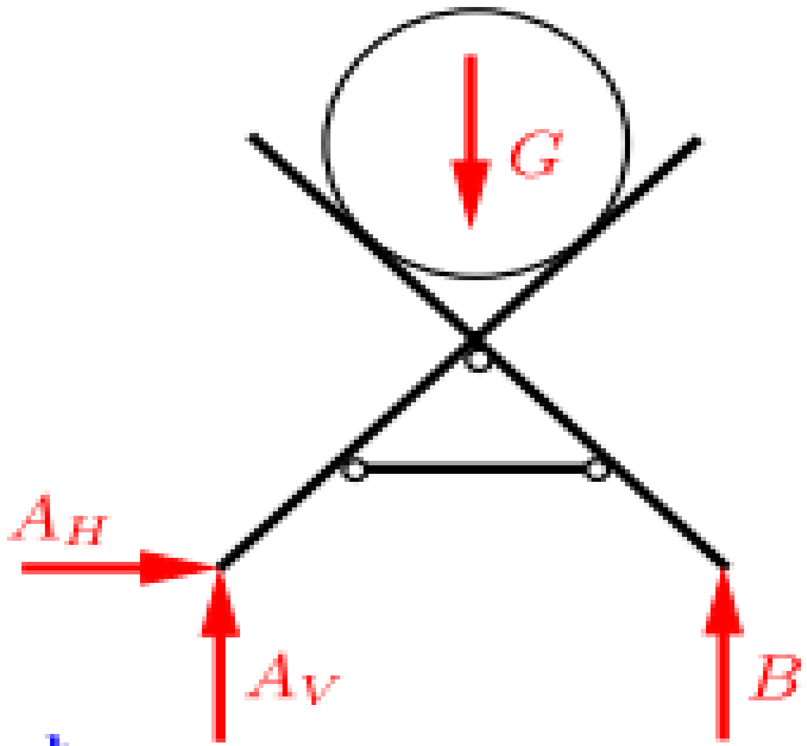

75 N
B_x
75 N
B_y
T
C_x
T
C_y
(d)
C_y
C_x
T
B_y
75 N
B_x
A_x
A_y



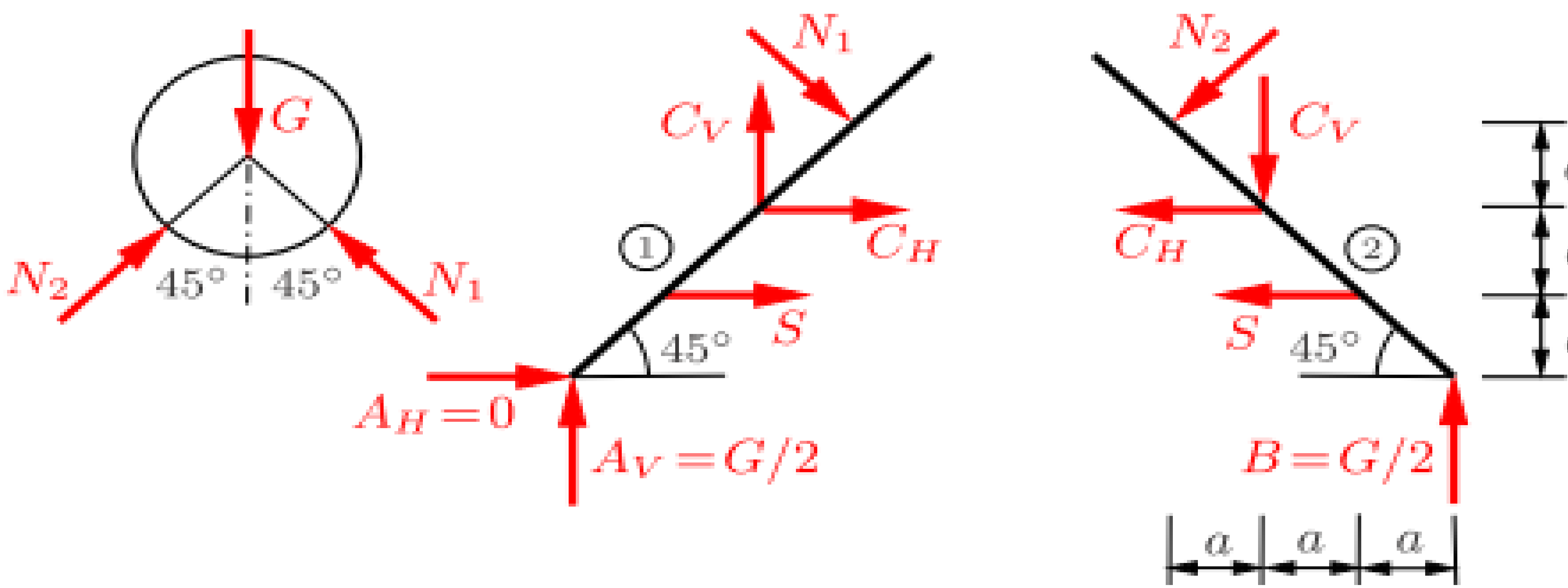
F
①
②
G
B
A
h
a
b
c
a
F
①
G_V
G_H
G_H
G_V
②
B
h
A_H
M_A
A_V
a
b
c
b
F
B
A_H
M_A
A_V
c



a

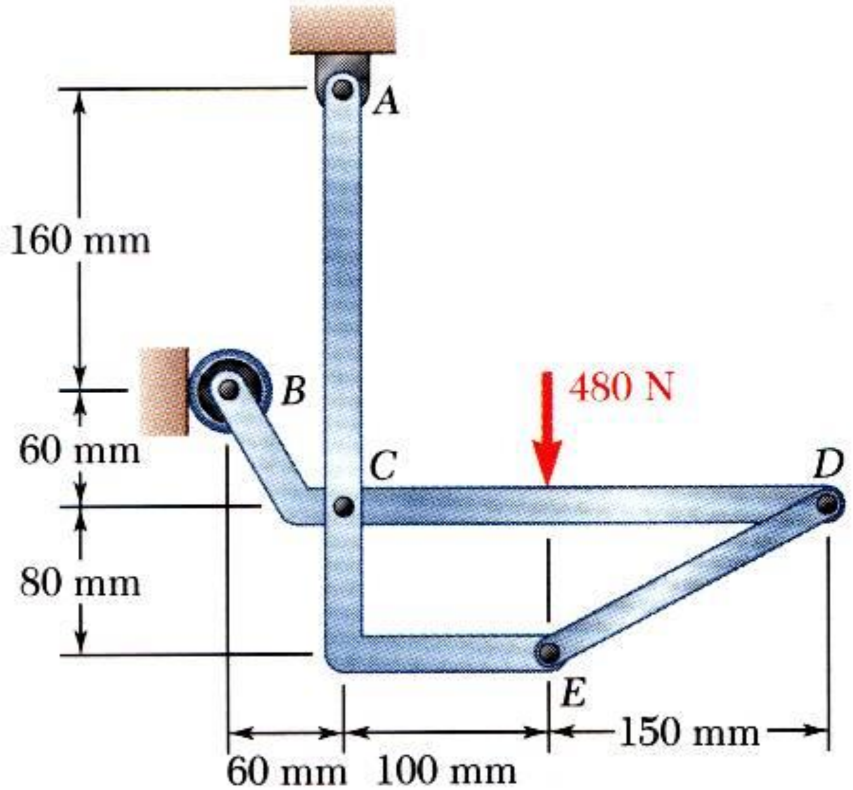


b



c

Sample Problem

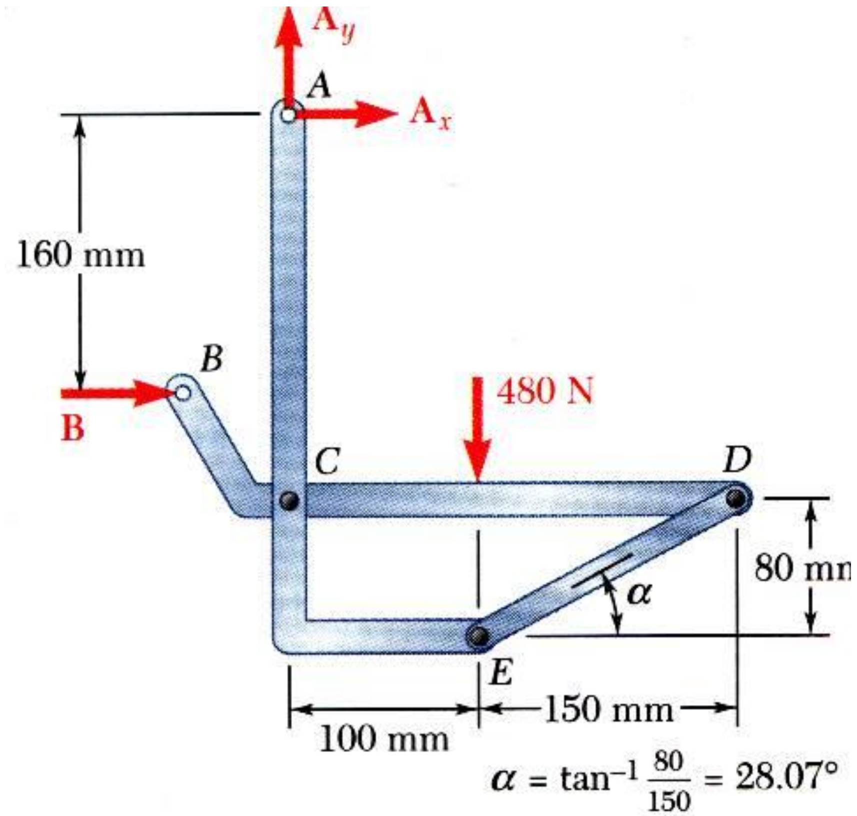


Members *ACE* and *BCD* are connected by a pin at *C* and by the link *DE*. For the loading shown, determine the force in link *DE* and the components of the force exerted at *C* on member *BCD*.

SOLUTION:

- Create a free-body diagram for the complete frame and solve for the support reactions.
- Define a free-body diagram for member *BCD*. The force exerted by the link *DE* has a known line of action but unknown magnitude. It is determined by summing moments about *C*.
- With the force on the link *DE* known, the sum of forces in the *x* and *y* directions may be used to find the force components at *C*.
- With member *ACE* as a free-body, check the solution by summing moments about *A*.

Sample Problem



SOLUTION:

- Create a free-body diagram for the complete frame and solve for the support reactions.

$$\sum F_y = 0 = A_y - 480\ \text{N}$$

$$\boxed{A_y = 480\ \text{N}\ \uparrow}$$

$$\sum M_A = 0 = -(480\ \text{N})(100\ \text{mm}) + B(160\ \text{mm})$$

$$\boxed{B = 300\ \text{N}\ \rightarrow}$$

$$\sum F_x = 0 = B + A_x$$

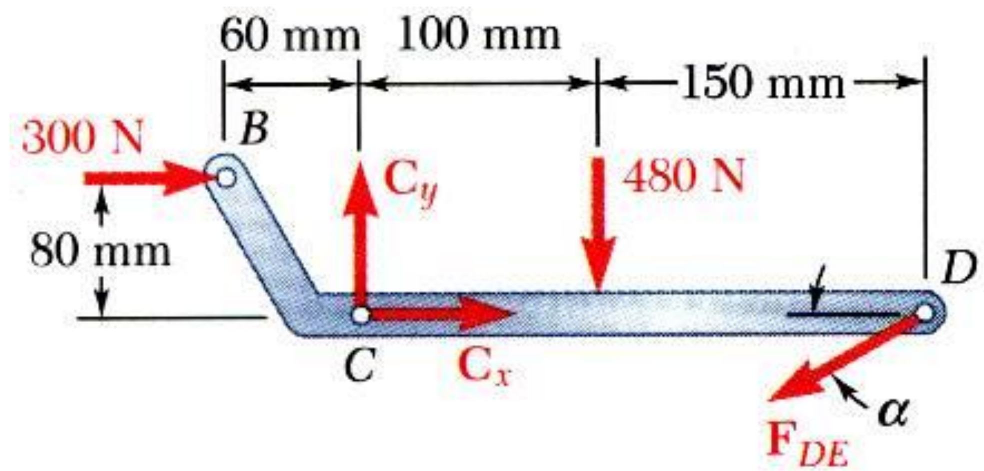
$$\boxed{A_x = -300\ \text{N}\ \leftarrow}$$

Note:

$$\alpha = \tan^{-1}\frac{80}{150} = 28.07°$$

Sample Problem

- Define a free-body diagram for member *BCD*. The force exerted by the link *DE* has a known line of action but unknown magnitude. It is determined by summing moments about *C*.



$$\sum M_C = 0 = (F_{DE} \sin\alpha)(250 \text{ mm}) + (300 \text{ N})(60 \text{ mm}) + (480 \text{ N})(100 \text{ mm})$$

$$F_{DE} = -561 \text{ N} \qquad \boxed{F_{DE} = 561 \text{ N } \ C}$$

- Sum of forces in the *x* and *y* directions may be used to find the force components at *C*.

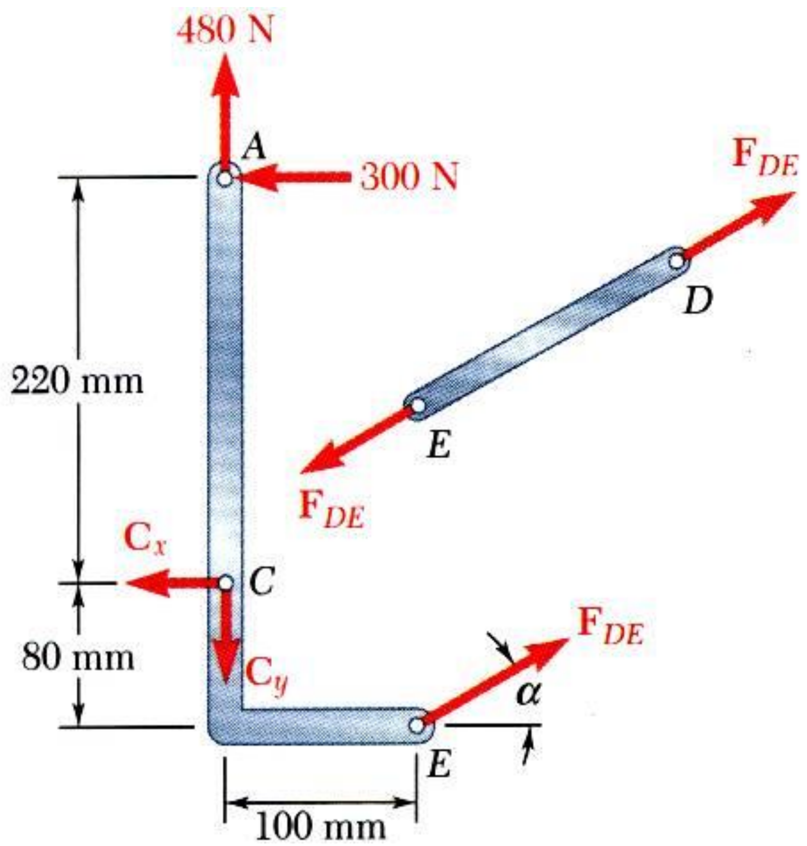
$$\sum F_x = 0 = C_x - F_{DE}\cos\alpha + 300 \text{ N}$$

$$0 = C_x - (-561 \text{ N})\cos\alpha + 300 \text{ N} \qquad \boxed{C_x = -795 \text{ N}}$$

$$\sum F_y = 0 = C_y - F_{DE}\sin\alpha - 480 \text{ N}$$

$$0 = C_y - (-561 \text{ N})\sin\alpha - 480 \text{ N} \qquad \boxed{C_y = 216 \text{ N}}$$

Sample Problem

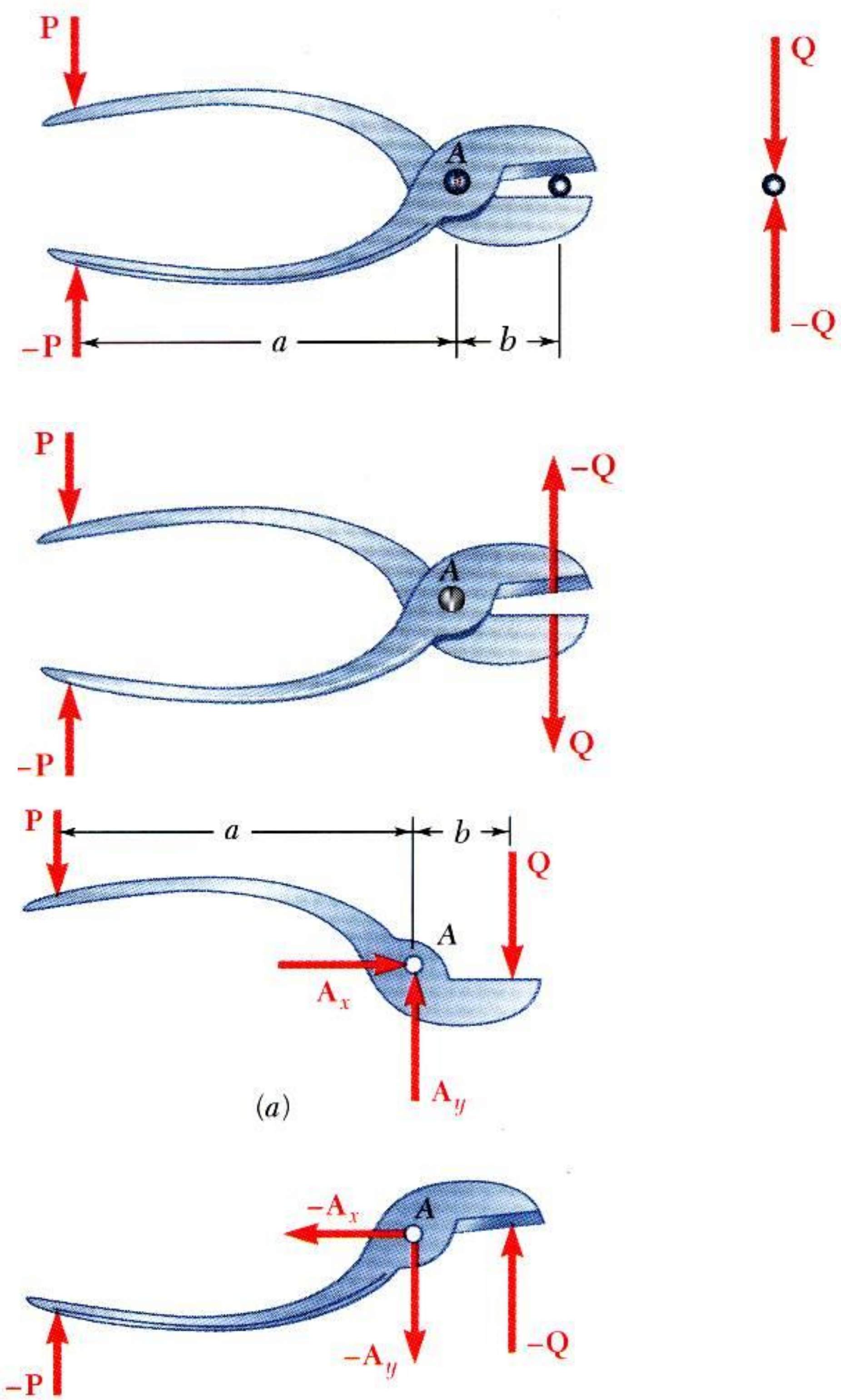


- With member *ACE* as a free-body, check the solution by summing moments about *A*.

$$\sum M_A = (F_{DE}\cos\alpha)(300\text{ mm}) + (F_{DE}\sin\alpha)(100\text{ mm}) - C_x(220\text{ mm})$$
$$= (-561\cos\alpha)(300\text{ mm}) + (-561\sin\alpha)(100\text{ mm}) - (-795)(220\text{ mm}) = 0$$

(check
s)

Machines



- Machines are structures designed to transmit and modify forces. Their main purpose is to transform *input forces* into *output forces*.

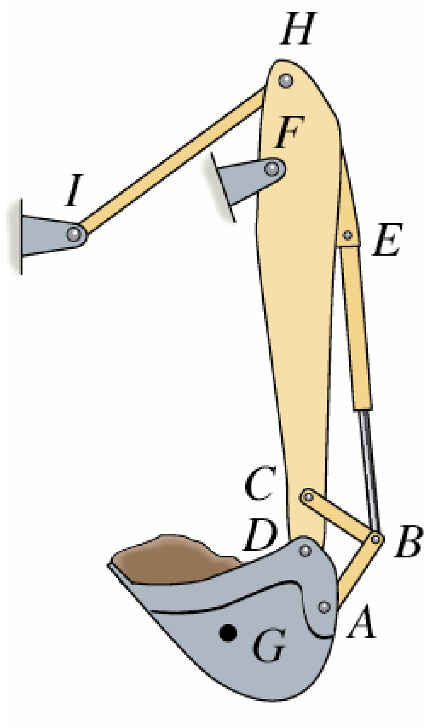
- Given the magnitude of ***P***, determine the magnitude of ***Q***.

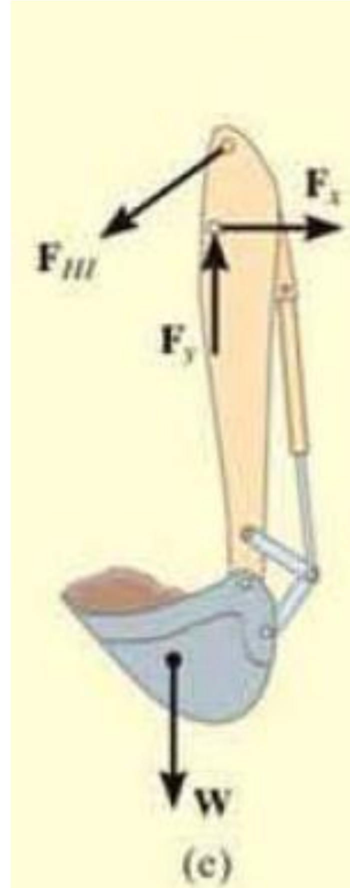
- Create a free-body diagram of the complete machine, including the reaction that the wire exerts.

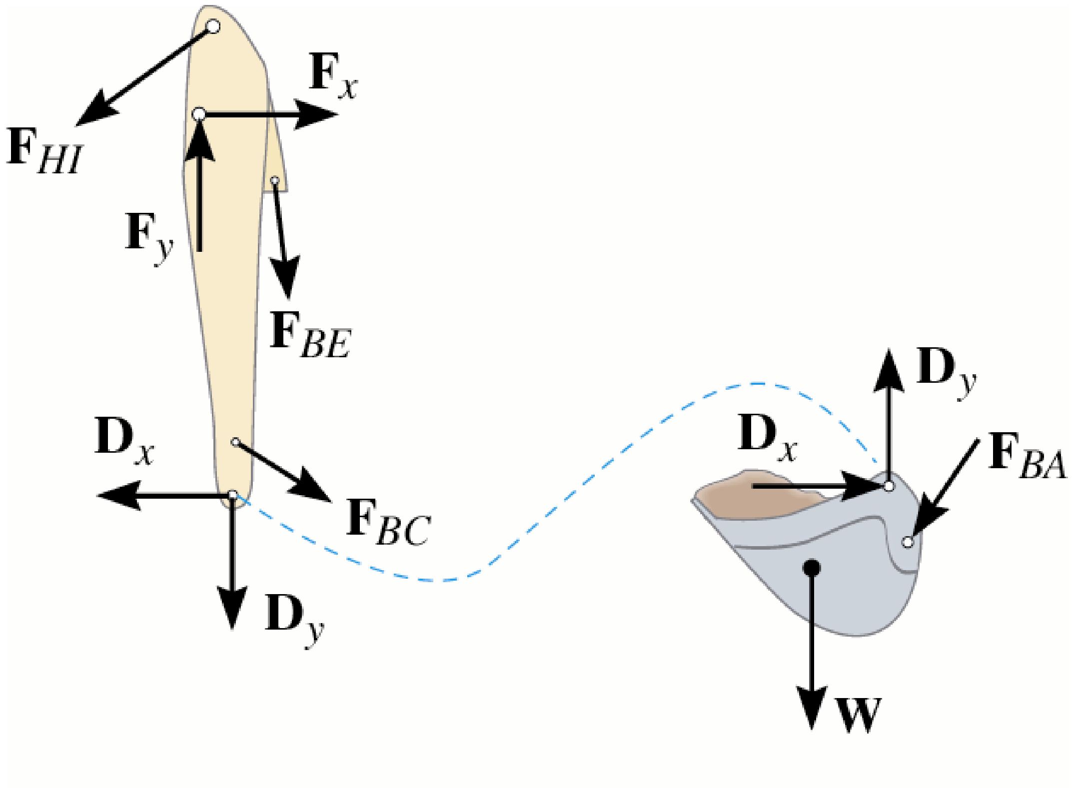
- The machine is a nonrigid structure. Use one of the components as a free-body.

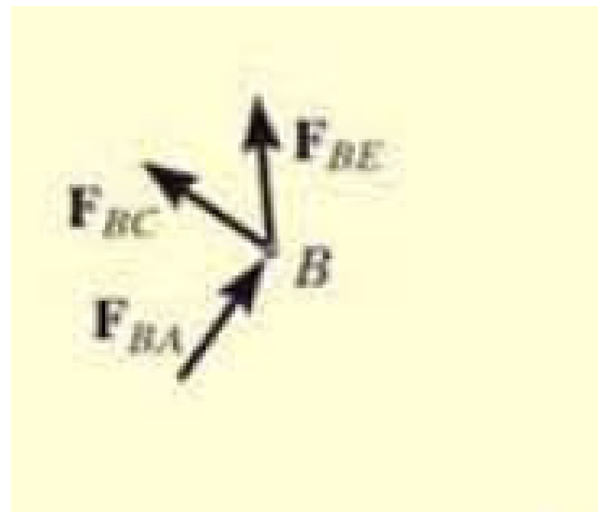
- Taking moments about *A*,

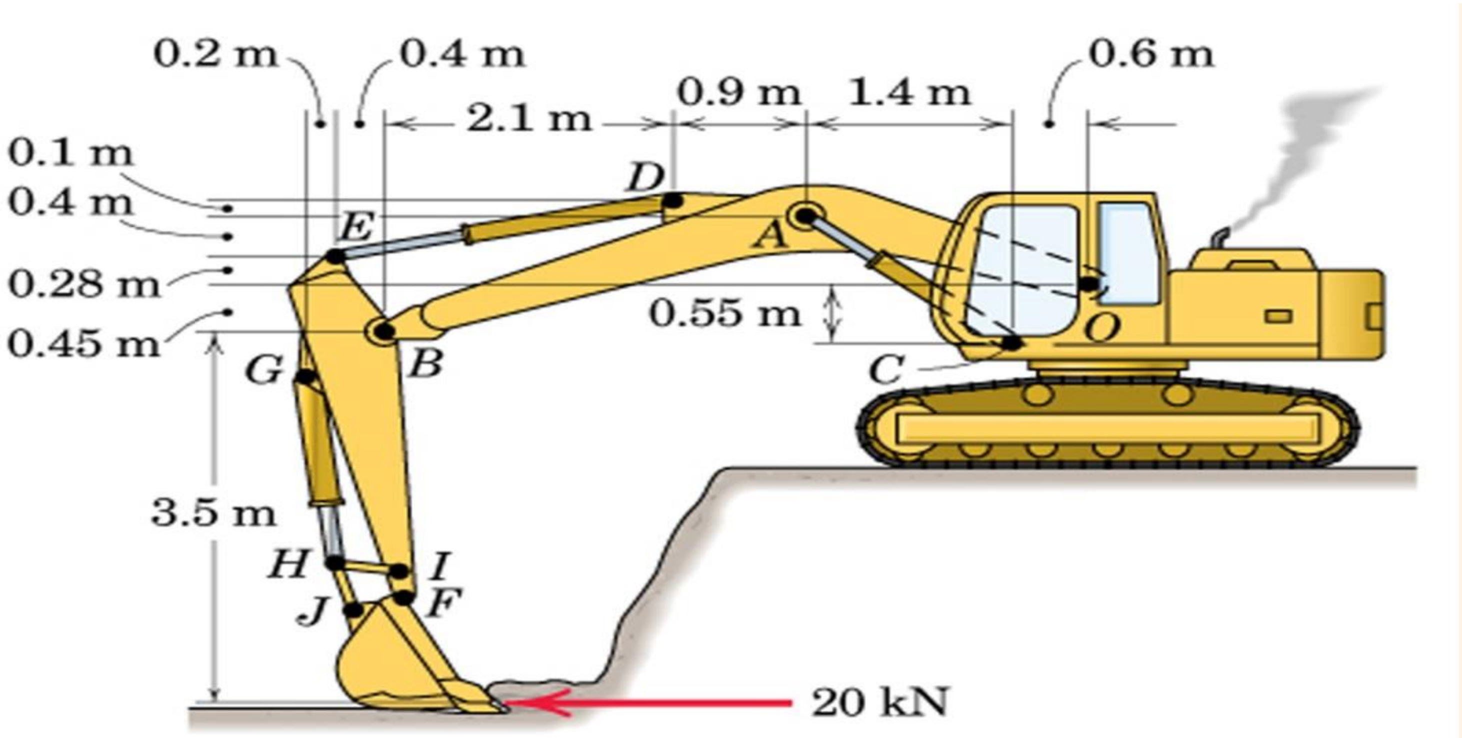
$$\sum M_A = 0 = aP - bQ \qquad Q = \frac{a}{b}P$$

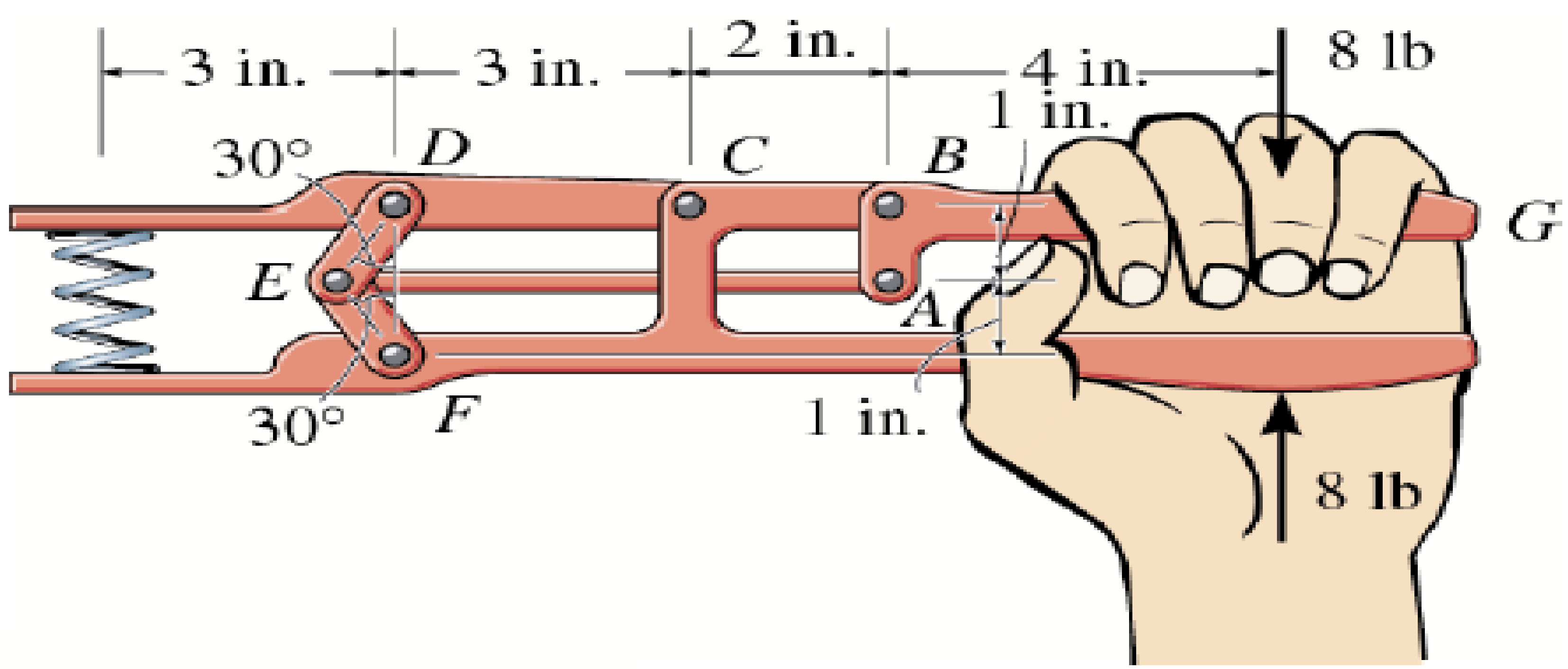

H
F
I
E
C
D
B
A
G


F_HI
F_x
F_y
W
(c)


F_HI
F_x
F_y
F_BE
D_x
F_BC
D_y
D_y
D_x
F_BA
W


F_BE
F_BC
B
F_BA


0.2 m
0.4 m
2.1 m
0.9 m
1.4 m
0.6 m
0.1 m
0.4 m
0.28 m
0.45 m
0.55 m
D
E
A
O
B
C
G
3.5 m
H
I
J
F
20 kN


3 in.
3 in.
2 in.
4 in.
8 lb
1 in.
30°
D
C
B
G
E
A
30°
F
1 in.
8 lb

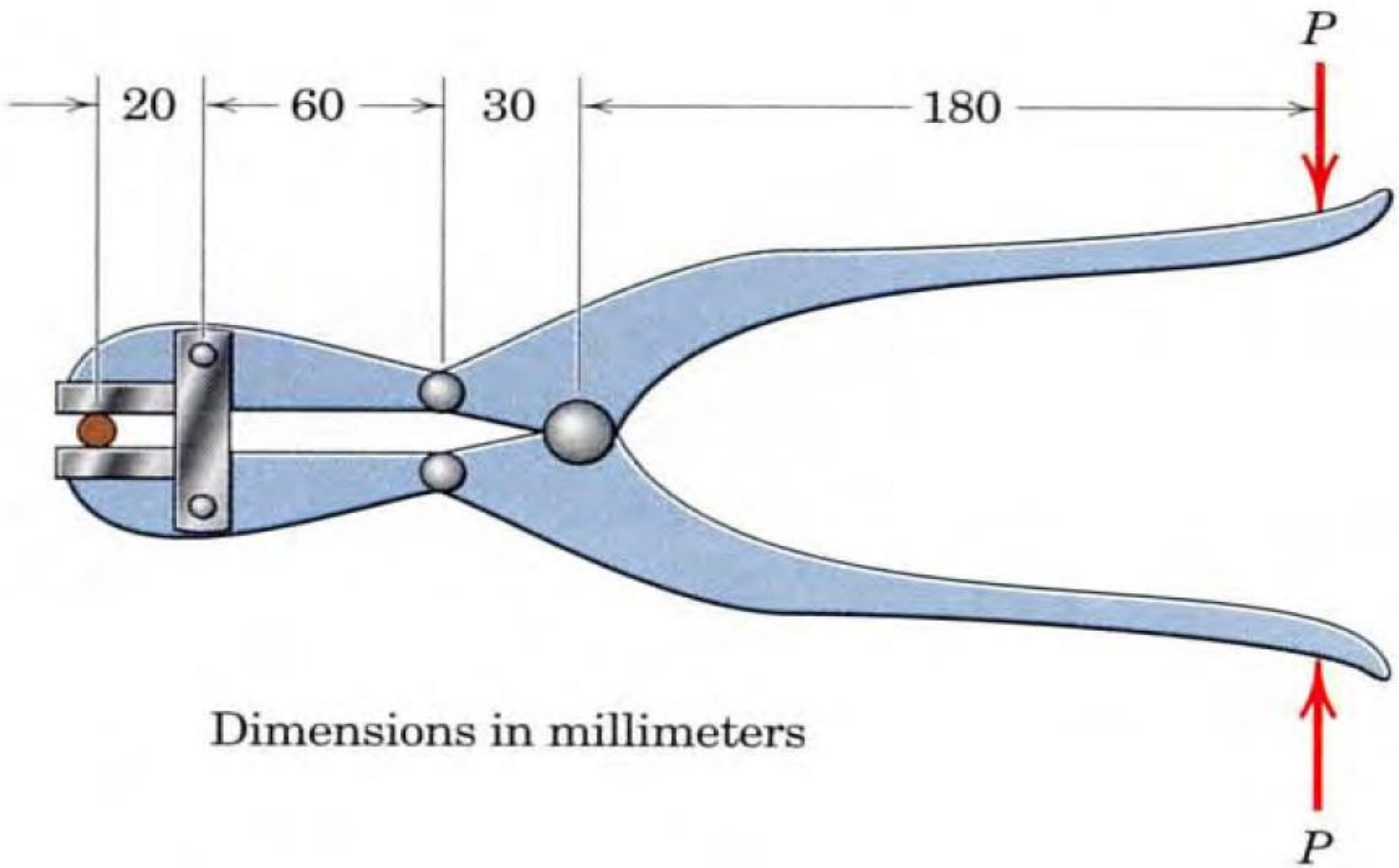
Solution procedures of Frames and Machines

- Firstly, In order to determine the *forces* acting at the *joints* and *supports* of a frame or machine, the *structure* must be *disassembled* and the *free-body diagrams* of its parts must be *drawn*.
- *isolate* each *part* by drawing its outlined shape. Then *show* all the *forces* and/or *couple moments* that act on the part.
- *Identify* all *two-force members* in the structure and represent their free-body diagram.
- *Forces* common to any two *contacting members* act with *equal magnitudes* but *opposite sense* on the respective members.

Example 2

4/81 A small bolt cutter operated by hand for cutting small bolts and rods is shown in the sketch. For a hand grip $P = 150$ N, determine the force Q developed by each jaw on the rod to be cut.

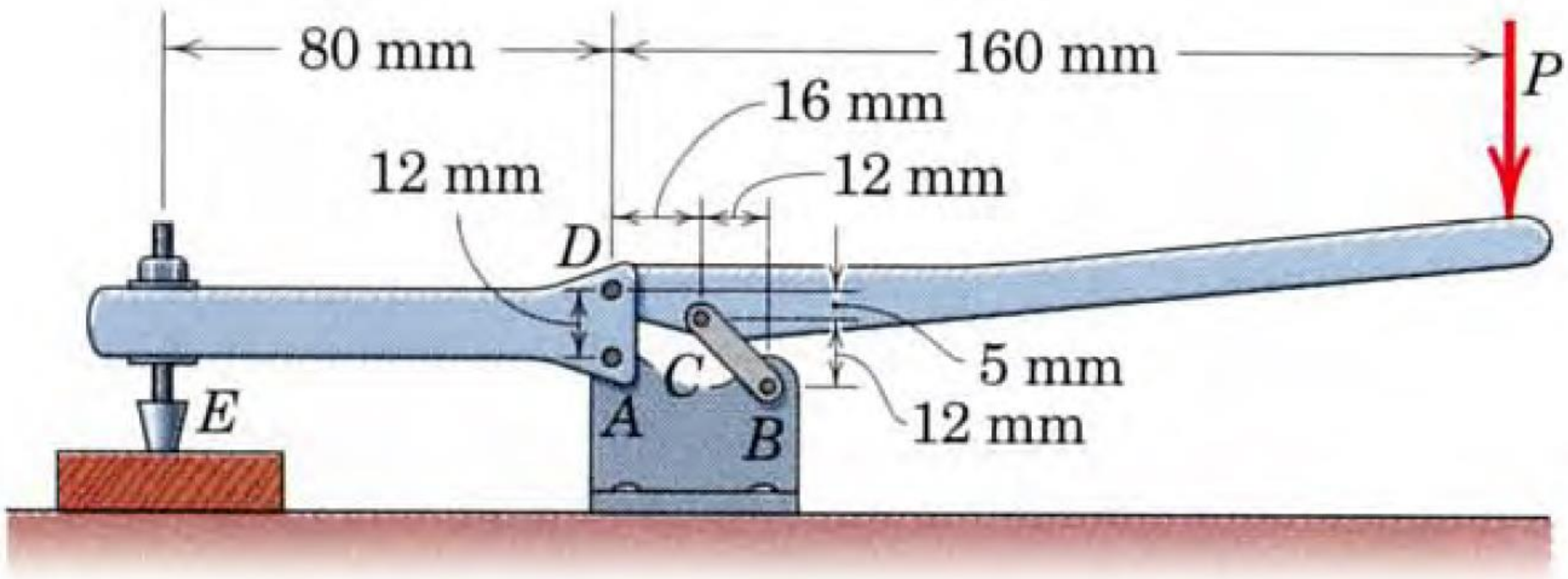
Ans. $Q = 2.7$ kN



Dimensions in millimeters

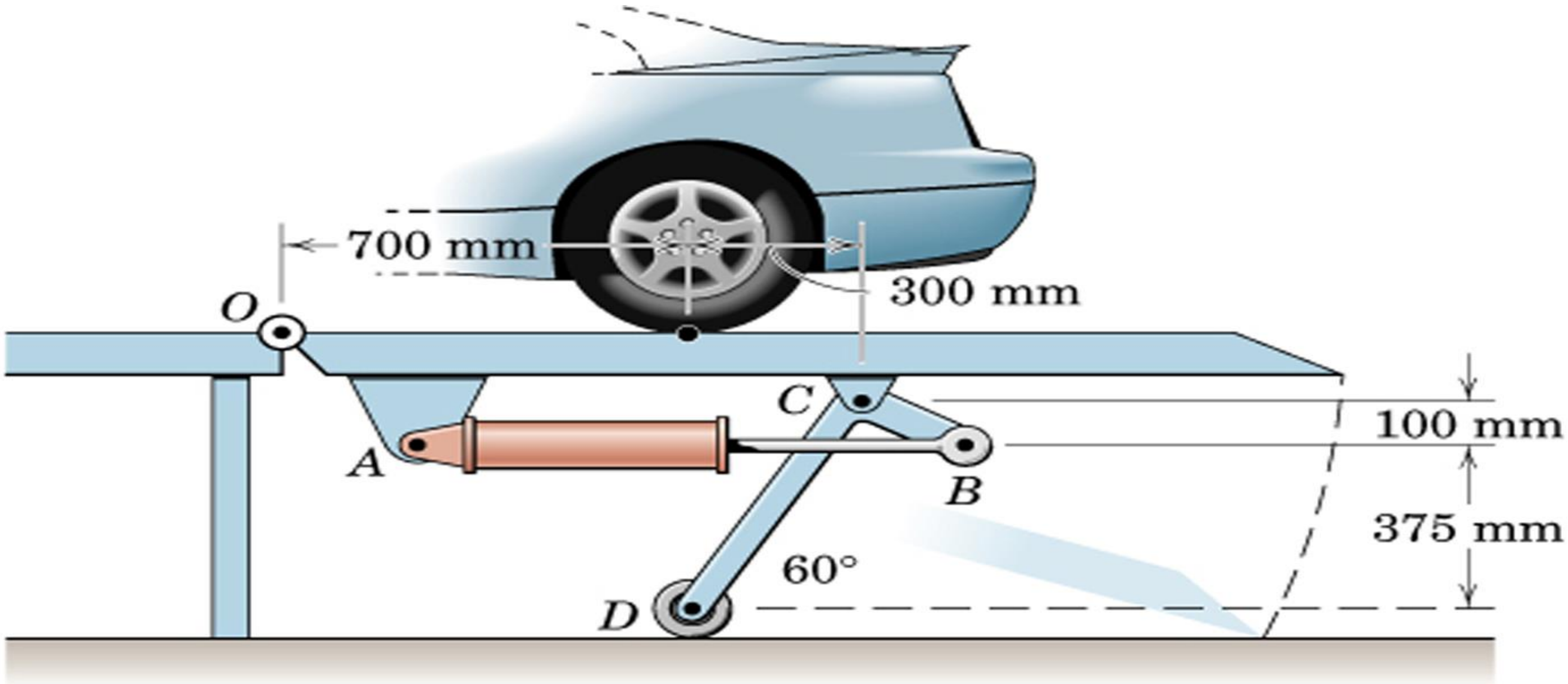
Example 3

Determine the vertical clamping force at E in terms of the force P applied to the handle of the toggle clamp..



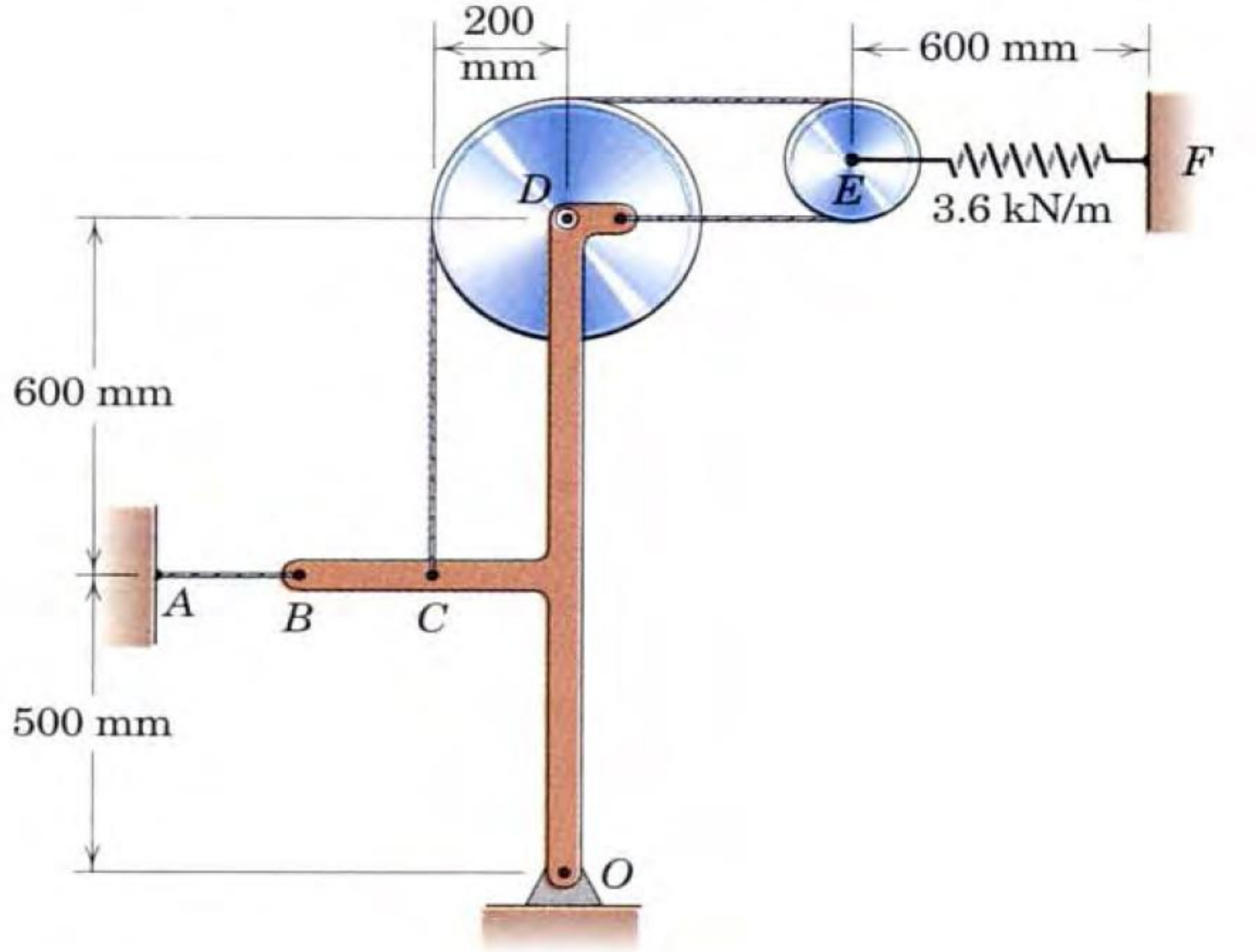
Example 4

The car hoist allowst the car to be driven onto the platform, after which the rear wheels are raised. If the loading from both rear wheels is 6 kN, determine the force in the hydraulic cylinder AB. Neglect the weight of the platform itself. Member BCD is a right-angle bell crank pinned to the ramp at C.



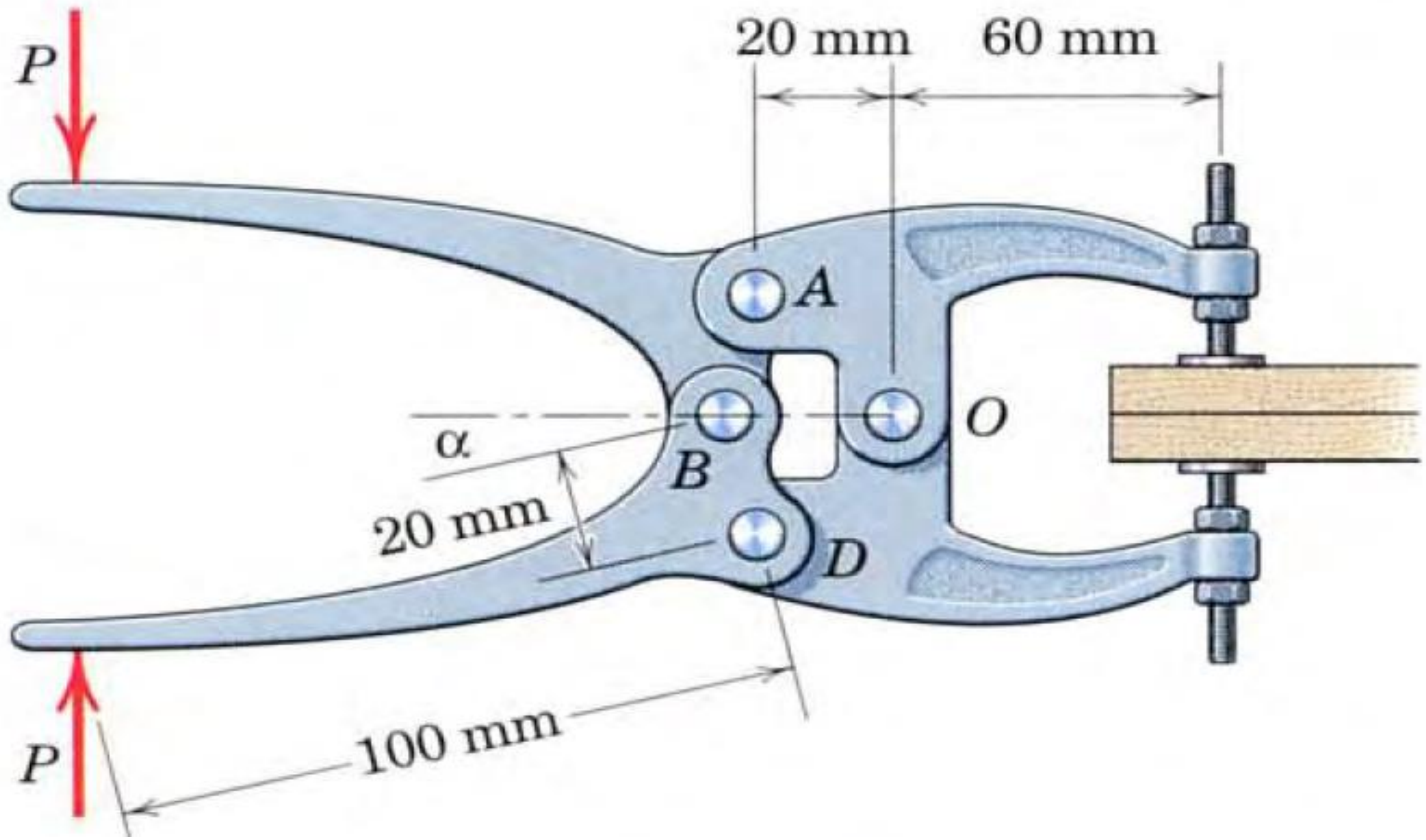
Review Problems

4/86 The unstretched length of spring EF is 300 mm. Determine the magnitude of the pin reaction at O.

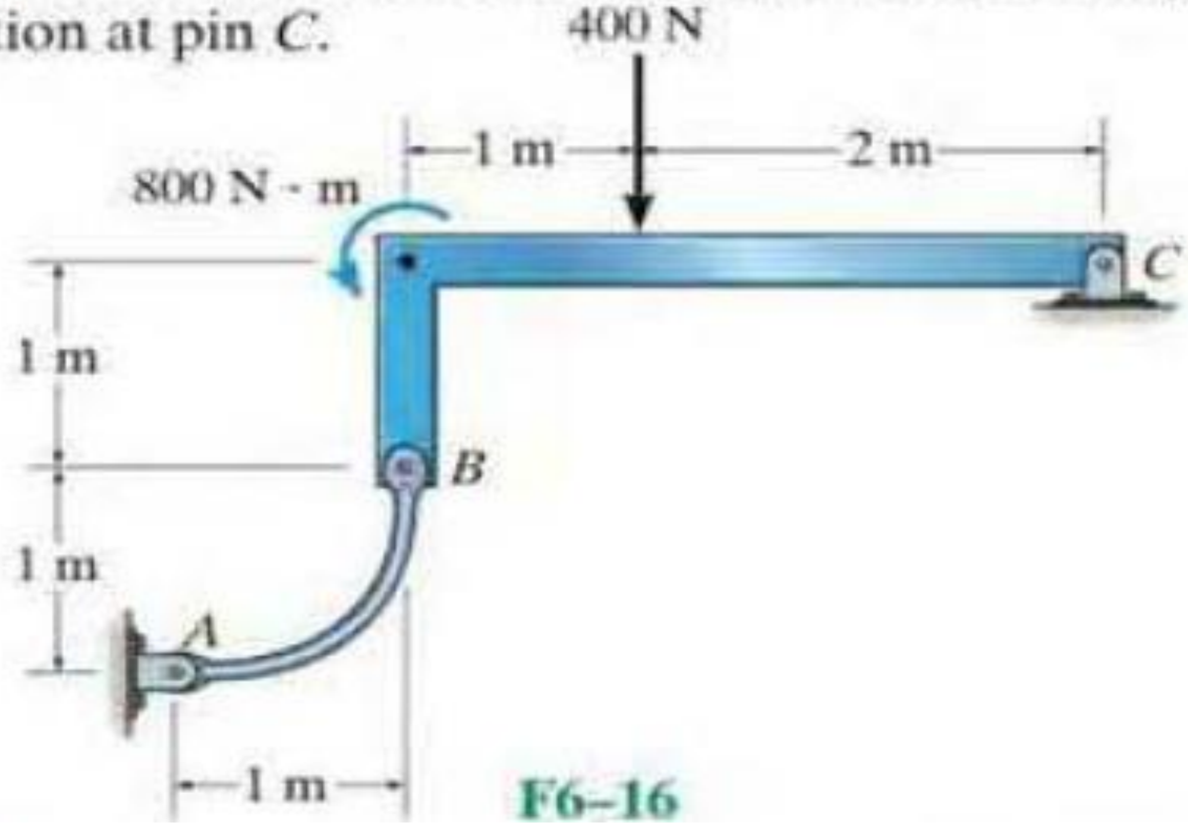


4/99 The toggle pliers are used for a variety of clamping purposes. For the handle position given by $\alpha = 10°$ and for a handle grip $P = 150$ N, calculate the clamping force C produced. Note that pins A and D are symmetric about the horizontal centerline of the tool.

Ans. $C = 1368$ N

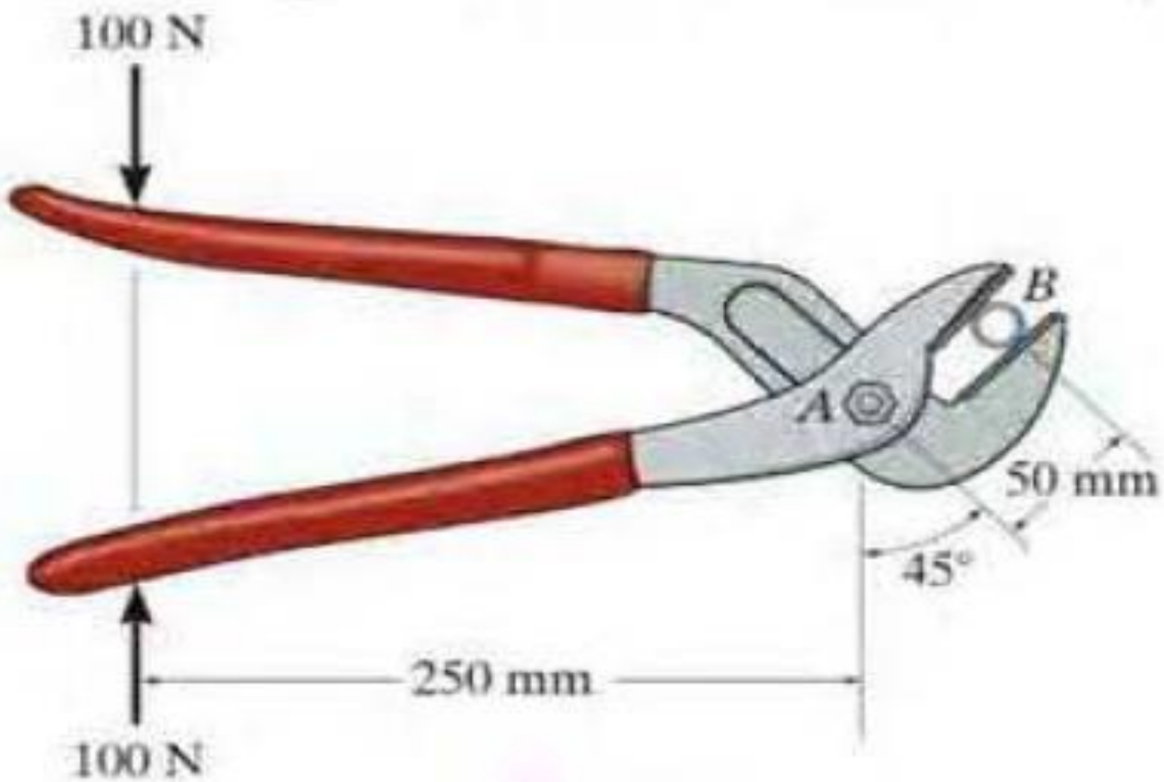


F6–16. Determine the horizontal and vertical components of reaction at pin C.



F6–16

F6–15. If a 100-N force is applied to the handles of the pliers, determine the clamping force exerted on the smooth pipe B and the magnitude of the resultant force at pin A.



•**6–73.** If the peg at B is smooth, determine the components of reaction at the pin A and fixed support C.