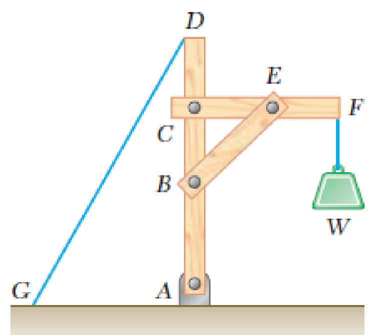
CHAPTER 6. STRUCTURAL ANALYSIS:FRAMES and MACHINES

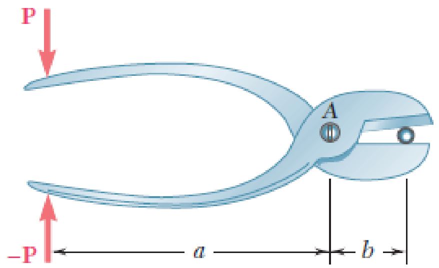
6.6. Frames and Machines

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.



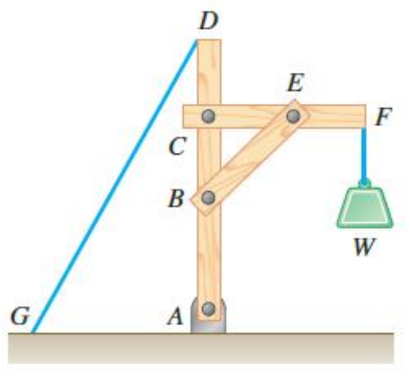
Frames are used to support loads, whereas **machines** contain moving parts and are designed to transmit and alter the effect of forces.

Provided a frame or machine contains no more supports or members than are necessary to prevent its collapse, the forces acting at the joints and supports can be determined by applying the equations of equilibrium to each of its members. Once these forces are obtained, it is then possible to design the size of the members, connections, and supports using the theory of mechanics of materials and an appropriate engineering design code.

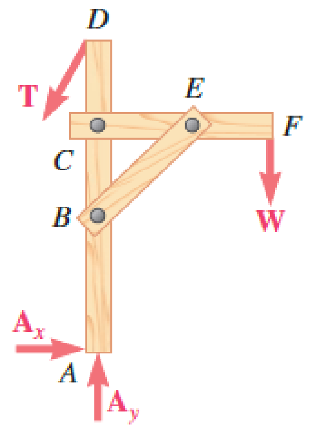


Free-Body Diagrams

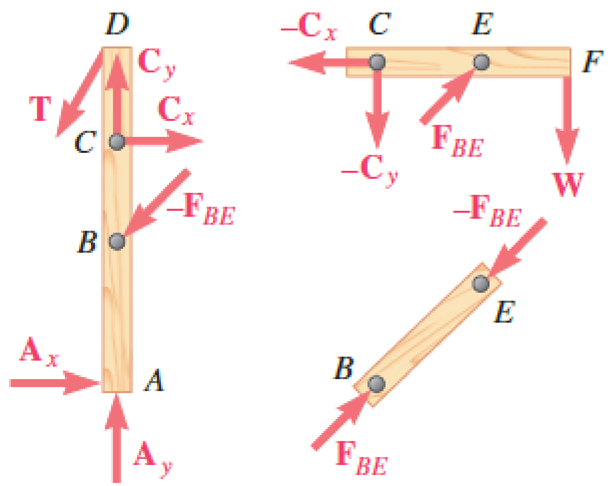
In order to determine the forces acting at the joints and supports of a frame or machine, the structure must be disassembled and the free-body diagrams of its parts must be drawn. The following important points must be observed:



- Isolate each part by drawing its outlined shape. Then show all the forces and/or couple moments that act on the part. Make sure to label or identify each known and unknown force and couple moment with reference to an established x, y coordinate system. Also, indicate any dimensions used for taking moments. Most often the equations of equilibrium are easier to apply if the forces are represented by their rectangular components. As usual, the sense of an unknown force or couple moment can be assumed.
- Identify all the two-force members in the structure and represent their free-body diagrams as having two equal but opposite collinear forces acting at their points of application. By recognizing the two-force members, we can avoid solving an unnecessary number of equilibrium equations.

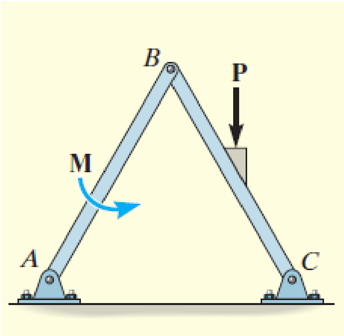


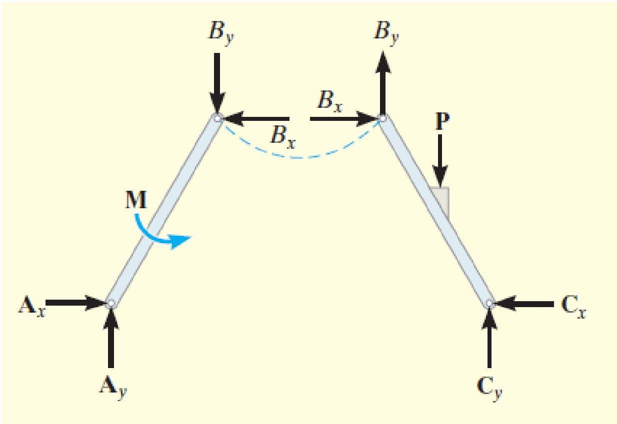
- Forces common to any two contacting members act with equal magnitudes but opposite sense on the respective members. If the two members are treated as a "system" of connected members, then these forces are "internal" and are not shown on the free-body diagram of the system; however, if the free-body diagram of each member is drawn, the forces are "external" and must be shown as equal in magnitude and opposite in direction on each of the two free-body diagrams.



How to draw the freebody diagrams of a dismembered frame or machine

i)





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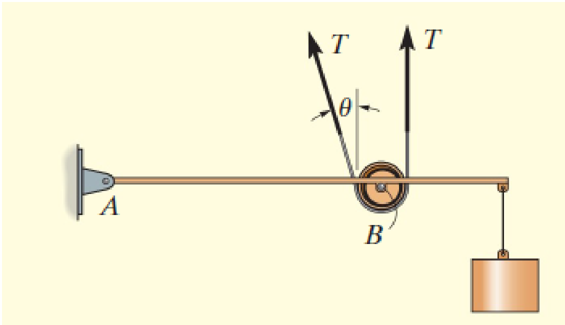

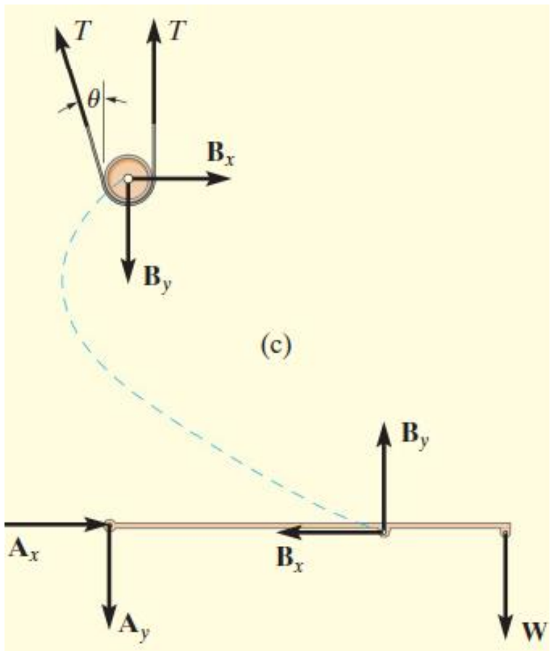

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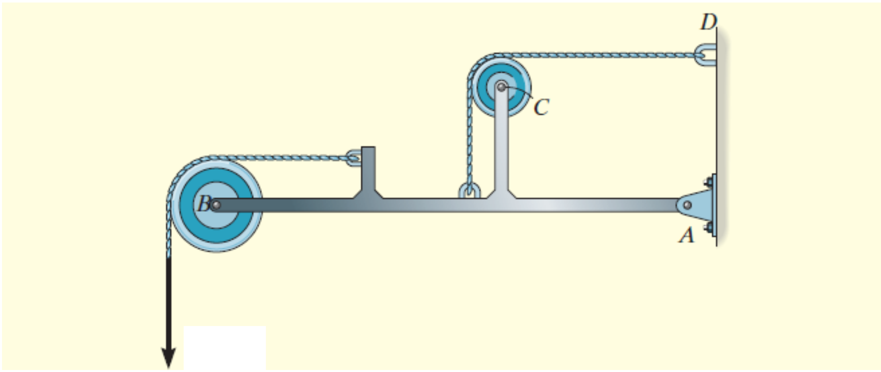

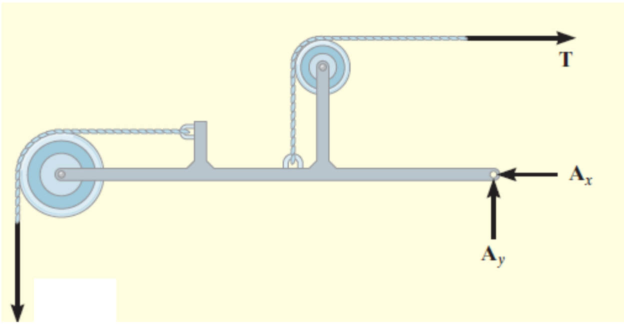

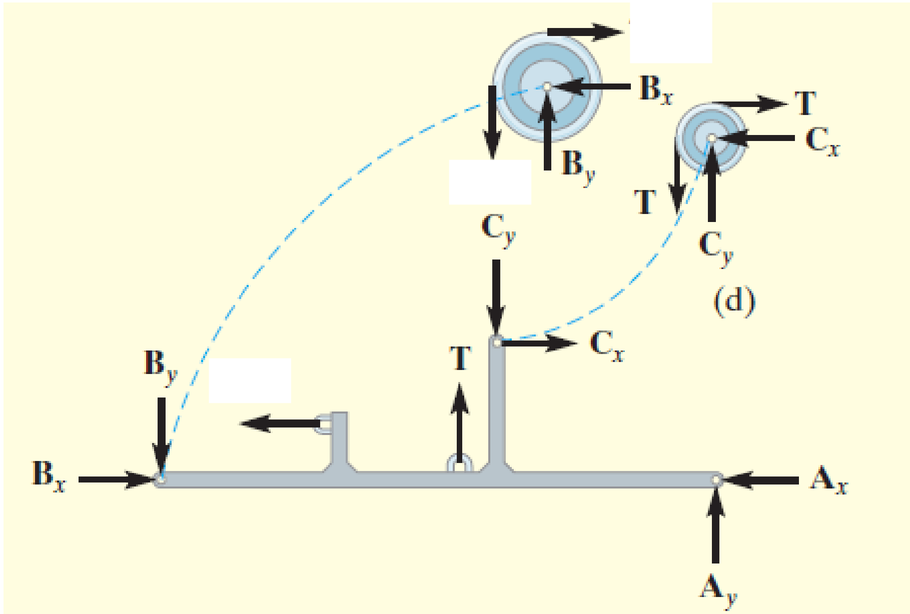

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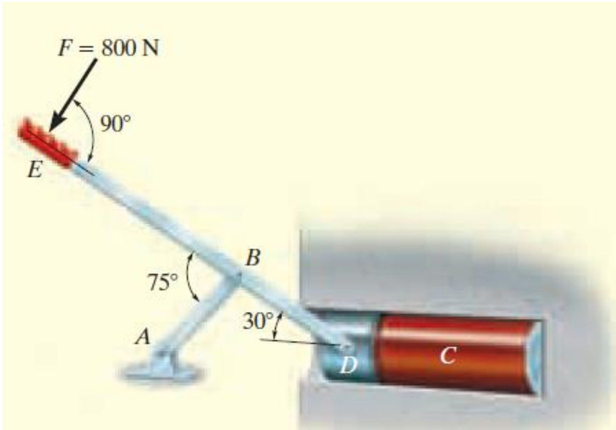
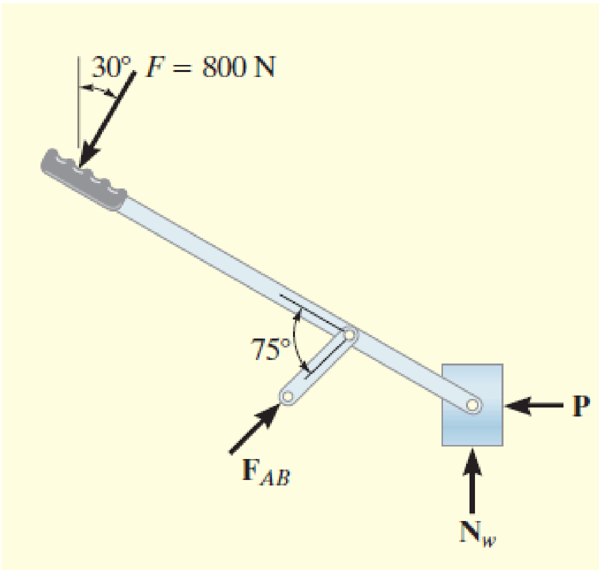
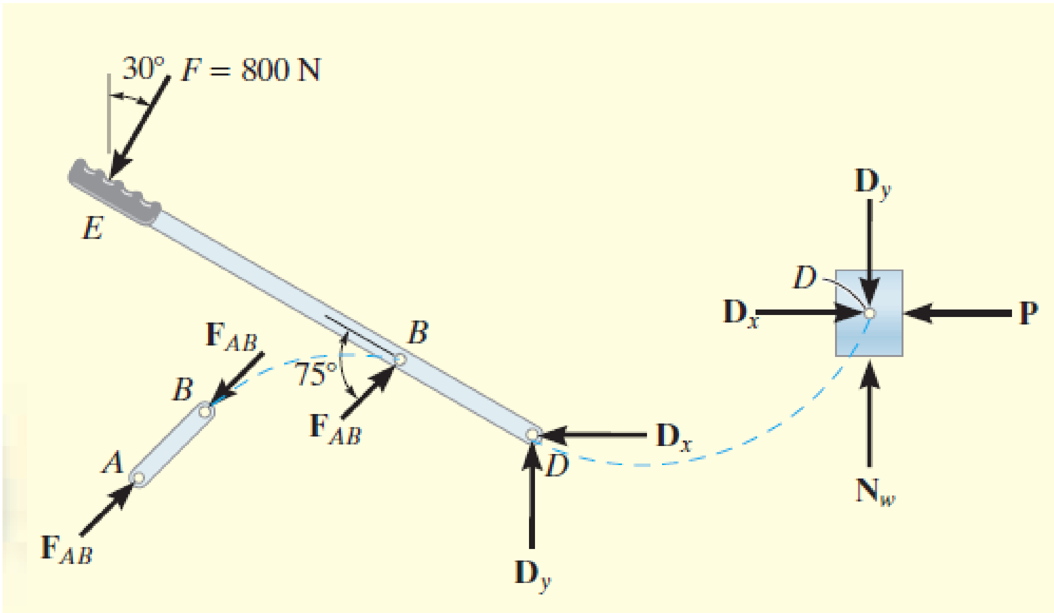


F = 800 N
90°
E
B
75°
30°
A
D
C



30°
F = 800 N
75°
P
F_{AB}
N_w



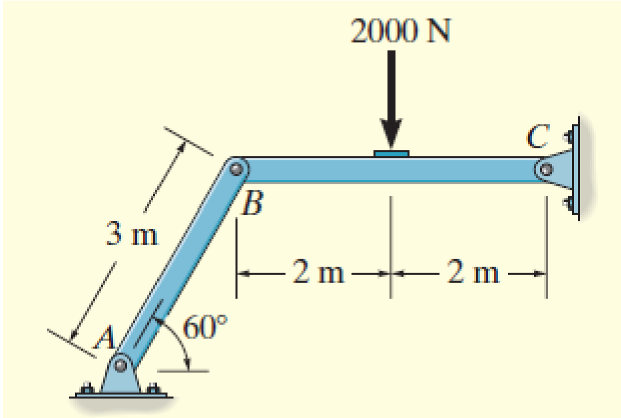
30°
F = 800 N
E
D_y
D
D_x
P
B
F_{AB}
B
75°
F_{AB}
D_x
A
D
N_w
F_{AB}
D_y

Procedure for Analysis

- Draw the free-body diagram of the entire frame or machine, a portion of it, or each of its members. The choice should be made so that it leads to the most direct solution of the problem.
- Identify the two-force members. Remember that regardless of their shape, they have equal but opposite collinear forces acting at their ends.
- When the free-body diagram of a group of members of a frame or machine is drawn, the forces between the connected parts of this group are internal forces and are not shown on the free-body diagram of the group.
- Forces common to two members which are in contact act with equal magnitude but opposite sense on the respective free-body diagrams of the members.
- In many cases it is possible to tell by inspection the proper sense of the unknown forces acting on a member; however, if this seems difficult, the sense can be assumed.
- Remember that once the free-body diagram is drawn, a couple moment is a free vector and can act at any point on the diagram. Also, a force is a sliding vector and can act at any point along its line of action.
- Count the number of unknowns and compare it to the total number of equilibrium equations that are available. In two dimensions, there are three equilibrium equations that can be written for each member.
- If the solution of a force or couple moment magnitude is found to be negative, it means the sense of the force is the reverse of that own on the free-body diagram.

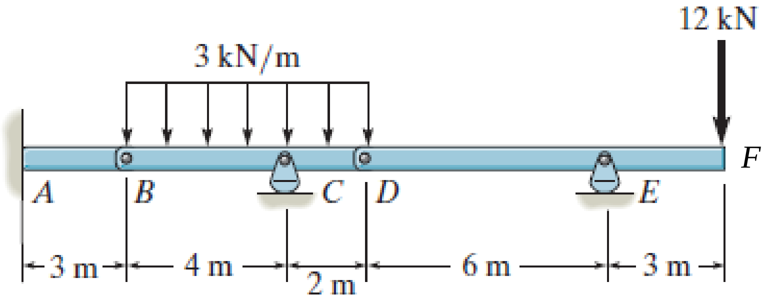
Example 7.

Determine the horizontal and vertical components of force which the pin at C exerts on member BC of the frame in the figure.



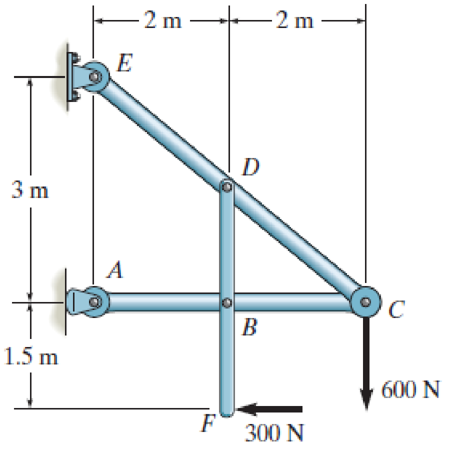
Example 8.

Determine the reactions at the supports A, C, and E of the compound beam.



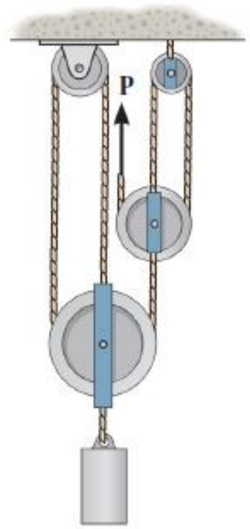
Example 9.

Determine the horizontal and vertical components of force which pin C exerts on member ABC. The 600-N load is applied to the pin.



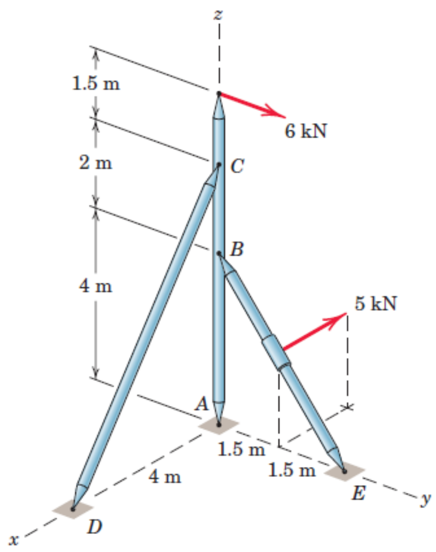
Example 10.

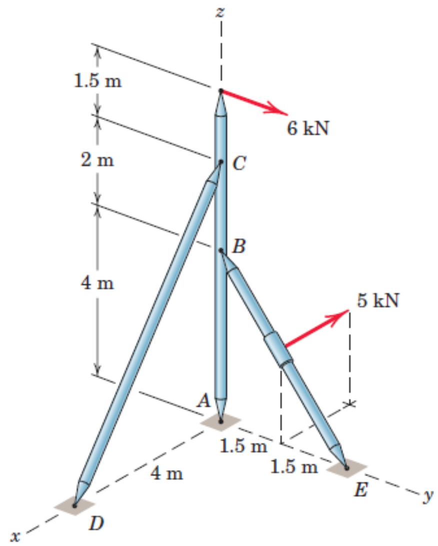
Determine the force P required to maintain equilibrium. The block weighs 100 N.



Example 11.

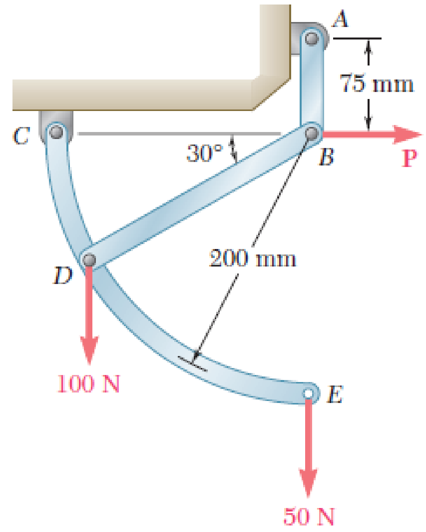
Determine the components of the reaction at A for the loaded space frame shown. Each connection may be treated as a ball-and-socket joint.

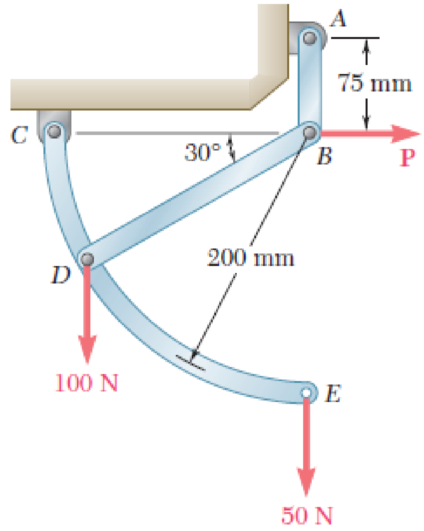



z
1.5 m
6 kN
2 m
C
B
4 m
5 kN
A
1.5 m
1.5 m
4 m
E
y
x
D

Example 12.

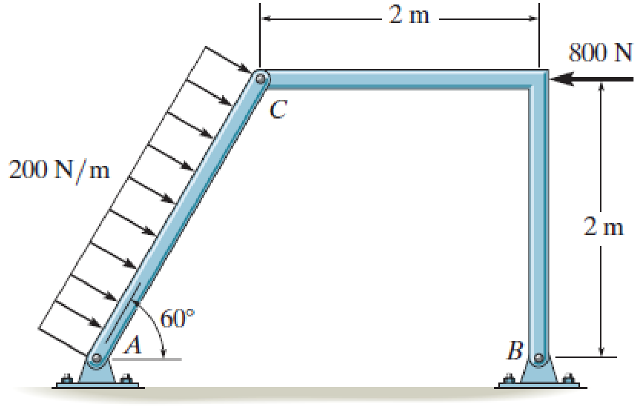
For the system and loading shown, determine (a) the force P required for equilibrium, (b) the corresponding force in member BD, (c) the corresponding reaction at C.




A
75 mm
C
30°
B
P
200 mm
D
100 N
E
50 N

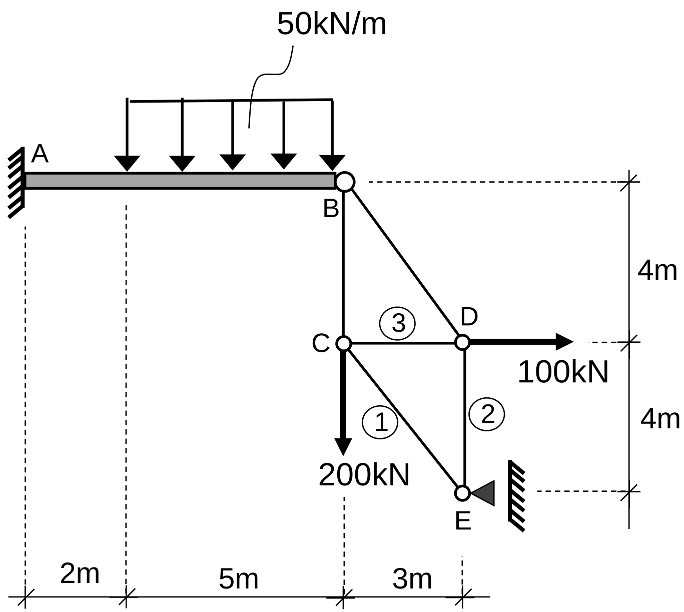
Example 13.

Determine the resultant force at pins A, B, and C on the three-member frame.



Example 14.

Find the support reactions and the forces in members 1, 2 and 3.



Example 15.

Find the support reactions and the forces in members

1 to 5.